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OPENING SESSION

COOPERATION AGREEMENT BETWEEN THE TECHNICAL UNIVERSITY DRESDEN AND AREVA NP GMBH

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ABSTRACT

As a result of the complete refurbishment of the Technical University Dresden (TUD) training reactor AKR and its equipment with the digital safety system TELEPERM XS by AREVA NP it is actually the most advanced facility in this category in Germany. Following the positive experience gained during project execution an agreement between AREVA NP and TUD was signed to bundle each organizations competence's in the interest of new recruits in the field of nuclear technology in 2006. The content and the experience with the cooperation are described in this paper. Conclusions show that both parties found an attractive way to support fellow young nuclear engineers.

1. Introduction

The Technical University Dresden (TUD) has a long lasting, continuous experience in educating students in nuclear technology, since foundation of a nuclear faculty in 1955. The up-to-date technical equipment, especially the training reactor AKR-2, in combination with well elaborated didactic basic lectures offers also the possibility for enhanced qualification of staff members from nuclear industry.

On the other hand, the know-how and the experience of well skilled personnel in nuclear technology are a valuable contribution and asset for the market success of nuclear companies in past years. The cooperation between the Technical University Dresden and AREVA NP offer a highly attractive possibility to the staff members of AREVA NP.

Consequently, both parties decided to bundle their competences and knowledge bases in the interest of young professional fellows, for nuclear technology in general, to improve the education of students at the university, to improve the education of young co-workers at AREVA NP, and to establish a symbiotic relation between both organizations. This cooperation opens new perspectives for both sides to pursue more than ever before the common goal: education and qualification of young people in one of the most prospective professional areas, i.e. in nuclear technology, and furthermore, to contribute to preservation of highly specialized competence in this field.

In 2003/04 the training reactor of the Technical University Dresden AKR was completely upgraded in a refurbishment comprising civil work as well as new electrical and I&C equipment.

One of the main steps was the complete modernization of the entire I&C-system by AREVA NP GmbH. The digital safety system, TELEPERM XS, which has already been implemented or contracted in more than 50 NPPs in 9 countries by 9 different OEMs (Original Equipment Manufacturers), served as the basis for the technical solution. Currently, the AKR-2 is the most up-to-date training reactor in Germany.

Based on the positive cooperation experience in this project for both sides and the recent development in the nuclear market world-wide, an agreement on further extension of this cooperation between the Technical University Dresden and AREVA NP GmbH was signed in 2006.

The cooperation was successfully established and has been continuously improved over the past 3 years. The positive feedback of participants from both sides in the contractual program confirms the successful cooperation between the university and industry on a win/win basis.

2. Training Reactor AKR

The training and research reactor AKR-1 (from the German **A**usbildungs**k**ern**r**eaktor) of the Technical University Dresden was put into operation in 1978. At that time the Technical University Dresden introduced appropriate courses for the education of nuclear engineers in order to contribute to fulfill the demands of industry, science and administration. Lectures in theory were combined with practical exercises at the training reactor based on an extensive program of fundamental experiments in the fields of reactor physics, neutron physics, nuclear technology, radiation measurement techniques, radiation protection, radiation dosimetry and others.
The full scale of this experimental program can be made available by small training reactors which can be operated with great diversity in terms of experimental intentions and without commercial restrictions.

The training and research reactor AKR is a thermal, homogeneous, solid material moderated zero power research reactor with maximum continuous power of 2 W. Safe operation of the reactor is guaranteed by a combination of inherent safety features, engineered safeguards and administrative procedures that allow students to operate the facility themselves.

A complete refurbishment of the reactor was started in 1998 and finished with the commissioning of the new facility (named AKR-2, see Fig. 1) in 2005, including a new licensing procedure and a comprehensive technical modernization of the facility. In the reactor refurbishment the I&C-equipment of the facility was based completely on the digital safety instrumentation and control system TELEPERM XS by AREVA NP. The nuclear instrumentation comprises 3 channels for the neutron flux measurement: two (logarithmic) wide range and one (linear) power range channel.

More technical details of the reactor design is referred in various publications [1], [2], [3], and the reactor's web site [4].

Training reactors like the AKR contribute to maintaining and enhancing nuclear know-how and competence. Even today with the current political circumstances in Germany (characterized by the intention to phase out nuclear energy generation), there is considerable demand for young engineers and scientists in the nuclear sector. The demand is driven by replacement of retired staff members at NPPs, nuclear industrial suppliers, continued work in the field of basic nuclear physics research, nuclear engineering, radiation protection, waste disposal, nuclear medicine, and the administration and technical surveillance organizations. A special demand has arisen in the nuclear industry due to new NPP projects in other countries of Europe and global regions like Asia and by world-wide modernization projects based on plant life-time extension.

In recent years, more than 1000 visitors each year took advantage of the possibilities of the AKR.

Fig. 1, Training Reactor AKR-2 of the Technical University Dresden

3. Program of the Bilateral Cooperation between TUD and AREVA NP

3.1. Motivation

Nowadays, nuclear industry has to satisfy an increasing number of contracts with domestic and international costumers due to modernization requirements or construction of new nuclear facilities world-wide in addition to when nuclear plants are decommissioned under ambitious aspects with regard to environmental protection and sustainability. Alone in 2006, the AREVA NP GmbH has recruited approximately 340 new staff members. Such a demand can actually not be satisfied by the current number of graduates of the universities in this field. Consequently, the majority of recently recruited personnel comes to the companies with miscellaneous professional specialization and experience without a nuclear background.
This situation opens up new possibilities for a concerted action with advantageous conditions for the universities as well as for the nuclear industry, and this was the idea behind a contract between AREVA NP GmbH, business unit NL (i.e. Nuclear Instrumentation), and the Technical University Dresden for an intended long lasting cooperation with the following bilateral interests:

- The university offers special training courses to young staff members from the company in order to improve corresponding competences in the sense "learning-on-the-job" to help them to assess and to solve the ambitious technical projects in nuclear technology in the comprehensive depth and quality. Universities have best conditions due to their education programmes, experiences and equipment.

- On the other hand, industry can contribute to support student's education at the university in an effective way. Referring to realistic examples, companies can show to the students that it is worth studying nuclear technology because a variety of interesting and ambitious demands exist. It is possible to show the students, in reality and in long term, that they have a future in the nuclear field. The intention must be to attract more young students, i.e. especially beginners, to encourage them to study nuclear technology. They will leave the university in a few years as a source of well educated personnel for the industry. At the universities, the attractiveness of courses in nuclear technology must be pushed considerably with such support from industry. This effect is applicable to the interest of corresponding institutes and chairs. Furthermore, students come into contact with companies as their possible employers in near future and a relationship can be founded at an early stage.

3.2. Fields and Status of Cooperation

According to the motivation, the main fields in the cooperation between Technical University Dresden and AREVA NP GmbH comprise the following four complexes.

3.2.1. Training and Education of Newly Recruited Personnel from AREVA NP

As an important aspect of the cooperation, training courses in reactor physics have been very successfully established using the possibilities of the AKR-2. The courses aim mainly at newly recruited personnel initiately of the business unit AREVA NL (I&C) but also at experienced staff members for their refreshment in reactor physics details. Each course has a duration of 5 days with a maximum number of 8 participants and is a combination between lectures on the basics in reactor physics and subsequent practical exercises at the reactor. It is a unique advantage of the course that participants can immediately combine theoretical knowledge with practical experience in reactor operation and its behavior. Especially this synergy effect is highly appreciated by the participants in the course.

Beyond the lectures the training courses include following exercises:

- Reactor startup and operation procedure,
- Control rod calibration (measuring of differential and integral reactivity weights of control/shutdown rods) and determination of excess reactivity,
- Critical experiment (determination of correct fuel loading),
- Adjoint flux function (reactivity effects of samples of absorbing and scattering material),
- Demonstration of neutron activation and decay of various radioisotopes,
- Identification of radionuclides by means of high resolution gamma spectroscopy (irradiation of different target materials and subsequent isotope analysis),
- Experimental determination of neutron flux density distribution across the reactor core,
- Radiation protection and shielding measurements,
- Radiation measurement techniques (characteristics of radiation detectors).

Every year a growing interest in this professional training could be stated:

2006	2 courses
2007	3 courses
2008	4 courses (3 already sold out, the 4th is in preparation)

It is a common intention of AREVA NP and TUD to invite to the reactor training courses not only employees from AREVA NP itself but also from other interested companies. Hence, also participants from NPPs and Siemens PG have already taken advantage of this program.

3.2.2. Visits of TUD Students to AREVA NP GmbH

Students should be brought into contact with industrial companies as early as possible. Thus, they are getting a realistic impression of their future working field and, last not least, if they are interested in the business area of the company, they can come easily in contact with people from a possible employer after graduation. On the other hand, the company can directly present its portfolio of tasks with the aim to attract the students and the chance arises to awake the interest of potential candidates for a subsequent job application at an early stage.

Consequently, it is a further successful part of the cooperation agreement between AREVA NP and TUD to organize excursions of students from the university. In past three years, these visits were invited by AREVA NP and became a constant milestone for those students of nuclear engineering.

Duration of each excursion is three days with an ambitious program, including

- Presentation of AREVA NP engineering offices and the test field for safety I&C-systems in Erlangen,
- Manufacturing of power plant reactor internals at AREVA Karlstein (incore measurement probes, cooling water level measurement instrumentation),
- Visit of a nuclear power plant (KWU-PWR Isar 2) including access to the reactor containment and the controlled area.

Participants in these excursions were 17 students in 2006 and 23 students in 2007, for 2008 the program is actually in preparation but according to the inquiries an again growing number of attendees is expected.

3.2.3. Regular lectures of AREVA NP experts at the university

Special lectures held by experts from industry can enrich considerably the quality of student education due to a symbiotic combination of practice and theory usually taught in university. Hence, regular lectures on nuclear technology with strong focus on safety I&C and presented by experts from AREVA NP have been placed in early semesters for all students in mechanical and electrical engineering as well as for students in higher semesters in the frame of their specialization to nuclear technology. Corresponding to the subsequently mentioned content it is the aim of these lectures to attract students for a professional future in the field of nuclear energy:

- Energy generation world-wide,
- Technology and economic aspects,
- Hierarchic architecture, topology and components for instrumentation and control (I&C),
- Prospects and chances of nuclear energy production.

The immediate success of such lectures can be measured in the level and depth of subsequent discussion between lecturer and students being usually very intensive.

As a general conclusion students very welcome such lectures as a supplement with practical background. In addition these lectures fulfill the intention to encourage students for a carreer in nuclear technology.

In a next step both parties intend to introduce a complete series of lectures on nuclear instrumentation at Technical University Dresden for students of nuclear and electrical engineering.

3.2.4. Provision of Promotion and Sponsoring Programs

It is of essential importance to keep and to further extend the competence in nuclear technology as safety requirements and criteria have to be fully considered at all times in existing nuclear installations. This has to be applied also to new and future reactor concepts to assure a safe, reliable and competitive energy production not limited to electricity provision.

The cooperation contract provides the opportunity for the students and graduates to enhance their expertise by combining the above mentioned theoretical knowledge with operational requirements of the nuclear industry.

Therefore, the cooperation contract between AREVA NP and the Technical University Dresden covers:

- work studies at experimental set-ups in the research and development departments of AREVA NP or in project execution at design or plant sites of nuclear power plants,
- work on diploma theses in those fields which are relevant for the industry and, on the other hand, which are highly challenging with their scientific background for the students as well,
- promotion of PhD studies for students of TUD.

4. Conclusions

After more than two years a very positive result can be stated in this cooperation, signed in 2006. The experience and response of the participants in all actions show that the contract is not only a paper, but it is effectively alive. The activities won recognition and found positive resonance on both sides, at all levels. The positive trend can be shown by an increasing number of training courses and participants at the Technical University Dresden as well as on a growing interest in works studies and diploma theses. Apart from these results the co-operation will be more extended by the scheduled lecture on safety I&C.
In summary this cooperation obviously demonstrates a reliable and trustful win-win situation and forms a solid base for further continuation and extension.

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Training Programmes for Industry

THE NFI TOKAI SD SYSTEM

- MANAGEMENT OF THE CAPABILITIES OF OPERATORS IN FUEL FABRICATION PLANTS -

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ABSTRACT

Since the JCO criticality accident occurred in 1999, even more emphasis has been placed on the management of nuclear safety in Japan. This is particularly true for the education of operators and the observance of operational procedures. Even prior to this accident, Nuclear Fuel Industries, Ltd., NFI, regarded the education and development of skilled operators very seriously and we have developed an education system, called the SD system (Skill Development system), to assure the careful education of the operators and the improvement of their skill in order to prevent human error events. Our education system in the Tokai works, is explained.

1. Introduction

1.1 Outline of NFI’s business activities

Nuclear Fuel Industries, Ltd., NFI, was established in 1972. Since then, it has been manufacturing nuclear fuel with modern equipments and facilities under the strict quality control. NFI’s business has grown to encompass a wide range of activities, such as development, design and manufacturing of nuclear fuel, reactor core management service, nuclear fuel-related engineering services, and also inspection and repair services. NFI has two manufacturing sites; Tokai Works, which manufactures BWR (Boiling Water Reactor) fuel, and Kumatori Works, which manufactures PWR (Pressurized Water Reactor) fuel, and has been developing its activities mainly through these two works.

1.2 Circumstance about nuclear safety in Japan

On September 30, 1999 a criticality accident occurred at a uranium re-conversion plant operated by JCO ,Ltd. Three plant workers were exposed to high levels of radiation in the accident. This resulted in death of two workers making this an unprecedented nuclear accident in Japan which had been utilizing nuclear energy for more 30 years at that time. The primary cause of the accident was the use of illegal procedures. After the accident, strong emphasis has been placed on the management of nuclear safety in Japan, especially on the education and training of operators and the observance of operational procedures. Even prior to this accident, NFI recognized the importance of them very seriously and we have developed a careful training system, to assure improvement of operator’s skill in order to prevent human error events. Also we have been trying to avoid mannerism by providing with many kinds of skills through the system. We introduce the system which we call the Skill Development system (SD system).

2. SD system

2.1 Structure of the SD system

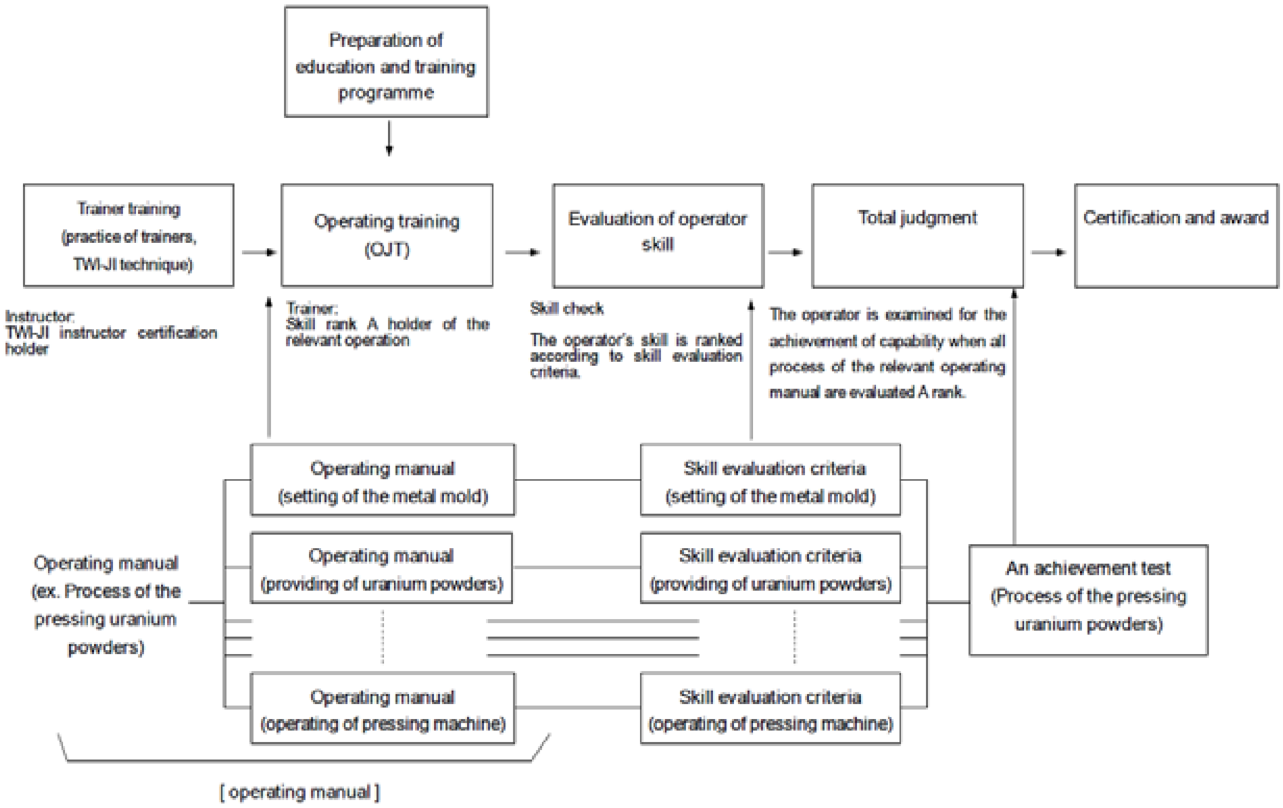
The SD system was introduced in 1986 to improve the skill of the operators and to assure the transfer of skills to the next generation. These are fundamentals for safe operations and product quality. The SD system is also proven as an effective tool for managing skill level of the operators.

The SD system is composed of the following four steps.

1. Preparation of instructors to educate trainers out of operators
2. Preceding education of the trainers by the instructors
3. On the Job Training (OJT) for operators by the trainers
4. Evaluation and certification of the operators' skill level

The SD system is featured as a system adopting many techniques of "Training Within Industry for supervisors – Job Instruction (TWI-JI) ". TWI-JI was developed in USA during 1940's as a method of teaching with easiness and immediate effectiveness. The instruction methods were introduced by many countries in the world, and also have been used as tools of business training by many companies in Japan.

Conceptual diagram of the SD system



2.1.1 Preceding training of the trainer

It is true that whether the training is successful and effective or not depends on the motivation of operator. We are also sure that more important factor for the success is existence of excellent trainers. Therefore we prepare an education programme for the instructor who trains the trainer. With the programme we nurture two new instructors per year. At first, two instructor candidates shall learn the TWI-JI methods for 6 days in the instructor training programme by external education institution and shall be certified as instructor. Then the certificated instructors teach TWI-JI techniques for 10 hours as trainer course to in-house potential trainers who have skill rank-A. (Skill rank will be mentioned later) Training method in TWI-JI has the following features.

- Fixed procedures.
- Based on discussion and demonstration.
- Emphasize practical skill over knowledge.
- Teaching with easiness and immediate effectiveness.

These characteristics are suitable for training of unskilled operator. In addition, TWI-JI’s credo, "If the worker hasn't learned, the instructor hasn't taught", is consistent with our education policy. From these reasons, NFI has been using TWI-JI methods since introduction of the SD system. Now, we have 23 instructors, and all of the operators aged 30 and older are learned TWI-JI technique by them.

2.1.2 OJT for operators

A designated trainer, who is certified as skill rank A for the relevant operating procedure and finished the trainer course, trains the operator with OJT. We explain the OJT procedures as below.

The first step, the line manager plans a training program for his operators, such as “who”, “which operation”, “when by” and “ to which rank of skill”, taking account of importance and priority of processes and experience of the operators.

OJT is carried out based on the operating manual. We have established it for each process, in manufacturing, inspection/chemical analysis, radiation control and facilities maintenance. In the operating manuals, we divide the operation into some processes according to TWI-JI’s technique, ”operation breakdown”, and emphasize vital points for the each process of safety and quality. We are trying hard to write down into manual even know-how of the operation such as knack and hunch to share them among operators and transfer them to the next generations.

Operating manual format

Process	facilities	Operating procedure	Essential points	Precaution for safety

During OJT, the operator is trained through “four basic steps”, (1) prepare the worker, (2) present the operation, (3) try out performance, and (4) follow up. Trainer shall coach the operator with patience and make sure of his understanding. As we recognize that an important point of OJT is to follow up the operator after coaching, we request the trainer to make additional coaching if necessary while watching job performance and workmanship of the operator.

2.1.3 Evaluation and certification of the operators’ skill level

After the operator is trained with OJT, he is appraised by the trainer. The operator’s skill level is ranked and authorized according to the skill evaluation criteria. We classify operator’s skill into the three classes, Rank A, Rank B and Rank C. We prepare criteria of the Ranks for each work in the operating manual. For the purpose of securing of skill’s reliability, we disallow skipping a rank.

Skill rank (Classification based on skill level)

Skill rank A	He has knowledge and skill about the operation enough to coach a member as a trainer.
Skill rank B	He has knowledge and skill to execute the operation alone.
Skill rank C	His knowledge and skill aren’t enough to execute the operation alone. He shall operate with coaching by a trainer.

Example of skill rank evaluation criteria

Operation name	Heating-up and cooling-down of a sintering furnace
Skill rank B	- He can implement heating-up and cooling-down operation of a sintering furnace with referring to the operating manual. - He can confirm the program of heating/cooling for the electric temperature control device. - He can identify a gas piping by a unique color. - He understands characteristics of each gas. - He can correctly set the graphite crucible with paying attention to its direction to furnace.
Skill rank A	- He understands seriousness of influence caused by malfunction of the gas supply system. - He can correctly teach the procedure of the operation to low ranker.

We judge the operator’s skill not only based on correctness of his operation but also based on his understanding of human error related- risk and past experience. The criteria prepared by this concept make sure to transfer valuable experiences to young operators. We also confirm his skill level is maintained once a year for Rank A operators, because it may decrease with time.

The skill management of our operators mentioned above has been used for preparation of our manning schedule, and it has been contributing to safety of the plant operation and high quality of our products.

The person who has Rank A skills for all of the operations in the specific process can take a final examination for all aspects of the process. If he successes in the examination, he is awarded the certification from the plant superintendent as a professional of the process. This recognition system is significantly contributing to maintain and assist operators' desire to improve themselves.

2.2 Horizontal development of the SD system

We have applied the SD system not only for manufacturing work but also for the other works surrounding it. (ex. radiation control, facilities maintenance)

It is said that accident or trouble is more probable to happen in unusual work or infrequent operation. We are trying to apply the SD training to such work and/or operation by periodical review of them and relevant operating manual including view point of "3H work" (Hajimete in Japanese: for the first time, Henkou: revised or modified, Hisasiburi: after a long time).

In general, Europe tend to aspire toward one-job skilled worker, Whereas Japan tend to aspire to multi-skilled worker. Both ways have drawback and advantage. NFI has been promoting for its workers to have many skills, because we should consider about flexibility in case of their absence due to illness, activation of workplace and cost reduction by optimization in arrangement of personnel while securing nuclear safety and workers' health and safety with the highest priority. We think that the SD system greatly contributes to development of the production activity.

2.3 Challenges for the future

We recognize it is important to improve efficiency of the OJT continuously. To make trainees' learning easier, we consider to visualize operating manuals and to show them in workplace by introducing large monitors so that operators can easily remember the procedures of operation.

3. Conclusion

Japan now faces a declining labour population due to its longstanding low birth-rate. In this circumstance, we have to maintain high skilled human resources necessary for operation of the fuel fabrication plant. We believe smooth skill transfer among operators and their generations is essentially important and achievable with the SD system. We therefore will maintain and improve the SD system continuously in the future.

Finally, we hope our experience of the SD system helps you to review and/ or plan control of your operators' skill and which contributes nuclear safety in the world.

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FINNISH SOLUTION TO INCREASED BASIC PROFESSIONAL TRAINING NEEDS IN NUCLEAR SAFETY

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ABSTRACT

The Finnish nuclear energy organizations have in cooperation arranged basic professional training courses on nuclear safety due to fast increased education needs. Especially the new nuclear power plant construction project turned the situation acute, but there was also a need to preserve the tacit knowledge of many nuclear experts retiring within the next ten years. From 2003, the YK courses have been arranged five times with altogether 270 participants. The need of this kind of complementary education is still seen high in Finland, and the YK6 course is to be arranged during the next winter. There has not been seen to be legal incompetence due to the likelihood of bias in the education even that the participating organizations have differing and/or opposing roles. It is seen that a real safety culture presumes that nuclear safety is a common goal, and even the competition for market shares is no obstacle for cooperation.

1. Introduction

Nuclear technology is facing a regeneration phase in Finland, and nuclear safety is a prerequisite for utilization of nuclear energy. In fall 2002, Finnish nuclear organizations started to discuss, how to find a solution to fast increased education needs in nuclear safety. Especially the new nuclear power plant (NPP) construction project turned the situation acute, but there was also a need to save the tacit knowledge of many nuclear experts retiring within the next ten years: the four NPP units began their operation nearly simultaneously 1977-1981. The education goal was seen common for all organizations in the nuclear energy area, and they decided to establish an organizing committee to develop and organize a basic post-graduate professional training course for new recruits and staff members. The developed national course on nuclear safety was entitled the YK course. Since fall 2003, YK courses have been arranged five times with above 50 participants and about 100 lecturers each time. The number of professionals with academic degree working within nuclear energy in Finland was estimated to be 600 in the beginning of this century, and has grown maybe 50 % now. Half of them have a special degree on nuclear energy. The national YK courses with altogether 270 students have been an essential help in this fast expansion.

The need for the course is not expected to decrease, vice versa: now there are three new environmental impact assessment (EIA) processes in different phases for three planned construction projects. However, TVO, Fortum, and as a newcomer also the Fennovoima utility must first have the Government's Decisions in Principle (DiP) in favour of the new units being considered to serve the overall interests of the society before they can seek for construction licenses. Also the Finnish Parliament must ratify these possible DiPs. The new unit of TVO is now estimated to be commissioned in 2011 with electric output of approximately 1600 MW.

2. Academic nuclear energy education system in Finland

Nuclear engineering and reactor physics are taught in two universities in Finland. The professorships are in the Department of Energy and Environmental Technology of the Lappeenranta University of Technology (LUT) and in the Department of Engineering Physics of the Helsinki University of Technology (TKK). However, there are only two professorships altogether in the nuclear energy area including fission and fusion energy. Nuclear energy related areas are taught also in several other universities (e.g. nuclear physics, radio chemistry, material sciences and construction, power engineering, automation, geology).

Four levels can be seen in nuclear energy education: first the basic courses on ideas of nuclear physics, engineering and safety, second the thorough education on the Master level, third the professional training courses, and fourth the post-graduate studies. The basic courses are given in some, and should be given in all universities giving degrees on nuclear energy related areas. In LUT the basic course gathers yearly much over hundred participants.

Masters level education on nuclear energy is given in LUT and TKK. A Finnish speciality in all technical areas is the tight connection of the technical university students with industry as well as research institutes and authorities. During the studies the students get acquaint with the industry and other bodies as summer trainees, and the diploma theses are often made straight for the other stakeholders, the students working outside the universities.

The post-graduate level education is a huge challenge with so few professors in the area, and international co-operation is thus very important. Both LUT and TKK are members of ENEN and WNU. The research on doctorate theses has mainly been carried out within the national research programs on nuclear safety, now SAFIR2010 [1] and KYT2010, and in the EU research projects participated by research institutes and universities.

In the professional training level after graduation the YK courses are the most extensive in Finland. They are especially important for those participants who come from other subject areas than nuclear energy but are needed to work e.g. in NPPs. There are also courses on radiation safety and waste management given separately. However, it must always be remembered that this kind of training courses cannot substitute the long-term nuclear energy education in universities.

3. Organization and structure of the YK courses

The YK course is aimed for basic post-graduate professional training of new academic recruits and staff members; i.e. for an audience of graduate engineers having their own expertise, but not necessarily that in nuclear engineering. The YK course structure and syllabus were originally based on a similar course developed by the IAEA [2], but it has been applied for Finnish needs, especially to include more information on the issue of new construction. All materials have been renewed, and are partly renewed again every year.

The organizations arranging the course are: Ministry of Employment and the Economy (TEM), Lappeenranta University of Technology (LUT), Helsinki University of Technology (TKK), Teollisuuden Voima Oyj (TVO), Fortum Oyj (Loviisa power station and the Fortum Nuclear Services Oy), Posiva Oy, the Technical Research Centre of Finland (VTT), and the Radiation and Nuclear Safety Authority (STUK). The Finnish application was developed in order to make visible different standpoints of all organizations in the area. Concretely, also the location of the different modules rotates between different organizations.

Best experts from Finland were chosen as lecturers, altogether about 100. They mainly come from the above mentioned organizations as well as the participants. Half of the lecturers came from the utilities TVO and Fortum, a quarter from the authority STUK, and the rest from VTT, universities and others. Actually, the right to send participants was "bought" by giving lectures. No fees are gathered except the power companies taking care of the running expenses.

.Part No	Course number	YK 1	YK 2	YK 3	YK 4	YK 5	Order YK 5
	Part subject	**The number of hours of lectures + team work**					
1	Principles of nuclear safety	10+2	7+1	7+1	7+1	5	**3**
2	Nuclear reactor principles	11+2	12+2	12+2	12+2	14+2	**1 + 10********
3	Radiation protection	2+1	3+1	4+1	4+1	2+1	**5**
4	Design of a nuclear power plant	20	13	13	13	9*+1	**2**
5	Siting considerations	3	1	1	1		
6	Licensing and construction of a NPP	8	6	6	6	4	**4**
7	Safety classification	4+1	2	2	2 +1	2	**6**
8	Quality management	6+1	4	4	4	3	**20**
9	Deterministic accident analysis	10+4	9+4	9+4	9+4	9+4	**7**
10	Probabilistic safety/risk assessment	10+4	7+4	7+4	7+3	4+3	**8**
11	Human performance	7+1	3	3	3	3	**9**
12	Operational safety	7	4	4	4	6***	**11**
13	Surveillance and maintenance programs	6+1	5+1	5+1	5+1	4+1	**12**
14	Plant modifications and upgrades	7	7	7	7	5	**14**
15	Limiting conditions for operation	5+2	5+2	4+2	5+1	3+1	**15**
16	In plant accident management	9	9	9	9	6	**16**
17	Decommissioning considerations	1	1	1	1		
18	Waste management	4	4	4	4	7**	**13**
19	Regulatory control	9	7	8	8	7	**17**
20	Emergency prepared-ness and response	6+1	6+1	4+1	4+1	4+1	**18**
21	Safety culture	5+2	5	4	4	3	**19**
22	Public communication, operational experience	4+1	5	4	4	2***	**21**
	Nuclear power plant & waste facility visits	+24	+24	+24	+24	+13	
		(=154+47)	(=125+40)	(=122+40)	(=126+39)	(=102+27)	
	Total course duration	**201 h**	**165 h**	**162 h**	**162 h**	**127 h**	
	Weeks / periods YK5	6	5	5	5	6	
	Lecturers, guides etc.	120	~100	~100	~100	95	
	Participants	51	56	52	55	57	

* number of lectures will again be increased in YK6 ** includes also the front end of fuel cycle
*** operational experience moved together with operational safety ****10.= test facilities and reactor

Table 1. The structure and volume of courses YK1-5 in 2003-2008

The course is arranged in six modules each lasting 2-4 days during 6 months. The nuclear safety subjects are extensively covered as seen in Table 1. The main part of the course is lectures, but visits to the operational NPPs and their waste facilities, full-scope simulator exercises, as well as group works are also essential parts of the course. The materials include about 2000 pages of slides and 900 pages of abstracts gathered by LUT, coordinator of the course. The focus is on the Finnish requirements on nuclear safety as well as the structures and practices of the Finnish operational and constructed NPP types.

The domestic need has been such large that there has not been room for foreign participants. Due to the very fast time table in the creation of the course for the first time, all the lecturers were gathered from Finland and the habit has not been changed so far. However, there is no principal obstacle to change the situation. Also the subcontractors working in Finland have been interested in the course. The Finnish experiences of the courses were dispensed within the EC 6th FP project NEPTUNO, the Nuclear European Platform for Training and University Organisations which worked in close contact with the ENEN association, the European Nuclear Education Network.

4. Development of the YK courses based on feedback and evaluation

The structure and the content of the courses have roughly remained the same, but some changes have been done based on the feedback collected from participants and lecturers [3]. The YK courses were also independently evaluated in 2007, and suggestions were given for further development [4]. These suggestions were partly taken into account already in the course YK5 just finalized. E.g. the YK5 course was arranged using shorter lecture periods, which do not disturb other duties of the participants as much as the whole week periods applied earlier.

The course has been gradually compacted mainly in order to decrease the overlapping of lectures. It can be seen in Table 1 that the compacting has been carried out in most of the topics. The overlapping is continuously seen as a problem mainly due to the large amount of lecturers. A problem is also that hundred lecturers cannot all be pedagogically professional teachers despite them all being professionals in their own fields. However, it has been seen that there still are more advantages of having many lecturers: differing points of view, e.g. by authorities and NPP workers as well as deeper expert knowledge are the most important. Summer seminars for the lecturers have been arranged from the year 2007 to increase the coordination.

There has been positive feedback on practical arrangements of the courses as well as on excellent lecturers with high expertise. Also the good team works and high quality materials have been remarked. However, the course should be more interactive. One way to do this would be to limit the quite large amount of participants in each course, which has been over twice of the amount applied in the international courses, but the education needs in Finland are too acute for this solution.

The wide content of the course has been seen acceptable even though the participants have seen that every topic is not as useful for everybody. The students have different backgrounds and it has now been decided to include preceding reading and exercises in the course. The heterogeneity of the knowledge level and the differing working areas of the audience make the teaching process challenging for the lecturers. However, the networking aspect of the common course has been seen to be an overwhelming benefit compared to separate courses. Participants have admitted that one important assignment of the YK courses is to get to know each other and all significant nuclear organizations in Finland.

The Finnish language is seen to be important in the materials because the NPPs utilize the course materials also in their internal training. However, the terms should be given and learned also in English.

5. Conclusions

The arranging of the YK courses has demanded a lot of work from the whole nuclear community in Finland. The straight yearly investment is at least 7 person years. However, this effort is seen to be very valuable in the education of new generation and in the knowledge management of tacit know-how as well. The need of this kind of complementary education is still seen high in Finland, and the YK6 course is to be arranged again during the next winter.

The course has been arranged and participated by Finnish nuclear energy organizations having differing and even opposing roles. However, there has not been seen to be legal incompetence due to the likelihood of bias in the education area. On the contrary, it is seen that a real safety culture presumes that nuclear safety is a common goal, and even the competition for market shares is no obstacle for cooperation in education.

Acknowledgements

The members of the organizing committee of the YK course, the lecturers, and the producers of the materials are acknowledged for enabling the course despite of their other duties.

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EDUCATION FOR THE NUCLEAR POWER INDUSTRY - SWEDISH PERSPECTIVE

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ABSTRACT

In Sweden, about 50 % of the electricity is produced by nuclear power. The nuclear power industry hires about 50 people per year on a masters or PhD level, and engineers on a bachelor's level are hired as reactor operators. Of these, essentially all have their background in other areas than nuclear engineering.

To educate the staff, the nuclear power industry has formed a joint education company, Nuclear Training and Safety Center (KSU). KSU provides education and training programs for all levels of professional skills. Reactor operators undergo an extended training program over many years, where training in simulators constitutes an important part. In addition, courses aiming at a deeper theoretical understanding of reactor physics and thermohydraulics are provided. The latter types of courses are given in collaboration with Uppsala University.

To ensure that nuclear competence will be available also in a long-term perspective, the Swedish nuclear power industry and the Swedish Nuclear Power Inspectorate (SKI) have formed a joint center for support of universities, the Swedish Nuclear Technology Center (SKC). SKC has established collaboration with three Swedish universities, where undergraduate and PhD education is undertaken. In the present contribution, the activities of these organizations will be outlined.

1. Swedish nuclear power – an introduction

About 50 percent of the Swedish electricity is produced by nuclear power. This puts Sweden among the top five countries when it comes to percentage of nuclear power in the electricity production. Counted by installed power per capita, Sweden is the number one nuclear power country in the world.

Twelve light-water reactors were connected to the power grid between 1972 and 1985. Of these, nine boiling water reactors (BWRs) were produced in Sweden and the remaining three reactors are pressurised water reactors (PWRs) originating from the USA.

Nuclear power has had a political dimension in many countries, but Sweden has in some aspects an especially complicated relation between politics and nuclear power. In 1978, a three-party coalition government resigned from office because of disagreement on nuclear power. To my knowledge, this is the only event anytime, anywhere where a government has resigned because of nuclear power.

In 1980, an advisory referendum was held on the future of nuclear power in Sweden, a referendum that can be described as an aftermath of the Three Mile Island (TMI) accident the year before. In this referendum, three alternatives were on the ballot, neither of which indicated operation of nuclear power indefinitely. One alternative was closure within ten years, and the other two, which were to a large degree identical, suggested operation of the already built or planned reactors, i.e., the twelve finally taken into operation, to be run "for their technical lifetime", after which no new reactors should be built. The votes for latter two alternatives were considered merged by the Swedish parliament. The technical lifetime was assumed to be 25 years by the parliament. Since the last reactor should go critical in 1985, this meant that nuclear power should be phased out by 2010, which was thereby set to be the final date of Swedish nuclear power.

Over time, the perception of nuclear power by the general public has become dramatically more positive. All recent polls indicate that a large majority, 60-80 % of the population, would like to continue running the existing reactors as long as they fulfil the safety criteria. About 20-30 % of the population would prefer new reactors to be built in favour of deployment of fossil fuel-based electricity generation, and less than 20 % would like to see a rapid phase-out of nuclear power [1].

By now, it is clear that the technical life span of these reactors is more than 40 years, and operation for 60 years is seriously considered. With the preset closure in 2010 approaching, it became increasingly clear that a nuclear power phase-out would be very expensive, and it would be detrimental to the environment. This resulted in a new parliamentary decision in 1997 to withdraw 2010 as closing date. Instead, it was decided to close two reactors, not because of safety reasons but to prove that the government was serious in its strive to phase out nuclear power. The remaining ten reactors should be “phased out with even time intervals”, but the exact time interval has never been defined.

All these political maneuvers have resulted in a situation where nuclear power for a long time was considered a no-future industry. Not surprisingly, it has not been a prime career choice for young people. As a consequence, the enrolment in nuclear engineering studies dwindled to very small numbers, and about ten years ago, less than ten students in the whole country graduated in nuclear engineering from the technical institutes. This perception has, however, changed dramatically in a rather short time lately. Nuclear power is no longer politically incorrect among young people. On the contrary, it is generally seen as environmentally friendly and economically sound.

These backgrounds are necessary to understand the current situation. For about twenty years, investments in the reactor park were hampered by the decision to close them, and the lack of attraction among young people led to that nuclear engineering almost vanished from the curriculum of Swedish universities. Because of this, the industry had a difficult time getting its personnel needs satisfied by the universities. Instead, the industry had to hire other types of engineers, often relatively mature in age, and to educate them at work.

2. Training and education in the industry

The Swedish nuclear power industry employs more than 50 new people per year for duties where knowledge of nuclear physics and engineering is required. Of these, only a minor fraction has reactor physics or nuclear engineering in their curriculum. The vast majority have engineering degrees with specialization in other fields, with electrical engineering, machine technology and engineering physics being the most common.

This category can roughly be divided into two subgroups, operators and others. A majority of the reactor operators today have high-school education only. There is, however, a strong trend that the newly employed operation staff typically has a bachelor’s level degree. There is a many-year career track to become an operator. A period of at least three but typically five years as general technical support at the power plant is required before education to become an operator is initiated. During this first phase, the staff undergoes an education programme of typically two years. For promotion to operator, an additional education programme of one year is mandatory. There are, however, two categories of operators, turbine and reactor operators. These fulfil different duties in the control room during regular operation, and are recognized as different positions. The turbine operator education always comes first and some continue to the second step to become reactor operator. Each of these two levels requires one year full-time education.

This education is composed of regular teaching as well as training in simulators. For all reactors, there are corresponding simulators. Until a few years ago, the simulators were located at the Studsvik site south of Stockholm, which then served as a central hub in the education. Recently, most of the simulators have been moved to the power production sites to increase the accessibility for the personnel.

Finally, there is an educational programme to become operative leader of the production (shift manager), which comprises about half a year. This programme is mostly focused on leadership aspects, organization, etc., but it also involves some technical education.

It is required by the nuclear power inspectorate that an operator undergoes education and training of at least ten days per year, whereof simulator training for at least five days per year. It is not uncommon that a person has dual competence, e.g., both as reactor and turbine operator, and therefore has to spend twice this time per year in simulator training. In reality, personnel with only a single competence, i.e., as turbine operator, nevertheless spends ten days on training.

To meet the educational demands, the power utilities have jointly formed a dedicated education company, called Nuclear Safety and Training Centre (KärnkraftSäkerhet och Utbildning AB in Swedish, abbreviated KSU) [2]. KSU is owned by the utilities with proportions roughly corresponding the share of the total nuclear electricity production. The company is non-profit in the sense that the employers are charged for the course participation of their staff, such that KSU neither makes profit nor loss when integrated over a few years. Due to this construction, the KSU courses are open to participants also from non-owner organizations, because the fees are set to cover the full costs for the education.

KSU owns and operates the simulators, and provides the regular teaching near practical operation. The courses on general understanding of reactor-relevant physics, from hereby referred to as higher education, is provided by the Division of Applied Nuclear Physics of the Department of Physics and Astronomy of Uppsala University [3].

3. Education at universities

To promote long-term sustainability of reactor-relevant research and education at Swedish universities, the Swedish Centre for Nuclear Technology has been established [4]. The centre is financed by the power plants in proportion to installed power, with added contributions from Westinghouse (Nuclear Fuel production in Västerås) and the Swedish Nuclear Power Inspectorate (Statens KärnkraftInspektion, SKI) [5].

The fact that the inspectorate contributes might call for an explanation. There is a long-term tradition in Sweden that the inspectorate primarily acts proactively. Thus, instead of just inspecting and handling the judicial aspects after possible incidents, the inspectorate involves itself in a continuing discussion with industry with the aim to guarantee or preferably also raise the security. The mission of the inspectorate to promote nuclear safety has been interpreted to also encompass support to education and research, because such activities are viewed as crucial to uphold a high safety standard.

SKC has long-term collaboration agreements with three universities, Chalmers Institute of Technology (Chalmers Tekniska Högskola, CTH) in Gothenburg [6], the Royal Institute of Technology (Kungliga Tekniska Högskolan, KTH) in Stockholm [7], and Uppsala University (UU) [3]. As part of these agreements, the universities have committed themselves to uphold positions relevant to SKC. In addition, SKC supports research projects. Without this support, it is likely that very little activities – if any – would have prevailed.

One particular aspect needed to understand the structure of the research and education is the absence of research institutes. Besides the Swedish Defence Research Agency, there are essentially no research institutes in Sweden. Instead, industry-oriented research is either carried out in industry itself or at the universities. A consequence of this feature is that only a minor fraction of the industry-oriented research at Swedish universities is financed by government grants. Instead, the large majority is financed by external industry grants to the universities, and nuclear engineering is no exception from this rule. In fact, essentially all the research and PhD education is financed via industry grants. Only the undergraduate education is to a significant degree government-funded, but this is a truth with qualification. There is a system to finance teaching that barely covers the costs for the actual teaching, but if no other funding was at hand, the teacher would have to work full time on teaching only just to cover the own salary costs. In reality, this would be impossible because it is out of question to fill the agenda so efficiently. Therefore, some additional funding must be present just to have the teaching capability available, and this is provided by SKC.

4. Synergy effects

With the organization outlined above, it has been possible to achieve an efficient utilization of limited resources. As has been described above, the KSU courses for industry personnel have been designed for newly employed personnel. A pre-requisite for such courses to be useful for the industry is that they are concentrated in time. This requirement, however, also makes them well suited for PhD students. Accordingly, whenever there are free seats available during a KSU course, PhD students from any Swedish university can participate. This has contributed to a marked increase in the total course volume. Moreover, the fact that course participants come from different backgrounds have resulted in increased student activity in the courses, simply because of the need to explain various concepts across professional barriers, and because questions are being asked from a wider range of perspectives.

Up to now, this collaboration has been established in general courses on nuclear power technology for newly employed industry personnel. The content of these courses is essentially basic reactor physics and thermo-hydraulics, with moments of nuclear power safety. Thus, these courses are giving a broad introduction to nuclear power, but they do not go deeply into the subject. Thereby, they are useful to PhD students working in areas related to nuclear power, but where the focus is not on reactor technology. A good example is nuclear chemists working with partitioning. For them, a broad view of nuclear power is useful to put their work into a larger perspective, but their cutting edge knowledge has to be in chemistry. Other examples are nuclear physicists, PhD students working with reactor applications like neutron scattering for materials investigations, boron-neutron capture therapy (BNCT), etc.

This student category is fairly large. For the students in more reactor-oriented research, these courses can provide an introduction, to be followed by more specialized courses. An example of synergy effects also in more specialized education is a two-week course on probabilistic safety analysis (PSA), where typically about half the participants come from academia and half from industry and the regulatory body. The course is provided by a commercial company that performs PSA studies on demand. Neither participant category is sufficiently large to carry the costs for such a course, but by joining forces, the total number of participants is sufficiently large to make the cost per participant realistic.

Recently, the cross-disciplinary collaboration has been taken a step further. As described above, in the introductory KSU industry-oriented courses above, PhD students have been accepted as participants for a few years. Since these courses are nowadays taught at a university, they are now available also to undergraduate students. For simple geographic reasons, up to now mostly local students have taken the chance to follow the course whenever there are available seats. This has resulted in a number of new aspects of this teaching. First and foremost, this has allowed an expansion of the total volume of nuclear power education. Because of this teaching, a team of five young professors has emanated, and suitable teaching material has been developed. This has opened new opportunities for other courses, targeting undergraduate education on nuclear engineering. Second, it has rapidly become popular among undergraduate students to follow these courses because of the unusual format. The students strongly appreciate the presence of industry personnel, because they benefit from their knowledge, and it makes the education feel more realistic. A common student complaint on undergraduate education is that it is poorly linked to industrial reality. Therefore, taking a course originally intended and designed for industry and where half the participants work in industry is perceived as an utterly positive experience.

5. Outlook

Sweden is a country with a small population on a relatively large area. This has to a considerable degree prompted the solution that courses within a relatively small subject, like advanced nuclear engineering, are organized in such a way that students and teachers meet full time during a relatively short period (one or a few study periods of 1-2 weeks each). With such an organisation, the education is already well suited for integration into a larger European perspective. The time and cost to travel is not dramatically different within Sweden and within Europe. Belgium has already re-organized its nuclear engineering education with a similar course structure, however for other reasons [8]. Moreover, in Belgium this has also been done for undergraduate education. Within ENEN [9], similar organisational changes have been undertaken in many European countries.

I believe it is possible that nuclear engineering education can increase both in popularity and quality, already in a short time perspective. Even if that happens, however, I do not foresee that this will lead to that industry can fill even half their vacant employment positions with well-educated nuclear engineers or doctors. Nuclear power is nowadays a mature technology, and in all mature technologies the required competence is primarily built by hiring people with general technology skills, followed by education for their particular duties through training programs. This has long been the situation in the paper and pulp industry, in forestry, mining, etc., i.e., mature industries. Because of this, training and education in industry is not likely to diminish even if the undergraduate education situation improves.

Sweden is such a small country that we simply cannot afford duplication in the long run. In this report, I have given a few examples of how synergy effects have been possible to achieve through cross-disciplinary activities during the last few years. I do not believe that all possibilities of collaboration for clever use of resources have been exhausted. On the contrary, I foresee increased synergetic activities. Last but not least, it should be stressed that efficient use of resources is not the only benefit that can be obtained through cross-disciplinary initiatives. Such approaches are also important because they have a potential to improve the quality. When people from various environments meet, new challenges and opportunities emanate, and this provides – more or less intrinsically – quality assurance.

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THE ESSENTIAL ELEMENTS OF AN ETTECTIVE EDUCATION AND TRAINING PROGRAM FOR NUCLEAR POWER PLANT SOFTWARE ENGINEERS

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ABSTRACT

It is realistic to start planning for training workforce for the imminent spurt in the growth of nuclear power generation capacity world-wide. In the U.S., the refurbishment of tens of existing plants; and design construction, and operation of at least thirty new power plants, will require the services of thousands of software engineers capable of handling tasks involving application of software in nuclear power industry. Software is critical for the operation of instrumentation and controls, nuclear reactors, safety systems, and many other key segments of a nuclear power plant. The next generation of software engineers must be familiar with the state-of-the-art processes for software engineering, quality assurance, standards, HCI, and software project management. This paper documents one of the first attempts to delegate a program for training software engineers with skills and competencies that map onto the application of software engineering in nuclear power plant design, construction, operation, and regulation.

1.0 Introduction and Background

1. 1 Nuclear Power and Software

In the list of major non-defense areas of concern for the U.S. and many other industrialized nations in the world, energy shortage ranks high. At this time, nuclear power (electricity) is rapidly becoming the preferred option for meeting the rapidly growing demand for electrical power. This phenomenon represents a paradigm shift in the U.S., where concerns about the safety of nuclear power plants (accentuated by the Three Mile Island accident, nearly twenty-eight years ago), and problems associated with the disposal/storage of used fuel, have resulted in no new nuclear plants coming on line during the last twenty-five years. Although about 25% of all nuclear power generating capacity in the world is located in the U.S., it accounts for only 15% of the total electricity generating capacity in this country. Therefore, even a doubling of this installed nuclear power generation capacity will keep the percentage of total electrical energy generated in the U.S. coming from nuclear power plants below 30% (compared with 62% in France). During the last few years, plans for the construction of thirty new nuclear power plants in the U.S. have been announced (1). Most of these plants will start generating electricity between 2015 and 2022. At the same time, a much larger number of new nuclear power plants are expected to become operational in other parts of the world, with China and India accounting for a major proportion of this total.

There have been very significant improvements in the design of nuclear reactor and, in most other components/systems in a nuclear plant during the last forty years. During the same time period, information technology that supports the instrumentation and control systems in these power plants has gone through several stages of increasing sophistication, complexity, and reliability. The most dramatic advances have occurred in software engineering, evidenced by the transition from: (i) analog to digital designs; (ii) text-based human computer interaction to Graphical User Interface (GUI) systems; (iii) traditional structured programming to Object-Oriented software designs; and (iv) stand-alone software to embedded software systems (2). Additionally, the classic development life cycle for software, which involved development and then maintenance, has been replaced by a process in which software undergoes modification to code and associated documentation due to a problem or the need for improvement or adaptation [ISO/IEC12207, 1995] (3). This change in the definition and process of software maintenance requires more direct involvement by user engineers, and utilization of Computer

Aided Systems Engineering (CASE) tools. Since the new concept of software maintenance requires regression testing of software being maintained, all previous test cases and results of these tests have to be retained as part of a “Configuration Management” repository (4).

1.2 Need for Training Nuclear Power Software Engineers

As stated earlier, the stagnation in the nuclear power industry in the U.S. during the last thirty years has created a situation in which nearly 40% of the 90,000 employees in this industry are expected to retire during the next five years. This attrition, coupled with the work force requirements for construction and operation of the planned new nuclear power plants during the next fifteen years, will create a need to add at least 80,000 trained professionals to the work force in this industry during the next fifteen years. Several thousand current workers in this industry will have to be retained to install and operate nuclear power plants incorporating new designs and operational protocols (5).

Although it is difficult to estimate the number of nuclear energy sector workers who will require training/re-training in the utilization of state-of-the-art software engineering techniques for maintenance of IT systems associated with the construction and operation of nuclear power plants, it would be realistic to assume that this is going to be a five digit number during the next fifteen years. This figure could be augmented significantly by professionals employed by foreign nuclear power companies who enroll in U.S. based software engineering training programs.

Currently, there are no academic programs in the U.S. for preparing software engineers for handling assignments associated with the utilization and maintenance of software in nuclear power plant design, construction, nuclear power plant construction project management, nuclear reactors, nuclear power plant simulators, and miscellaneous operational and regulatory tasks.

The required academic/training programs should be designed to expose the trainees to new software engineering processes/techniques, and the coverage of traditional computer science topics (programming languages, logic, etc.) should be somewhat limited (6) (7). Therefore, an effective program for training nuclear power software engineers should enable the trainees to: (i) acquire adequate knowledge of basic software engineering processes (e.g., Object-Oriented software engineering); (ii) IT application development life cycle (e.g., Rapid Application Development (RAD) methodology); (iii) IT Project Management Applications (e.g., MS Project, Primavera); and (iv) CASE tools utilization. Special emphasis must be placed on Information Security, in view of the terrorist threats aimed at nuclear power plants. The IT elements in the operation of nuclear power plants are among the most vulnerable terrorist targets. Therefore, nuclear power plant professionals need to become well prepared to identify and mitigate IT security related threats in nuclear power plants (8).

2.0 Overview of Software Engineering Skills Needed by IT Professionals in Nuclear Power Industry

A meaningful overview of software engineering skills needed by IT engineers in nuclear power industry should start with the identification of software applications in the design, construction, and operation of nuclear power plants. The next step should be the determination of skills that a professional must possess in order to handle the tasks associated with the creation, implementation, and maintenance/upgrading of these applications. An overview based on this methodology should provide a logical foundation for determining the curriculum/content of an appropriate academic/training program for software engineers in the nuclear power industry.

2.1 Software Applications in Nuclear Power Plants

The design, construction, and operation of a nuclear power plant are the three major segments of a major nuclear power plant project. Because of the unique nature of nuclear energy and serious concerns about safety of power plant workers and general public, safety and security are viewed as a critical element in the design, construction and operation of a nuclear power plant. Safety is so important that safety systems account for 25% of the capital cost of a typical nuclear reactor (9). During the last fifteen years, terrorist threats have made security of nuclear power plants a high priority consideration in the location and operational planning of nuclear power plants. Since most nuclear power plants are relatively well protected against physical attacks, there is a real possibility that terrorists will concentrate on the penetration/hacking of software systems embedded in the instrumentation and control systems for nuclear power plant operation, and electric power transmission (9) (10).

Considerations documented above, coupled with the standard practices associated with nuclear power projects, justify the following list of five relatively distinct application domains for software:

(1) Nuclear Power Plant Design (Reactor, Cooling Systems, Instrumentation and Control, Facilities, etc.)
(2) Nuclear Power Plant Safety (Reactor Safety, Radiation Safety, Hydraulic Systems, Mechanical Systems, etc.)
(3) Nuclear Power Plant Construction (Site Selection, Project Management, Logistics, etc.)
(4) Nuclear Power Plant Operations (General Operations, Fuel Storage, Waste Storage, Power Distribution, etc.)
(5) Nuclear Power Plant Security and Regulation (Physical Security, Cyber Security, Incident Reporting, etc.)

Each of the five application areas listed above can be broken down into tens of discrete or overlapping applications. Doing so would be beyond the scope of this presentation, but would be important when decisions concerning narrowly focused training and education programs are made. In this paper, it would be sufficient to identify the areas of learning and knowledge acquisition that are important for a software engineer in nuclear power industry. These five application areas provide a logical context for determining the learning objectives and skills that should be focused on by students/trainees being prepared for careers in software engineering within the nuclear power industry. Additionally, given the dynamic nature of information technology in general, and software engineering in particular, it is important to consider the state-of-the-art and related trends when we conceptualize and formulate a curriculum/training program to enhance/upgrade the skills of software engineers in this industry.

The rationale presented above leads to the following five knowledge/skill areas that should be covered by an education/training program for nuclear power plant software engineers.

(a) Software Modeling and Analysis (including Software Practice)
(b) Software Design (Including Verification and Validation)
(c) Software Evolution and Process
(d) Software Quality
(e) Software Project Management

Since these five learning/skill areas do not map directly onto the five application areas, it would be appropriate to display the correspondence between the application areas and knowledge/skill areas. This correspondence is displayed in Table 1. In the next section, an overview of a five course certificate program for training/educating nuclear power plant software engineers is presented.

Software Application Area	Software Modeling and Analysis	Software Design	Software Evolution and Process	Software Quality	Software Project Management
Nuclear Power Plant Design	***	*	*	*	*
Nuclear Power Plant Safety	***	***	***	***	
Nuclear Power Plant Construction	*				***
Nuclear Power Plant Operation	***	***	***	***	*
Nuclear Power Plant Security & Regulation	***	***	***	***	*

Software Engineering Knowledge/Skills

Legend: * Marginally Relevant
*** Very Relevent

Table: 1
Software Application Areas and
Software Engineering Knowledge/Skills

In the next section, an overview of a five course certificate program for training/educating nuclear power plant software engineers is presented.

3.0 Curriculum for Certificate Program for Nuclear Power Systems Software Engineers.

3.1 Learning Objectives

The list of software engineering knowledge/skills that are desirable for a nuclear power systems engineer to posses can be embedded in a set of five three semester credit hour courses leading to a certificate. These courses are:

(i) Modern Software Modeling and Analysis
(ii) State-of-the-art Techniques for Software Design
(iii) Software Evolution and Process
(iv) Software Quality Assurance
(v) Software Project Management

It is appropriate to mention that courses similar to those listed above are being currently taught at various institutions. However, the currency of these courses is often questionable, and unless all five courses are planned and developed as a set, there will be gaps in the spectrum of skills and competences that a successful nuclear power systems software engineer should possess. After acquiring this certificate, an individual should be able to: (i) determine client needs and convert them into software requirements; (ii) have an understanding of selected models and methodologies currently utilized for software design, development, testing, and implementation; (iii) design effective applications/solutions in the nuclear power systems domain, and implement them for the benefit of power plant operators; (iv) plan and manage significant software development projects, and (v) keep up with new models, processes, technologies and standards as they come into the public domain.

3.2 Summary Description of the Courses in the Proposed Set

(1) Modern Software Modeling and Analysis

- Modeling Foundations/Principles, and Types of Models (E-R Models, Object-Oriented Modeling, Business Process Modeling, etc.)

- Software Requirements Analysis
    - Fundamentals of Analysis (Robustness, Correctness, Quality, Traceability, etc.)
    - Requirements Analysis Considerations (System Boundaries, Scope Crawl and Requirements Management, Architecture Requirements Interaction, Stakeholder Involvement)
    - Requirements Specifications (Documentation, Languages UML, SCR, RSML, etc.)
    - Requirements Validation (Prototyping, Acceptance Testing)

(2) Software Design
- Design Concepts and Issues (Principles, Architecture, etc.)
- Architectural Design Styles (Layered, Transition-Centered, CSLA)
- Human Computer Interaction (User Centered HCI, Cognition, Visualization, Acceptability/Usability)
- Detailed Design/Design Tools/Evaluation (Component Design, Components System Interface, Design Metrics, etc.)
- Verification and Validation (V & V Strategy, Review and Testing HCI Evaluation, V & V Reporting/Follow up)

(3) Software Evolution and Process
- Software Evolution (Modeling, Asking, Planning, System/Process Re-engineering, Reverse Engineering, Refactoring)
- Software Process (Infrastructure, Personnel, Tools, Process Modeling/Measurements, Process Definitions, Life Cycle Models (SOLC, DSDM, RAD), Process Standards (ISO, CMM)

(4) Software Quality Assurance (SQA)
- SQA Concepts (Definitions, attributes, costs, dimensions)
- SQA Standards (ISO 9000 Series, ISO/IEEE12207 Standards)
- SQA Processes (Models/Metrics, ISO 15504 & EET-CMM Processes etc.)
- Quality Assurance (Planning, Techniques for Process Assurance)
- Product Assurance (Product Quality Models, defect tracing and prevention, product quality attributes and metrics)

(5) Software Project Management
- Management Concepts (PM Models, role, organizational structure)
- Project Planning (WBS, Scheduling, Resource Estimation/Allocation, Risk Management)
- Organization and Personnel (Structure, Communications, Staffing, Training, Management)
- Project Control (Monitoring/Reporting, Analysis/Correction, Change Management, Performance Standards)
- System Configuration Management (Revision Control, Release Management, CM Tools, CM Processes, Maintenance)

Variations of the suggested curriculum may be appropriate in the context of specific work situations and/or academic experience/background of the trainees.

4.0 Conclusions and Recommendations

The relative stagnation in the nuclear power industry in the U.S. during the last thirty years has created a work force situation which requires a well planned and urgent response. As explained in section 1.0, the quantum changes in nuclear power technology, and the ongoing and anticipated growth in nuclear power generation capacity during the next fifteen years could be impeded unless trained workforce is prepared to replace current workers and fill positions that will be created in the near future. Software engineering is a vital element in the design construction and operation of nuclear power plants. The nuclear reactor designs have gone through three or four generations of design changes in fifty years, but software engineering goes through similar changes in ten years. The instrumentation and control systems, reactor safety systems, and information systems in nuclear power plant operations are being transitioned from analog to digital technology. Similarly, very significant changes/improvements have been incorporated in human computer interaction systems in nuclear power systems. Therefore, it is critical to train a new generation of software engineers who can handle tasks in all facets of nuclear power plant design, construction, operation, and regulation.

It is recommended that a specialized training program/curriculum for nuclear power software engineers be developed and implemented. Given the fast pace of changes in nuclear power technology and software engineering processes, it is essential to focus the software engineering training on the applications of software in specific segments of nuclear power plant design, construction and operation. It is critical to ensure that the curriculum/content of the proposed education/training programs emphasize state-of-the-art knowledge and competencies. Additionally, the software engineering process should receive as much attention as specific software techniques. The trainees should become adequately aware of the applicable standards for software engineering, case tools, software quality assurance methodology, and software project management process. In view of the high level of concern about nuclear power plant safety and security, the software engineering training must cover cyber-security considerations, and safeguards against terrorist threats.

It is recommended that nuclear power industry consult professional organizations and institutions like ACM, IEEE, Software Engineering Institute (SEI), INPO, CONTE, and ANS in developing the curriculum for training software engineers for nuclear power industry. The set of five courses presented in section 3.2 of this paper is an example of such a curriculum. Since the need for training the next generation of software engineers is an important issue for nuclear power industry outside the U.S., organizations such as European Nuclear Society and its counterparts in Asia and Africa should also be co-opted in this effort. In view of the anticipated spurt in the growth of nuclear power generation capacity, the urgency of training a large number of software engineers for this industry cannot be over emphasized.

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FROM AN "OPERATORS TRAINING FACTORY" TO BECOMING THE SOURCE FOR NUCLEAR-POWER PROFESSIONALS

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ABSTRACT

Ten years ago Spain decided to provide full scope simulators for every Nuclear Power Plant.

Their start-up coincided with the Spanish NPP´s Generational Change and they are playing a very important role in the training process for the new employees who will be responsible for running the plants in the future.

Since 1984, when the Spanish Government declared a nuclear moratorium, the number of students who decide to study Nuclear Engineering has declined.

In fact, some of these degrees are no longer available at several Spanish Universities. Therefore, when the Spanish Nuclear-Power Industry needs Technicians to work at its companies it faces a lack of young people with the necessary knowledge in this field.

This industry has turned to TECNATOM which had been playing the role of an "Operators Training Factory" and has now used its experience to turn electrical, mechanical, instrumentation and other specialized engineers into nuclear experts using the full scope simulators and other training tools.

1. Introduction

1.1 Spanish Nuclear Power Plants

Nowadays, Spain has eight nuclear reactors producing electricity in six different sites with a total power of 7727 Electric Megawatts (1).

Seven of these plants were started up in the eighties and they were deployed across the Spanish geography, from North to South and from East to West.

Nuclear Generation is a very important Energy Source in Spain and represents 9.09% of the installed power but 18% of the average power supply (2).

All the plants are working full power all year round and only stop once every twelve or eighteen months for refuelling shut down.

Fig.2 Spanish Nuclear Power Plants

NPP	Mw	YEAR
ALMARAZ-1	977	1981
ALMARAZ-2	980	1983
TRILLO	1066	1988
ASCÓ-1	1032	1983
ASCÓ-2	1027	1985
VANDELLÓS	1087	1988
COFRENTES	1092	1984
STA. Mª. GAROÑA	466	1971
TOTAL	7727	

Fig.1 Spanish Nuclear Power Plants Information

1.2 Industrial Environment and other circumstances

If we try to define the Industrial Environment it is easy to come across with adjectives like uncertain, complex, stormy, global,… and everybody agrees that it is under constant ongoing changes.

The Nuclear Industry is part from today's reality and it is exposed to the same circumstances: organizational leaves, internal promotions, organizational changes, competition, acquisitions and mergers.

In addition to the previous statement seven of the Spanish Nuclear Power Plants were started up in the eighties and currently are undergoing their generational change.

When companies try to recruit professionals with a vast training in these technologies, they realise that there are not enough graduates with this skill, because the number of students who decided to study Nuclear Engineering began to drop when the Spanish Government declared the nuclear moratorium.

A lot of the students decide to study energy disciplines because their interest in green energies, as a consequence of their important advertising campaigns, and not because they do not want to work in the nuclear industry as some time ago.

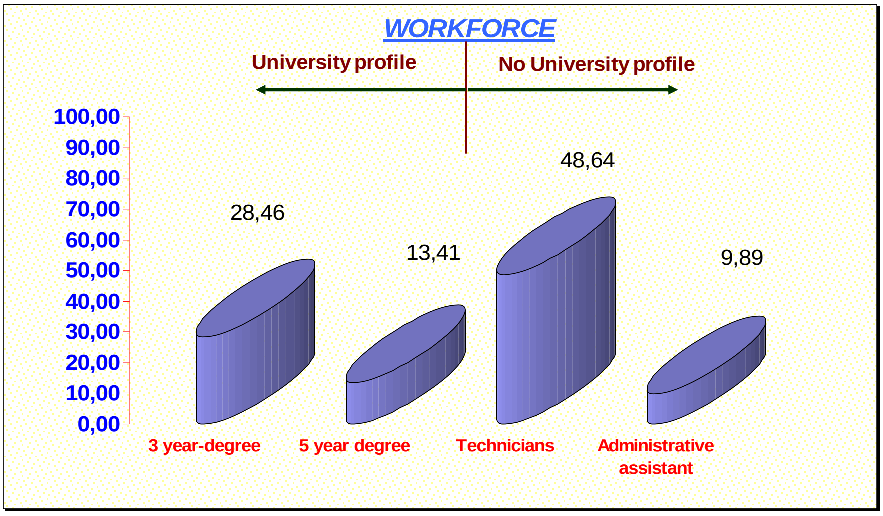

Fig.3 University Profiles in NPP´s

Furthermore, Nuclear Power Plants are located far from the main cities and graduates around 27 years old do not like to move to small villages where there are not a lot of social activities or it could even be very difficult for couples to find a job as a result of the lower industrial activity.

Moreover, 42% of the workforces are graduates, and the plants demand two different degree profiles to cover their job vacancies, three-year degree profiles or five-year degree profiles.

63% of these graduated workers have three-year university degree, which means 13.41% of the workforce (fig.3).

There is not three year-degree in Spain with any nuclear studies. Thus, these new employees must be trained in these technologies before they begin to work.

Besides that, the utilities need qualified professionals from diverse disciplines such as instrumentation, mechanical, electrical… and in their university program of studies nuclear technologies is not included.

It is fitting to point out the fact that in 2007 the Spanish Regulatory Body (Consejo de Seguridad Nuclear-CSN-) published a compulsory rule requiring the plant to have a training program for its personnel. The CSN demands to carry out these programs before working in the plant.

2. How to Transfer Knowledge In the Face of Generational Change

There are a lot of definitions for Managing Knowledge.

Managing Knowledge means to deal with creation, development, diffusion and squeezing knowledge to get organizational capability (3).

Tecnatom has been involved in this process since 1999 when the Spanish NPP Generational Change began, acquiring experience in this field.

The first aim in transferring knowledge is to employ those university graduates who are going to run the plant in the future. The problem is how to make this industry appealing to this new generation taking into account the situation focus on section 1.2.

At this point, the companies have to make their projects attractive to these new employees by providing more possibilities to develop their professional skills, as well as better career development and professional growth possibilities.

They must create a pleasant working environment that will allow them to develop and improve their professional and human skills, moves on innovation, encouraging the participation and fostering learning and team work

Managers should provide their employees key to success by modelling and giving support, looking for the balance between demand and delegation.

And of course this industry has to pay an additional amount to this new employee’s just to assure their loyalty and prevent them from attrition.

Organizational knowledge is a mixture of knowledge and skills. To manage means to deal with and take advantage of it. The Company has to provide the necessary training to perform their job.

Fig.4 Training course in Tecnatom

Knowledge Management is a combination of explicit knowledge and the learned tacit experience of the Master Workers.

The simulators shorten the learning period and make it possible to turn explicit knowledge into tacit knowledge, thereby helping students to become acquainted with this tacit knowledge by using the simulator (4).

Tecnatom is the Spanish Operator's Training Centre, "*Operators Training Factory*", whose mission is to train the operating personnel of the Nuclear Power Plants in technology, knowledge of processes and understanding of their technological fundamentals as well as the development of skills and diagnostic capabilities via practical scenarios on simulators and on the job training. Additionally safety performance is reinforced through soft skills training programs. Its training programs are based on Tecnatom's own Systematic Approach to Training methodology (SAT/ESC), which has been implemented in domestic and foreign plants.

Tecnatom's experience makes Tecnatom attractive to collaborate with the plants in this Generational Change.

Tecnatom has the knowledge to provide customized training for the new employees and the tools for improving a gradual and constant learning assimilation through simulators. Tecnatom "*has become the source for nuclear-power professionals*".

3. The Source for Nuclear-Power Professionals

The Spanish Nuclear industry has turned to TECNATOM which has been playing the role of an "Operators Training Factory", to use its experience to turn electrical, mechanical, instrumentation and other specialized engineers and skilled workers into nuclear experts by using the full scope simulators and other training tools such as workshops and labs.

TRAINEES	
RO/SRO (Licences)	150
FIVE-YEAR DEGREE	150
THREE-YEAR DEGREE	58
SKILLED WORKERS	90
TOTAL	**448**

Fig.5 New students trained in Tecnatom since 1999

During these years Tecnatom has managed engineering training programs by analysing, designing, developing, implementing, and evaluating all the process by means of application of the Training Manual associated to every job position.

Tecnatom also welcomes students from many universities in addition to engineering, such as biology, psychology, law, education, business, mathematics, physics, and chemistry to provide personnel for all the Organization Levels in the plants.

Nowadays we are using simulators not only to train Control Room Operators, but Non-License Personnel. Although this was not the original simulators goal, it makes it easier:

- To understand how the reactor works
- To become familiar with I&C aspects
- To broaden their knowledge in systems
- To know the lay-out of the plant
- To become familiar with emergency preparedness and response procedures
- To assimilate the importance of plant shut down and start up and other critical plant conditions.

Simulators also help to develop Soft-Skills like:

- Preventive human error techniques
- Effective Communication
- Team working
- Conservative decision making
- Leadership
- Safety Culture

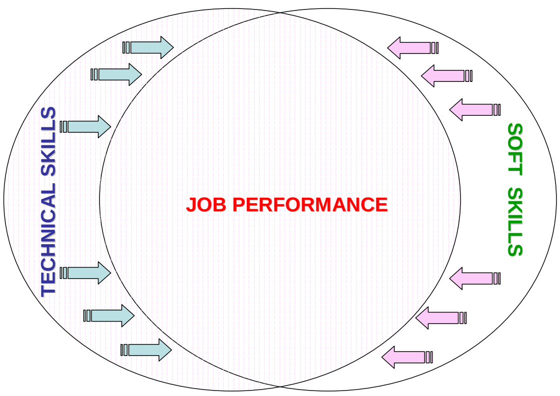

Fig.6 Job Performance

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ENS et 2008
CONFERENCE AREVA TA – CORYS TESS

«VOCATIONAL TRAINING DESIGNED AND IMPLEMENTED BY AREVA TA AND CORYS TESS FOR NUCLEAR INDUSTRY »

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1 AREVA TA AND CORYS TESS PRESENTATIONS

1.1 PRESENTATION OF AREVA TA AND ITS TRAINING ACTIVITIES

The business unit AREVA TA is composed of 2300 people ; its core business activities in nuclear energy is :

- Design of french naval propulsion reactors and land-based prototypes.
- Engineering of a new experimental reactor (Jules HOROWITZ Reactor).
- Production and manufacturing activities :
  - Operating and maintaining nuclear facilities (reactors, fuel storage pools, other facilities).
  - Constructing a power test reactor (RES).
  - Manufacturing fuel for naval propulsion reactors and land-based prototypes.
  - Realising nuclear tests, especially on AZUR research reactor.
  - Qualifying and upgrading nuclear reactor components.
  - Conditioning fuel for dry storage.

The AREVA TA Training Centre has a staff of 22 permanent persons and provides vocational training in its two locations in the south of France, in Aix en Provence and within the Cadarache Nuclear Centre.
The Training Centre implements training sessions on sites, in different countries, and organises catalogue training as well as sessions that meet specific client needs.

Our main training themes are:

- Nuclear engineering and operation and related technologies.
- Training on research reactors and/or simulators (jointly with CORYS TESS).
- Nuclear safety and safety culture.
- Risk prevention.
- Complex systems engineering.
- Project management.
- Nuclear propulsion.

Our main clients are :
France : French Navy, EDF, AREVA NP, AREVA Group, French Atomic Energy Commission (CEA), Nuclear Safety and Radiological Protection Institute (IRSN), AREVA and CEA subcontractors.

Foreign countries : SCK CEN, SUEZ Group (Belgium) - IAEA (Lithuania) - Russian shipyards and institutes (Russia) – CNESTEN (Morocco) - NWU, NECSA (South Africa)

Training session using a research reactor

1.2 PRESENTATION OF CORYS TESS AND ITS TRAINING ACTIVITIES

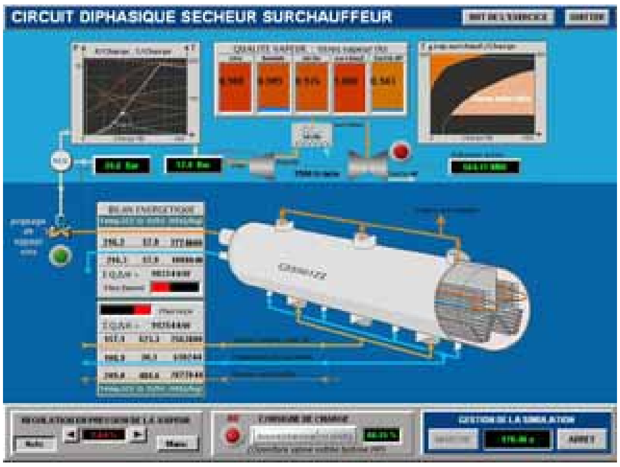
Spin-off of the CEA (French Atomic Energy Commission), CORYS TESS is specialised in the design and production of simulators for training and engineering studies in the power industry and transport sectors.

CORYS TESS is composed of more than 230 engineers, technicians and experts and is organised in multidisciplinary teams : physicists, modelling specialists, software developers, ergonomists, trainers, graphic designers, …

CORYS TESS is a world leader in the design and production of simulators; over 450 simulators are installed in 25 countries on all continents. CORYS TESS has a large know-how acquired in the fields of nuclear, thermal and electric power, and rail transport.

CORYS TESS has from the outset provided training services in the nuclear field, involving sessions on simulators and reactors. CORYS TESS is able to optimise the customer's training systems by integrating multimedia training tools used locally or from distance.

French EPR engineering and full-scope training simulator (under construction)



Example of multimedia training tools

1.3 AREVA TA AND CORYS TESS TRAINING TEAM

The prime objective of nuclear electrical power producers is to take great care of maximum human safety while securing the best possible availability of their facilities, increasing equipment durability and minimising environmental impact.
In addition, the rapidly changing business environment requires more and more flexibility from the personnel as, in one way or another, the working environment is constantly adapted to the evolving needs.

As a result, CORYS T.E.S.S. and AREVA TA have decided to set-up commonly the organisation of a training centre for the energy industry. This consists in the delivery of an integrated training management system where the requirement to offer a procedural training ("do what you are supposed to do") is obviously addressed but completed with knowledge based training ("understand what you are doing").
CORYS T.E.S.S. and AREVA TA propose products and services for energy industry training integrated in a unique concise training system, including distant learning software, simulation, CBT, training development, training support and training delivery on various tools including actual research reactors, and simulators.

CORYS T.E.S.S. and AREVA TA have both a huge experience in the field of training plans for nuclear facilities' staff.
For more than twenty years, CORYS T.E.S.S. has used SILOETTE, a pool reactor located at CEA Grenoble for training power plant staff (EDF control operators and loading supervisors) as well as research reactor

staff from various facilities (Marcoule's PHENIX, Saclay's OSIRIS, Cadarches's EOLE-MINERVE in France, Mol's BR2 in Belgium or Petten in the Netherlands).
AREVA TA has used AZUR at Cadarache for training Framatome (AREVA NP) and EDF operating and test engineers under long-term contracts (pluri-annual), for the start of the French electricity producing nuclear program, and to train operating teams for reactors operated by AREVA TA. On another hand, AREVA TA has been training more than 4500 seamen over the last 40 years in the management and maintenance of naval propulsion reactors. Up until 1990, this training course used the Land-based Prototype (PAT) which was, for training, followed by the New Generation Reactor (RNG) and the research reactor (AZUR).

2 NUCLEAR TRAINING CONTEXT IN EUROPE

Among the needs in vocational training in Europe, the following two main themes are in very close relation with the nuclear renaissance.

2.1 BASIC TRAINING FOR (NEW) ENGINEERS WITHOUT NUCLEAR BAKGROUND AND WORKING ON NUCLEAR ACTIVITIES

There is a strong need for high level training of young specialists in the nuclear sector.
This is due to the combination of the ageing of the actual manpower and the starting of nuclear renaissance. It is critical to maintain the safety and efficiency of the existing nuclear installations and to build and prepare the development of the next generations of facilities. Well designed training is therefore necessary, allowing the handling of the technical challenges with safety assurances.

2.2 SAFETY CULTURE FO ALL PERSONNAL WORKING ON NUCLEAR ACTIVITIES

Nuclear Safety Culture is a topic of paramount importance for all nuclear operators as well as for all operators of installations dedicated to radiology and radioteraphy. Besides the operators, it concerns also the regulators and related support organisations. Its efficient practice is an absolute must in Europe and in the world for the extension in life and possible redeployment of the nuclear power plants, for the production and transport of fissile materials and radioisotopes, and for research activities related to the above and to fusion.

The Safety Culture dissemination contributes to harmonisation according to high standards, and promote the mutual recognition of good practices and behaviours throughout Europe.

3 VOCATIONAL TRAINING DESIGNED AND IMPLENTED BY AREVA TA AND CORYS TESS

3.1 PARTICIPATION OF CORYS TESS AND AREVA TA TO SUEZ NUCLEAR TRAINEES PROGRAM

The SUEZ Group has organized a very important training program for their newcomers (SNTP, acronym for Suez Nuclear Training Program). CORYS TESS and AREVA TA participate in this program.

CORYS TESS has in charge the PWR course which is organised on 7 days. This course is done within SUEZ Company and more than 80 trainees are concerned for 2008. A second track is planned for 2009.

This course is interspersed approximately in a middle of the SNTP program and allows :

- Understand how physical phenomena are involved in PWR operation
- Understand (and explain) PWR control

The following table sets the detail of this program :

<table>
<tr><th>Day No.1</th><th>Day No.2</th><th>Day No.3</th><th>Day No.4</th><th>Day No.5</th><th>Day No.6</th><th>Day No.7</th></tr>
<tr><td>Opening</td><td>RHRS-CCWS</td><td>Operating limits and conditions</td><td>Neutronics and Reactor physics</td><td rowspan="2">Power operations</td><td rowspan="2">Power operations</td><td>Engineered safeguards systems</td></tr>
<tr><td>Secondary loop</td><td>CVCS</td><td>Neutronics and Reactor physics</td><td>Power interaction</td><td>Turbine trip unit operations</td></tr>
<tr><td rowspan="2">Steam Generator
PZR
Main Coolant Pumps</td><td>CVCS</td><td rowspan="2">Neutronics and Reactor physics</td><td rowspan="2">PWR main control channels</td><td rowspan="2">Power operations</td><td rowspan="2">Power operations</td><td>Final assessment</td></tr>
<tr><td>Operating limits and conditions</td><td>Session closure</td></tr>
</table>

This course is organized both with classic classroom training (in yellow on the program) for the theoretical part and with principles based simulators for the practical part (in blue on the program).

For this training, CORYS TESS installs several simulators on client's standard PC's. In this way, the trainees can work in pair for the practical part of the program.

AREVA TA has designed and developed and currently implements the "Waste management" and "Radiation protection" modules. This course is done in the first part of the SNTP program.

3.2 SAFETY CULTURE TRAINING DESIGNED AND IMPLEMENTED BY AREVA TA

Since 1994 AREVA designs develops and implements Nuclear Safety Culture training sessions for the AREVA TA personnel (operation and engineering) with the following characteristics.

NUCLEAR SAFETY CULTURE - Type program

AIMS **The course aims to build awarness of the importance of nuclear safety on a daily basis :** ◆ Achieve a better understanding of the implications related to commitments made, ◆ Exchange experience based on real-life situations, ◆ Identify targets for improving safety	**METHODS** ◆ Interactive discussions ◆ Study of real cases ◆ Group work (exchanging experience) **TRAINEES** **Engineers and technicians involved in safety, in charge of achieving and maintaining nuclear safety in engineering and operations**
PROGRAM ◆ How nuclear safety is organised, knowing what's at stake ◆ Making commitments in terms of nuclear safety, ◆ Discovering targets for improvement, communication and solidarity **Practical aspects** ◆ Developing a questioning attitude ◆ Drawing up and using procedures ◆ Providing and using feedback ◆ Developing an efficient communication	**SPEAKERS** **Engineers with an excellent knowledge of the different areas of nuclear safety and who have received a specific "training of trainers"** **Number of participants : 8 to 14 per session** **Duration : 2 days**

For many years, AREVA TA realises specific training sessions for different clients :
AREVA NP Services: “culture safety” training including, “nuclear safety culture” and “security culture”.
SUEZ Group: “nuclear safety culture” including the specificities of the country, of the company, of the NPP.

Our training scheme objective:
To train personnel in understanding and controlling nuclear and conventional risks in accordance with environmental requirements.
Our objective is in line with the commitments made under the AREVA nuclear safety charter and the TA nuclear safety plan.
These commitments are anchored in our organisational principles and are completely transparent. They build on a safety culture shared by all personnel (AREVA TA and subcontractors) and continually maintained by periodic refresher training.
They are implemented through safety health and environmental management systems.

4 TRAINING TOOLS AND EXPECTED EVOLUTIONS

Significant experience is required to develop or adapt materials that transmit clear, accurate, and easily understood information to trainees.

- ***Written materials:*** Written materials should contain practical examples, exercises, and necessary numerical data.

- ***Audio-visual media:*** A number of audio-visual media are used in training programs, including films, videotapes and videodiscs as well as slides. The advantage of these materials is the ability to transmit information which would otherwise be difficult to describe by oral presentation.

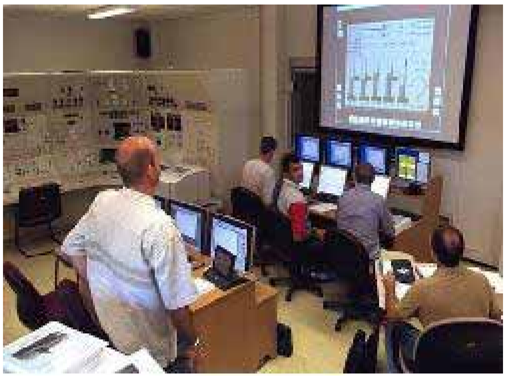
- ***Models and mock-ups:*** Models are used to supplement classroom training, and mock-ups have proven valuable in developing some practical skills, scale models with cutaway sections are used in training for some complex components.

Radiation protection training installations

Hydraulic test facility

- ***Computer-based training:*** The purpose of CBT is to provide continual and consistent training for personnel. The combination of classroom lessons and self-paced, individualized instruction permits training at times convenient to the trainee's work schedules.

- ***Simulators:*** The staff-training objectives that have to be positively met are multiple: to better operate the systems, to increase the safety, to anticipate the incidents and reduce the risks of faulty manoeuvres and to manage efficiently the emergency situations. The training of the operators to extreme behaviours of the system appears therefore more and more as a necessity, and towards this, simulators are the most obvious and most efficient means.



Naval Nuclear Propulsion Simulator

Basic Principles PWR Simulator

- ***Research Reactors:*** They provide an essential practical approach, on the nuclear facilities, to the physical phenomena of reactors. Performing operations on an actual reactor is an irreplaceable experience in an education plan. It allows federating complex theoretical knowledge with practical common sense. It also permits confirmed operators to ask and answer the questions that routine often hides.

All of these different training tools can be developed and operated by AREVA TA and CORYS TESS.

Thanks to the latest computing technologies, the use of simulation as a support of training activities may be generalised, either in "training-centre" configurations or on a stand-alone, mobile basis, thus allowing to face the new training needs of nuclear field.

USE OF REAL-TIME, MODEL-DRIVEN 3D VIRTUAL REALITY SIMULATIONS FOR NUCLEAR PLANT OPERATOR TRAINING AND FAMILIARISATION.

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ABSTRACT

The use of fully interactive 3DVR simulations driven by high-fidelity nuclear plant models allows significant cost savings over the use of physical equipment to achieve required training targets. Changed training requirements due to nuclear plant modifications and operational feedback can be much more readily and cheaply accommodated by changes in simulation software, rather than physical changes in a hardware-based training solution. A high-fidelity interactive 3DVR training solution has been developed by L3 to provide operator procedural training and equipment familiarisation for a complex nuclear safety-related system on the next generation of Royal Navy Astute Class Attack Nuclear Submarines. The generic 3DVR simulation technologies developed and implemented by L3 have applicability not only in the training of submarine crews but also in the much wider arena of nuclear training and nuclear plant familiarisation. In principle any nuclear plant system or subsystem could be emulated virtually and subsequently coupled to a real-time simulation model.

1. Introduction.

Comprehensive and detailed equipment maintenance training forms an important part of the safe operation of any technically complex plant, aviation [1,3] and nuclear systems [2] being an obvious example of this requirement. There are a number of current approaches to providing maintenance training to plant engineers over a wide range of engineering disciplines. The first and most obvious approach is to have a physical 'off-line' copy of the equipment to be maintained, which can be dismantled and reassembled as required within the boundaries of maintaining passive equipment – i.e. equipment which does not have any complex functional interactivity with other plant systems, a pump, or motor, for example. For more complex, dynamic equipment, and particularly those plant systems with safety and monitoring implications, such a passive maintenance approach is unsatisfactory, and a more sophisticated level of operator/engineer training interaction is required. This again can be satisfied by having a physical copy of the system to be maintained. However, using a complex system for training purposes implies the need for some form of simulation to accurately model/drive the behaviour so that the correct operator/engineer responses to any maintenance procedures can be quantified and assessed as the procedure is implemented. This approach avoids the need to physically replicate the entire plant of which the system is a part, but still involves the cost of having physical control panels.

The third approach, and the one that forms the basis of this paper, involves the use of a virtual 3-D simulation environment. This avoids the use of physical equipment, which has obvious advantages from the point of view of changed training requirements or equipment upgrades based on new technologies. The cost savings and safety aspects of such an approach are obvious, as is the relative ease, compared to physical equipment, with which the training environment can be modified and/or upgraded. The 3DVR training and simulation methodologies developed by L3 have currently been implemented for one submarine nuclear-safety related subsystem. However, the simulation techniques are sufficiently generic to be applicable to not only the training of submarine maintenance engineers but also to the much wider arena of nuclear training and nuclear plant familiarisation. The security-sensitive nature of the subject material related to this particular training simulation implies that there will be no in-depth discussion of the systems functional details. However, enough of the global simulation architecture and methodology can be described to at least give some appreciation of the approach used.

2. Simulation System Description.

For the purposes of this paper, the system of interest comprises a highly complex Reactor Control and Instrumentation (RC+I) system, coupled to a high-fidelity model of the associated submarine systems. This in turn is coupled to an interactive 3-D, pictorially accurate representation (exactly as seen on the boat) of the instrumentation cubicles. The graphical representation of the instrumentation cubicles has identical functionality to that on the boat, so operations performed on the individual components, switches, circuit boards etc. on the 3DVR components will have effects identical to those that would be observed on the boat if the same operations were performed on the real equipment. Figure 1 below gives a detailed overview of how the individual components of the simulation interact with each other. The numbered (1 to 12) system components in Figure 1 below are those that comprise/interact with the 3DVR RC+I trainer. The RC+I simulation is a functional enhancement of the whole boat Manoeuvring Room Trainer (MRT) simulation, which is an exact physical replica of the operator control panels in the boat control room, coupled to a high-fidelity simulation model.

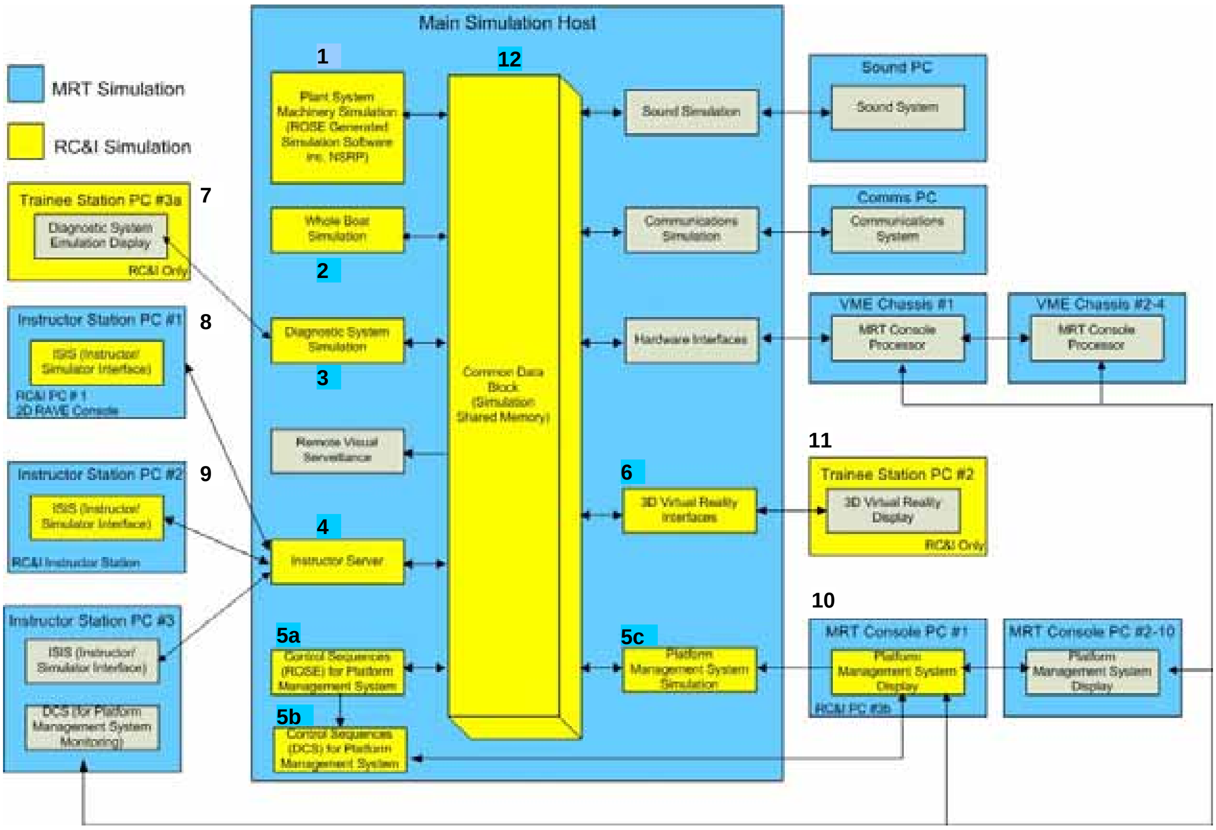

Figure 1 – Detailed overview of simulation model components.

The main simulation host is comprised of several components. The first is the mathematical simulation model of the boat systems. This is the 'Plant System Machinery Simulation' (1) above. This encompasses the reactor model, primary and secondary systems as well as other boat systems - mechanical, electromechanical, hydraulic, control and instrumentation. Also modelled in complete functional detail are the automatic protection (guardline) logic and associated control and instrumentation systems. The 'Whole Boat Simulation' (2) denotes the hydrodynamic aspects of the boat simulation. The 'Diagnostic System Simulation' (3), and 'Diagnostic System Emulation Display' (7) are an integral part of the 3DVR training solution and work synergistically with the operations performed by the trainee on the interactive 3D instrumentation cabinets. The 'Instructor Server' (4) is simply an interface for the Instructor Operator Stations (8) and (9), from where the entire training session is co-ordinated. Sections 5a, 5b and 5c are concerned with the Platform Management System, or PMS, which is a complex control and monitoring software package which has very significant global control and display functionality on the boat. This interfaces with (10), the PMS display terminal, which is also an integral part of the 3DVR solution. Sections (6) and (11) comprise the 3DVR interface, which will be described in more detail later. Finally, section (12), the Common Data Block, or CDB, is the simulation datapool.

3. Interactive 3D interface.

The interactive 3D trainee interface with the detailed simulation model is composed of a number of component subsystems. The first and most important subsystem is the instrumentation cabinet 3D mimic. This is derived from a number of sources, as outlined in Figure 2 below.

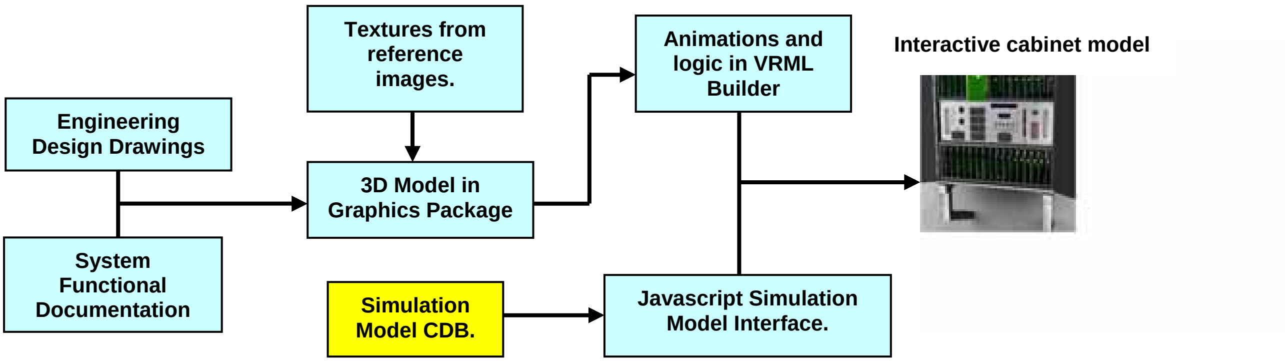

Figure 2 – Construction of interactive 3DVR instrumentation cabinet

Communication of the interactive 3D cabinet with the simulation CDB is based on a client-server architecture (Figure 3), the cabinet being accessed via a web browser.

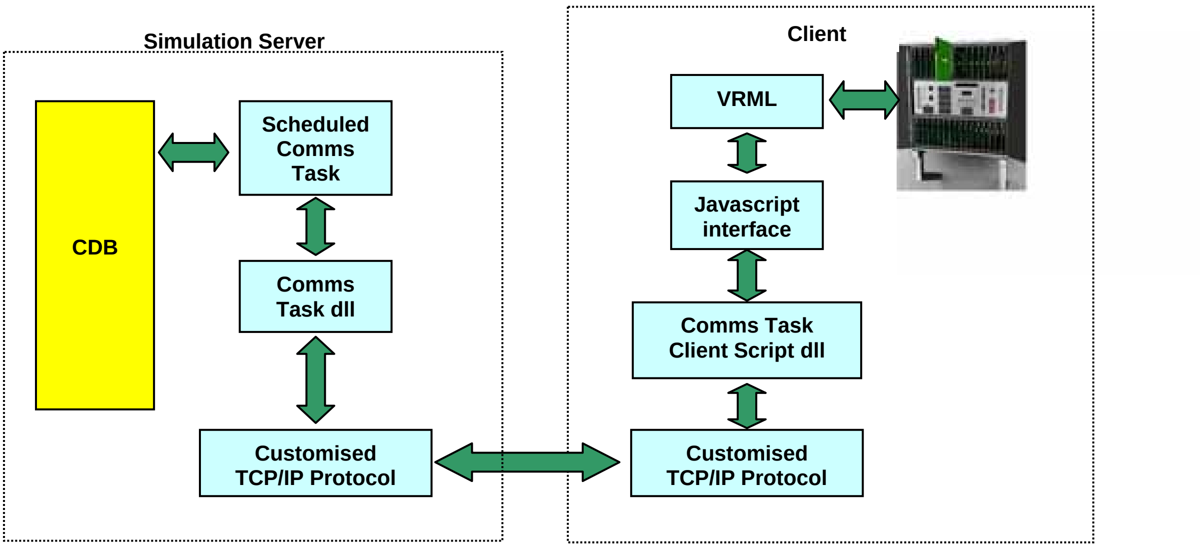

Figure 3 – Client-server communications for 3DVR instrumentation cabinet.

4 Training Requirements - Active Maintenance Training

The RC+I trainer is active in the sense that a sophisticated physics-based and engineering-based simulation model lies behind the 3DVR interface, and provides identical functionality to the interface as would occur on the boat. The majority of the processing logic for control and Instrumentation systems that regulate and monitor the reactor plant are housed in a number of instrumentation cubicles. The electronic modules which comprise these systems can exhibit faulty behaviour and the maintenance engineer is typically required to diagnose the fault(s), carry out repair by replacing the defective component and then bring the systems back on-line without adversely affecting the plant state. A typical training scenario using the 3DVR trainer is outlined below.

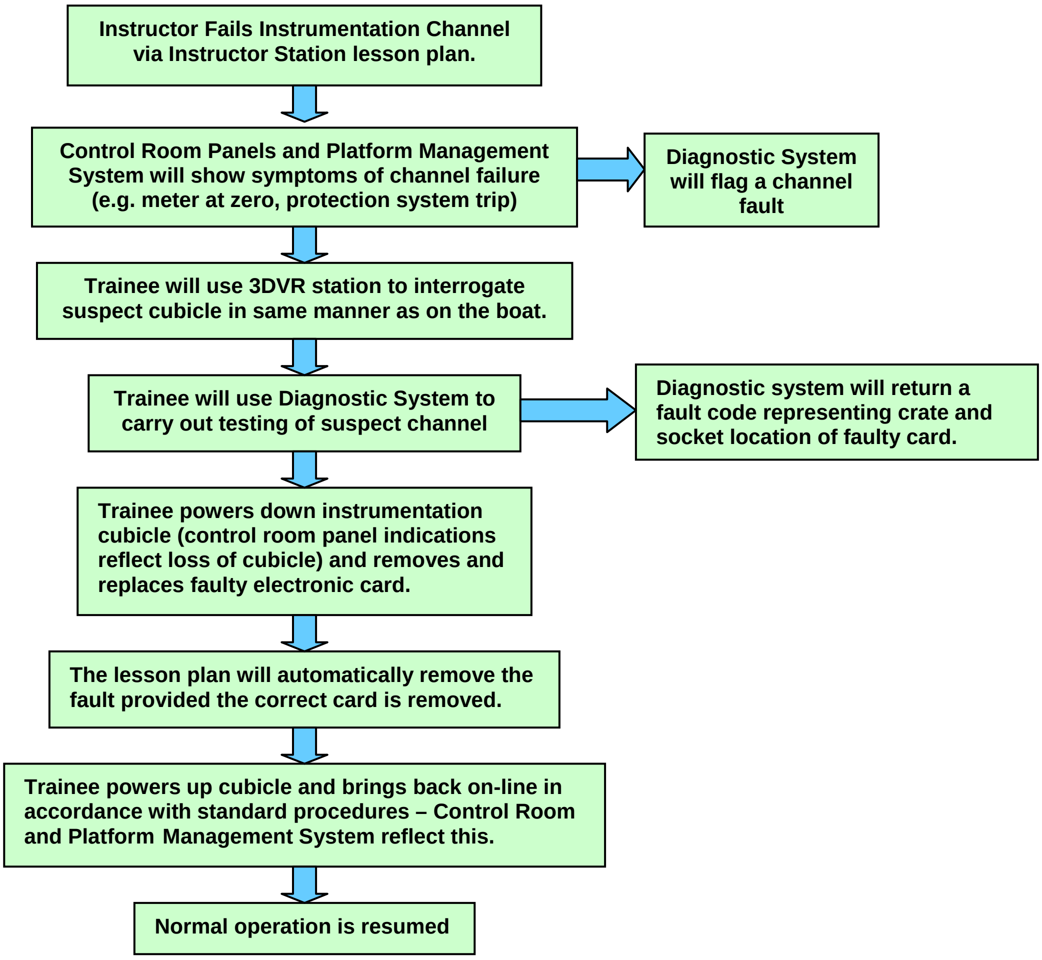

Figure 4 - Typical training operations sequence using the 3DVR trainer

Initiation of the training scenario is automated by use of a lesson plan functionality in the Instructor Operating station. This allows lesson-driven modification of any of the simulation parameters, giving complete flexibility over the construction of any training scenario.

5 Training Requirements – Maintenance Training (Subsidiary systems)

Part of the RC&I solution are offline maintenance workstations which contain high fidelity 3DVR models of various systems on the boat. These systems provide either control, monitoring and/or safety functions. Training functionality is again based on full operator interactivity with an accurate engineering-based, 3D model which can be manipulated (virtually) in exactly the same manner as the real equipment. Demonstration, training, and assessment modes are available for the trainee. A text-to-speech facility gives verbal instructions to the trainee based exactly on the wording and structure of the boat SOPs. The demonstration mode allows simple observation of correct procedures, with verbal commentary based around correct operational procedures; the 3DVR will animate each part of the procedure in sequence with the commentary. The training mode allows the trainee to perform the maintenance procedure without verbal cues. Each 3D model contains various sensors which once enabled by touch, allow the trainee to dismantle and carry out maintenance.
Finally the assessment mode, timed if necessary, monitors the trainee's progress through the SOP providing an accurate assessment of whatever skills and knowledge has been acquired by the trainee from the demonstration and training modes.

6. Summary

The automated lesson-driven instructor toolset allows much greater flexibility in terms of dynamic fault injection and adds to the sense of realism regarding the system behaviour. The solutions and methodologies implemented in this particular training solution have obvious applicability to conventional plant nuclear maintenance training, as well as nuclear plant familiarisation. It is the intention of L3 to fully explore the exciting possibilities afforded by this 3DVR training design approach for several nuclear plant types, both existing and proposed.

7. Conclusions

- The use of a 3DVR model of submarine nuclear-safety instrumentation platforms driven by a high-fidelity real-time simulation has allowed significant cost savings and increased training flexibility compared to the use of a physical copy of the equipment.
- The interaction of the trainee with the virtual trainer is enhanced by the existence of the full-boat simulation underlying the 3DVR solution, which again, increases the sense of functional realism from a training efficacy perspective.
- Ease of modification of the training environment due to operational feedback from boat operations or changed/upgraded equipment can be readily accommodated in the current solution, at significantly less cost than would be the case with more traditional hardware-based training implementations.
- In principle any nuclear plant system or subsystem could be emulated virtually and subsequently coupled to a real-time simulation model.

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A SUGGESETION TO DEVELOP SUSTAINABLE HUMAN RESOURCES FOR RADIOACTIVE WASTE DISPOSAL PROGRAM IN JAPAN

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ABSTRACT

In Japan, needs of human resources for radioactive waste disposal program are expanding with the progress of the program. On the other hand, available human resources have been shrinking due to recent market-oriented principles even in universities as well as industries. Especially in Japan, diminishing human resources are decentralized in more than one implementing body and research organization. To solve this situation and secure sustainable human resources, a suggestion is made from wide discussions by the members from the organizations concerned, such as the implementing bodies, universities, research organizations.

1. Introduction

In Japan, needs of human resources for radioactive waste disposal program are expanding with development of the third generation low level radioactive waste disposal program of JNFL (Japan Nuclear Fuel Limited) and the siting activities for geologic repository of NUMO (Nuclear Waste Management Organization of Japan). On the other hand, human resources have been shrinking in the research organizations such as JAEA (Japan Nuclear Energy Agency) which had large resources at the research and development stage of the program. Recent market-based principles would not allow universities as well as industries concerned to nurture and secure sufficient human resources for the program. Especially in Japan, diminishing human resources are decentralized in more than one implementing body and research organization. To solve this situation to obtain sustainably human resources for the program in Japan, a suggestion is made from wide discussions by the members from the organizations concerned, such as the implementing bodies, universities, electric power company, research organizations and the regulatory organization.

2. Flow of discussions

Preliminary discussions were conducted in 2002 and 2003 to conclude a basic view of human resource development for geological repository program [1]. On the basis of this conclusion, wide discussions were conducted in 2005 and 2006 by the members from the organizations concerned. Flow of the discussions is shown in Fig.1. This paper introduces some parts of the whole discussions.

3. Features of human resource development for radioactive waste disposal program

Human resource development for radioactive waste disposal program contains some common and uncommon features to those for nuclear power programs in quantities and qualities. As a first step, features of human resource development for the program were perceived;

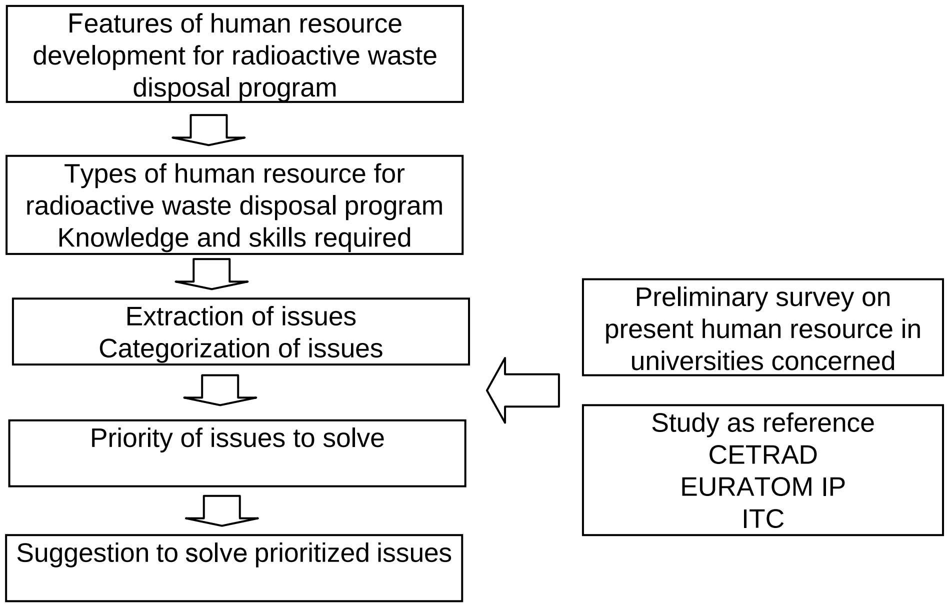

Fig.1 Flow of discussions

- Very long time span of the program requires human resources to create up-to-date knowledge and technologies and definite transfer of the knowledge from one generation to succeeding generations.
- Multiple realms of the program require human resources who have multidisciplinary knowledge.
- Uncertainties in the schedule of the program need a flexible framework for human resource development.
- Public trust essential for the program would be obtained through the safety regulation sectors. For this, sufficient capable human resources need to be secured in these sectors from early stage of the program.
- Technical information would be concentrated in the implementing bodies in the advanced stage of the program. This asymmetry in the information would cause some difficulties in human resource development of the other organizations.
- In Japan, the human resources are decentralized in more than one implementing body and research organization.

4. Types of human resources

In the process of the program, different sectors require human resources with various abilities to perform their own functions. These human resources are categorized into the following types. Suitable procedures for the development of each type were discussed in [1].

- Core human resources; they have broad and profound multidisciplinary knowledge on the disposal to act as key person in each sector. They are responsible for passing the whole knowledge on the program to the next generation. Numbers required are very small, between 10 and 20 for all sectors in Japan, but not sufficient now.
- Practical human resources; they have some specialties required to practice the program, such as civil engineering, mechanical engineering, nuclear engineering, and geology (defined as I-type human resource). They will perform various practical tasks in the program. In addition to their specialties, they should be inspired to have general fundamental knowledge of the disposal (defined as T-type human resource). This type of human resources would be developed according to the practical demand.
- Outside supporters; they would give wide-ranging supports and encouragement to the program from outside.

5. Present situation of human resources in universities

Universities have an important role to supply fresh human resources to the program. Recently, universities have been losing their teaching and researching man-power in this area due to market-based principles over universities. A preliminary survey on the present situation of human resources in the university laboratories involved in research on radioactive waste disposal was conducted with questionnaires to 15 laboratories (10 nuclear or energy engineering and 3 civil or environmental engineering). Results are used to make suggestions to support the university laboratories concerned. Questions are related to the following subjects;

- State of the research activities on radioactive waste disposal
- Structure of the teaching staff
- Jobs for the graduates
- Research funds to secure the teaching staff

5.1 State of the research activities on radioactive waste disposal

Research budget excluding personnel costs is from 3 million Japanese yen (JPY) to 20 million JPY, averaging 9 million JPY per laboratory. As the subsidy from the government has been decreasing, most laboratories are forced to obtain supplementary funds from outside of the universities.

5.2 Structure of the teaching staff

The 15 laboratories have in whole 21 teaching staff engaged in education and research on radioactive waste disposal. They consist of nine professors, nine associate professors and three teaching fellows. More than half of the professors are over 55 years old. The associate professors are concentrated between 40 and 50 years old. Teaching fellows are all under 40 years old. This structure shows aging of the man-power and shortage of young man-power in the universities laboratories concerned.

5.3 Jobs for the graduates

About 40% of the masters (total 89 persons) obtain jobs in nuclear power industries including electric power companies and research organizations. But 60% of the doctors (total 14 persons) obtain jobs in non-nuclear power industries. It is hard for them to get jobs in nuclear power industries due to their own high speciality. Very few of all can get jobs in the implementing bodies and the research organizations to utilize their knowledge and skills.

5.4 Research funds to secure the teaching staff

Some universities allow the laboratories to secure man-power by outside funds. The averaged amount of the research funds corresponding to secure one person per year including all costs, such as salary and research expenditure is summarised as below.

- A professor needs more than 20 million JPY per year. Three laboratories claim more than 30 million JPY for a professor.
- An associate professor needs 17 million JPY per year.
- A teaching fellow needs 8 million JPY per year.

6. Suggestion to nurture and secure the human resource

As a first step to establishing sustainable human resource development for the radioactive waste disposal program, the following suggestion is made from the discussions;

- Conduct research and development projects funded by the government with some views to develop human resource. For example, the projects should conprise workshops to share the research achievements and seminars to activate young engineers and researchers.

- Boost the university laboratories concerned
  - The implementing bodies and the research organizations should show the quantities and qualities of their jobs to the university laboratories. This would help the laboratories to secure students who are interested in this area.
  - The government should provide the research funds with enough term, more than five years and enough amounts to employ young teaching and researching staff. They would be developed to well-skilled I-type human resource (single specialty) in the process of the research.
  - I-type human resource such as post-doctors should be converted to T-type human resource (one specialty with general knowledge) through activities in relevant societies and participation in net work research.
- Role of the implementing bodies
  - Communicate their policy and plan on employment of fresh man-power with the universities.
  - Provide the funds of basic research to the laboratories from long term view point of nurturing young human resources.
- Role of the research organizations
  - Conduct research with the outlook to supply their human resources to the implementing bodies and the regulatory organizations.
  - Employ fresh human resources from universities to compensate the man-power transferred to the implementing bodies and the regulatory organizations.
  - Utilize their facilities for training and education with collaboration of the organizations concerned.
- Establish a system to coordinate the human resource development in Japan. Considering many organizations are involved in the radioactive waste disposal program, sustainable collaboration among the organizations including the universities would be practicable in this system. Its functions are;
  - To check the process of the human resource development and share the information
  - To prepare and renew the human resource data base
  - To plan training courses for the practical human resources and seminars for the top management of the organizations and the industries related to the program.
  - To create a carrier-up system. This should include exchange of the staff among the organizations concerned.

7. Ending remarks

Considering the features of radioactive waste disposal program, a suggestion is made to forward a sustainable human resource development for the program in Japan. This suggestion contains various activities by the government, the implementing bodies, and the research organizations. One of them is to boost the university laboratories involved in the program. A coordinating system among the organizations concerned is proposed to plan and check the human resource development in Japan.

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Acknowledgments

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EUROPEAN SCHOOL ON EXPERIMENTS, THEORY AND EVALUATION OF NUCLEAR DATA (EXTEND)

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ABSTRACT

The CANDIDE (Coordination Action on Nuclear Data for Industrial Development in Europe) consortium launches the first European School on Experiments, Theory and Evaluation of Nuclear Data (EXTEND). The target group of this course are young professionals, primarily recently employed staff in nuclear industry and at research centres, as well as PhD students in the field. The course contains lectures on introduction to nuclear data, experimental methods, application-oriented nuclear theory, evaluation and validation, data handling, nuclear data needs for sustainable energy systems such as GEN-IV reactors and ADS, and outlook to the future. Laboratory exercises will be conducted on cross-section measurement at a reactor, cross-section measurement at an accelerator-based neutron source, theory and data handling. The school will take place September 2008, in Budapest. The ambition is that after the pilot session in 2008, EXTEND should become a recurring event.

1. Introduction – the CANDIDE project

CANDIDE, Coordination Action on Nuclear Data for Industry Development in Europe [1], is an EC-supported Coordination Action (CA), launched with the ambition to establish a durable network on nuclear data efforts that are important in the context of minimising the high-level waste stream of nuclear energy. This implies optimal incineration of all actinides that nowadays constitute spent nuclear fuel, in critical and sub-critical reactors. As a consequence, the scope of CANDIDE encompasses transmutation in fast critical reactors as well as sub-critical accelerator-driven systems (ADS). The purpose is to identify the needs for improved nuclear data, assess the present status of knowledge, and to estimate what accuracy can be reached with state-of-the-art techniques.

This goal cannot be reached without collaboration between industry, academia and research centres. Moreover, education and training are essential for success in this realm. Thus, CANDIDE addresses the following two objectives:

- Establishment of better links between academia, research centres and industry end users of nuclear data. This is reflected in the project name.

- Assessment of nuclear data needs for advanced nuclear reactors. The emphasis is on the radioactive waste issue, i.e., either waste transmutation in critical or sub-critical devices or minimizing the production of nuclear waste in future nuclear reactors, as envisaged in some fast critical systems.

For a long time activities concerning all aspects of nuclear data for commercial nuclear power reactors, i.e., nuclear data production, theory, evaluation, validation and industrial use, have been part of a well-organized international community, monitored by large international organizations, like OECD/NEA [2] and IAEA [3]. The present coordination of nuclear data needs and evaluation efforts is for example channelled through the OECD Nuclear Energy Agency in the Working Party on International Nuclear Data Evaluation Co-operation (WPEC) [4], where activities between the participating projects in Japan (JENDL), the United States (ENDF), Western Europe (JEFF) and non-OECD countries (Russia, BROND; China, CENDL; and the IAEA-based FENDL) are covered. Within the WPEC, a High Priority Request List (HPRL) has been established to find and review data users' needs and to serve as a guide for scientists planning measurements and developing nuclear theory and data evaluation programs. Present requests cover for example new evaluations of cross-sections and uncertainties for advanced reactors.

Recently, a new nuclear data community has been formed around the production of nuclear data for accelerator-driven systems, while the other ingredients of traditional nuclear data work (e.g. evaluation and validation) have to a large degree been missing up to now. The CANDIDE project aims at establishing links for this new community to the existing structure of coordinated nuclear data activities in general, and to provide links to industry in particular.

Another recent development in Europe has been the enlargement of the EU, which opens new possibilities in the realm of nuclear data. Integration - both of different research communities and between new and previous member states - is an important objective of the CANDIDE project. Moreover, improved training and integration are essential parts of the CA, exemplified by the development of EXTEND as part of the project.

In the public literature, the concept of transmutation is quite often used in a restricted sense, synonymous to accelerator-driven systems for incineration of spent nuclear fuel. CANDIDE has been designed with the intention to consider transmutation in a broader, more general sense, i.e., incineration of spent nuclear fuel by changing the nature of the elements through nuclear reactions. As a consequence, the scope of the proposed CA will encompass minimal production and transmutation of waste in fast critical reactors as well as sub-critical accelerator-driven systems (ADS).

The purpose of CANDIDE is not to produce new experimental data or evaluations, but to review the current modes of nuclear data production, assess the present status of our knowledge, estimate what accuracy can be reached with state-of-the-art numerical simulation techniques, identify the needs for improved nuclear data, and suggest appropriate actions to be taken to meet those needs. A large fraction of the existing data were obtained far back in time, and it might be beneficial to identify cases where new experiments on already measured reactions could exploit technology improvements. Key input is expected from industrial partners, since they are closely involved in application of nuclear data libraries and their performance.

The final result of CANDIDE will be a report describing the state-of-the-art and giving recommendations to EC outlining how nuclear data research should be organized in FP7 and beyond. Moreover, the organisation of workshops and a training course will lead to broader European involvement in the subject.

2. The EXTEND school

As outlined above, the CANDIDE project is not limited to involvement of existing activities, but will also promote growth for the future. Therefore, an important part of the project is the development of a dedicated training course on nuclear data for young professionals, the European school on Experiment, Theory and Evaluation of Nuclear Data (EXTEND). The target group of this course are young professionals, primarily recently employed staff in industry and at research centres, as well as PhD students in the field.

Summer schools in nuclear engineering (e.g., the Eugene Wigner School on Reactor Physics [5] within the ENEN [6] association or the Frederic Joliot - Otto Hahn summer school [7]) are regularly organized, and there are relatively frequent summer schools on fundamental nuclear physics. Up to now, however, there have been few initiatives to bridge these two communities. EXTEND has been designed to fill this gap. Moreover, the course will provide a meeting place for young professionals in corporate industry, research centres and academic research, aiming at fostering improved connections between these types of organizations. In addition, EXTEND will put emphasis on being a meeting place of the long-established and new EU member states.

Course content

The course contains lectures on the following topics:

- Introduction to nuclear data
- Experimental methods
- Application-oriented nuclear theory
- Evaluation and validation
- Data handling
- Nuclear data needs for ADS and Gen-IV
- Outlook to the future

The following laboratory tutorial exercises are performed:

- Cross-section measurement at a reactor
- Cross-section measurement at an accelerator-based neutron source
- Theory
- Data handling

The local reactor at BME will be used as well as the accelerator laboratory in Debrecen. The theory tutorial will be performed using the TALYS nuclear cross section code [8]. TALYS is a very user-friendly code that calculates predictions of nuclear cross sections with a minimum input from the user, i.e., the code selects a suitable nuclear theory model unless the user specifies what theory to be employed.

Finally, the data handling tutorial is a set of exercises in data retrieval from the international nuclear data banks, use of suitable visualization tools, etc. Several Web interfaces exist for retrievals, and Fig. 1a shows a screen shot of the evaluated data Web search of the NEA. For the visualization and manipulation of nuclear data, the NEA developed free software JANIS [9] will for example be used. It allows the user to access numerical values and graphical representations without prior knowledge of the storage format. It offers maximum flexibility for the comparison of different nuclear data sets. Developed for engineers and physicists who use nuclear data for their applications with user-friendly navigation tools making it particularly suitable for educational purposes. The nuclide browser of JANIS is shown in Fig. 1b.

Fig. 1. Evaluated (EVA) nuclear data retrievals (a, left) from the NEA web site (www.nea.fr/html/dbdata/eva) and the JANIS software start page (b, right).

In addition to the lectures and tutorials, there will be a tour to the Paks nuclear power plant. In this study visit, the industrial use of nuclear data will be highlighted.

The school will take place September 1-12, 2008, at the premises of the Budapest University of Technology and Economics, located centrally downtown Budapest. There is no fee. The participants will be provided accommodation including full board at the guest facilities of the Budapest University of Technology and Economics.

Additional information is provided by the EXTEND web site, candide.nri.cz/extend.php, or by contacting Jan Blomgren, EXTEND director. The ambition is that after the pilot session in 2008, EXTEND should become a recurring event. Moreover, the constitution of the EXTEND team is such that the focus could optionally be extended to reactor-related issues such as criticality, and more general nuclear energy issues.

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AN INDUSTRY WIDE APPROACH TO ATTRACTING WORLD CLASS GRADUATE TALENT IN AN INCREASINGLY MARKETPLACE - NUCLEARGRADUATES

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ABSTRACT

The Nuclear Decommissioning Authority (NDA) has a remit under the Energy Act (2004) 'to maintain and develop the skills for decommissioning and nuclear clean-up'. In the recent NDA graduate survey (Ref.1) and in work conducted by Cogent (Ref.2), there is evidence that the age profile is skewed towards older workers and there are likely to be skill shortages in the medium term in key areas. The NDA is also looking to achieve a step change in performance as it introduces commercial innovation, openness and transparency and world class performance as key tenants to re-structuring the industry.

This paper details the NDA's 'nucleargraduates[1]' programme, and how it has brought together partners from the United Kingdom's nuclear decommissioning, defence and process sectors to create a unique programme which enables graduates to experience life throughout the supply chain and regulators.

1. Introduction

1.1 The Nuclear Decommissioning Authority (NDA) is a non-departmental public body, set up in April 2005 by the UK Government under the Energy Act 2004 to take strategic responsibility for the UK's nuclear legacy. Following research into the needs of the nuclear industry (Ref.1) within the UK. It has created a 'stakeholder' group which includes Site Licence Companies, regulators and supply chain companies to allow a programme which encapsulates secondments and training that gives exposure to three cohorts of graduates across an entire industry.

1.2 The appetite for this programme is born out of the NDA mission, 'To deliver a world class programme of safe, cost-effective, accelerated and environmentally responsible decommissioning of the UK's civil nuclear legacy in an open and transparent manner and with due regard to the socio-economic impacts on our communities'.

1.3 In line with the mission, the NDA's main objective is to decommission and clean-up the civil public sector nuclear legacy safely, securely, cost effectively and in ways that protect the environment for this and future generations. The NDA does not carry out clean-up work itself and so it is important that those that will deliver, and those potentially interested in delivering, have the right skills set in place to meet the needs of the modern nuclear industry.

1.4 The UK as a whole is suffering from a skills shortage in keys areas such as Science, Technology, Engineering and Maths. The squeeze on talent is particularly prevalent at graduate level.

[1] "nucleargraduates" is the brand name for the NDA National Graduate Scheme

2. The 'nucleargraduates' programme

nucleargraduates

Fig. 1 The brand identity of the NDA National Graduate Scheme

2.1 The NDA has developed three facets that will enable closer working in the nuclear industry around graduate attraction, recruitment and development:

- The nucleargraduates programme
- A joint application tracking system
- Programmes of joint working on attraction and development

2.2 The nucleargraduates programme is driven by a group comprising of companies across the industry including the NDA, Site Licence Companies, Regulators and the supply chain. Uniquely, the programme offers no 'specific job' with the NDA after the two year programme is completed. The programme will be integrated into the existing partners' schemes to ensure smooth progression. The Graduate's progress after 2 years will be facilitated by a careers service and formal rules governing the behaviour of partners.

2.3 Target graduates include those from the following disciplines areas:

- Civil, electrical, chemical and mechanical engineering
- Environmental sciences
- Finance, procurement and project controls

These disciplines will be expanded for the later cohorts to include areas such as materials, health physics, safety case writing and chemistry.

2.4 The graduates go through a series of four secondments:

- Six months spent working with NDA staff
- Six months working on secondment at a Site License Company or Parent Body Organisation
- Six months spent working with touch points of the nuclear industry such as Tier 2/3 suppliers, government agencies and departments, regulators, local councils, defence and operational organisations or unions
- A three month secondment abroad in either a national authority, e.g. the Department of Energy or international supplier

2.5 Throughout the programme four periods of training will also be carried out. All secondments are in a specific work discipline (e.g. civil engineering) and will have defined projects. Training will be structured and aligned with relevant 'Institute' competencies to ensure a route through to chartered status for any graduates wishing to follow this line. There will also be an emphasis on behavioural and technical training to ensure a broad experience for those going through the programme.

2.6 Attraction and recruitment will be formed from two areas:

- Recruitment of "second jobbers" and the 'hidden graduate pool' - through innovative marketing, agencies and online recruitment
- Traditional 'milkround' recruitment, focussed on advertising, careers fairs, university liaison and specific targeting of particular courses

2.7 A bespoke Socio-Economic Programme, named *Footprints*[2], will deliver:

- *'10% Time'* - a voluntary work in the community programme, which will compliment other training areas, focussing on 'the skills agenda' and bringing the NDA into the heart of the community
- Society 'programme days' introducing the graduates to the role of the industry in society through bespoke away days. These will include visits to facilities such as the Scottish Government, prisons, schools, FE colleges, farms etc. The 'Footprints' programme is themed around specific strands such as education, innovation, community and governance and is targeted at geographical areas aligned to NDA's socio economic plan (Ref.3).

2.8 An online Applicant Tracking System will be used to streamline much of the application and assessment phases of the recruitment phase and capture graduates not suitable for the NDA programme that may be of interest to stakeholders.

2.9 Other areas of joint working such as graduate attraction, academic and skills conferences are planned to highlight the opportunities to academic communities for graduates.

3. Major Achievements to Date

3.1 The first cohort of 13 graduates start on 21st April 2008. These graduates come from a variety of science, engineering and commercial backgrounds. There programmes and training have been defined and planned secondments include the NDA, Sellafield Ltd, Magnox North, Rolls Royce, Jacobs and the Environment Agency. Locations include England, Scotland, Wales, France, the United States and Japan.

3.2 A joint applicant tracking system has been created which will manage those applying to the UK's nuclear industry. Over 1,500 graduates applied for the programme in the first month of the programme opening.

4. Conclusion

4.1 The UK's nuclear industry is at a cross roads in terms of graduate recruitment. The nucleargraduates model of joint working has provided a beacon of best practice for solutions to meeting the increasing challenges of skills shortages for a growing industry.

4.2 Whilst numbers are limited at present (30 places over the next 2 years) success of the programme will lead to developing options for expansion of the original scope to aspire to a larger and more collaborative arrangement of a truly National Graduate Scheme for all participating partners.

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[2] Footprints is the name of the corporate social responsibility element of nucleargraduates

NUCLEAR INDUSTRY TRAINEE PROGRAM FOR NEWLY RECRUITED ENGINEERS

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ABSTRACT

As of 2007, AREVA NP in Germany continues to face a dramatically increasing demand for competent staff for a new six week modular trainee program for nuclear engineers.
All new engineers are invited to attend this trainee program. Here, they learn about the AREVA group and AREVA NP operations. Technical knowledge is enhanced by training on layout, functions, instrumentation and operation of the different types of nuclear power plants, primarily Boiling Water Reactors, Pressurised Water Reactors, and their main systems and components. Furthermore an introduction to quality management, nuclear safety principles and nuclear engineering is given to the trainees.
This paper presents an overview of the needs for and objectives of AREVA NP's trainee program, and the concept for development and implementation of this new program. It discusses initial experiences from the first implementations and the next steps for upcoming courses.

1. Introduction

In 2003 the consortium of AREVA (then Framatome) and Siemens started the turnkey construction of the fifth Finnish nuclear power plant in Olkiluoto, which is the first order of its kind in Western Europe for more than 20 years. Furthermore the possibilities of new construction projects in Flamanville, France or Taishan, China, and also the perspectives of additional plant construction projects in countries like South Africa, Great Britain or the Baltic States have now led to a dramatic increase in demand for additional personnel. However, the present shortage of competent employees, particularly intensified by the reticent role of the German educational facilities (universities, technical colleges …) regarding nuclear matters, and the severe company rivalry for hiring the best talents on the market, nowadays poses an overwhelming challenge.
Today's introductory training programs for newly recruited personnel have to instruct engineers from different technical disciplines. In order to boost the needed development within the company, training not only has to establish the basis for knowledge and skill transfer but also has to maintain talent progression and preservation. In a five year perspective, recently hired talents shall become the backbone of the AREVA group. Therefore, it is also very important that new employees understand and adopt the group's values in order to comply with its commitments.

2. Approach for development of technical competence

Facing these conditions, AREVA NP started a trainee program for engineers in Germany in April 2007. It was recommended that every newly recruited engineer had to participate in this program during his period of vocational adjustment within AREVA NP.

The main objectives which had to be covered by the new program were to accelerate the development of nuclear and technical competencies of the participants and thereby to ease an efficient integration of the new personnel into the engineering workforce. Additionally on-the-job-training which bind human resources in an unproductive way should be minimized as well as the time and effort needed for a general qualification for newly recruited employees.
Various already existing training modules were taken as a basis for the development of the whole program. Thereby it was possible to develop and implement a six week training course within a short space of time, including a one week break for self-study,.

Module	Duration
Standard introductory course for new AREVA employees	3 days
Overview quality management	2 days
Nuclear safety	2 days
Introduction to nuclear engineering	3 days
Introduction to nuclear technology and NPPs	
(short) boiling water reactor introductory course (overview + specific details incl. SWR1000)	7 days
(short) pressurised water reactor introductory course (overview + specific details)	8 days
(short) enhanced pressurised reactor technology course (supplement to PWR Introduction)	3 days
Accompanying events	2 days
	in total 30 days

Fig 1. Overview of the program modules

Course Day	Week day	date	Presentation (Subject / Title)
17	TU	06.11.2007 *08:30-16:00 h*	Layout and design of the primary circuit and its components, functions and operation of the primary circuit
18	WE	07.11.2007 *08.30-16.00 h*	Overview of the PWR auxiliary systems with focus on the volume control system
19	TH	08.11.2007 *08.30-16.00 h*	PWR auxiliary systems with focus on: Nuclear residual heat removal system, extra borating system, nuclear ventilation systems with activity monitoring
...			
22	TU	13.11.2007 *08.30-16.00 h*	Physics of the reactor core Reactor core internals, nuclear instrumentation >> Visit of an operating facility
...			
25	FR	16.11.2007	**08:30 h: PWR-Test** from 09:30 h EPR-Training

Fig. 2. Extract from the course program (module Pressurised Water Reactor)

As can be seen in Fig. 1, the following training modules have been selected:

- Standard introductory course for new AREVA employees – This course gives an introduction to AREVA with topics concerning organisation, cooperate policy and history, including an overview of AREVA scope of supplies and services. Furthermore human resource issues and market situations are presented. Safety culture as well as the basics of quality management is attributed to this course.
- Two short introductory courses (one for Pressurised Water Reactor and one for Boiling Water Reactor) – A course, which describes the general fundamentals of the entire plant, the functional and operational mode of the primary circuit and the secondary circuit with regard to a Pressurised Water Reactor; and the nuclear steam supply systems together with an overview of the steam condensate feedwater system with regard to a Boiling Water Reactor. It covers the description of core components and the physics of the reactor core, and gives an overview of the auxiliary and ancillary systems and the operational behaviour of the plant, as well as of the dedicated control systems. Finally incidents and accidents are also discussed (see Fig. 2).
- Overview course - Evolutionary Pressurised Water Reactor (EPR) – This course gives a description of the design and development objectives of the EPR and summarizes the difference to AREVA's II generation NPPs. Furthermore it gives an overview of the safety concept focussing on safety systems and severe accidents (e.g. core melt).
- Introduction to nuclear engineering – Organizational structures of the different engineering departments (system, process, component etc …), their main processes and the tools employed are presented.

For the training method, instructor led classroom training outside was selected. The choice of a non "in house" location for this training was a conscious decision to allow the participant the full concentration in lectures as well as to enhance networking amongst other trainees.
While the first module was given by around 20 instructors from different departments, trainers from the Training Center and specialists from the engineering departments carried out the technical part. The introduction to nuclear engineering was given by the department manager of all the different engineering departments.
The participants were able to take notes during the lessons as they were provided with the necessary training material, such as a copy of the presented slides and/or the attributed textbook. In addition, video were also shown in some lectures. For the technology courses, exercises and self-study were performed under the supervision of an instructor. To lighten up the day, guided tours around nuclear power plants and on-site manufacturing facilities were made available to the attendants.
The training was evaluated by regularly collecting trainee-feedback, subdivided into questions concerning the general terms, the administration, the content of the training material and the skill of the trainers. To evaluate the acquired level of knowledge, tests were performed after one technical module had been completed.

3. First Experiences

Since April 2007 four consecutive runs of the nuclear engineering trainee program have been carried out by the Training Center of AREVA NP. Up until now about 100 newly recruited engineers have participated in the program.
Generally the feedback from trainees was positive. They pointed out that they had received a good overview and introduction to nuclear engineering and nuclear technology. Networking between participants from different departments was recognised as a further advantage in their forthcoming daily work. Compared to most of their previous employers the trainees highly

esteemed the investment AREVA NP made to have increased the competence of their newly recruited personnel.
Critical comments were related to overlapping and inconsistencies of the technical content. Furthermore some topics were covered in too much detail during the classroom lectures. More time for repetition, teamwork and self-study was suggested.
These deficiencies could be expected in advance, as already existing independent courses were used as a basis for the development of the whole program. Therefore the modules of the program have been continuously reworked and further developed since the program began in 2007. The first improvement was the introduction of tutorials at the end of each topic, regarding the time balance between lectures and repetition. A parallel rework of general training material on Boiling Water Reactors could be adapted in parts for the third run of the trainee program, so that BWR module training material could be actualised and harmonised. Unifying the training material on Pressurised Water Reactors and on the Evolutionary Pressurised Water Reactor, and including a comparison between Generation II and III reactors, was the last improvement measure. The material could be used in the fourth run. Overall the material is now better suited to the training of newcomers to the nuclear field.

4. Next Steps

The fifth run of the nuclear engineering trainee program will begin at the end of May. The feedback from trainees demands yet another enhancement of some tutorials. Additionally the fifth run will concede more focus to nuclear engineering by discussing case studies, e.g. how a valve should be designed and which steps must be completed before commissioning. But also former reactor operators and shift supervisors will outline reports based on their own experiences in the operation of a nuclear power plant.
Moreover AREVA NP now has decided to modify the program to cover the needs beyond the requirements of nuclear engineering. The prospective program will be broken down into smaller packages and units, to be attended over a time period of about two years after recruitment. According to individual specific previous knowledge and dedicated job position it will be possible to select only those modules which are required. It is also foreseen that different training settings will be used, namely classroom training including lectures and accompanying exercises as well as online courses, self-studies and continuing on-the-job-training under the supervision of a mentor. This will be supplemented by advanced training on an engineering simulator. To allow training to be much more effective the training period will be extended and the training itself will be much heterogeneous.

Module	Duration
Company introduction for new AREVA employees	2 days
Quality management, safety culture and human performance	2 days
Technical overview of plant business	1 day
Nuclear basics and history	1 day
NPPs basics focused on EPR	5 days
Nuclear industry events	1 day
	in total 12 days

Fig 3. Proposed introductory new hire training program

As can be seen in Fig. 3, the following training topics have been selected for the proposed introductory new hire training program:

- Company introduction for new AREVA NP employees
- Quality management, safety culture and human performance
- Technical overview of AREVA NP business – deals with the organisation, interfaces and processes within AREVA NP (business development, project management, design, procurement, erection, commissioning, operation and maintenance) illustrated on one new construction project example and one backfitting project example.
- Nuclear basics and history – includes fission, radioprotection, fuel cycle, the role of moderator and coolant and the different nuclear types.
- NPPs basics focused on EPR – deals with the background of Pressurised Water Reactors basics illustrated using the EPR.
- Nuclear industry events – gives a description of the Three Mile Island, Chernobyl …, events, which includes root cause, human error (if applicable) and lessons learnt.

Additionally, the above training program will be harmonised over the different international regions of AREVA NP. This allows the same levels of competence within the company to be reached on an international level, as well as the use of existing training facilities and human resources to be improved.

5. Conclusions

The first experiences made were quite positive. The nuclear engineering trainee program is well accepted by the nuclear engineering departments. The newly recruited engineers were provided with all the information required for a successful career within the company. Concurrently, enhanced commitment of new personnel to the company may be observed, together with an increased identification.

As a result of the nuclear engineering trainee program within AREVA NP, the company will be well prepared for the expected extension of their business activities worldwide – an increase in new construction and backfitting projects.

CHALLENGES OF EDUCATION AND TRAINING FOR A SLOVENIAN NUCLEAR SERVICE PROVIDER

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ABSTRACT

Generation exchange and expected new constructions in nuclear industry dictate serious reconsideration of personnel knowledge and skills availability. This is not a paramount objective only for the regulatory bodies, institutes, research facilities and NPPs, but also for support industry, including service providers to NPPs. The article illustrates a specific situation in Slovenia and presents a case on the leading Slovenian nuclear service provider NUMIP Ltd. and its daughter company Q Techna Ltd. Discussed is their effort to systematically develop and implement an educational and training program in support of their services to nuclear power generation. Apart from their own and supplemental personnel, Q Techna Ltd. has started to provide training and certification to others in the market. The article is intended to emphasise the importance of the topic for nuclear service providers, and shows a specific effort made despite a small domestic market and limited resources.

1. Introduction

Recently, the situation in nuclear education and training described in OECD/NEA Report [9] has changed due to expected renaissance of nuclear power generation. Consequently, the education and training require even more attention, also on the part of nuclear industry to assure appropriate long-term measures. Even though there are some programs and activities going on at the governmental level, most of the privately owned enterprises have to find their own way to stay and grow in the nuclear business. The paper describes a case on the leading Slovenian nuclear service provider, NUMIP Ltd.

2. Specific situation in nuclear power generation in Slovenia

Many aspects related to nuclear education and training in Slovenia are similar to the ones in other European countries. Yet, when the fact that there is only one nuclear power plant in the country, half-owned by Croatia, is taken into account, the situation can be observed on a different scale. Krško NPP (one unit, two-loop Westinghouse PWR, 700 MWe) follows U.S. Codes and Standards, including 10CFR50, App. B and ASME B&PV Code, as well as Standard Technical Specifications accepted and approved by the Slovenian regulatory body, which imposes certain specifics to education and training. There is no other nuclear power generation facility in the country, which significantly narrows the market for domestic nuclear service providers. The nuclear maintenance services market in Slovenia has been further reduced by the plant’s transition from 12 to 18-month fuel cycle and by shortening outage durations. Apart from decreasing revenue, 18-month cycle implies challenges to maintaining domestic contractor personnel skills, experience, knowledge and qualifications [1].

The Slovenian government has adopted the Baseline for a long-term assurance of support activities in the area of nuclear and radiological safety [11]. Based on that, a Program on a long-term assurance of support activities in the area of nuclear and radiological safety was prepared and consequently confirmed by the Slovenian government in 2006. It actually addresses research and education institutions, organizations authorized by the Slovenian Nuclear Safety Authority and the government-owned industrial support organizations. For privately owned organizations, a burden of assuring adequately educated and trained employees remains their own. Looking at a big picture in terms of maintaining the existing plant and potentially constructing and later maintaining a new one, it is clear that industrial support should be treated as important as other organizations involved in nuclear power generation in Slovenia. Most of the countries with nuclear industry are interested in having adequately developed domestic nuclear support industry.

In the forecast by GEN Energija [5] the needs for newly employed personnel were assessed, taken into account construction and operation of new LILRW repository and Unit 2 of the Krško plant. The results, a total of 2000 additional workers will have to be employed around 2013 (above the 2006 figures), out of which 500 with at least university degree. For contractors, this means an increase in the range of at least 1200 people. Taken into account that an average time to train a newcomer after joining the company is around five years at least for engineers, the time to act is now. These figures are significant for Slovenian circumstances, even more so, as it will be difficult to get qualified workforce even from abroad due to the expected high demand in new plant constructions elsewhere in the same timeframe. Apart from highly educated experts, it is obvious that we have to take into account also appropriate trade workers suitable for nuclear construction and maintenance. Especially welders and fitters are in great demand. For illustration, the “American Welding Society predicts that by 2010 demand for skilled welders may outstrip supply by about 200.000 in US only” [12]. And the situation in the EU is unlikely to be any better.

3. NUMIP Ltd. in brief

NUMIP Engineering, Construction, Maintenance and Production Ltd., was established in 1996 and currently employs 65 people. One third of them hold a university degree, another third are technicians, the rest are highly skilled workers. For complex projects, such as regular outages at the nuclear power plant, around 400 people from up to 30 partner companies are mobilized and managed. NUMIP regularly provides the following regular outage services to the nuclear power plant: pump maintenance - primary side; cranes and fuel handling equipment servicing; containment hatch and air locks opening/closure and servicing; reactor vessel services including disassembly/assembly, handling of internals, cleaning of flange and studs; maintenance of primary valves and operators; HVAC servicing; fitting and welding; crane operation and maintenance; snubber maintenance and testing; various repairs and replacements of piping, vessels, etc. Further, its services to the nuclear market comprise of installation and modification implementation; project management; field engineering; quality assurance and quality control; fabrication of spare parts and structural elements; representation of Enertech, U.S.A. on the CEE territory. From its foundation, the company has been carefully developing its core competencies for nuclear industry with a special emphasis on specialized technical knowledge and skills; modern project management organization, methods and techniques; efficient management of several contracted companies; integrated quality system (ISO 9001, ISO 14001, OHSAS 18001, 10CFR50, App.B); personnel experience and qualification tracking system, continuous improvement process, etc. Further, it systematically provides for a long-term development.
In 2001, NUMIP acquired Q Techna, specialized in quality assurance and quality control, which has grown into a leading Slovenian QA/QC institute, accredited for five NDE methods, currently employing 22 people.

4. Providing education and training for NUMIP's personnel

As indicated above, NUMIP is facing a great challenge to maintain the skills of existing personnel for providing limited amount of services to NPP's on the one hand and to develop personnel to get ready for the new wave of NPP construction on the other. The main issue is to bridge the gap of few years between now and the participation in the expected construction of a new unit at Krško. A trade-off between demand (current and future) and employment needs is inevitable, even though it is obvious that we have to invest in education and training now to meet the needs in the future.
To keep pace with changing environment and markets, NUMIP tries to systematically deal with the education and training of its personnel. For the range of its services, several main areas should be covered with education and training, as illustrated in Figure 1. All of them are intertwined with project management which is the main process in the company.

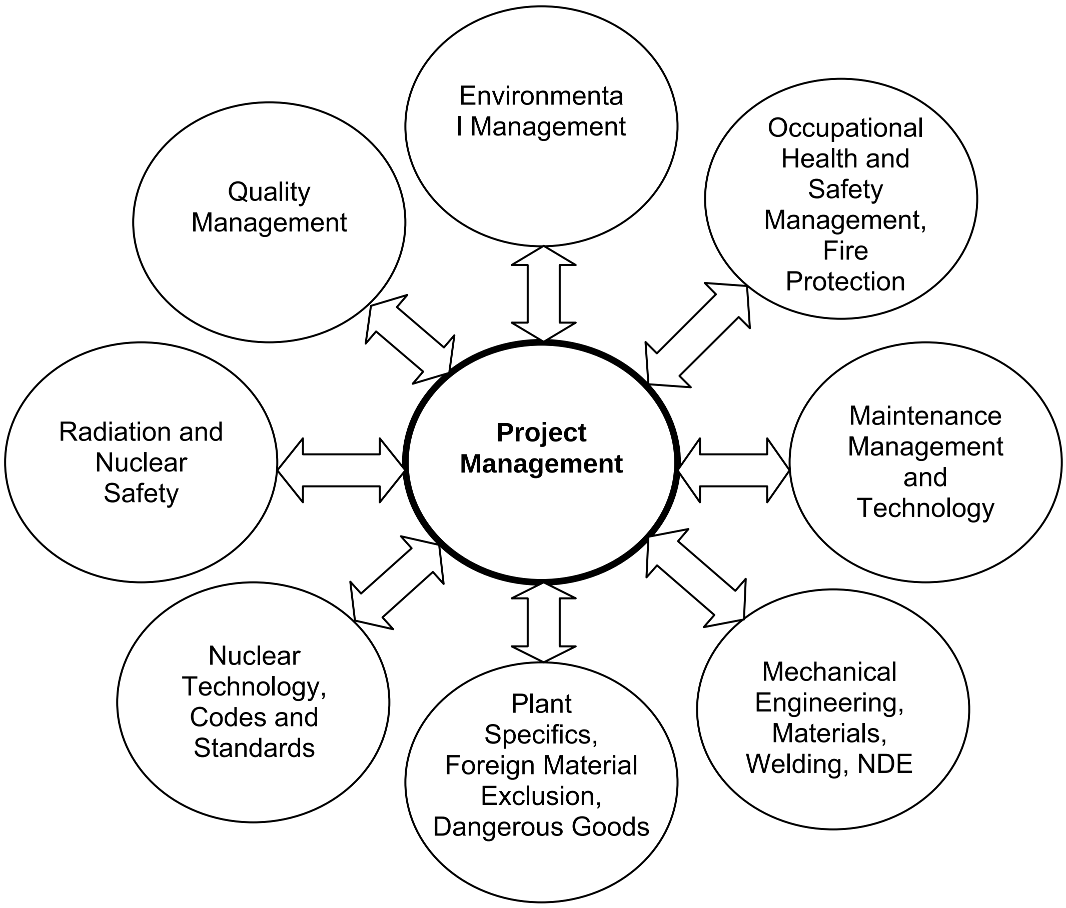

Fig 1. Main areas relevant for education and training in NUMIP Ltd.

As these areas are very diverse, NUMIP uses different ways of obtaining appropriate training and education, i.e. external (domestic and foreign), internal and on-the-job. Training guidelines [8] are used to the extent possible.

Domestic external
Apart from education at Slovenian universities, domestic training comprises of the following:

- NPP Technology courses, delivered by Nuclear Training Centre of the Jožef Stefan Institute, dealing with nuclear and reactor physics, thermal-hydraulics and heat transfer, radiation protection, electrical engineering, materials, nuclear safety and technological systems of NPP.
- Radiation protection courses

- Courses on different nuclear topics, delivered by IAEA

NUMIP also cooperates with universities, provides visiting lectures, supports the thesis work, grants scholarships for students of applicable studies, internships, etc.

Foreign external
Personnel are occasionally sent to different trainings abroad especially aiming at foreign (mostly US) codes and standards, especially ASME B&PV code and EU sponsored courses such as Nuclear Safety for NPP subcontractors.

Internal
Internal training has been increasingly used for specific topics, especially for project management practices, materials, quality management, occupational health and safety, fire protection and, recently, preparation of personnel for work in foreign NPPs in accordance with internally developed procedure. The latter comprises of lectures on: Fitness for Duty, Station Organization & Administration, Nuclear Power Plant Overview, Nuclear Security, Industrial Safety, Fire Protection, Quality Programs, Site Specifics, Radiological Orientation, Nuclear English, etc. Internal assessments are provided after the training to verify the knowledge gained.

On-the-job
This is one of most widely used practices for training of NUMIP's personnel and it requires appropriate mentoring. It is becoming really important as groups of our workers are gaining new skills and experience through work in foreign NPP's, mostly in the USA and France. Strong cooperation with big players at the domestic plant also provides opportunities of gaining new knowledge and skills. On-the-job training, especially through work in foreign NPPs is considered to be an important prerequisite for future participation in new plant constructions.

Apart from the training and education described above, NUMIP plans to focus on the following to keep increasing its competences in the future:

- Use training capabilities and mock-ups of big players for different purposes;
- Employ graduates from a Nuclear Engineering program at the new Slovenian Faculty of Energy Technology;
- Send engineers to post-graduate programs, such as ENEN MSc in Nuclear Engineering;
- Convey the message to the government that the competent nuclear support industry is in the nation's best interest regardless of its ownership.
- Promote the need for an educational program for European Nuclear Technician (like European Maintenance Technician, financed by Leonardo da Vinci program).
- Provide as much services as possible to foreign NPP's in order to maintain and develop knowledge and skills.
- By participation in foreign new plant constructions raise resources in nuclear field and prepare for a new unit construction in Slovenia.

5. Training and certification services of NUMIP's daughter company

Q Techna Ltd., a 100% owned daughter company of NUMIP, has been active in the nuclear power plants since its establishment. Key activities performed are inspections and non-destructive examinations. When preparing for the accreditation for the SIST EN ISO/IEC 17025, level III personnel were needed for all accredited NDE methods. For that reason, the first group of experienced inspectors went to Germany for additional training and certification. Recently, Q Techna has become the first accredited institution for NDE in Slovenia. Simultaneously, it became obvious, that our country lacked an appropriate personal training and certification system, even though the demand was increasing. Consequently, Q Techna decided to establish its own training and certification centre providing personnel training and certification in accordance with European (EN 473) and American (CP-189) standards. The programs are delivered in Slovenian language and lay a lot of emphasis on nuclear specifics which in Slovenia mostly refer to ASME B&PV Code. For certification purposes, Q Techna continues cooperation with its German partner. During the last six years, over 500 individuals passed training and certification in their centre. It is a great advantage that Q Techna can request experts it has certified for support in execution of large plant outage projects. This is a guarantee that contracted personnel are also knowledgeable of nuclear specifics. Such scheme had practically been impossible before the centre was formed. Q Techna permanently follows new requirements of codes and standards. In the future, it plans to put more emphasis on specifics related to maintenance of different plant components and to constructions of new NPPs. The latter inevitably introduce new inspection requirements. Further, new training programs are planned to be developed for inspection of mechanical components. One of the main obstacles for faster development of these is lack of certification schemes which may also change in the future.

6. Conclusion

The fact that “nuclear is different” is well understood by most of the players in nuclear industry. This is also crucial for service providers and they have to organize their education and training accordingly. Taking into account that human and financial resources, together with availability of appropriate training programs are limited, the organizations have to make smart decisions as to what trainings and education to choose. The case described in the article shows how a relatively small company can make quite a significant effort despite a narrow domestic nuclear market.

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COMPREHENSIVE EDUCATION AND TRAINING ACTIVITIES AT JAEA NUCLEAR TECHNOLOGY AND EDUCATION CENTER

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Nuclear human resources development (HRD) in Japan has been identified as one of the most important issues these years in nuclear society, mostly due to the decrease of nuclear engineers in industries and students in universities, and to the difficulties of technical transfers. Nuclear Technology and Education Center (NuTEC) at Japan Atomic Energy Agency (JAEA) aims at comprehensive nuclear education and training activities, which cover 1) education and training for domestic nuclear engineers, 2) cooperation with universities and 3) international cooperation. The main feature of NuTEC's training programs is that the curricula places emphasis on the laboratory exercise with well-equipped training facilities and expertise of lecturers mostly from JAEA. The wide spectrum of cooperative activities have been pursued with universities, which includes newly developed remote-education system, and also with international organizations, such as with FNCA countries and IAEA.

1. Introduction

Nuclear human resources development (HRD) in Japan has been identified as one of the most important issues these years in nuclear society, mostly due to the decrease of nuclear engineers in industries and students in universities with the coming peak of replacement of nuclear power reactors around 2030, and to the difficulties of technical transfers between old and young generations. The council on Nuclear HRD among industries, government and universities has been established in September 2007 to investigate mid and long term HRD strategy in Japan. Nuclear Technology and Education Center (NuTEC) was established as HRD division in 1958 soon after Japan Atomic Energy Research Institute (JAERI) was founded in 1956. Japan Atomic Energy Agency (JAEA) established by the integration of JAERI and JNC in 2005 clearly identifies nuclear HRD as one of the missions. NuTEC's HRD activities are conducted in line with governmental policy(1) and programs(2), and aims at comprehensive nuclear education and training program. The main feature of the NuTEC's training program is that the curriculum places emphasis on the laboratory exercise using well-equipped training facilities at JAEA and expertise of lecturers mostly of JAEA(3). NuTEC is aware of the social needs in nuclear HRD and updates its training programs in response to these needs, which include cooperative activities with universities, international training with Asian countries and international cooperation under the scheme of FNCA and IAEA.

2. Education and training for domestic nuclear engineers

There are 3 categories of training for domestic nuclear engineers; courses for radioisotope and radiation engineers, nuclear reactor engineers and national test examinees. Thoroughly-studied lectures and specially prepared texts are used in each of the courses. Technical visits to related facilities including large-scale and advanced facilities, such as J-PARC, NUCEF, NSRR and HTTR, are arranged in most of the courses to enlarge trainee's experiences.

2.1 Training courses for radioisotope and radiation engineers

Training courses for radioisotope and radiation engineers first begun at the Radioisotope School situated in JAERI-Tokyo in 1958. At present, NuTEC provides 6 courses for radioisotope and radiation engineers. All of these courses aim on systematic acquisition of wide variety of knowledge and handling techniques of radioisotopes and radiation through lectures and laboratory exercises. In “Basic Radiation Course”, “Radiation Safety Management Course” and “Radiation Protection Basic Course”, participants learn subjects, such as radiation safety related law, biological effects of radiation, radiation measurement and safe handling of radioisotopes and radiation. The other 3 courses; working environment expert course and 2 radiation protection supervisor courses are legal qualification courses, in which the participants are entitled to obtain a license after the completion of the courses. The current status and total number of participants from each course are shown in Table 1. The accumulated number of participants is more than 14,300 (as of JFY 2007).

Table 1 Training Courses for Radioisotope and Radiation Engineers

Name of Course	Period	Accepted number/time	Frequency	Total number of participants until FY.2007
Basic Radiation Course	15 days	12	Once/year	8,225
Radiation Safety Management Course	14 days	12	Once/year	308
Radiation Protection Basic Course	4 weeks	12	Once/year	200
1st Class Working Environment Expert Course	2 days	16	Twice/year	587
1st Class Radiation Protection Supervisor Course	5 days	32	8 times/year	4,851
3rd Class Radiation Protection Supervisor Course (since JFY. 2006)	2 days	32	3 times/year	143

2.2 Training courses for nuclear reactor engineers

The Nuclear Engineering School was launched at JAERI-Tokai in 1959. At present, 3 courses are provided for nuclear reactor engineers as shown in Table 2. The most significance of these courses is “Reactor Engineering Course”. Since 1959, it has contributed in training nuclear reactor engineers for nuclear power plants, nuclear facilities and research institutes. This course provides comprehensive knowledge of nuclear engineering, nuclear fuel engineering, radiation management and related regulations and laws through various lectures, laboratory exercises and facility visits. Other 2 courses are available as introductory courses: “Nuclear beginners Course” broadly guides through the field of atomic energy, “Introductory Neutron Experiment Course” provides fundamental knowledge required for the use of neutrons, and to familiarize the trainees to its application technology towards the use of J-PARC. The accumulated number of participants is more than 3,000 (as of JFY 2007).

Table 2 Training Courses for Nuclear Reactor Engineers

Name of Course	Period	Accepted number/time	Frequency	Total number of participants until FY.2007
Nuclear Beginners Course	4 weeks	24	Once / y	1,108
Reactor Engineering Course	3 months	12	Twice / y	1,888
Introductory Neutron Experiment Course	3 days	16	Once / y	95

2.3 Training courses for national test examinees

There are 4 courses in preparation of national examinations; “Licensed Reactor Techniques supervisor”, “Professional Engineer on Nuclear and Radiation”, “1st Class Radiation Protection Supervisor” and “Nuclear fuel Protection Supervisor” as shown in Table 3. The training aims at systematic acquisition of knowledge and consists mostly of lectures. Every course contains subjects on its related law/ordinance/regulations. Past examinations are analyzed and mock examinations are conducted in some training courses. Participants are from electric utilities, nuclear fuel handling plants, RI/radiation handling facilities including staffs from JAEA. The accumulated number of participants is more than 2,300 (as of JFY 2007).

Table 3 Training Courses for National Test Examinees

Name of Course	Period	Accepted number/time	Frequency	Total number of participants until FY.2007
Licensed Reactor Techniques Supervisor	10 days	20	Twice / y	1,864
Professional Engineer on Nuclear and Radiation	10 days	32	Once / y	16
1st Class Radiation Protection Supervisor	6.5 days	30	Once / y	232
Nuclear fuel Protection Supervisor	7.5 days	25	Once / y	196

3. Education and training for JAEA personnel

NuTEC conducts 39 courses for JAEA Personnel. These courses are off the job-site training (OFF-JT) and are provided to compensate on the job-site training (OJT). There are 2 categories of courses; safety training courses (13 courses) and nuclear engineering training courses (26 courses), and these courses can be participated stepwise from fundamental courses to application courses. The fundamental courses are designed as basic and necessary training for recruits and primary-grade engineers of nuclear facilities, such as, “Radiological measuring training course” and “Nuclear fuel cycle engineering course”. On the other hand, the application courses are designed as skill-up training for expert engineers, such as “Safeguard course” and “Reprocessing engineering course”. All these courses have special features, i.e., 1) very short period, 2) practicable, 3) open for anyone from 15 JAEA sites (about 4,000 personnel). About 50,000 s have attended these training courses since 1980.

4. Cooperation with universities

4.1 Cooperation with Graduate School of University of Tokyo

In response to the recent expanding needs in the nuclear field, the University of Tokyo has established a new system in 2005 for the nuclear education by setting up two graduate schools; Nuclear Professional School (NPS), and Department of Nuclear Engineering and Management (DNEM). The former is a one-year education system to produce specially qualified engineers in the nuclear field. As NPS is located next to JAEA Tokai, JAEA has a close and wide-range cooperation in the education of NPS students through NuTEC. JAEA dispatched 5 visiting professors and about 60 lecturers for the lectures in 2007, which covered about 60% of all lectures in this school. Around 90% of the experiments in this school are conducted with JAEA facilities instructed by JAEA researchers and engineers. The number of experimental instructors dispatched from JAEA was about 60 in 2007. The education program of DNEM is performed in Tokyo for the graduate students for 2 or up to 5 years. JAEA dispatched 4 visiting professors to DNEM in 2007.

4.2 Cooperative Graduate School Program

Under an education system provided by MEXT (Ministry of Education Culture, Sports and Science), NuTEC has been cooperating with many graduate schools based on the agreements between JAEA and each university. Currently JAEA has cooperation agreements with 14 graduate and one undergraduate schools. Totally 53 JAEA researchers were dispatched as visiting professors or associate professors to each university in 2007. JAEA also accepted about 20 students from these universities for nuclear studies.
A new remote-education system, called Japan Nuclear Education Network (JNEN), has initiated in April 2007 under the cooperation framework among JAEA and 3 universities. JNEN is a multi-directional education system connecting the remote sites of the participating universities and JAEA through Internet. Many kinds of lectures are available through the system at real time. In the first year, 2005, the special agreement for JNEN was signed among JAEA and three universities; Kanazawa University, Tokyo Institute of Technology, and Fukui

University. Through JNEN students of each participating university can take lectures from different universities or JAEA, such as reactor engineering, fuel reprocessing and geological disposal of nuclear wastes. A lecture on the basic nuclear-chemistry from Tokyo Institute of Technology, for example, was distributed to other two universities, and about 50 students in 3 universities took the lecture at each university simultaneously, as illustrated in Fig. 1. Under this program, some experimental courses were also performed using JAEA nuclear facilities to strengthen the effect of the nuclear education by JNEN. The experiments included handling of actual nuclear materials. Such experiments are considered to be highly important and valuable to the participating students. Two universities are scheduled to join JNEN in 2008, and some more are expected to join in the coming years.

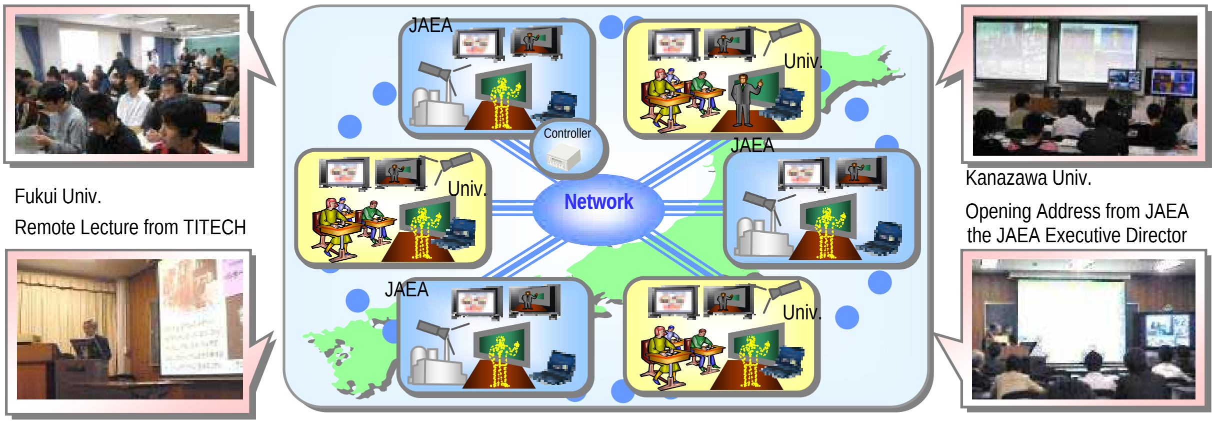

Fig.1 Concept of JNEN Remote Lecture System

4.3 Cooperation with Nuclear HRD Program

A new nuclear HRD Program consisting of 6 subjects has been initiated in May 2007 by MEXT and METI (Ministry of Economy, Trade and Industry) of Japan to support universities and colleges in the education of nuclear engineering and science. For the first year, the programs from 35 universities and 8 technology colleges were adopted, and about half of those universities/colleges expected some kind of cooperation with JAEA, such as dispatch of lecturers, use of nuclear facilities and facility visits. NuTEC has supported in the arrangements to meet these needs.

5. International cooperation

Soon after its foundation, NuTEC organized an international training course, the UNESCO Isotope Training Course, in 1958. NuTEC continued to conduct International Basic Courses for Radioisotope and Radiation for Asian countries, which were completed successfully in 1971 for the utilization of radioisotopes. From 1977, under the sponsorship of MEXT, NuTEC has been conducting International Atomic Energy Safety Technology Training Project to strengthen the training system of nuclear engineers in Asian countries. For the safe utilization of nuclear energy, the project includes three training programs: Instructor Training Program (ITP), Joint Training Course (JTC), and Safeguards Training Course.

5.1 Instructor and Joint Training Courses

NuTEC has been conducting two kinds of training course; Instructor Training Program (ITP) and Joint Training Course (JTC) as more effective and efficient method for developing instructors in a self-sustainable manner for certain Asian countries. ITP is a training program held in Japan to train the instructors who are to be enrolled in JTC, which is held in the partner's country (Fig.2). To develop teaching ability and techniques as an instructor, several participants are first invited to NuTEC to join the ITP for 4 to 6 weeks. They will learn teaching techniques that match their countries' needs and then join the JTC as co-instructors with NuTEC's instructors. Through this system, participants accumulate training experiences in

JTC in their own country to become main instructors. After four-year JTC, the same course named Follow-up Training Course (FTC) is repeated for four more years to ensure its self-sustainability.
Up to now, ITP and JTC had been conducted bilaterally with Indonesia from 1996, Thailand from 1996 and Vietnam from 2001. The theme of the courses is based on the needs in the steering committee meeting held between each country, but all the courses place emphasis on the laboratory exercise with well-equipped training facilities at JAEA and with key-equipments implemented in each country. We believe that the laboratory exercise is essential for the supply of high quality training course. Indeed, the combination of ITP and JTC has proved very effective in technology transfer and stable enrolment of lecturers. The percentage of enrolment of ITP trained instructors is 70 to 92% in those countries. Also, due to the development of self-sustainable instructors, there has been various extended effects, such as development of local young lecturers, development of a new training course and contribution for educational and research activities using supplied training equipments.

Fig.2 JTC in Thailand

5.2 FNCA related activities

Since 1999, NuTEC has organized a workshop to promote HRD activities in Asian countries under the framework of FNCA (Forum for Nuclear Cooperation in Asia) (4). Currently the project focuses on ANTEP (Asia Nuclear Training and Education Program) activity, a network system by utilizing existing nuclear training and education resources in 10 member states, i.e., training and education programs, nuclear research facilities and experts to meet each country's HRD needs. It was agreed at the FNCA Panel Meeting "Study Panel for Cooperation in the Field of Nuclear Energy in Asia" in Tokyo, 2007 that sharing relevant information among FNCA member states on HRD toward nuclear power is important and recommended that information exchange and cooperation on HRD be enhanced by effectively utilizing the FNCA web-site as the first step. This was approved at the Coordinators Meeting in March 2008(5). At present, information on the ANTEP needs with its priority are being updated/uploaded and the results for its possible matching between needs and programs are shown on the FNCA HRD web-site (Fig.3).
(http://www3.tokai-sc.jaea.go.jp/nutec/fnca/fnca.htm)

Fig.3 FNCA-HRD website for ANTEP

5.3 Cooperation with IAEA

NuTEC has been organizing safeguards training courses once every two years and contributing to ANSN (Asian Nuclear Safety Network) in close cooperation with IAEA. The Safeguards Training Course invites about 10 trainees from the countries concluding a safeguards agreement based on the non-proliferation treaty for 2 weeks to join the intensive on-the-job training consisting of safeguards technology in Japan, IAEA safeguards technology, supplementary protocol, IAEA system of accounting and physical protection. The course place emphasis on practice, discussion and laboratory exercises to enhance understanding. The selection of trainees and lecturers are conducted in close cooperation with IAEA (Fig.4).

Fig.4 Classroom Lecture

The Asian Nuclear Safety Network (ANSN) activity has started in 1977 as an Extra Budgetary Program of IAEA supported by Japanese government. ANSN aims to strengthen nuclear safety of nuclear power plants and research reactors in this region by pooling and sharing existing and new technical knowledge and practical experiences for the Asian nuclear facilities of today and future. Within this framework, an Internet-accessible database has been set up and operated by the Education and Training Topical Group, with a hub center organized by Japan Nuclear Energy Safety. NuTEC, in cooperation with Radiation Application Development Association in Japan, has contributed to the ANSN activities by providing the database with a variety of information in the field of nuclear safety.

6. Summary

In a situation that we are facing the "Nuclear Renaissance" ahead worldwide, NuTEC at JAEA aims at comprehensive nuclear education and training activities in response to the domestic and international needs. The main feature of NuTEC's training program is that the curricula places emphasis on the laboratory exercise with well-equipped training facilities and expertise of lecturers mostly from JAEA. The wide spectrum of cooperative activities have also been pursued with universities, which includes newly developed remote-education system, JNEN, and with international organizations, such as with FNCA countries and IAEA. The accumulated number of trainees to date amounts to almost 110,000 (Japan:54,500, JAEA personnel:52,700, international: 2,550). With more extended and close cooperation with domestic and international organizations, NuTEC's HRD activities will hopefully and further be conducted in more effective and efficient manner in future.

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SKILLS RENEWAL IN THE NUCLEAR INDUSTRY

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ABSTRACT

The ageing workforce is a concern for the entire nuclear industry at a time when environmental issues such as low-carbon electricity generation are the focus of much public preoccupation. The development of a new electricity generation mix including the building of Gen III NPPs is one of the solutions.
The recruitment of a significant number of young engineers will be required for these future projects and to replace the employees who are approaching retirement.
EDF is now developing and sponsoring, jointly with French and non-French universities and "*Grandes Ecoles*" a major education programme focused on an International Masters Degree dedicated to Nuclear Energy, open to French and non-French students.
During a two-year programme, students will follow a foundation course in nuclear energy, before specialising in different fields such as Engineering, Operations, Decommissioning, Waste management, and the Fuel cycle.
This programme will start in September 2008.

1. Introduction

1.1. The energy context

2007 saw increased awareness of the fact that:

- Energy is becoming a rare and expensive commodity, with the oil price sustainably above $100 a barrel, involving potential consequences for the competitiveness of economies and energy supply security.
- Tackling climate change will be one of the major challenges of the XXIst century.

Global energy needs are increasing just as fossil-fuel resources are reaching depletion: oil companies such as Total forecast peak oil, after which oil production will decline, during the next decade, which is to say tomorrow. Peak gas will follow around twenty years later.

In electricity, International Energy Agency (IEA) forecasts show a need for massive investment over the 2000-2030 period, involving the construction of 660 GW in Europe, where the period of overcapacity is now well behind us, 850 GW in North America and 800 GW in China.

Never before has there been such an opportunity to rethink our primary energy choices. Choosing where to focus will need to take into account three key factors:

- the price of resources
- the security of supply
- the preservation of the environment and, particularly, the reduction in greenhouse gas emissions.

The taking into account of the first two criteria has forced many players to revise their plans to use gas for electricity generation. Some are turning to coal but may be deterred by its high carbon emissions, since CO2 capture/sequestration technology is currently only expected move into the industrial phase towards 2030.

Nuclear is profitable in current fossil conditions. In addition, renewable energies and Energy Saving have a direct impact on the saving of resource. However, unless there is a significant technological breakthrough such as the storage of electricity, renewable energies, which have a low level of concentration and provide only intermittent supply, are likely to remain only limited back-up solutions.

Fissile energies are currently the only technologies which enable the use of fossil energies to be reduced. The medium and long-term forecasts from the IEA suggest that all methods of energy generation will be needed to meet demand. Nuclear will very probably be part of the solution in many countries.

Nuclear has considerable advantages. Only 5% of the cost relates to uranium ore with the rest geared to processing. It is thus, stable, predictable and has a low level of sensitivity to fluctuations in international commodity prices or the dollar.
It is the only thermal energy to generate large quantities of electricity, at a reasonable cost, without greenhouse gas emissions.

The IPCC[1]-GT III report, published on 4 May 2007, takes a positive view on nuclear in the summary for decision-makers. The EU Council meeting of 8 and 9 March 2007 concluded that "the European Council notes the Commission's assessment of the contribution of nuclear energy in meeting the growing concerns about the safety of energy supply and CO2 emission reductions." These points were reiterated in the closing speech at the World Energy Council chaired by Pierre Gadonneix, Chairman and CEO of EDF, on 15 November 2007 in Rome.

1.2. The international situation

First Finland, then France and, more recently, China have decided to build EPR reactors.

In the United States, the NRC has renewed its authorisation process and the Energy Policy Act of 2005 introduced significant financial incentives. Power plant projects have been announced. The implementation of a new policy for the reprocessing of spent nuclear fuel (GNEP) is an additional supporting factor.

The British government has announced the role of nuclear in the renewal of the existing generation assets in the United Kingdom. Different reactor types have satisfied the licensing process.
Large countries such as India and Brazil have included nuclear in their planning for energy generation.

[1] Intergovernmental Panel on Climate Change

In Asia, in addition to China and India, Japan and Korea are continuing their programmes to build nuclear power plants.

In France, 80% of electricity generation is from nuclear (86% of EDF generation) while, in Europe, this technology is responsible for more than one third of electricity.

For the past thirty years, EDF has operated pressurised water nuclear reactors, whose obligations and advantages are well known. The operating obligations include the safety of individuals, the safety of the facilities and the transparency of information. If nuclear is properly managed and controlled, as it is in France, it may be considered one of the safest sources of energy.

2. Bottlenecks

If we leave aside mineral resource capacity which is currently artificially depressed (40 to 50 years) due to the lack of prospecting over the past 15 years, industrial companies point to two main bottlenecks:

- The availability of large-scale forges

Currently large-scale forged components (particularly nozzle support rings) are manufactured in Japan, with significant constraints on manufacturing lead times and risks of non-negligible delays in the event of faulty manufacturing. Boiler manufacturers are looking at a number of options (new factories, etc.) which will need to be combined, for financial reasons, with the appropriate localisation of the factories, taking into account the marked depreciation in the dollar relative to the euro.

- Skills renewal

In most countries, the nuclear power plants were built and commissioned over a short period, mainly between 1970 and 1985. The Chernobyl accident put this technology on hold for around twenty years.
Employees recruited by the nuclear industry during this period are now approaching retirement and must be replaced in terms of both their number and skills. Recruitment will need to be increased in order to build and operate the new power plants planned by many countries.
Thus, in France, we estimate that 40% of the engineers and executives in this industry will retire over the next decade. During this period, we are going to have to recruit around 1,200 engineers annually, including 500 per year for EDF.
In France, as in many countries, engineering recruitment has been at a very low level over the past 15 years. As a result, training opportunities in engineering schools, technology institutes and universities have been cut back. Furthermore, given this reduced demand for engineers, teaching positions have not been renewed and only a few qualified individuals remain, most of them relatively advanced in years.
Finally, the most able students have turned to professions other than technical: in France, some 30% of engineering graduates have opted for careers in banking, trading, insurance and consultancy (2006 APEC figures).

3. Skills renewal in the nuclear industry

A detailed mapping exercise of engineering training in the nuclear field was carried out in 2007 by the High-commissioner for Atomic Energy (French CEA) on behalf of the French government. It highlights the need to increase the number of training opportunities. Capacity in France is currently slightly above 300 graduates per year and can be rapidly increased to around 900, which is still not enough to meet French needs (1,200 per annum, see above).

In order to support this growth and meet requirements in France but also internationally, EDF has engaged in some major initiatives in this area, supporting and participating in the development of a number of programmes:

3.1. Engineering training

EDF is supporting engineering school final year specialisations in energy and particularly nuclear. The curricula have been developed or strengthened in numerous schools, most of which will be operational in autumn 2008.
Sensitive areas such as operating chemistry, safety and radiation protection will be the subjects of new specialisations.
The development of apprenticeship internships is being encouraged.
The strengthening of Atomic Engineering (French GA) staffing by the National Institute for Nuclear Science and Technology (INSTN) is already underway. This specialist training for French and non-French engineers will see the number of students increase from 45 to 150 individuals per year over a four-year period.

3.2. Specialised Masters Courses (Post Master Professional certificate)

A number of specialised Masters courses (one year Post Master specialist training) will be operational as of the autumn of 2008 with the support of EDF. For example:

- Nuclear safety from design to operations, including the transport of nuclear materials and waste.
- Nuclear engineering and the chemistry of the fuel cycle.

This training is intended for a more limited number of students (both French and international). Industrial companies will be able to recruit the future experts they require from amongst these students.

3.3. "Nuclear Energy" International Masters

EDF is supporting the creation of a "Nuclear Energy" International Masters with numerous partners in the academic world:

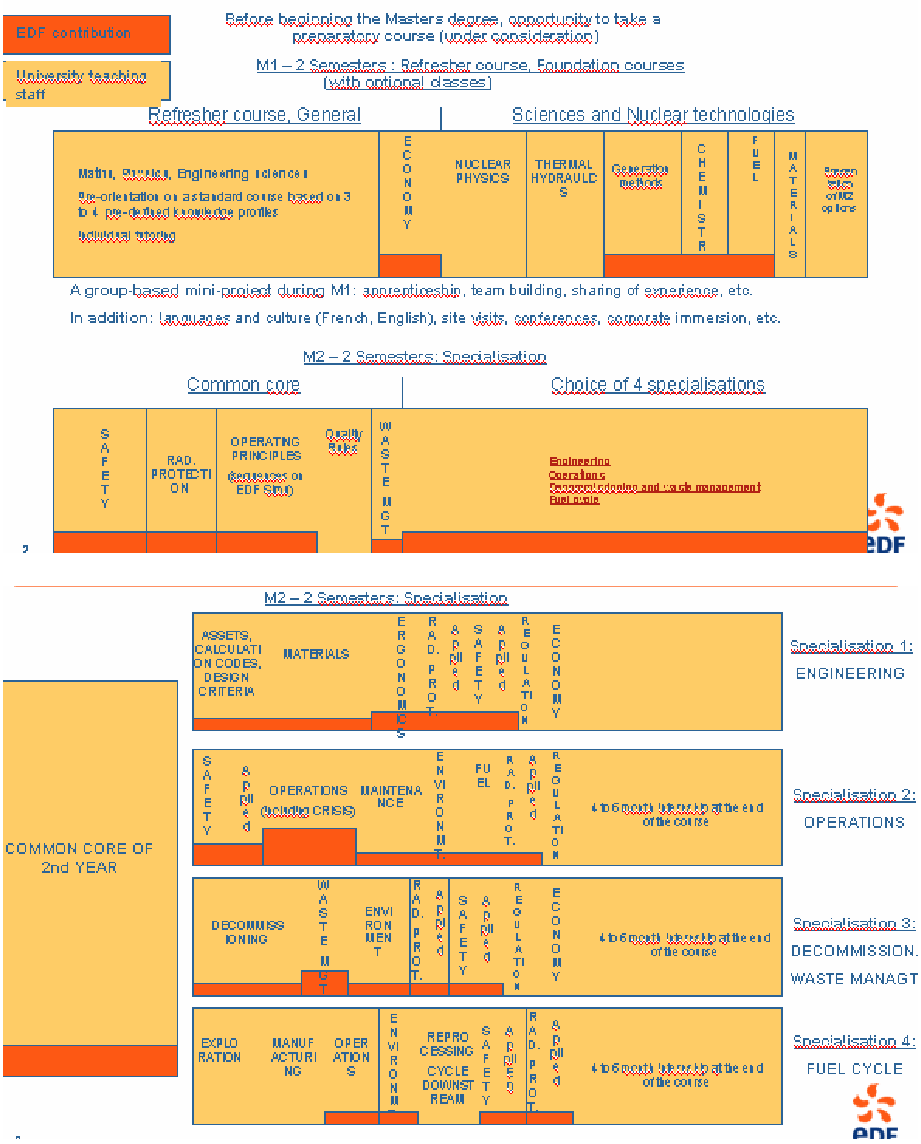
- A number of engineering schools: *Ecole Polytechnique*, *Ecole des Mines de Paris*, *Ecole Nationale des Ponts et Chaussées*, ENSTA, *Ecole nationale des Arts et Métiers*, *Ecole de Chimie de Paris* (regrouped within *ParisTech*), *Ecole Centrale Paris*, *Supélec*
- *Université de Paris-Sud* (Orsay)
- INSTN

This high-level training is aimed at French or non-French students holding a Bachelors degree in a scientific subject.
Lasting for two years, the course will give participants all the knowledge they require to pursue a successful career in the nuclear industry.
In order to foster the international dimension of this programme, the classes will be conducted in English.

The curriculum will be based on around 1,000 hours of training, organised in four major phases:

- Personalised refresher courses at the beginning of the programme
- Coursework to acquire a foundation in nuclear science and technologies
- Applied knowledge (safety, radiation protection, etc.), focusing on the transverse and systematic understanding of the nuclear industry
- Specialisation in a major area with a choice of options: engineering, operations, decommissioning and waste management, fuel cycle.

An internship in the industry and the submission of a Masters thesis with a view to securing the diploma will end the programme.
The overall framework is presented below:



Part of the programme will start in September 2008 (capacity 50 students) and the programme will be fully operational in autumn 2009 (200 students).

EDF will make grants available to non-French students in order to enable them to follow this programme in the best-possible conditions and to begin their career within the EDF Group (parent company and subsidiaries or affiliates).

3.4. Support for these programmes

In addition to active participation in the development of these curricula, EDF will provide support in various ways:

- Creation and financing of teaching and research professorships linked to certain areas of the International Masters,
- Award of grants to French and non-French students,
- Increased internship opportunities and thesis proposals,
- Increase in the number of EDF employees giving courses in engineering schools and universities,

- Availability of EDF “full scope” simulators to students in these programmes who will be able to take "discovery" courses,
- Closer relations with schools and universities and with students in order to highlight career opportunities in nuclear energy.

4. European Foundation for Tomorrow’s Energies

All these initiatives will be the responsibility of the "European Foundation for Tomorrow's Energies" which has just been created by EDF with a view to developing training and research dedicated to renewable and sustainable energies, including, of course, nuclear.
This Foundation is under the aegis of the *Institut de France* whose scientific authority is renowned worldwide.

With an initial annual budget of €5 million, this Foundation will provide the funding critical to the success of these programmes, particularly the International Masters.

With a prestigious Scientific Advisory Council, the foundation will organise international events on "low carbon" energy issues, including decentralised generation.
It will award an annual “International Prize for Tomorrow's Energies”, in recognition of an individual or group of individuals’ contribution to a significant advance or educational initiative in this field.

ASSESSMENT OF THE 2007 WNU SUMMER INSTITUTE

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ABSTRACT

An assessment of the 2007 World Nuclear University Summer Institute (WNU-SI) held in Daejeon, Korea from 14 July through 24 August 2007 was carried out by Fellows and Mentors. Three different assessment components were completed using the 2007 WNU-SI website during the six weeks of the Institute: (1) Assessment of each Lecturer & lecture topics (2) Assessment of Mentors and (3) Post-Institute assessment of the entire Summer Institute. The questionnaires consisted of yes-no questions, some multiple choice, and open-ended questions. This paper details the process and results of the assessment, leading to findings and recommendations for future WNU-SI programmes.

1. WNU Summer Institute 2007

The World Nuclear University Summer Institute 2007, held in Daejeon, Korea from 14 July through 24 August 2007, produced yet another major success in exposing an elite group of young nuclear professionals to the global aspects of nuclear technology. Following the highly successful WNU Summer Institutes held in Idaho Falls and Stockholm in 2005 and 2006, respectively, the 2007 event drew 102 Fellows from 35 countries; the highest number of participants so far.

The purpose of the Summer Institute is to provide a unique educational experience aimed at building future global leadership in fields of nuclear science and technology from among promising young nuclear professionals [1]. To this end, the Summer Institute is designed to enable participants to

- Gain awareness of cutting-edge knowledge and broad international perspective on issues related to peaceful applications of nuclear technology
- Hear from leading thinkers and educators on topics relevant to nuclear applications
- Experience practical teamwork and establish lasting bonds with peers from many nations
- Be inspired to commit themselves to advancing the global contribution of nuclear science and technology.

The 2007 programme was designed to achieve the Summer Institute goals, and consisted of many components, including:

- ***Lectures*** by international experts on a variety of issues that will influence the future use of nuclear technologies
- ***Team Building Activities*** designed to initiate and enhance relationships and teamwork among Fellows
- ***Small Working-Group (Breakout) Sessions*** led by Mentors to promote sharing of differing perspectives and to discuss major ideas/issues presented by the lecturers.
- ***Case Studies*** in nuclear law, safety culture, radiation effects and radiological protection, knowledge management and public communication on nuclear issues.

- ***Distinguished Speaker Presentations*** by persons who have made notable contributions in the nuclear domain, bringing ideas and information related to their achievements in the real world of nuclear energy, painting “big pictures” and encouraging the Fellows to think of an exciting career dealing with challenging issues.
- ***Global Issues Forum*** dealing with significant nuclear issues with international implications, including: Non-proliferation policy; reprocessing policy; limitation of fuel production and enrichment capacities etc. This provided an opportunity for self-directed intensive teamwork amongst the Fellows with Mentor guidance.
- ***Field Trips*** to several Korean nuclear and industrial sites, including Kori NPP, Wolsong NPP, Doosan heavy industries, Hyundai automobile plant, Pohang steel company plant, Pohang accelerator laboratory, National fusion research centre and Korea atomic energy research institute.
- ***Receptions, Social Events and Group Recreational Activities*** to encourage socialization and strengthen relationships among Fellows, Mentors, presenters and other Institute participants.

Participants are classified into four main groups:

- The 102 Fellows were from 35 countries with an average age of 32. Twenty-two per cent were female. The majority of the Fellows (66%) held an MSc or PhD degree in nuclear science or engineering, 7% were still pursuing a nuclear related PhD, and some have a non-scientific background, including law, business etc., but had some professional nuclear knowledge. 93% of the Fellows were professionals.
- The 14 Mentors were experienced, internationally diverse senior level professionals in the nuclear field, facilitated the working-group (breakout) sessions, which comprised groups of about ten Fellows from different countries.
- The 34 Lecturers made presentations on the following areas:
  - Global settings: World energy demand and supply, climate change, clean water shortage, global emission reduction, nuclear technology in sustainable development, and a survey of nuclear politics;
  - International regimes: Safety standards and global safety culture, safety and security; non-proliferation and safeguards, radiation effects and radiological protection, waste management, decommissioning, and nuclear transport;
  - Nuclear industry operations: Nuclear excellence and operational focus, risk assessment, industry economics, nuclear fuel market, and public communication;
  - Technology innovation: Next generation nuclear reactors, advanced fuel cycle, new technologies including hydrogen and fusion, non-nuclear technologies, and space applications.
- The 15 Distinguished Speakers were leaders in nuclear and related fields, spoke in a very direct and informal way with the Fellows.

2. Assessment Process

The assessment process was designed to gain as much information as possible with a view to better understanding what worked well and what needed to be improved, and to making future WNU offerings even more effective.

Three different assessment components were completed by 102 Fellows and 14 Mentors using the 2007 WNU-SI website (www.2007wnu-si.org) during the six weeks of the Institute: (1) Assessment of Lecturers and lecture topics (2) Assessment of Mentors and (3) Post-Institute assessment of the entire Summer Institute. Fellows and Mentors carried out the assessments using on online mechanism.

The questionnaires consisted of yes-no questions, some multiple choice, and open-ended questions. A four-point Likert scale [2] was used in the multiple-choice questions of the post-Institute assessment. Answers to open-ended questions were categorized using qualitative data analysis technique [3].

The summary data and analysis results regarding the value and effectiveness of the 2007 WNU-SI were obtained using quantitative and qualitative analysis. All the assessments carefully have been analysed, the findings and recommendations are discussed for the next SI.

3. Assessment Results

3.1 Lecturer & Lecture Topic Assessment

Most Fellows and Mentors provided their responses on the SI website soon after the lecture during five of the six weeks of the institute. One week was a technical tour. The average number of respondents was 99 for Fellows (out of 102) and 12 for Mentors (out of 12). The questionnaire consisted of the following yes-no questions and gave opportunity for comments for every Lecturer and lecture topic. The average "yes" response followed the question:

- Do you recommend that the Lecturer come to the WNU SI next year? (90% Fellows and 80% Mentors)
- Do you recommend the topic for WNU SI next year? (94% Fellows and 92% Mentors)

Table 1 shows the number of Lecturer & lecture topics whose ratings fall within each percentile band. The number who received affirmative responses of more than 70 per cent is 34 for Fellows and 27 for Mentors. Concerning lecture topics, the figure is 37 for Fellows and 33 for Mentors. The results will be used as the basis for inviting Lecturers and to choose lecture topics at the next Summer Institute.

Table 1. Number of Lecturers & lecture topics in the values of the yes response score (The total number of Lecturers and lecture topics is 37)

Yes response score (%)	Number of Lecturers		Number of lecture topics	
	Fellows	Mentors	Fellows	Mentors
90 -100%	27	21	31	30
80 – 89%	4	5	4	1
70 – 79%	3	1	2	2
60 – 69%	2	2	0	1
50 – 59%	1	4	0	3
40 – 49%	0	1	0	0
30 – 39%	0	2	0	0
0 – 9%	0	1	0	0

3.2 Mentor Assessment

The purpose of the Mentor assessment was to learn about the Fellows' perspective regarding the Mentor program and the effectiveness of their particular Mentor. Another purpose was to enhance future Institutes. The survey consisted of four statements, to which you could respond "always or sometimes" and two "yes-no" questions. There was also an opportunity for comments: and comments as follows:

- My mentor is easy to talk to… (90%, always)
- My mentor encourages open discussions in the group (87%, always)
- My mentor listens respectfully to my ideas (92%, always)
- My mentor is a good coach for the group (77%, always)
- Would you recommend your mentor to come back to next year's WNU Summer Institute? (93%, Yes)
- Was the mentor program of value to you personally? (90%, yes)

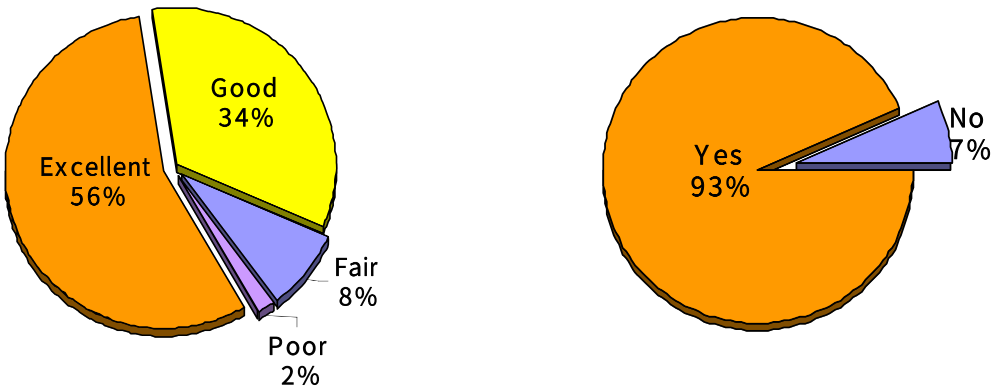
It is noticeable that Fellows answered "always" in over 75% of Fellows. Ninety-three per cent of Fellows were happy to recommend their Mentors to come back to next SI. It also is noteworthy that ninety per cent of those responding said the mentor program was of value to them personally.

According to the comments, some Fellows thought Mentors should be more proactive in making Fellows explore their own ideas, and reduce their involvement during discussion; on the other hand, some Fellows wanted Mentors to join fully Fellows' discussions and to share their experience and knowledge. The balance between supporting is clearly difficult one to maintain. Overall, however, the data obtained supported the strong impression of those who participated in the Institute that the mentor program was an important and valuable component of the Summer Institute.

3.3 Post-Institute Assessment

The questionnaire consisted of 14 main items; 39 multiple-choice questions, 10 yes-no questions and 39 open-ended questions. The 14 main items covered in the post-Institute assessment are as follows:

- ***Local Organisation:*** Hotel, WNU staff on-site services, Social and cultural activities, Special Korean lectures, Internet access, SI web-portal
- ***WNU-SI 2007 Programme:*** Announcement, Communication with Fellows before the SI, Objectives of the SI, The Mentors role in general, General Curriculum, Distinguished speakers, Technical tours
- ***Overall assessment:*** Overall assessment



(a) (b)

Figure 1. Average value of the post-Institute assessment results: (a) multiple-choice questions, (b) yes-no questions.

The total number of respondents per item ranged between 96 and 109 with an average of 104. In the Figure 1 (a) and (b), we can see that more than 90 per cent of the respondents evaluated the 14 items positively. This means the Fellows were satisfied or greater with almost all aspects of the Summer Institute.

There were some interesting findings based on data obtained:

- More than half of Fellows learned about this SI through their organisations, and 15 per cent of Fellows learned from previous Fellows.
- The Fellows' two main objectives in attending were to improve their knowledge and their understanding of global nuclear issues, and to network with Fellows professionals.
- Fellows thought the most useful aspect of the WNU-SI was providing opportunities of networking with Fellows, and a great understanding of global nuclear issues.
- Fellows wanted more lecture time on nuclear safety, public communication and reactor technologies, less time on nuclear law. Fellows also wanted to add lectures on safety,

anti-nuclear arguments and leadership; they also wanted more time on forum issue activity.

- Fellows wanted to have more free time to know each other and to have social room to talk.
- The WNU Summer Institute website was received a good evaluation. However while it is considered effective for getting and sharing information, some Fellows wanted an FTP site for large uploads and downloads.

There are some recommendations based on data from the assessment process.

- The SI should be targeted toward less experienced professionals.
- Distinguished Speakers' presentations should focus more on their work experience and lessons in leadership.
- During small group sessions, there should be less time reviewing lectures, and more time on activities.
- Put the FTP site on the SI website for large uploads and downloads.

The questionnaire helped to provide data on the 14 items that the Summer Institute organiser wished to assess. The data obtained will be useful when considering how much time and effort to expend on the various elements of the Summer Institute.

4. Conclusions

An assessment was carried out to obtain summary data and analysis regarding the value and effectiveness of the 2007 WNU Summer Institute. The Fellows and Mentors completed assessments of each Lecturer and Mentor and a post-Institute assessment of the entire Summer Institute. The data obtained was carefully analysed, the findings and recommendations were discussed for the next SI.

The assessment has shown that the goals of the SI were accomplished and the 2007 WNU Summer Institute was an outstanding success. Two key benefits to the Fellows have been stated repeatedly: (1) obtaining a much broader global perspective on many aspects of the nuclear field, (2) the opportunity to interact with international peers in the nuclear field that will lead to lifelong professional relationships and personal friendships.

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Improving Plant Performance through Improved Human Performance

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Introduction

The US commercial nuclear industry is, by almost all counts, a major success story. Safety levels and electric production are at unprecedented high and continue to exceed even high industry goals. Nuclear energy continues to keep the highest priority on performance improvement programs and highly trained/qualified people that maintain its record setting safety and reliability of operations. Along with this, recent political support has led the way for utilities to seriously consider the construction of new plants.

In spite of this, the current debate on nuclear energy continues to roil, making it more important than ever to make sure the industry continues to capitalize on its fine record of safety and efficiency that it has displayed over the last two decades. In fact, some who scan current articles detail the intensity of the debate on whether or not nuclear energy should be seriously considered as a partner in the war on global warming. Consequently, the more the industry can demonstrate a safe and efficient record, the stronger its position as a viable option to declining fossil fuels.

The resulting challenge is how to more effectively manage risk and improve performance even further in a generally high performing organization. Newer technology and more training by themselves are not the answer. Rather, the answer will lie in the human side of the organization and management's ability to tap into the unused potential of employee commitment and productivity. It is people who offer the greatest potential for organizational success. Given the fact that human performance has been demonstrated to yield higher rates of return than physical capital, it makes good business sense to determine how to encourage the behaviors in the workplace to manage the risk that will accompany efforts to boost the nuclear industry to new heights of excellence. This means effectively developing a performance improvement culture through identifying measurable performance indicators and determining how behaviors can best be influenced to improve those indicators. It also means seeing a culture of performance improvement and risk management as a strategic planning tool rather than a solution to a particular problem.

Description

One of the most effective ways to develop this culture of performance improvement and effectively managing risk is to apply the principles of Human

Performance Technology (1), or HPT, to the nuclear workplace. HPT is a relatively new field that has been emerging over the several decades. Its principles are derived from the research and practice of behavioral and cognitive psychologists, instructional technologists, training designers, organizational developers and various human resource specialists. Relying heavily on general systems theory as applied to organizations, HPT takes a systemic approach to risk assessment and performance analysis/ change as opposed to making piecemeal interventions which often happens in designing training programs intended to be the only fix specific short term organizational behavior problems.(Stolovitch and Keeps, 1999) Specifically, HPT methodology emphasizes examining any given problem in relation to the more global aims of the setting or environment within which the problem is identified. Its consistent driver is measurable performance and the structuring of elements within the system to improve and reward desirable performance and effective risk management. In general, HPT is more than another way to look at training, HPT is a systemized process that combines selection, analysis, design, development, implementation, and evaluation of programs to most cost effectively influence human behavior and accomplishment. (Brethower, 1999; Rosenberg, Coscarelli, and Hutchison, 1999; and Rummler, 1999) By taking a systems view of organizations rather than discreetly focusing on pockets of concern within an organization, it seeks to link the actions and interventions of all the organizational elements that affect overall performance. It does this through identifying, among other things, current performance levels, required performance levels for effective risk management, exemplary performance, and developing measurements for each step in the process. It examines such things as the external and organizational environments as well as the influences that directly impact individual performance.

Direct application to the nuclear industry is evident when considering the temper of the times. For nuclear organizations to stay viable performance improvement processes will have to be part of their culture in order to better manage risk and to achieve and maintain ongoing success. Greater plant performance will be directly related to greater human performance. To be successful, the nuclear industry, like any other organization, must clearly understand its purpose, structure itself to achieve that purpose, structure appropriate internal relationships, establish a realistic incentive/reward system, establish efficient work processes and assure knowledgeable and supportive leadership (Dean, 1999).

Conclusion

Using the principles of Human Performance Technology can provide a structure for helping the industry in general as nuclear facilities individually take steps to accomplish these goals. Taking strategic steps to develop these elements will result in higher levels of production efficiency, better risk management, higher customer service/satisfaction and an ability to successfully meet ever changing environmental and business demands. Human Performance Technology is proven effective methodology to help in the successful development of these strategic steps. This session will offer a discussion of the basics of HPT, as well as some specific examples of how it can be applied to nuclear facilities to effectively manage risk and drive enhanced performance.

1. Human Performance Technology (HPT) has its roots in what was the National Society for Programmed Instructions (now known as the International Society for Performance Improvement – ISPI). ISPI offers certification programs and its principles are currently supported by other professional organizations such as the American Society for Training and Development (ASTD) and the International Federation of Training and Development Organizations.

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Experimental Facilities for Education and Training

Research Reactor Coalitions - Promoting Nuclear Education and Training

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Abstract. The IAEA, in line with its statute and mandatory responsibilities to support its member states in the promotion of peaceful uses of nuclear energy, has initiated new activities with the objective of promoting formation of coalitions of research reactor operators and stakeholders. The aim of this effort is to promote concrete examples of enhanced regional cooperation, to form networks of research reactors conducting joint research or other shared activities, and to form a voluntary, subscription-based, self-financed coalitions of research reactor operators. The objective is to increase research reactor utilization and thus to improve sustainability at the same time enhancing nuclear material security and non-proliferation objectives.

This paper will describe the Agency's efforts to enhance nuclear education and training in a number of IAEA Member States, including in Europe and Latin America, within the context of the Research Reactor Coalitions Initiative. The paper will recount activities undertaken since the beginning of 2007 to develop coalitions of research reactors to expand nuclear education and training activities, including transfer to developing member states of power reactor operator and other practical training courses that are already successfully implemented at a European research reactor. It will discuss ongoing activities to strengthen and expand nuclear education and training activities through research reactor coalitions involving research reactor operators in Austria, Argentina, Colombia, Jamaica, Mexico, and Russia, and other countriesamong others. It will also discuss how to including facilitate access to research reactor facilities for representatives of of countries and user organizations using nuclear science techniques in countries without research reactors.

1. Background

In order to continue to play a key role in the further development of peaceful uses of nuclear energy, research reactors need to be financially sound, with adequate income for safe and secure facility operations and maintenance, including planning for eventual fuel removal decommissioning.

Over the past several decades, trends in nuclear research have resulted in a more competitive environment for research reactors. In a context of declining governmental financial support, research reactors are increasingly challenged to generate income to offset operational costs, in many cases by seeking commercial sources of income. However, reactors operating at low utilization levels have difficulty providing the service availability and reliability demanded by many potential users and customers, Thus low utilization is itself a significant obstacle to increasing utilization, and thus improving sustainability

To address the complex of issues related to sustainability, security, and non-proliferation aspects of research reactors, and to promote international and regional cooperation, the Agency has undertaken new activities to promote Research Reactor Coalitions and Centres of Excellence. This integrates Agency regular and extra-budgetary funded program activities related to research reactors, national and regional IAEA Technical Cooperation projects, especially “Enhancement of the Sustainability of Research Reactors and their Safe Operation Through Regional Cooperation, Networking, and Coalitions” (RER/4/029) and “Nutritional and Health-Related Studies Using Research Reactors” (RAF/4/020; AFRA IV-12), and is also supported by a grant from the Nuclear Threat Initiative (NTI).

In the area of research reactor coalitions for nuclear education and training, the Agency has developed important contacts and working relationships with institutions involved in the well-established European networks on nuclear education and training, such as ENEN and NEPTUNO, that are discussed in other papers at this conference. The IAEA seeks to use these as models and resources for strengthening nuclear education and training in IAEA Member States in other regions.

The nuclear education and training activities being undertaken in the Research Reactors Coalitions Initiative are also complementary to a variety of other IAEA programmes and activities – such as enhancing nuclear knowledge and knowledge preservation, and for establishing the infrastructure required by potential new nuclear power countries – but the primary objective of this effort is to improve utilization, and therefore sustainability, of research reactors.

2. Concept outline

From the operational perspective, coalitions will facilitate peer group sharing of best practices, improve information availability to members, and reinforce/develop the operating disciplines of safety and quality control. From the business perspective, coalitions will provide support for strategic and business planning and improved market awareness, and so help to increase reactor utilization, generate additional revenues and justify additional governmental support.

From the public perspective, coalitions will have the opportunity to enhance the information available to help retain and build confidence in reactor operation.

A coalition, or network, of research reactors for education and training will share experience and concepts for training methodologies and courses, and allow training courses to be adapted or tailored to specific needs, for example language. It can also match user requirements to the expertise and equipment available within the coalition, potentially including access to, and optimizing the use of, specific capabilities available at different sites within the coalition.

There is not a “one size fits all” solution, coalitions can take several different forms according to the needs and capabilities of their members. Possible coalition variants include bilateral sub-contracting, joint venture or other supply arrangements between pairs of research reactors; informal peer group networks that can share best practice information;, and broad, formal coalitions that are capable of effectively marketing their members’ services and representing their interests in common, as well as setting standards for all members. It is expected that formal coalitions will also facilitate access by non-reactor owning countries/members, with financial subscriptions paid in return for access to reactor services, thus avoiding the new construction or operation of marginally supported reactors.

In most cases, it is envisaged that coalitions will not start with full scope implementation, but rather will develop from relatively modest starting points (e.g. involving two or three reactors/partners), and will evolve by expanding their scope of implementation as the confidence of the members, and their governments, increases. For example, a simple, bilateral backup supply arrangement may grow into an informal network, and eventually become a subscription-based coalition.

3. Concept benefits

A coalition is expected to have both specific and general benefits to participating research reactors. The specific benefits of a coalition will derive from improved strategic and business planning (using IAEA-TECDOC-1212 “Strategic Planning for Research Reactors” as a guide) and joint marketing of the services of its participant reactors (scientific/research activities and commercial products), with the coalition thus able to:

- Optimize the services offered on a geographical basis, and reduce operational costs.
- Make maximum use of expertise or equipment at a particular facilities, and perhaps enable particular facilities to specialize in services in which they could have a "comparative advantage."
- Use the combined expertise of the participant facilities to best advise and serve their customers. This would help increase customer knowledge of, and access to, the radiation services, and support the customer with a more reliable and comprehensive customer service.
- Improve the utilization and sustainability of individual research reactors, and increase overall levels of demand to the mutual benefit of all market participants (suppliers and customers). Additional reactor utilizations would generate revenues, or help make the necessary justifications for additional local governmental support, thus improving sustainability. The additional funding could assist individual reactors to pay for operational, safety and security improvements.
- Develop a common methodology for calculating costs of reactor services to include spent fuel management and eventual decommissioning liabilities.
- Provide assistance to reactors planning or undergoing conversion from Highly Enriched Uranium to LEU including sharing of experience and planning expertise.
- Address needs of user groups without access to a research reactor in their Member State(s).

4. IAEA Activities and Progress

A. General

The Agency's role is to serve as catalyst and a facilitator of ideas and proposals. Meetings held by the IAEA in August-September 2006 resulted in preparation of a grant request on research reactor coalitions which was submitted to the Nuclear Threat Initiative (NTI) and approved in October 2006. A parallel Regional Europe Technical Cooperation project was approved in November 2006 by the IAEA Board of Governors.

From October 2006-January 2007, the IAEA conducted informal consultations with a wide number of research reactor operators, commercial entities, research reactor irradiation services users, and other stakeholders. Approximately fifteen "notional proposals" for coalitions covering a range of subjects and virtually all geographic areas were initiated, which became the basis of the Agency's initial activities in 2007. Following initial discussions with possible participants, several of the notional proposals were further elaborated and then became the basis for exploratory meetings in fall 2007.

From an early stage, a key IAEA partner in this effort has been the Atominsitut TRIGA reactor of the Vienna University of Technology, which is heavily involved in European nuclear education and training networks such as ENEN and NEPTUNO and also has a successful program of nuclear education and training activities for both academic and professional purposes.

B. Coalitions for Nuclear Education and Training

1. Argentina

The IAEA together with the Technical University of Vienna/Atominstitut (ATI) conducted a mission to Buenos Aires, Argentina on 22-23 October 2007 for discussions with the Instituto Dan Beninson (IDB) of the Argentine Atomic Energy Commission (CNEA) on establishing a coalition for nuclear education and training. Agreement was reached on a cooperative relationship between the ATI and IDB and action items were specified. IDB agreed to facilitate provision of Argentine experience in neutron noise and reactor kinetics measurements to ATI. Following the meeting, ATI provided information on its educational programmes and courses (e.g. manuals, schedules, course equipment, target groups). The IAEA made arrangements for the provision of IAEA-developed power reactor simulation codes to IDB. The IAEA will also facilitate the participation in 2008 of an IDB observer at an ATI power reactor operations training course at the TRIGA in Vienna as a first step in assisting IDB to enhance similar courses for nuclear power plant operators in Argentina.

2. Caribbean

An IAEA-ATI mission took place at Centro Nuclear ININ (Instituto Nacional de Investigaciones Nucleares), Mexico on 30-31 October 2007 for discussion of a Caribbean regional research reactor coalition. A preliminary agreement was reached regarding formation of such a coalition between the three research reactors in Colombia, Jamaica, and Mexico. This coalition is intended to serve as a regional resource for nuclear education and training, nuclear science, and analytical services for other countries in the Caribbean region that do not have research reactors. The focus of its activities will be on training and services for neutron activation analysis (especially for environmental applications) and for health physics and radiation protection. A draft "Practical Arrangement" to serve as the legal basis for the coalition is under review by the parties, a reactor operator certification course will be carried out by ININ for Colombian research reactor operators, and Jamaica has formulated a course on neutron activation analysis. It is envisaged that a regional workshop will be held late in 2008 or early 2009 to introduce the capabilities of the coalition to potential regional users.

3. Mexico

An IAEA-ATI mission took place in Mexico on 29 October at Centro ININ for discussions between ININ and the Laguna Verde Nuclear Power Plant. These discussions focused on establishment of practical power reactor operator training courses for Laguna Verde at the TRIGA research reactor at ININ. ATI presented information on the practical reactor operations courses that it presently offers to staff from Slovak, German, and U.K. reactor operators and institutions. A meeting protocol was agreed between the participants, and follow-up discussions later took place between ININ and Laguna Verde. As a result, ININ held a trial reactor operations training course at its TRIGA reactor 26-28 March 2008 for training managers of the Laguna Verde Nuclear Power Plant, and plans to offer the course regularly in the future for Laguna Verde personnel on a contractual basis.

4. Russia

IAEA and Russian experts held exploratory meetings on research reactor coalitions in Dmitrovgrad, Russia on 5-6 September 2007 and in Vienna on 13-14 December 2007. Meeting protocols were concluded that specified a number of possible areas for coalitions among Russian research reactors and/or with research reactors outside Russia, in particular for education in nuclear science and engineering. A mission was organized to Moscow and Obninsk, Russia on 12-14 March 2008 focusing specifically on coalitions for nuclear education and training. Visits took place to nuclear education and training centers and academies in Moscow and Obninsk and discussions were held with the Russian Federal Atomic Energy Agency (ROSATOM) Moscow Advanced Training Institute (MIPK), Moscow State Engineering Physics Institute (MEPhI), and the Central Institute for Continuing Education and Training in Obninsk (TsIPK).

The IAEA encouraged these institutions to collaborate in developing and offering training courses on 'managing nuclear research institutions and research reactors in a competitive environment' for Russian nuclear research institutes, research reactors and nuclear institutions in other Russian-speaking countries. Such training courses would build upon training activities that have already been conducted by these institutions. The IAEA stated that if a coalition of the relevant Russian institutes and other appropriate outside expert institutions were to offer a pilot course on this subject, the IAEA would organize a group fellowship to facilitate the attendance of managers operating Russian-origin research reactors in neighbouring Russian-speaking countries. It was also noted that such a course could serve as an initial step for the development of a future broader "Nuclear MBA" course that is of interest to ROSATOM.

5. Other

An IAEA organized Workshop on Advanced Strategic Planning for Research Reactor Coalitions (Europe region) was held in Vienna from 17-19 December 2007. The final report of the workshop contains suggestions from each of the participants regarding ideas for cooperation and collaboration with other research reactors and for concrete proposals for research reactor coalitions. These include a Nuclear Education and Training Coalition (potentially involving Armenia, Azerbaijan, Austria/ATI, Czech Republic/CTU, and Italy). The IAEA will be carrying out further efforts in 2008 in regard to formation of such a coalition.

The IAEA has also had discussions regarding cooperation with the Jules Horowitz Reactor (JHR) regarding support for training of scientists from countries involved in the JHR project.

5. Conclusion

The IAEA Research Reactor Coalitions Initiative had a promising start during its first full year of formal activity. The IAEA has successfully played the role of "catalyst" and facilitiator of ideas. As a result – and perhaps most importantly – the coalitions concept seems to be gaining international acceptance, with the term frequently used in international research reactor meetings and discussions. As further evidence of this, a number of countries and institutions have formulated and are developing on their own proposals for coalitions.

In particular, a number of cooperative relationships or nascent coalitions are under development to promote and enhance nuclear education and training. It appears that the coalition model can be utilized as yet another tool by the international community to strengthen nuclear education and training and to help develop nuclear scientists and technical staff to meet upcoming human resource requirements in nuclear power engineering, including research and development, nuclear medicine, nuclear safety and radiation protection, etc.

The IAEA will continue to work vigorously in the next years to further develop the cooperative relationships and coalitions for nuclear education and training cited and remains open to other suggestions and proposals from other Member States and institutions.

FUTURE OPERATION OF THE 37 YEARS OLD HUNGARIAN TRAINING REACTOR

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ABSTRACT

At the Budapest University of Technology and Economics a pool type training reactor of 100 kW nominal power has been operating since 1971. The Institute of Nuclear Techniques as the operator of the reactor and the reactor itself play an important role in the higher nuclear education and research in Hungary. The first generation of the reactor staff was retired during the last few years therefore a special program was started for renewing the operational and educational staff. In 2006 and 2007 the Periodic Safety Review had to be done. The paper describes the facility itself and the recent actions in human resource management and knowledge management, and also the new safety analysis methods which were applied during the recent Periodic Safety Review.

1. Introduction

The share of the four Paks NPP units in the Hungarian electricity production is 38%, which properly indicates the importance of nuclear energy in Hungary. In the early 60's, one decade prior to the start of the construction of the Paks NPP, the country began to prepare for domestic nuclear technology and the preliminary steps for commissioning of the training reactor were also taken. The construction at the Technical University of Budapest was started at the end of 1966 and was finished in 1971, the first criticality was reached in the same year in May. The training reactor has been successfully serving Hungarian nuclear expert education and technical education of physicists, engineers and teachers for the last 37 years.

Hungary prepares for extending the lifetime of the four VVER-440/213 type units at the Paks site; if this project succeeds, those units will finish the operation between 2032 and 2037. Discussion on possible construction of new nuclear units in Hungary was recently started. Both lifetime extension and construction of new units require continuous nuclear expert supply. The training reactor may provide a good basis for this purpose. On the other hand the further operation of this facility for the next two decades requires renewal of different technical systems and the generation-change of the operating and educational personnel.

In 2006 and 2007 the Periodic Safety Review (PSR) was carried out in the training reactor. In June 2007, the Hungarian nuclear safety authority issued the operating license for the next 10 years based on the PSR report. During the PSR study the safety of the reactor was re-evaluated, the development of a new 3D neutron kinetics code was started, and modern Computational Fluid Dynamics (CFD) methods were applied for performing the safety analyses of the special (aluminium-coated, magnesium and uranium-oxide mixture filled) EK-10 fuel for LOCA and RIA transients.

2. The training reactor

The training reactor is operated by the Institute of Nuclear Techniques (NTI) of the Budapest University of Technology and Economics (BME). The training reactor is a Hungarian designed pool-type reactor located at the university campus (see Fig. 1.).

The reactor core is made up of 24 EK-10 type fuel assemblies, which altogether contain 369 fuel pins. The fuel is 10%-enriched uranium-dioxide in magnesium matrix. The UO_2-Mg mixture is inside a 1.5 mm thick aluminium cladding, the active length is 50 cm. The total

mass of uranium in the core is approximately 29.5 kg. The horizontal reflector is made of graphite and water, while in vertical direction water plays this role. The highest thermal neutron flux – $2.7 \cdot 10^{12}$ n/cm^{2}s – was measured in one of the vertical irradiation channels.
Seven neutron measurement channels are used for reactivity control and power regulation. The detectors are ex-core ionization chambers, two of which operate in pulse mode in the start-up range, four operate in current mode and one is a wide range detector. In all power ranges two independent doubling time and power level signals can initiate automatic reactor trip.
The reactor is only operated when student laboratory exercises or research activities require it. Operation at 100 kW power level for many hours is quite rare; usually it occurs once a week during the semesters. This results a very low burn-up: only 0.56% of the initial ^{235}U content has been used up and 3.4 g ^{239}Pu and 12.3 g fission products have accumulated. Therefore, there has been no need to replace any of the fuel assemblies since 1971. Strict water chemistry regime has been maintained in the reactor pool in the last four decades, therefore no corrosion problem of the aluminium surfaces has been observed during the annual visual inspections.
The training reactor is the scene of reactor operation exercises for undergraduate and graduate students and also serves as neutron- and gamma-radiation source. Irradiation of different samples can be carried out with two pneumatic dispatch systems, with 20 vertical irradiation channels and 5 horizontal beam tubes. The reactor has radiochemistry, neutron- and reactor physical laboratories, as well as laboratories for radiation protection measurements. Extensive research work is going on in the institute and at the training reactor too.

Figure 1. The reactor building and the reactor core at nominal 100 kW power

3. Education in the training reactor

The most important part of the undergraduate education is supporting the education of engineering-physicists at the BME. The NTI holds the nuclear-related courses of the engineering-physicist faculty. The main fields of the courses are reactor physics, thermal hydraulics, nuclear safety, radiation protection, nuclear measurements and instruments and radiochemistry. The education of other engineering faculties (mechanical, chemical, electrical) is also supported by the NTI. The NTI performs educational activities for other Hungarian universities as well.
Due to the transformation of the Hungarian higher education, the former university education strategy will be transformed into the two-cycle BSc and MSc educational concept. The former engineering-physicist education will be replaced with the Physics BSc and MSc education (Faculty of Natural Sciences) with an increased number of students. The Nuclear Engineer specialization of the Energetic Engineer BSc-education (Faculty of Mechanical Engineering) has increased the number of students since 2006 as well. The starting of nuclear related engineering MSc course is in progress too.
The main fields of the post-graduate education are the PhD school and the post-graduate training course for nuclear reactor engineers. The NTI hosts the reactor-physical and nuclear

technical parts of the Physics PhD School of the Faculty of Natural Sciences. There are about 10 PhD students – with state-financed or self-financed scholarship – engaged in research activities at the NTI.
In addition, the post-graduate nuclear reactor engineering training has an increasing popularity. In 2006 a record number of students (36) applied for and was admitted to the training. The number of students increased due to the planned extension of the operating license of the Paks NPP. The nuclear reactor engineer education has a 40-year history at the NTI, but the interest in the course fell down following the start of the commercial operation of the Paks NPP units. The training program has an essential role in the lifetime-extension project since the number of the well-trained professionals is decreasing significantly due to retirement at the NPP, authorities and technical support organizations.
The institute participate also in the ENEN (European Nuclear Education Network Association), aim at the integration of the European nuclear education. The first and most successful course of the ENEN is the Eugene Wigner Course for Reactor Physics Experiments, the main emphasis of which is to perform reactor physics experiments to enhance the knowledge of the students in nuclear engineering and reactor safety [1]. Three research- and training reactors in three different countries (Vienna – Austria, Prague – Czech Republic, Budapest – Hungary) are concerned with this course. The 21 day long course was first started in 2003. In the last 4 years 58 participants from 12 countries accomplished the course. The participants are mainly MSc students but PhD students and young experts can be found among them as well.

Some typical measurement exercises in the training reactor (see Fig. 2.):

- Neutron activation analysis
- Determination of thermal neutron flux in the reactor core using neutron activation analysis
- Determination of the thermal neutron flux axial distribution in the core
- Investigation of delayed neutron parameters, determining of uranium concentration in samples
- Reactor operation exercise
- Measurement of the void coefficient and the control rod reactivity worth
- Measurement of thermal neutron diffusion length in graphite
- Criticality experiment
- Measurement of gamma- and neutron dose rate

The utilization of the training reactor and its laboratories is quite high due to the different education programs. Beside the regular university education there are about 2 to 3 thousands of secondary school students visiting the reactor annually, which helps the secondary school teachers in the basic nuclear physics education.

The reactor is used, among others, in the following research fields:

- Activation analysis for radiochemistry and archaeological research
- Analysis of environmental samples
- Determination of uranium content of rock and other samples
- Biomedical applications (BNCT)
- Nuclear instrument development and testing
- Experiments in reactor physics and thermal hydraulics
- Development and testing of neutron tomography methods for safeguards purposes
- Development of noise diagnostic methods
- Investigation of radiation damage to instruments/equipment
- Radiochemical analysis of different samples supporting the Hungarian Atomic Energy Authority in fight against illicit trafficking of nuclear and radioactive materials.

Figure 2. Student exercise in the control room and with the pneumatic dispatch system

4. Human resource management and knowledge transfer

The colleagues who were participated in the start-up of the reactor and assured the safe operation of the reactor during the first three and a half decades are now retired or preparing to retire. Their replacement requires a special program which has been planned and was implemented in the last 3 years. In the most important positions the number of employees was doubled in 2 years in order that the young colleagues could work together with the experienced ones day-by-day. This ensures the most effective transfer of special operational and maintenance knowledge. The young experts have successfully obtained their licenses for reactor operation and they are able to operate the reactor alone.

For a more effective technical knowledge transfer a modern, computer-based 3D CAD model has been developed based on the 40-45 years old drawings. This has been proved to be effective from more viewpoints:

- differences between many old drawings and the implementation have been revealed;
- the young employees could learn reactor construction in a more effective manner through the problems arisen during the development of the 3D CAD model;
- there are up-to-date drawings which may be continuously updated according to the future modifications of the reactor.

A long-term technical development plan was also outlined to ensure the extended operation of the reactor.

5. Renewal of the technical systems

During the last 3 years the following main actions were made at the training reactor:

- Refurbishing a part of the ventilation system;
- Renewal of the pneumatic dispatch system;
- Restoration of the classroom in the reactor building;
- Application of state-of-the-art 3D reactor-physical and thermal hydraulical simulations in the safety analyses;
- Building of a new document archive for old and new safety reports, procedures, manuals, research reports and books;
- Development and use of a modern intranet site serving general information source for the reactor operators and the collective of the institute;
- Actions for the conservation of collective knowledge.

6. Periodic safety review

In 2006 and 2007 the Periodic Safety Review (PSR) was carried out for the training reactor. The volumes of the Periodic Safety Review report [2]:

0. General Evaluation
1. General Description of BME Training Reactor
2. Equipment Qualification
3. Safety Analyses

4. Aging Management Program
5. Safety Performance
6. Use of Operational Experience and Research Results
7. Procedures
8. Organization and Administration
9. Human Factors
10. Radiological Impact on the Environment
11. Investigation of Compliance with the Hungarian Nuclear Safety Regulations
12. Emergency Response Plan of BME Training Reactor
13. Utilization of BME Training Reactor and its Experimental Equipments
14. Experimental Results

We have very limited information about the material, thermo-physical, mechanical and geometrical properties of EK-10 type fuel elements which were produced in the sixties in the Former Soviet Union. Although the previous safety analyses made in 1997 contained detailed power excursion and LOCA calculations, these calculations were based on several uncertain thermo-physical and mechanical parameters.
For this reason we recalculated the behaviour of the EK-10 fuel rod in the worst case power excursion accident and LOCA scenarios. The thermal-hydraulic processes were investigated by the three dimensional CFX code and the connecting stress analyses were performed with the COSMOS FEM code.
To reduce the effect of the thermo-physical and mechanical parameters' uncertainty from the calculations, we are planning to develop an experimental apparatus to measure the thermal conductivity, specific heat capacity at constant pressure, density and thermal expansion coefficient of UO_2-Mg fuel as a function of temperature.
Based on the above described PSR the Hungarian Atomic Energy Authority has issued the operating license for further 10 years. However, different safety enhancement activities and further analysis have to be made in the next 3 years. During the PSR the development of a new 3D neutron kinetics code was started, and modern Computational Fluid Dynamics (CFD) methods were applied for the safety analyses of the special (aluminium-coated, magnesium and uranium-oxide mixture filled) EK-10 fuel for LOCA and RIA transients.

7. Summary

In the paper a general overview of the activities at the Hungarian Training Reactor was given. The replacement of the reactor staff and the critical systems were started in the last years. After the Periodic Safety Review in 2006 and 2007 the following main steps are planned for the near future:

- Renovation of the radiation monitoring system and the connected data acquisition computer;
- Reconstruction of the safety and control rod drives;
- Renewal of the nuclear measuring chains;
- Preparation for spent fuel transportation and possible replacement of the core;
- Refinement of the decommissioning plan;
- Further analyses for Design Basis Accidents, further developments of safety analysis methods and codes;
- Enhancements of operational manuals and regulations.

The further operation of the training reactor at least until 2027 is planed.

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THE CZECH NUCLEAR EDUCATION NETWORK ASSOCIATION (THE ROLE OF TRAINING REACTOR VR-1 IN NUCLEAR EDUCATION IN THE CZECH REPUBLIC)

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The paper is dedicated to the memory of Prof. Karel Matějka, Ph.D., the founder and the first president of the Czech Nuclear Education Network Association, the training reactor VR-1 project leader and the founder and head of the department, who unexpectedly deceased on the 13th March 2008 at Prague.

ABSTRACT

In according to present European and worldwide activities, Department of Nuclear Reactors initializes an idea of CENEN – "Czech Nuclear Education Network", national institution which aims its effort to nuclear education in Czech Republic. Association is based on principles of ENEN – "European Nuclear Education Network Association" founded as part of 5th European Framework Programme. The main objective of the CENEN (as well as ENEN in European level) is the preservation and further development of a higher nuclear education and expertise. This idea should be realized through the co-operation between Czech universities involved in education and research in the nuclear engineering field, research centres, nuclear industry and regulatory body. CENEN promotes and further develops the collaboration in nuclear engineering education of academicians, engineers and researches; ensure the quality of nuclear engineering education and training.

1. Introduction

The Czech Nuclear Education Network Association was established on 5th May 2005, as a voluntary academic association developing education and training in nuclear engineering in the Czech Republic. The CENEN has 12 academic members – departments of Czech technical universities offering nuclear education and 4 associated members – institutions of Czech nuclear industry, research and development, and legislative offering practical experiences and professional excellence. Association progress is still in developing phase, main goal is knowledge and education materials exchange, experimental facilities for education sharing, collaboration framework definition; members are preparing first joint summer/winter school of nuclear engineering in 2008 now. At the present date the CENEN academic members are The Czech Technical University in Prague (specializing in nuclear reactor theory, dosimetry, nuclear chemistry, waste management, nuclear heavy machinery and mechanical engineering, and power electrical equipments for NPP's), The University of West Bohemia in Plzen (nuclear mechanical and power electrical engineering), The Brno University of Technology (NPP's operation, nuclear mechanical and power electrical engineering), The VSB-Technical University in Ostrava (nuclear mechanical engineering), and The Institute of Chemical Technology in Prague (nuclear chemistry and waste management). The associated members are The Nuclear Research Institute at Rez plc (leader in Czech nuclear R&D), The CEZ plc (energy producer, operator of two Czech NPP's), The SKODA JS plc, member of the OMZ group (nuclear heavy machinery producer and NPP's designer), and The State Office for Nuclear Safety (state regulatory body). The CENEN organization is shown in figure 1.

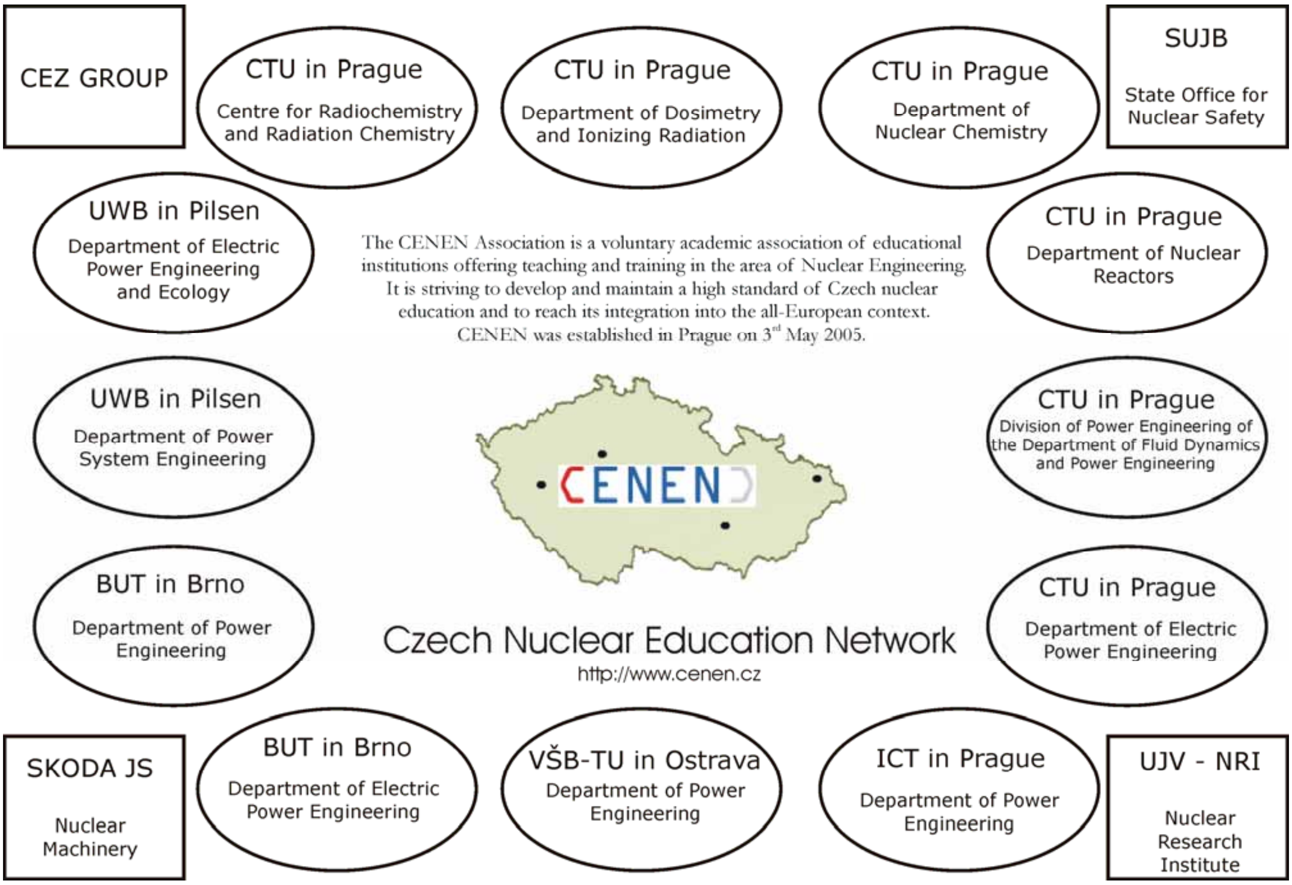

Fig.1: Scheme of the CENEN organization

2. The VR-1 reactor

Present basis of CENEN collaboration is in common utilization of the training reactor VR-1, which is operated by the Czech Technical University in Prague, Department of Nuclear Reactors. The VR-1 reactor has been in utilization from 3rd December 1990. It is a pool zero power reactor and is based on the Czech project using Russian IRT fuel. Maximal thermal neutron flux is 1E8 n.cm^{-2}.s^{-1}. There is no burn-up of the fuel. However, during its operation the fuel was two-times changed. In the middle of 90's IRT-2M fuel was changes to IRT-3M fuel, both with 36% of enrichment. In 2005 within the RERTR programme fuel was renewed to IRT-4M type with 19.7% of enrichment. The VR-1 was the first completely converted research reactor on the world with this type of fuel. After the 2005 there were two years of modernization. New independent power measurement and operation power measurement systems were installed. Both systems are completely digital. New technology systems, dosimetry and monitoring systems, as well as security and HMI were put into the operation. The area for students was enlarged, so seven groups of two or three students can measure simultaneously. Special devices for students' exercises and tasks were also innovated - there are new devices for study of dynamical properties of reactor, void coefficient, delay neutron fraction measurement, etc. The reactor VR-1 was ceremoniously reopened on 3rd December 2007 by the President of the Czech Republic Prof. Václav Klaus. In January 2008 the reactor was approved by state regulatory body to the next 10 years of operation.

3. The role of VR-1 in the education within CENEN

For students from CENEN institutes (as well as for some other universities from Czech Republic, Slovakia, and Germany) are prepared courses of Reactor theory introduction, Research reactors operation, Reactor Dosimetry, Neutron and gamma dosimetry, Reactor dynamics, and other specialized courses. Courses may long for a day as minimum (two experimental exercises) or for couple of days. The specialized courses include reactivity measurement using various methods, void coefficient measurement, delayed neutron fraction measurement, neutron spatial distribution, reflector studying, etc. Students are also using the VR-1 for their Bachelor or Master Degree theses. Each year are served approximately 250 university students. The VR-1 reactor is also one of nuclear facilities where students perform their measurements during well-known Eugene-Wigner

Reactor Course. Training reactor VR-1 also serves as general public education device, training facility for future specialists of the CEZ's NPP's, and as a research reactor for irradiation and R&D.

Fig.2: View of the VR-1 reactor hall during ceremony of reopening after innovation

4. The CENEN plans

Essential aim of CENEN is increase attractiveness for nuclear engineering studies; open studies for wider number of students and incorporate Czech nuclear education into European network. Future objectives should be also definition of Czech Master of Science Degree in Nuclear Engineering (like European nuclear M.Sc. standard), promotion of exchange of students and teachers participating in the frame of CENEN network, and establishment of mutual lectures and training courses. Activity in founding national education network is also motivated by successful work of BNEN. The CENEN plans organize first summer school for students this year. The one week intensive course will be full of lectures and seminars from various very special nuclear topics. Students should obtain information which is not provided during standard lectures. The CENEN project partners also plan to share experimental facilities which provide regional universities, they are creating internal database of lectures, exercises, students' theses, mentors, peer reviewers, books, educational materials, etc. Partners plan to participate in European projects like ENEN, collaborate with Russian universities and research centres. Emphasis should be in cooperation with specialists from associated members, professionals from research and industry.

UTILISATION OF RESEARCH REACTORS IN EDUCATION AND TRAINING PROGRAMS ORGANISED BY THE ATOMIC ENERGY COMMISSION

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ABSTRACT

As a part of the French Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution that provides to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications, including nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on research reactors. We present here the utilisation of CEA research reactors for training courses organised by the INSTN.

1. Introduction

As a part of the French Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution under the join supervision of the Ministries in charge of Education and Industry. It has been created in 1956, when France decided to launch a nuclear programme, in order to provide to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications, including nuclear reactor theory and operation. Since 1956, the adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on experimental facilities located either at the INSTN or more generally on the CEA research Centres.

We present here this strategy and the utilisation of CEA research reactors for training courses on nuclear reactor operation. This use is illustrated by two experiments that are carried out on ISIS reactor as a part of a global program that include the control of sub-criticality during fuel loading, the approach to criticality, the control rod calibration, the measurement of rod worth by the rod drop technique, the study of the temperature effects, the role of the delayed neutrons, exercises on reactor operation and control, the operation of the neutron detection systems, and radioprotection measurements.

2. INSTN mission and strategy

The INSTN mission is to disseminate the CEA knowledge and know-how qualification in all disciplines related to nuclear energy applications amongst academic and scientific institutions as well as industry. The INSTN headquarter is located at the Saclay CEA Centre, 20 km South of Paris. It also has four branches set up in the CEA centres located at Grenoble, Cadarache Valrhô-Marcoule, and Cherbourg-La Hague.

Yet in 1956, a one year specialisation course, so called “Génie atomique”, was launched in order to provide engineers with a high level of qualification in nuclear engineering including reactor physics. This specialisation course has contributed to the qualification of up to 140 engineers per year since 1956. The number may exceed 150 engineers in the next years due to the strong need in nuclear engineers in the French industry.

In order to contribute to the development of the INSTN activities, between 1956 and 1960, it has been established that the institute should be equipped with experimental facilities in order to give students and future operating personnel a comprehensive understanding of the nuclear physics. It was also decided to use some of the experimental reactors on the different CEA research Centres to enlarge the INSTN capability.

3. Use of experimental reactors

For nuclear reactor engineering, the INSTN strategy included the fabrication of two facilities at the INSTN headquarter in Saclay. The headquarter was then successively equipped with a sub-critical assembly (URANIE) in 1956 and with an Argonaut reactor (ULYSSE) in 1961.

URANIE was constituted by a hexagonal assembly of 217 elements (natural uranium with a total mass of 2,5 tonnes) placed in a vessel filled with water and equipped with AmBe neutrons sources and neutron detectors. This facility was used until the 80's for neutron experiments in sub-critical states

ULYSSE reactor is an Argonaut type reactor with a nominal power of 100 kW that was especially designed for training courses. It was constructed between January and June 1961 and was started up in July 1961. From this date it was mainly used for training courses and experimental purposes until the decision to shut down the reactor, after more than 40 years of operation, was taken in 2003. At this time, the leading strategy of completing theoretical courses with training course was confirmed and it was decided to transfer the teaching activities to another experimental reactor, so called ISIS and located on the CEA Saclay Centre.

ISIS reactor is an open core pool type reactor with a nominal power of 700 kW. From 2004 until 2006, ISIS reactor, went through a major refurbishment of the control system in order to adapt the reactor to the educational and training activities (see "Training courses on ISIS reactor at Saclay research center, B. Alvado & F. Foulon, in this conference proceeding). This refurbishment included the development of a supervision software used to display different screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor. For training activities, the maximal power was limited to 50 kW according to its license renewed in 2006. After the restart of ISIS reactor in 2006, ULYSSE reactor was definitively shut down in February 2007 and the training activities were transferred on ISIS reactor in March 2007. Figure 1 shows the control room of the ISIS reactor were the training courses are carried out.

In parallel to this evolution of the training activities at the Saclay Centre, other experimental facilities have been used to carry out training courses on other CEA research Centres. In Grenoble, SILOETTE reactor, with a power of 100 kW, was used for training from 1973 until 2001, when the reactor was definitely shut down. In Cadarache, EOLE and MINERVE reactors, which are low power reactors (≤ 100 W), are still in use for training courses in the frame of the INSTN missions.

Thus, today three reactors are being used for training courses in the frame of the INSTN missions : ISIS reactor in Saclay and EOLE and MINERVE reactor in Cadarache. In 2007, about 100 training courses have been conducted on these reactors. Courses are typically carried out with a group of up to 10 persons and have a duration of 3 hours.

 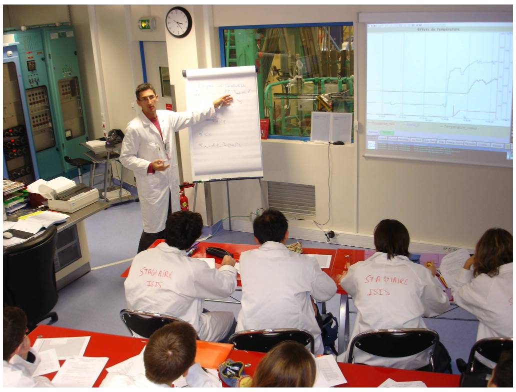

Figure 1 : Photographs of the control room of ISIS during a training course showing the control board of the reactor (left) and the projection of the supervision screen used to follow the evolution of the reactor parameters.

The training courses are addressed to a wide range of public including students from universities and from engineer schools, operators of research reactors (qualification of reactor personnel), professionals with interest in reactor theory and operation (operators, researchers, regulators, engineers, administrative staff), as well as teachers from undergraduate schools. For the later, this contributes to a diffusion of the knowledge and interest in nuclear sciences amongst the students at an early stage in undergraduate schools.

Depending on the trainees and on the associated pedagogic goals, the persons are following from 3 to 18 hours of training courses on nuclear reactors, either to have a global understanding and demonstration of reactor operation, or to study in details the various aspects of reactor operation. Two experiments carried out on ISIS reactor are presented in paragraph 4.

Future trend shows a strong increase in the need of engineers and operating personnel specialised in reactor theory and operation. Only in France, it is estimated that more than 5000 young students will have to be specialised in nuclear engineering for the need of the French nuclear industry in the next 10 years, increasing the need for training courses on experimental reactors.

4. Experiments carried out in training courses

We will review in this paragraph two experiments that are carried out in the frame of the INSTN educational and training activities. For each experiment emphasis is given on the safety of reactor operation.

- Control of the sub-criticality during fuel loading

The evolution of the counting rates N on the low level neutron detection systems is recorded during core loading with the last four fuel elements. The evolution of the inverse of the counting rate 1/N (when the neutron density is stable due to the neutron source) as a function of the number of fuel element is shown in Figure 2. The quantity of U5 and the position of each element added in the core are also indicated. On the left part of figure 2, the core configuration including the element position is given. The evolution of the neutron density is observed with a neutron detector in position BN1 (see Fig. 2).

According to the neutron kinetics, in the presence of a neutron source, the neutron density N in the sub-critical state reach an equilibrium that depends on the core reactivity ρ. Thus we have 1 / N ∝ - ρ / Sθ_c, with S the neutron flux of the source and θ_c the neutron lifetime at criticality.

1/N being proportional to - ρ, with ρ negative, the reactivity of the core is increasing and approaching zero (critical state) by negative values (since the reactor is still sub-critical) by the addition of the fuel elements. The observed 1/N variation strongly depends on the characteristics and position of the fuel elements.

The addition of the fuel elements in positions 31 and 21 induces a larger increase of the core reactivity seen by the detector placed in BN1 than the addition of elements in positions 84 and 82. This results form proximity effect : BN1 is much close to positions 31 and 21 and thus is more sensitive to the increase in neutron density by the addition of those two elements.

The curve also shows that the decrease in 1/N is not proportional to the mass of U5 added to the core. In fact the core is constituted with both new elements with a mass of U5 of about 457 g (n° 31 and 84) and used elements (n° 21 and 8 2) with burn up exhibiting values up to about 10^5 MWJ/T. The addition of the used elements not only results in an increase of the core reactivity, which is proportional to the mass of U5 introduced, but it also results in a modification of S in the previous equation. In fact we observe the increase of the S term contributes to a stronger decrease of 1/N than the addition of U5.

From the safety point of view, it is show that the criticality can be reached only by the addition of fuel elements. Since fuel elements have usually varying characteristics, criticality could be reached if the fuel loading plan is not correctly followed. Thus the evolution of the neutron density, through the neutron detection systems has to be strictly followed and analysed during fuel loading to detect any abnormal evolution of the core reactivity. This analysis has to take into account both the fuel element characteristics (mass of U5, burn up, position to the Be reflector) and the relative position of the neutron detection system to the fuel elements.

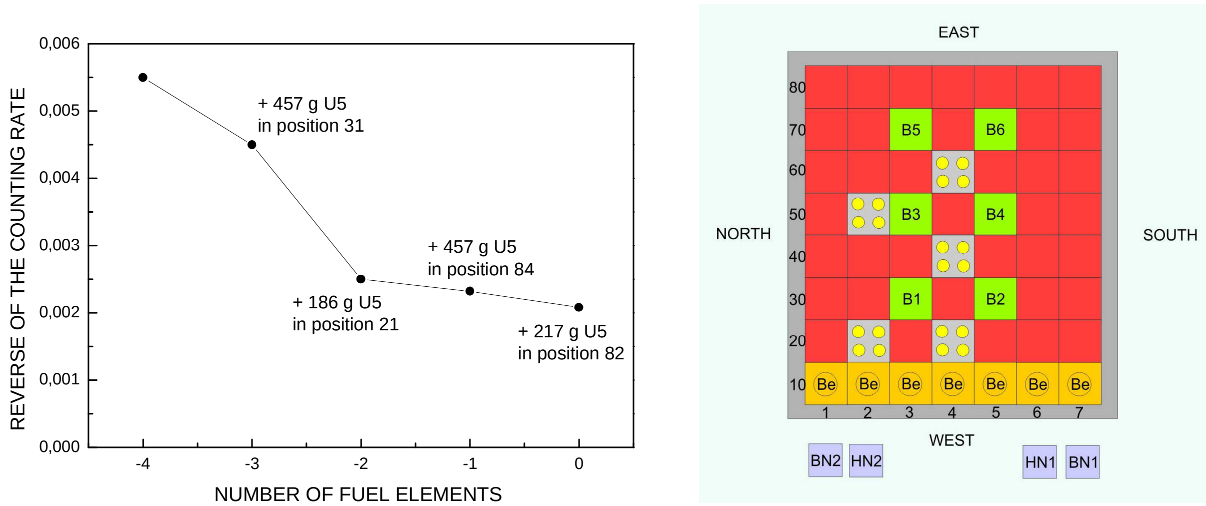

Figure 2 : Evolution of the reverse of the counting rate (when the neutron density is stable due to the starting neutron source) as a function of the number of fuel element missing in the core, and core configuration on the right hand side.

- Measurement of rod worth by the rod drop technique

The global worth of a rod can be measured by the rod drop technique. The reactor being critical with the rods B2 and B5 in their upper position (safety rods), B3 and B4 in the bottom position, B6 in its critical position and the rod B1 in its upper position, the rod B1 is dropped.

Following the drop the evolution of the neutron density in the core is recorded using the neutron detection systems BN1 and BN2.

From these measurements and using curves established from the neutron kinetic equations the global worth of the rod is found. Figure 3 shows the calculated curves giving the ratio $n(t)/n_0$, i.e. the neutron density at the instant t after the rod drop divided by the initial neutron density, as a function of the rod worth and for different time intervals after the rod drop (2 s, 4 s, …). From the data recorded on detection systems BN1 and BN2, the $n(t)/n_0$ values are reported in this figure. The global worth of B1 is then established : about 1190 pcm, seen from position BN1, and about 1790 pcm, seen from BN2 position.

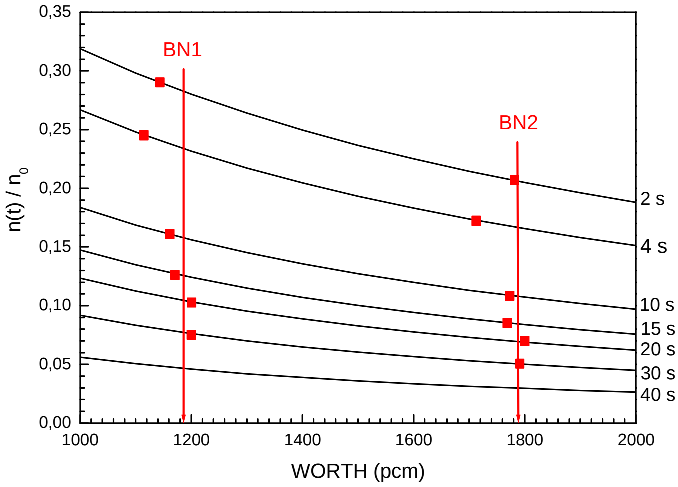

Figure 3 : Calculated curves giving $n(t)/n_0$, as a function of the rod worth, for different time intervals after the rod drop (2 s, 4 s, …) ; experimental data obtained on BN1 and BN2 detection system after B1 rod drop.

The B1 rod worth seen from position BN1 is lower than from position BN2 because BN2 is closer to the rod B1 so that the drop of B1 induces a larger modification of the neutron density around BN2 than around BN1. Thus the real global worth of B1 for the whole reactor core, i.e. the global worth is not affected by proximity effects, is closer to the value measured by BN1 than by BN2. Repeating B1 rod drop with B2 rod in its lower position, i.e. lowering the neutron density around B2 and thus BN1 before the rod drop, would have contributed to even decrease the global worth seen by BN1. From a practical and safety point of view, this experiment shows that the apparent global worth of a rod strongly depends on core configuration and on the position from which this worth is seen.

5. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides to students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. From this date, the adopted strategy is to complete theoretical courses and training courses on simulators by training courses carried out on CEA research reactors. The experience gained over more than 50 years show that this approach brings tremendous benefits. For students that can carry experimental work on research reactors, training courses on a reactor gives a great and unique opportunity to get an insight in the reactor kinetics and to get further interest in this domain of science and technology. For all trainees including the reactor personnel and regulators, the training courses ensure a practical and comprehensive understanding of the reactor operation and contribute to their qualification in this domain. Training courses also contribute to an improvement of the safety of the reactor operation especially when empathies are given to the impact of each operation and effect on the safety of the reactor operation, both in normal and incidental situations.

THE IAEA NETWORKS FACILITATING TRAINING AND DEMONSTRATION OF DISPOSAL AND DECOMMISSIONING TECHNOLOGIES

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ABSTRACT

Since 2001, the IAEA has been successfully operating the IAEA Network of Centres of Excellence for Training in and Demonstrations of Disposal Technologies in Underground Research Facilities (URF Network), which is showing to be a very effective and efficient vehicle for training of professionals in the field. Several Member States with operational underground research facilities have come together in a Network and are offering the use of their facilities for joint training and R&D activities to countries having less advanced programmes.

Using this positive experience of "networking" international efforts, the IAEA is planning to improve its response to the growing number and complexity of requests from Member States by introducing similar Networks in other activity areas. The International Decommissioning Network (IDN), launched in September 2007, is expected to play a pivotal role. Another Network to bundle international efforts in low level waste disposal area is also currently being developed.

1. Introduction

A continued focus of IAEA activities is to support Member States to secure and sustain human resources for the nuclear sector, by both replacing retiring staff and building new capacity. To fulfil one of its statutory functions the IAEA assists Member States, particularly developing ones, in their efforts to build and sustain nuclear know-how and training in all areas of nuclear technology for peaceful purposes. Emphasis is being placed on innovative approaches to facilitate the transfer of information and expertise among Member States in order to improve the response of the IAEA to the growing number and complexity of requests from the member States – at a time of budget and staff constraints.

Since 2001, the IAEA has been successfully operating the *IAEA Network of Centres of Excellence for Training in and Demonstrations of Disposal Technologies in Underground Research Facilities* for high level waste and spent nuclear fuel. In the frame of this Network, Member States with advanced geological disposal programmes and operating underground research facilities are offering the use of their facilities for joint training, research and development activities to countries having less advanced programmes. Experiences gained in the operation of these underground research facilities, and through associated experimentation and demonstrations are being transferred to the participating Member States through hands-on work in these facilities. This "networking" mechanism is showing to be a very effective and efficient vehicle for training of professionals in the field. Using this positive experience of networking international efforts, the IAEA is planning to introduce similar Networks in other activity areas, e.g. decommissioning and disposal of low level waste.

2. Network for Training in and Demonstration of Disposal Technologies in Underground Research Facilities (URF Network)

2.1 Background

The international community has been studying the geological disposal concept for almost 50 years. However, worldwide, there is only one geological disposal facility for long-lived radioactive waste that is in operation. For the last decades waste management specialists have been agreeing upon that geological disposal is the preferred option for the management of high level and long lived radioactive waste and spent nuclear fuel. Recent progress provides increasing assurance to the waste management community that sound technical solutions underpinned by good scientific investigation are available. Most of the technologies required for geological disposal have been developed, and work is continuing to complete the development of those technologies that still need to be demonstrated to assure that disposal can be effected. However, establishing public confidence in geological disposal is an important concern. Member States faced with the radioactive waste disposal issue are at various stages in the process. Some have selected favourable sites, have well-developed research programmes in underground facilities and have been given official government approval, backed by the public, to advance towards the establishment of a geological repository. Other countries are still in the earliest stages of site identification and discussion of the issue with the public. The development of underground facilities, in several countries, has been contributing towards moving from the theory to the practice.

In 2001, under the auspices of the IAEA, several Member States in which underground research facilities were operational came together in a *Network of Centres of Excellence for Training in and Demonstration of Disposal Technologies in Underground Research Facilities (URF Network)* and offered the use of their facilities for joint training, research and development activities with other Member States. These underground research facilities are extremely expensive to build and operate, and depend on international collaborations for funding. Historically, these collaborations had been between Member States with advanced waste management programmes. The IAEA-based Network embraces countries which have not got the resources to establish underground facilities to do the research needed to develop confidence in the concept of geological repositories for radioactive waste.

2.2 Objectives of the URF Network

Although, as stated above, geological disposal programmes in Member States are in various stages of development, construction of a geological repository for high level and spent fuel waste is not contemplated for at least a few decades in almost all cases. The IAEA URF Network is being developed with this time frame in mind, i.e. starting without delay, in order to assist lesser developed Member States, in a few decades to establish the broad and robust network of international expertise needed to ensure the efficient development of safe nuclear waste disposal systems worldwide.

The most important objectives are the following:

- To encourage the transfer and preservation of knowledge and technologies. While participation in current URF activities is the primary interest for some Member States and will be a benefit to all, many other Member States, especially developing countries, would need assistance for earlier phases of geological disposal studies.
- To supplement national efforts and promote public confidence in waste disposal schemes. Topical workshops and seminars may be organized, addressing important issues like monitoring and retrievability. Such activities could also be valuable in providing specialists new in this field with an understanding of both technical and non-technical issues that influence waste disposal technology.

- To contribute to the resolution of key technical issues. Member States can suggest any key technical issues of common interest as proposal for cooperative projects.

Thus, the URF Network provides a mechanism to ensure that Member States are appropriately aware of the latest state-of-the-art international technology in geological disposal. The Network helps to ensure that, as necessary, Member States have access to professional persons who are trained in the relevant disciplines, and part of an international community that serves as a platform to discuss matters of general concern. Thereby, the general public in each Member State should be assured that their professionals are both familiar with and capable of applying the appropriate technology to their own projects concerning the geological disposal of high level waste and spent nuclear fuel.

2.3 Membership

The Network consist of

- *Network Members,* who are owners of unique facilities in Member States, which can be recognized as Centres of Excellence having demonstrated high quality research and have offered their facilities to be part of the Network; and
- *Network Participants,* who come from any interested Member State, with or without an established programme for geological disposal but aware of the necessity of its implementation as solution for their high level or spent fuel waste.

The membership of the core group (who are Members) is dynamic, according to programme's development in Member States and availability of underground or even surface facilities. Since 2001, the core group of the Network has expanded from two facilities in Belgium and Canada at the beginning to include now almost all underground facilities and some supporting surface facilities in the following Member States:

- *Belgium* (HADES URF in Boom Clay Strata; SCK-CEN),
- *Canada* (Underground Research Laboratory – URL; AECL),
- *France* (Underground Test Facility, Tournemire; IRSN),
- *Germany* (Deep Disposal in Abandoned Iron Ore Mine Konrad; DBE Technology),
- *Sweden* (Äspö Hard Rock Laboratory; SKB),
- *Switzerland* (Grimsel Test Site in Granite and Mon-Terri URL in Clay Stones; NAGRA),
- *UK* (Geoenvironmental Research Centre; Cardiff University) and
- *USA* (Yucca Mountain Project, the Waste Isolation Pilot Plant and LBNL; US-DOE).

Recent inclusions of the Network are IRSN (France) and DBE Technology (Germany). Discussions are currently on-going to extend the Network further in 2008 to other Agencies, e.g. ANDRA (France) and JAEA (Japan). The underground research facilities allow for work to be carried out in major geological media, e.g. clay, crystalline, salt and tuff, in which geological repositories for radioactive waste are expected to be developed. These are complemented by well-equipped surface institutions in which desk and laboratory studies are carried out.

For those Member States with less well-developed infrastructures, there is the opportunity for their nationals and programme participants to undertake work in any or several of the Network's Centres of Excellence. Network Participants are regularly asked to express their needs over a period of several years. Being a long-term project, Participants' needs can be addressed over a long period of time consistent with a country's nuclear waste management programme. So far twenty-two Member States have taken advantage of the opportunities that the Network provides.

2.4 Role of the IAEA

The IAEA's Nuclear Energy Department coordinates and facilitates the activities of the Network and, otherwise, acts as Secretariat to the Network, including maintaining records of its activities in a web based platform. The IAEA promotes interactions between Network Members and Participants and coordinates the offers from Network Members with the needs expressed by Network Participants. In this respect the IAEA organizes annual Project Review Meetings in which Network Members and Participants report on their activities and define future action accordingly. The Network Members usually meet in a preparatory meeting ahead of the Project Review Meeting to discuss the proposals made by the IAEA Secretariat and the action plan.

The Department of Technical Cooperation of the IAEA plays a major role in supporting per year 2 to 3 training courses for 10 to 15 participants each and some fellowships and scientific visits for candidates from developing Member States hosted by the Network Members. In general, the Network Members provide both physical facilities and the experienced personnel for the training at no cost to the IAEA. This also provides trainees and fellows with a flexible and interesting learning experience and allows them to become more familiar with technologies, concepts and approaches of other countries.

Whenever possible, appropriate linkages between the Network and other IAEA implementation tools like the Coordinated Research Programmes are established to optimize approaches and resources. Cooperation is also looked for with activities of other international or regional programmes, e.g. those of EC.

2.5 Current status and future outlook

Till now, more than 150 candidates from over 20 countries have taken part in 12 training courses and many fellowships and scientific visits organized in Belgium, Canada, Czech Republic, Finland, Germany, Hungary, Sweden, Switzerland and USA. Three more courses will be provided in the second half of 2008 in Canada, Japan and UK.

Initially, the courses focused on the historical developments of underground facilities and on the associated fundamental scientific and technological aspects of geological disposal. Both the Participants and Members of the Network have subsequently agreed that the courses should be extended to include subjects such as numerical modelling and its development and validation through underground work and, more generally, aspects of societal acceptance in the development of geological waste disposal programmes. Further topics in this direction, e.g. performance assessment, site characterization, etc., have been suggested by Network Participants as response to a recent questionnaire survey. Currently, based on these responses and the offers of the Network Members, detailed programme for training and fellowship during the period 2009 – 2011 is under development.

The positive response by Member States to the activities of the URF Network over the past five years has demonstrated that the Project is providing important benefits that are not available through other avenues. Given the renewed interest in development of nuclear power, a declining availability and adverse environmental effects of traditional hydrocarbon resources, and rising international demand for energy, it is desirable that the Network Project should continue to build on what has been a very promising start. Continuation of the Network is entirely consistent with the IAEA mandate to ensure the safe and sustainable application of Nuclear Energy. Also the Network Project can contribute to the recognized requirement for nuclear knowledge maintenance and management.

Further information on the Network and its activities is available at the following website:
http://www.iaea.org/OurWork/ST/NE/NEFW/wts_network.html .

3. The International Decommissioning Network (IDN)

3.1 Background

Based on the success achieved with the International URF Network, a second network built on the same principles was launched by the IAEA Departments of Nuclear Energy, Nuclear Safety and Security, and Technical Cooperation during the General Conference in September 2007. It was followed by a Technical Meeting held at the IAEA in October, where the Terms of Reference, modus operandi and 2008 programme of work were finalized.

The need for this Network stems from the large number of nuclear installations, including power reactors, research reactors and many other fuel cycle facilities that have already ceased activity or are approaching the end of their operational lifetime and will need to be soon decommissioned. Many of these facilities are small and widely distributed geographically, e.g. more than 250 ageing or shut down research reactors. Appropriate steps need to be taken to prepare for their future decommissioning. In developing Member States, decommissioning programmes are often influenced by the availability of resources, i.e. knowledge, experience, infrastructure, funding capabilities and consequently, decommissioning strategies need to be tailored to cope with those constraints.

Those working in the decommissioning field have strongly endorsed the value of a more 'hands on' approach to the sharing of decommissioning skills and knowledge, particularly between experienced organizations with proven areas of excellence and those facing decommissioning challenges for the first time.

3.2 Mission and Objectives of the IDN

The International Decommissioning Network "strives to render decommissioning timely, cost-effective and safe through sharing information and guidance."

Primarily organized along regional lines, the IDN aims to assist participants to take full advantage of the Agency's established mechanisms for Technical Cooperation. In general, the IDN will fulfill the following functions:

- Support decommissioning of nuclear facilities in Member States, particularly those with less developed nuclear infrastructure, by providing access to decommissioning skills, knowledge and projects;
- Provide a mechanism whereby decommissioning organizations may exchange information under the aegis of the IAEA to pursue the promulgation of good practices and the longer term retention of knowledge relevant to decommissioning.
- The IDN will also provide specialist advice and technical guidance on the IAEA's programme in the area of decommissioning – services such as "peer reviews" – which are expected to expand in response to the expressed needs of the participants.

In recent years the demand for assistance in the field of decommissioning has exceeded the Agency's ability to respond in a timely and effective manner. In many instances, national organizations require similar types of assistance to get their decommissioning projects underway. A Regional Project in decommissioning, which has served the needs of decommissioning experts in the European Region for the past several years, has provided an excellent model for increasing the help participants can provide to each other. Furthermore, all participants, including those from Member States with developed decommissioning programmes benefit from the "networking" activities, since they also share perspectives and technical experience directly with each other.

3.3 Participation in the IDN

The IDN is open to all Member States and will be of interest to those engaged in or actively planning for decommissioning. The IDN forms a loose coordination "Net" for a number of existing "networks" forming in a sense a "Network of Networks" – for activities both within and outside of the IAEA, e.g. the DeSa Project (for safety assessment) and the R^2D^2 Project (for demonstration of research reactor decommissioning). Regional "hubs" centred around a real decommissioning demonstration project, offer a venue for "Participant" training and other forms of regional cooperation, while receiving assistance from "Members.

3.4 The role of the IAEA

The role of the IAEA follows closely the model established by the URF Network. By acting as a "catalyst" for events, stimulating Members to host events showcasing their unique capabilities and providing regular email "updates" on ongoing or planned activities in the field of decommissioning, the IDN can play an important role to extend the "reach" of regular decommissioning programme activities.

3.5 Current status and future outlook

The work to launch the first "events" under IDN sponsorship ("cost-free" to the Agency), building on an on-going Regional Project has begun in earnest, with initial events open to IDN participants, e.g.:

- Workshop on materials-management and clearance with ENRESA, 16-20 June 2008
- Group Scientific Visit to Mol for "size reduction of components for decommissioning of nuclear facilities", planned for October 2008
- The "Web presence" for the IDN has been established and continues to grow, e.g. through web-pages outlining current activities: http://goto.iaea.org/decommissioning; and click "web update"
- a regular e-mail "update" is issued bi-monthly
- Experiments with "on-line" topical presentations and discussions are being scheduled.

The work programme for the IDN will be reviewed and updated at the Annual Meeting (Forum) of the IDN, 5-7 November 2008. This forum will follow immediately on from a "lessons learned" session on the peer-review of MAGNOX decommissioning currently underway.

Programme evolution needs to consider balance of activities based on interests expressed:

- Emphasis on "Hands on" training and demos
- Highest interest in decommissioning of smaller facilities such as Research Reactors, Fuel Cycle facilities
- Over time, develop activities addressing the particular issues of smaller facilities such as medical or research laboratories
- Focus on topical areas reflecting inputs received (TM)

Also, the planning and hosting of activities needs to focus on regions where there is the greatest expressed interest, viz. Europe and Asia, with "seed" activities being held in Africa and Latin America.

4. International Low Level Waste Disposal Network (DISPONET)

Following the same approach of the two Networks described above, the IAEA is proposing to focus its support for low level waste disposal via a forum (Network) for a prompt, open and efficient transfer and exchange of knowledge gained through learning from the experience of others. The Agency wishes to support organizations, either currently engaged in or actively planning for disposal programmes, through their inclusion in a network to effectively cooperate and coordinate relevant actions.

Exchange of information on the development or the operational experience with existing facilities is expected to build credibility of the national disposal programmes of the recipient participants. The Network will also provide a forum to share approaches to specific issues such as disposal of a typical waste, e.g. graphite, radium and disused sealed sources. All will benefit from the best ideas put forward by the participants in the Network. Merging more informal exchanges together with programmed actions inside the Network is expected to increase the effectiveness and efficiency of the Agency's training and development work.

The Network is being established to increase efficiency in sharing international experience in the application of proven practices for disposal of low and intermediate level radioactive waste. In particular the IAEA intends to:

- coordinate support to organizations or Member States with less advanced programmes for disposal of low level waste, by making available the relevant skills, knowledge, managerial approaches and expertise from Member States with operating disposal facilities;
- organize an expanded range of training and demonstration activities with a regional or thematic focus providing hands-on, user-oriented experience and disseminating proven technologies;
- facilitate sharing and exchange knowledge and experience amongst organizations with advanced designs and disposal facilities in operation; and
- create a forum in which expert's advice and technical guidance may be provided on the Agency's programme in the area of low-level waste disposal.

The following is the tentative schedule to formally launch the Network:

- Consultants' Meeting, Vienna, 21-22 April 2008 to define the TOR, i.e. objectives, scope, method of work and road map of DISPONET, and identify potential Members and Participants.
- Technical meeting, Vienna, 28-30 October 2008 to formally launch DISPONET in presence of both Members and Participants.

5. Overall Observations and Conclusions

The development and increased use of "Network" concepts for training offered in waste management by the IAEA reflects both a response to pressure for more engaging and hands-on activities from Member State organizations, and a recognition that traditional means of offering services "one-to-one" cannot work in the expanding demands of the "nuclear renaissance". Approaches which seek to involve all participants in activities where they have a common interest, and to pursue "cross-cutting" opportunities between the various programme areas of the IAEA is beginning to pay dividends. These results are encouraging to both IAEA staff and colleagues (participants) from Member State organizations

DEVELOPMENT OF PC-BASED NPP SIMULATION PROGRAMS FOR TRAINING AND EDUCATION

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ABSTRACT

PC-based NPP basic principle simulators have been developed for over 15 years at Budapest University of Technology and Economics Institute of Nuclear Techniques (BME NTI) with two main goals: to provide the nuclear engineering education with tools capable to illustrate the fundamental physical processes of an NPP and to serve the regular basic retraining of the technical personnel of the NPP Paks (VVER440/213).
Our latest plant analyser is based on APROS which is a commercially available system code for modelling one-dimensional, two-phase flow processes in nuclear power plants and other industrial facilities.
A detailed APROS model of Paks Unit 3 (VVER-440/213) is under development at the BME NTI since 2000. The model contains the primary and secondary circuit with the emergency systems, the essential control and protection signals and the containment. The model was extended within the frame of a PHARE project, thus making capable to calculate beyond design basis accidents.

1. Historical overview

PC-based NPP basic principle simulators have been developed for over 15 years at Budapest University of Technology and Economics' Institute of Nuclear Techniques with two main goals: provide the nuclear engineering education with tools capable to illustrate the fundamental physical processes of an NPP and serve the regular basic retraining of the technical personnel of the NPP Paks (VVER440/213).
The development of the first simulator called PC^2 was started in 1988 for demonstrating the dynamic processes of the primary circuit. It was followed by an analyser program (STEGENA) for detailed studies on the thermodynamic and thermohydraulic processes going on in the horizontal steam generators of a VVER-440 plant. The next phase in the evolution was the development of a secondary circuit simulator (SSIM) in 1995. This program was written for MS Windows platform. The model describes the dynamic processes of the secondary circuit in quite fine details. The simulation extends for all the main components: steam generators, turbines, condensers and preheaters are all comprehensively modelled.
The latest version of PC^2 was released in 2000 also for MS Windows platform. This program can be used for demonstrating the main reactorphysical processes and the most important thermal-hydraulics processes in the six primary loops for educational purposes.
Elaborate educational conception and student exercises belong to all three simulators. Both the simulators and the educational aids have proven to be useful and effective in the course of retraining at Paks NPP and the nuclear engineering education at the Budapest University of Technology and Economics, as well.

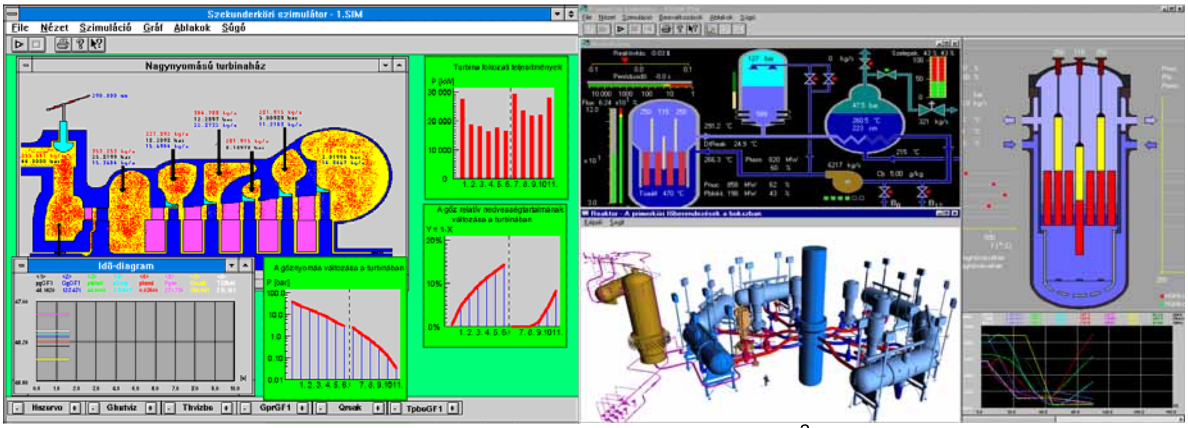

Fig. 1. Typical screens of the SSIM and PC^2 simulators

2. APROS model of Paks NPP

APROS (Advanced Process Simulator [1]) is basically a one-dimensional, two-phase thermal-hydraulic system code, similar to RELAP, ATHLET and CATHARE. Numerical models for one- and three dimensional reactor kinetics, automation and electrical systems, containment processes and core degradation are also available. The code package contains a graphical user interface (GRADES) and pre-built component modules (pressurizer, steam generator etc). APROS is developed by VTT and Fortum in Finland.
A detailed APROS model of Paks unit 3 (VVER-440/213) is under development at the BME Institute of Nuclear Techniques since 2000. The model was extended within the frame of a PHARE project, thus making capable to calculate containment processes and beyond design basis accidents [2].

2.1 DBA model

The model of the primary circuit contains the six primary loops, the reactor pressure vessel, and the pressurizer with the related control and protection signals. The model of the Emergency Core Cooling Systems (ECCS) contains the three independent trains of the active ECCS (high- and low pressure injection system), the four hydroaccumulators, and the related control and protection signals. The model of the secondary circuit contains the six steam generators with their steam- and feed water piping, the Main Steam Header, the two turbo generators, the condenser, the low- and high pressure preheaters, the feed water pumps, and the feed water tanks. The control and protection signals for the secondary circuit were built into the model too, with the auxiliary and emergency feedwater systems.

2.2 Containment model

The containment model of APROS uses a lumped parameter approach. The gas region is homogeneous mixture of non-condensable gases and steam. It was first used for modeling the Loviisa and Olkiluoto units, so the initial validation has been done for Westinghouse-type containment with ice condensers and for a typical BWR containment with a suppression pool. Before modeling the hermetic compartments and the passive pressure suppression system (bubble condenser tower) of a VVER-440/213 plant, the code was validated with EREC experiments.
In the current model of the Paks-specific VVER 440/213 unit the hermetic compartments are described with 24 nodes. The two halves of the steam generator (SG) room, the pump room, reactor pressure vessel cavity and ventilation center were modelled by one node each. Hermetic valve corridors, hydroaccumulator and pressurizer compartments and other smaller dead-ended volumes were modelled as one big “dead-ended” volume connected to both SG boxes. The connecting channel between the bubble condenser (BC) tower and the SG boxes was modelled as two identical nodes (the left and the right channel).
At the units the BC tower has 12 water trays for condensing the steam generated during a LOCA event. The BC tower has 4 air traps for capturing and holding non-condensable gases (3 water trays are connected to 1 air trap). In the APROS model the surface and the volume

of the 12 water trays are considered in 4 water trays. All 4 air traps are modeled in APROS. The BC tower was modeled with 16 nodes: 8 nodes for tower atmosphere and 4-4 nodes for water trays and air traps.

2.3 Severe accident model

The severe accident calculation package of APROS consists of four modules for calculating different physical processes related to fuel damage and core melting [1]. These modules are initialized and started in the model only after the maximum fuel cladding temperature reaches a preset value.

- GENFLO: thermal hydraulic model of the VVER-440 reactor pressure vessel. The calculation takes into account the degraded geometry of the core (swollen fuel pins, relocated fuel pellets etc.). The boundary conditions (pressures in and coolant injections into the downcomer and upper plenum) are provided by the thermohydraulic model of the primary loops.
- SARELO: model for simulating the degradation of the reactor core. This module describes the behaviour of the solid core structures from the solid state via relocation into the molten stage. The model describes the core overheating, oxidation, cladding melting, fuel relocation, control rod melting and finally fuel melting. Initially the materials are solid, but during the transient they can melt. The radiation and conduction heat transfer between zones are simulated. The chemical reaction between high temperature zirconium cladding and steam is also calculated.
- COPOMO: corium pool model simulating the behaviour of the melted core inside the reactor pressure vessel. It calculates transient behaviour of corium first on the core support plate, from which it relocates through the core barrel into the lower plenum of reactor pressure vessel. From corium heat is transferred into the surrounding steel structures of reactor pressure vessel or core barrel depending on the location of the corium. Due to the heat transfer part of the surrounding steel structures may melt and part of the molten corium may become solid again.
- FIPROMO: module for calculating the release, transfer and deposition of fission products. It keeps track of the fission product masses and decay heat production in each node of the simulation model. The fission products are divided into six independent groups depending on their chemical behaviour:

The events after reactor vessel failure (direct containment heating, molten core-concrete interaction) are not modelled in the current version.

The above described model can be used to simulate the whole NPP unit in design basis accidents and even in severe accidents until the molten core penetrates the reactor pressure vessel. The APROS code with the VIPROS visualisation system can be used for safety analysis in the case of design basis accidents.

3. The VIPROS visualization tool

A new visualization program called VIPROS (Visualisation for Process Simulators) was developed for the plant analyzer at BME NTI. VIPROS can use the output data file of any simulation software (RELAP, ATHLET, ASTEC, APROS etc.) for illustrating the thermohydraulic processes by plotting time diagrams and graphical animations. For this reason the VIPROS program is a suitable tool for understanding the complicated thermohydraulic processes, and it can be used not only in research and engineering but in education as well. The code is written in C/C++ using the open source FLTK toolkit. VIPROS is a cross-platform application: it was successfully compiled and run on MS Windows, Linux and Mac OS X. The present version of VIPROS is generated for the visualization of APROS severe accident simulation model of Paks VVER-440/213 unit developed in the frame of the HU2002/000-632-04-02 PHARE project [2].

Examples of VIPROS windows can be seen on Fig. 2 through Fig. 4.

- Fig. 2 shows the temperatures in the primary side (and steam generator secondary side) nodes. The status of the pressurizer (PRZ), Main Coolant Pumps (MCP1 through MCP6), HPIS pumps (TH10, TH20, TH30), LPIS pumps (TJ12, TJ22, TJ32), hydroaccumulators (TH50, TH60, TH70, TH80) are shown in this window. Some information about the secondary side also can be seen here: data about the SG valves, turbine bypass valves (KR), atmospheric relief valves (AR) etc.

- Fig. 3 is very similar to Fig. 2, but it shows void fraction in the nodes instead of the temperatures.
- Fig. 4 shows the temperatures in the confinement system (with numbers and color coding), and the status of the bubble condenser tower.

Complex thermohydraulic processes – which are very difficult to trace in a unit control room, or in a full-scope simulator, or even with time diagrams produced by system codes – can be visualized with VIPROS, for example two-phase flow in the primary loops, opening of loop seals, ECCS water injection, flashing in the core etc.

The APROS-VIPROS system is used for investigating different design basis and beyond design basis accidents (for example loss-of-coolant accidents with different break size and location). It is also used in university teaching.

4. References

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[2] Ismo Karppinen, Markku Hänninen, Ari Silde, Dr. Attila Aszódi, András Csige, Győző Fejérdy, Mika Harti, Eerikki Raiko. Development of the APROS nuclear plant analyser for the Paks NPP, Hungary. *Final report, PHARE project: HU2002/000-632-04-02*. 2005.

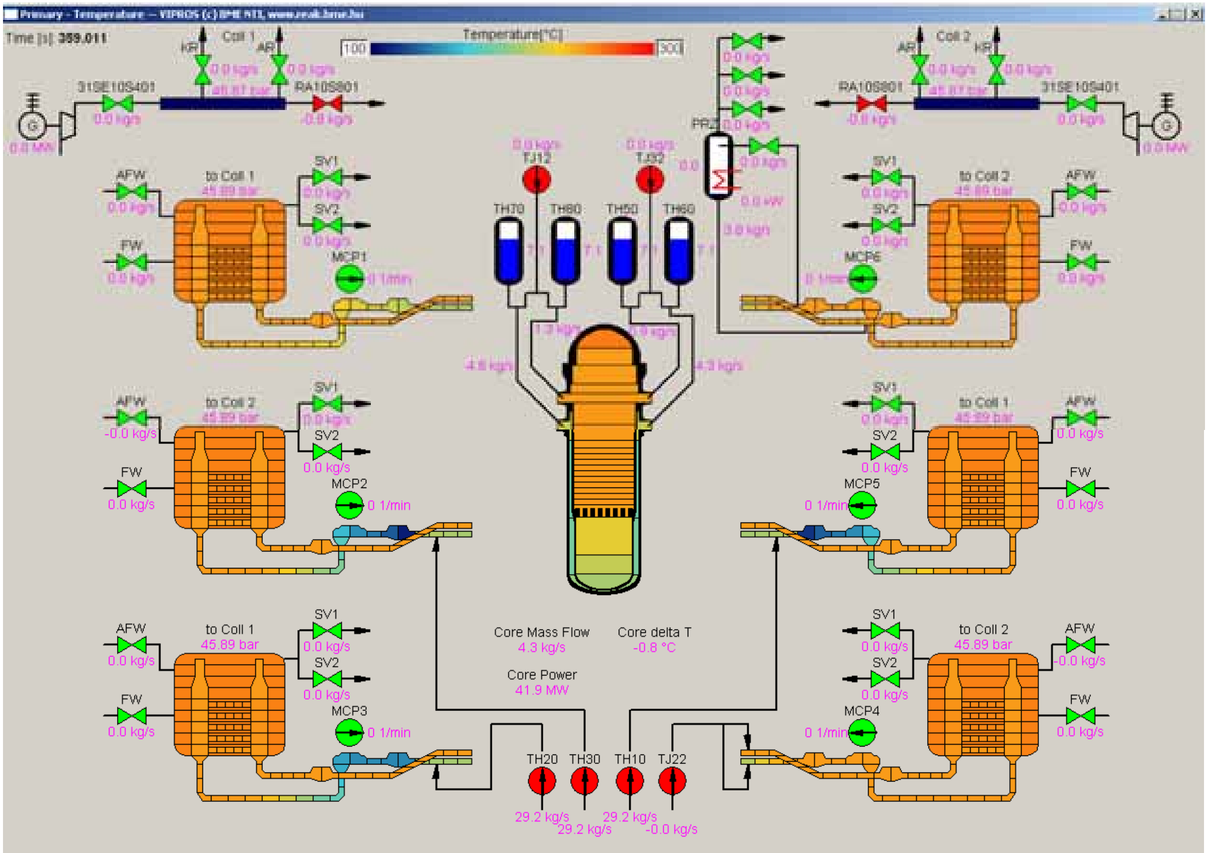

Fig. 2. Example of temperature distribution in the primary circuit nodes (VIPROS)

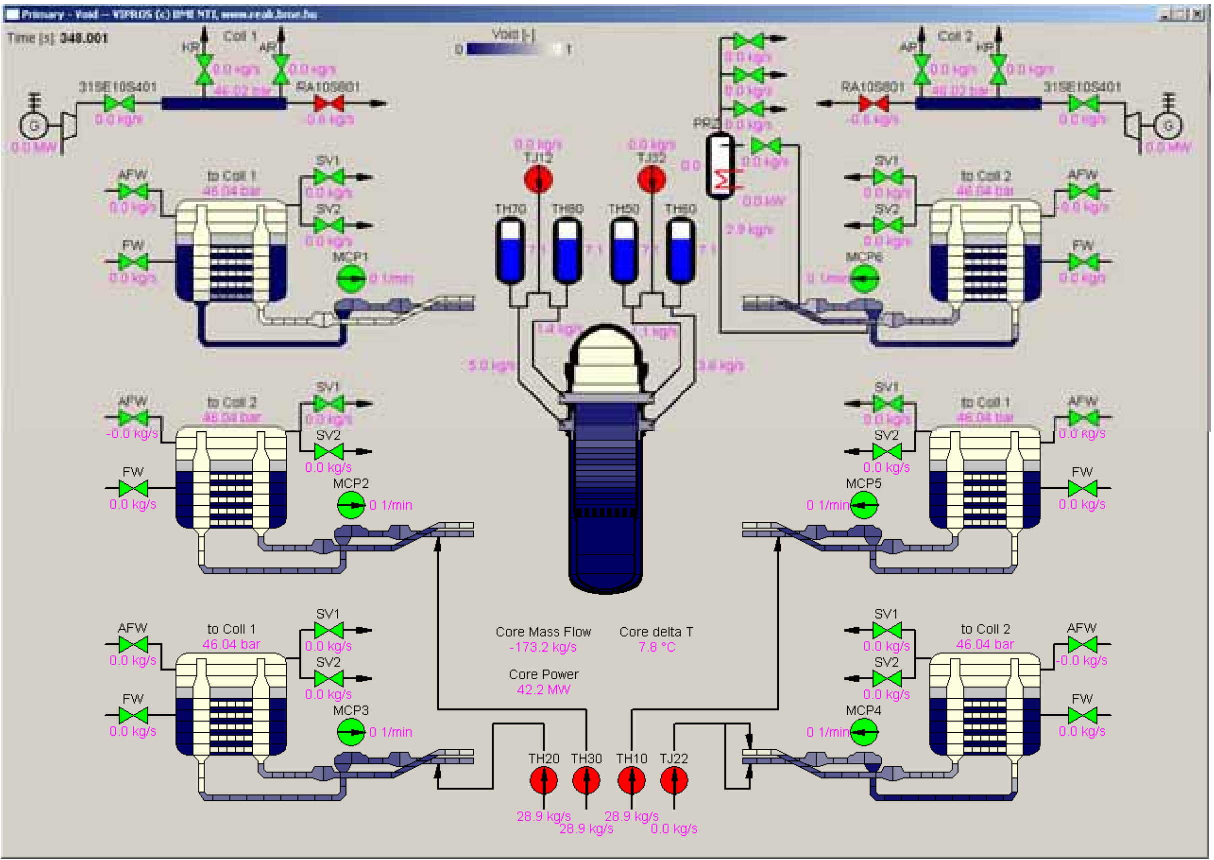

Fig. 3. Example of void fraction distribution in the primary circuit nodes (VIPROS)

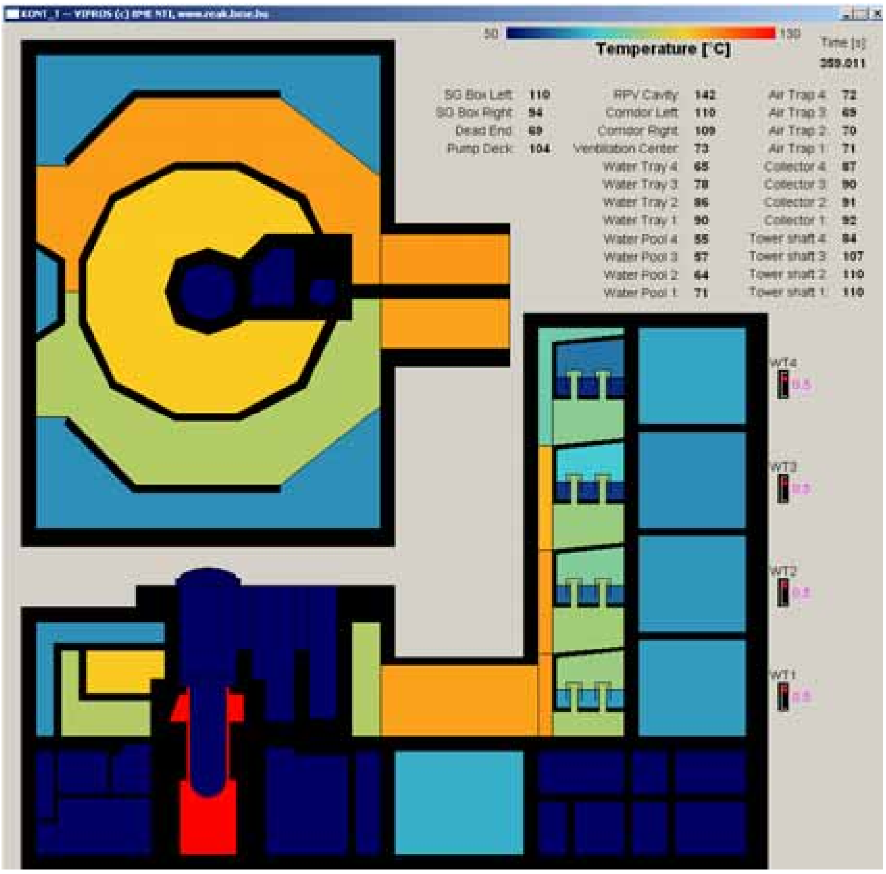

Fig. 4. Temperature in the hermetic confinement rooms (VIPROS)

JOSEF UNDERGROUND EDUCATIONAL AND TRAINING FACILITY

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ABSTRACT

The Josef Underground Educational Facility (Josef UEF) is a new multidisciplinary facility employed primarily for the teaching of university students. Other activities include research and cooperation on projects commissioned by the private business sector. Almost 600 meters of renovated underground areas provide a wide range of research opportunities for young scientists involved in underground structures, geotechnics, geochemistry, engineering geology and material engineering. The facility is particularly suitable for work on experimentally oriented doctoral dissertations, students having the choice of either joining research projects currently underway or indeed, initiating their own projects.

1. Introduction

The Josef Underground Educational Facility (Josef UEF) is a new Faculty of Civil Engineering, Czech Technical University in Prague facility which opened in June 2007. The facility is located about 50km south of Prague near the Slapy dam close to the village of Čelina in the Příbram district. The Josef UEF is employed primarily for the teaching of students from the CTU and other universities. Other activities include research and cooperation on projects commissioned by the private business sector. The construction of the facility was inspired by a similar educational facility in the USA and by foreign underground laboratories. The combination of education and research as well as its multidisciplinary approach make the Josef UEF unique not only at the domestic but also at the European scale. The aim of this paper is to inform postgraduate students interested in underground construction, geotechnics and geology about the diverse opportunities provided by the Josef Educational Facility. It is hoped that the authentic underground environment and the various research projects currently underway at the Josef UEF will both provide new information for students and inspiration for dissertation topics.

2. Description of the Josef UEF

The Josef UEF is situated in a former gold exploration gallery. This extensive underground complex is made up of tunnels and galleries with a total length of almost 8km, 600m of which have so far been renovated and are being used for educational and research purposes. It is planned that the rest of the tunnels and galleries will be renovated in the near future. The surface support facility containing cloakrooms, a small lecture room, WC and showers is currently situated in temporary facilities. Modern support facilities including offices for administrative purposes, accommodation, workshops and surface laboratories will eventually be located in a currently disused surface building, plans for the reconstruction of which have already been made. Renovation will commence as soon as administrative and financial circumstances permit. The Josef exploration gallery runs in a NNE direction across the Mokrsko hill rock massif. The total length of the main drift is 1835m, with a cross-section of 14-16m^2. The overlying rock thickness is 90–110m. Two parallel tunnels lead from the entrance portals, each having a length of 80m and a cross-section of 40m^2. The main exploration gallery is connected to various exploration workings by numerous insets, which follow ore formations and provide access to two further levels. 90% of the breakings are unlined. The end of the main gallery is connected to the ground surface by means of an unsupported 110m vent. A plan of the gallery is shown in Fig. 1.

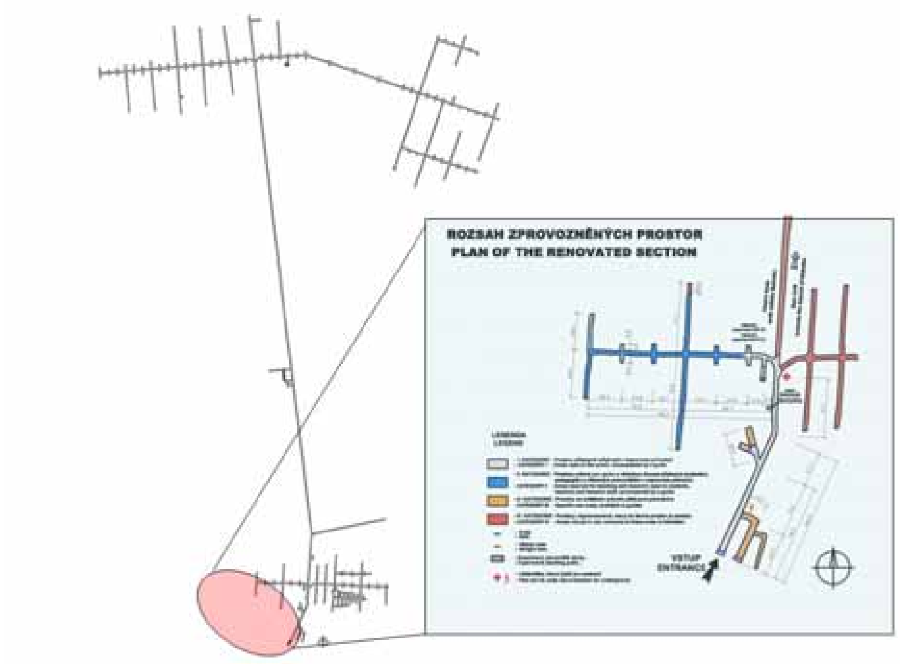

Fig. 1. Plan of the Josef gallery

3. Josef gallery - past and present

The excavation of the Josef exploration gallery commenced in 1981 and the gallery was in operation for ten years. In 1991 exploration of the area ceased and the gallery was closed whereupon it began to deteriorate rapidly. The Faculty of Civil Engineering, CTU realised the potential that this by now somewhat dilapidated underground complex provided for educational and research use and in 2005 an agreement on the use of the gallery for such purposes was signed between the faculty and the Ministry of the Environment which owned the complex. Renovation work, carried out by Metrostav Ltd at its own expense, commenced almost immediately. In February 2007 Metrostav handed the complex over to the faculty. The costs related to the operation of the Josef UEF are funded from the JPD3 European Structural Fund. Teaching programmes commenced at the Josef UEF at the beginning of the academic year 2007/2008. The main goals are to provide students both with practical experience and university courses which satisfy the demands of the commercial world. Besides teaching, several multidisciplinary research projects will commence in 2008.

4. Research

The size of the Josef underground gallery and its geological diversity allow the participation of a wide spectrum of those interested in experimental research. Underground “in situ” research involving direct contact with the rock massif is an important aspect both in the research potential of the Josef UEF and in overall long term Faculty of Civil Engineering planning.

4.1 TIMODAZ

Presently, the Faculty is actively involved in the TIMODAZ project which is supported by the EU's 6th Framework Programme. TIMODAZ is an acronym of the project's title "Thermal Impact on the Damage Zone around a Radioactive Waste Disposal Vessel in Clay Host Rocks". TIMODAZ is an international research project one of the participants in which is the Centre for Experimental Geotechnics, a Faculty experimental facility and the operator of the Josef UEF. The aim of the research is to investigate the effects of long-term thermal load on lining stability; the concept behind the research i.e., to determine the "ideal" form of spent nuclear fuel transformation technology in the mid- to long-term, follows extensive global discussion on this theme. Any eventual spent fuel transformation technology will require the safe removal of spent fuel from deep underground disposal. The extreme long-term functioning of the lining around the disposal vessel is one of the premises for the safe removal of spent fuel canisters from the engineered barrier. The long-term effects of heat could well bring about a severe reduction in the stability of the lining caused either by deterioration in the strength properties of the lining material or by the occurrence of deformations resulting in a collapse in the shape of the lining. The experiment will consist of two physical tunnel lining models which will simulate two extreme cases of the effects of temperature on lining stability:

- An underground silo experiment at the CEG laboratory
- An "in situ" experiment within the Josef gallery

4.2 "In situ" experiment TIMODAZ

This experiment will simulate a thermally loaded lining (90°C) which is not permitted to deform towards the rock massif and which therefore will experience an increase in stress. Long-term continuous measurement performed on the fully-instrumented model will prove whether or not stresses exceeding the strength properties of the lining material are likely to develop within the lining (Fig. 2). A short drift in the renovated part of the Josef gallery (the West Čelina belt) was chosen for the construction and performance of the experiment. The rock environment within which the experiment is being constructed consists of tuffites with a high compression strength (230 MPa). Thermal conductivity is in the range of 3.6 W/mK; specific density is approximately 2740kg/m3.

Fig. 2. Installation of thermometers

4.3 ENEN-II

The Josef UEF is also involved in the ENEN-II project which will consolidate the results obtained by the European Nuclear Education Network Association (ENEN) and partners in the FP-5 ENEN and FP-6 NEPTUNO projects. Work at Josef will expand ENEN involvement into other than nuclear engineering disciplines including radiation protection, radiochemistry, radio-ecology and the geological disposal of radioactive waste, attracting universities and other educational establishments currently active in these fields and by doing so will extend ENEN output from the purely academic to include practical professional training.

5. Teaching

Currently, the Josef UEF's main activity is teaching. In September 2007 the underground complex saw the commencement of regular instruction following specially designed CTU study plans. It is envisaged that over 300 students will take advantage of the Josef facility in the first year of teaching To date, courses have focused primarily on various aspects of underground structures – e.g. underground engineering, rock mechanics, underground urbanism, geotechnics, engineering geology, an introduction to mining techniques and surveying. It is envisaged that the following academic year will see an expansion in the number of courses in cooperation with the Czech Technical University's partner universities (Charles University and Institute of Chemical Technology). In addition to underground structures and geotechnics, students will be able to gain practical experience in geology, mineralogy, geological mapping and applied chemistry. It is planned that the expansion project will be financed from European structural funds. The courses are distinctively practically oriented, thus providing students with a unique opportunity to take real measurements and perform real experiments in an authentic environment. In order to provide support for both the practical and theoretical parts of the various teaching courses several innovative features have been installed in the underground complex with more in the pipeline. The geotechnical features installed to date include:

- a convergence polygon where students have the opportunity to learn and practice measurement techniques and to study their role in the NATM method
- a contact stress measurement demonstration as an element of the wider geotechnical monitoring process
- several blast hole patterns to demonstrate various blasting techniques
- rock and soil bolting and nailing demonstrations
- a replica of an historic wooden tunnel support system
- an exhibition of mining equipment

Student visits to the facility vary according to course requirements and are organized at several levels. A typical first visit to the UEF will aim to provide the student with an initial practical insight into issues involving soil and rock mechanics and underground structures.

As the course progresses, the student returns to Josef for further practical training at which time the number of students is limited allowing each student more tutor time and resources to successfully complete the various demanding tasks involved in the course (e.g. drilling etc.). The Josef Gallery is particularly suitable for experimental work on bachelor and diploma theses. Teaching programs are provided by three Faculty of Civil Engineering CTU departments - the Centre for Experimental Geotechnics and the Geotechnics and Special Geodesy Departments (Fig. 3).

Fig. 3. Practical course of underground geodesy

6. Conclusions

The Josef Underground Educational Facility has ambitions to become a unique European multidisciplinary facility providing high-level practically oriented courses for university students, special training for building company staff and high standard facilities for both domestic and international research projects. A number of outstanding international research projects are to commence in the very near future. The Josef UEF's educational and experimental research activities coupled with the authentic environment provided by the former gold exploration gallery provide an excellent opportunity for postgraduate students involved in underground structures, geology, geochemistry, underground geodesy, rock mechanics, mining engineering etc. to participate in multidisciplinary research projects or to further their own projects and ideas. The full potential of the facility will be realised within the next two or three years by which time the whole of the underground complex will have been renovated. A design project focusing on the reconstruction of the remaining unused underground galleries is currently in the preparation stage. Ambitious underground research projects require suitable surface support facilities. The currently disused two-storey building at Josef, which was donated to the Faculty of Civil Engineering by the Ministry of the Environment, will eventually be converted into a modern surface facility with offices, laboratories, workshops etc. The Josef UEF project has seen support both from representatives of the Faculty of Civil Engineering and the local authority (the Chotilsko municipality). Preliminary agreements with various partner organisations both from the Czech Republic and abroad have already been signed (Charles University in Prague, Institute of Chemical Technology, SCK.C etc.) which, we believe, augers well for the future of this ambitious and unique facility.

7. Acknowledgement

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TRAINING IN NUCLEAR TECHNOLOGY IN AN ANTI-NUCLEAR ENVIRONMENT

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ABSTRACT

The 250 kW TRIGA Mark II reactor operated by the Atomic Institute is now the only nuclear facility in Austria. Although Austria follows a dedicated anti-nuclear policy the Atomic Institute enjoys a relative undisturbed nuclear freedom in its nuclear activities. This allows to use the research reactor not only for academic training but also for international training course especially in nuclear technology. Typical examples of periodic training courses are

- Courses for junior IAEA safeguards trainees
- Courses for staff of the NPP Bohunice and NPP Mochovce (Slovak Republic)
- Courses in cooperation with the University of Manchester for NTEC students and junior professionals

The presentation will outline typical training programmes and summarize the experience with international training courses.

2. National Activities

Since its initial operation the Atomic Institute of the Austrian Universities was founded as an inter-university institute where students from all Austrian universities may carry out their post-bachelor specialisation in the fields of

- Neutron- and Solid State Physics
- Nuclear Technology
- Radiochemistry
- Low Temperature Physics
- Radiation Protection
- Nuclear- and Astrophysics
- X-Ray Physics

According to the university curricula students have to enrol a certain number of practical and theoretical courses to be completed with a practical Masters Thesis. Since that time the Atomic Institute of the Austrian Universities offers about 80 theoretical and 10 practical courses within the above fields. Especially two courses on “Reactor Physics and Kinetics” and on “Reactor Instrumentation and Control” attracted many students as they were trained directly at the TRIGA Mark II reactor. The students work in a group of 4-5 students, they have to summarize their results and a written test completes the course which is valued with 3 ECTS. A list of the exercises of the “Reactor Physics and Kinetics” is given below:

- Measurement of the thermal neutron flux density in the reactor core
- Measurement of the epithermal and fast neutron flux density in the reactor core
- Determination of the importance function and the void-coefficient
- Determination of the neutron absorption cross section according to the danger coefficient method
- Measurement of the reactor period
- Radiation protection around a research reactor
- Critical experiment
- Control rod calibration and determination of the core excess reactivity

- Sub-critical safety rod calibration
- Determination of the reactivity value of uranium fuel and graphite elements in different core positions
- Reactor power calibration and determination of the temperature coefficient of the reactivity
- Demonstration of a reactor pulse with different reactivity insertion

A list of the exercises of the “Reactor Instrumentation and Control” follows:

- Introduction into a typical reactor instrumentation
- Reactor safety principles
- Calibration of the nuclear channels
- Measurement of control rod drop times
- Neutron flux measurement with compensated ionisation chambers
- Fission chambers
- Self-powered neutron detectors
- Simulator program for PWR

Further practical courses offered at the Atomic Institute is “Radiation Protection” and “Radiochemistry”.

In the years between 1972 and 1978 part of these courses plus some theoretical courses were integrated in the program of a Technical School to train technicians as future staff of the NPP Zwentendorf. After the negative referendum on 5.11.1978 this training was stopped but the regular students training at the Atomic Institute was not influenced.

However the strong Austrian anti-nuclear policy and the Chernobyl accident reduced the number of MS and PHD students in the nuclear field up to about 1995. Since the mid-90ties the number of students in nuclear technology is again increasing due to two facts:

- An increased cooperation with the IAEA
- The decommissioning of the 10 MW ASTRA reactor at Seibersdorf in July 1999

Also during that period bilateral cooperation with Czech Republic and Slovak Republic increased at an university level by student exchange and student group excursions, this fact will be important later in view of trans-national cooperation and knowledge exchange. Since the mid-90ties the Atomic Institute was also heavily involved in public discussions on Eastern European WWEER NPP’s as the Austrian Government created a “Nuclear Forum” to support it’s anti-nuclear policies against neighbouring countries. The Atomic Institute remained a scientific and technical centre of nuclear competence (1) which was strongly ignored by the Austrian media but highly appreciated as a discussion partner for New EU Member countries.

The strong ties between the Atomic Institute and the IAEA is reflected in many cooperation activities especially in soft- and hardware development for safeguards and security instrument development (2-11). In many projects the IAEA received high quality academic work and the students were supported financially by the IAEA. Some of the students were later employed by the IAEA due to their excellent scientific and technical knowledge.

3. International Activities

As first large international activity in nuclear education the Atomic Institute took part in the ENEN and NEPTUNO projects (12,13). In this context the Atomic Institute produced an extensive catalogue on all nuclear educational activities at European universities (14) which acts still as a very valuable document for follow up projects. Out of these cooperation contacts with other European universities initiated and resulted typically in an international course between four universities (Bratislava, Budapest, Prague and Vienna) called the Eugene Wigner Course which is carried out since 2005. At this course about 15 students and young professionals rotate in groups of 5 between 4 universities carrying out practical exercises at 3 different research reactors. This course is also credited according to the Bologna agreement by the home universities of the students with 3 ECTS.

Another co-operation started in 2007 by signing a contract with the Dalton Institute/University of Manchester. Within the Nuclear Technological Education Centre (NTEC) two groups with maximum 6 students spend a week of practical training in reactor physics and kinetics and in reactor instrumentation and control at the TRIGA reactor of the Atomic Institute.

Further since a few years the Atomic Institute also cooperates with the TU Bratislava in the Slovak retraining program of staff members of the NPP Bohunice and NPP Mochovce. Groups of 4 staff members carry out a selected group of exercises from the above list during 3 days, in addition selected ppt presentation on subjects of interest are included. Another international co-operation is the participation at an EU project called Integrated Infrastructure Initiative for Material Testing Reactors Innovations (MTR+I3) (15) which is concentrated in the preparation of the operation and utilization of the Jules Horowitz reactor. The Atomic Institute has taken over the Work Package Leadership 2 on training of reactor staff in cooperation with Belgium, Czech Republic, France, Greece and Portugal. The program is subdivided into three task which deals with

- Define target groups for training and needs in the MTR field and potential candidates per year
- Training programs within the European Unions, strengths and weaknesses, information from European training programs in nuclear field (academic and practical) such as ENEN, NEPTUNO and Eugene Wigner course (multinational training course between Austria, Czech Republic, Hungary and Slovak Republic supported also by the IAEA)
- Define training programs adapted to the particular needs of the various target groups Integration of the MTR programs in the European training programs. Training program could be delivered in two complementary sites, new sessions dedicated to MTR in existing programs in order to attract young persons in the MTR field.

4. Conclusions

Although the Atomic Institute is located in a strict anti-nuclear environment both politically and supported by continuous negative media information, the Atomic Institute manages to carry out it's international contacts successfully even with an obvious increase during the past decade. It further helps to improve the international relations in the nuclear field by active co-operation even in spite of lack of national support.

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Science, Engineering and Technology in Education

MINA-2008: A RENEWED APPROACH TO MASTERING NUCLEAR ENGINEERING AND APPLICATIONS IN SPAIN

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ABSTRACT

Inspired by the nuclear renaissance, the challenge of preserving nuclear knowledge and expertise and the bases of the European Education Area, CIEMAT has initiated a renewed venture in nuclear education and training: MINA (Master on Nuclear Engineering and Applications). MINA intends to build an actual bridge between University education and professional skills demanded at present by nuclear industry and organizations. In short, MINA will enable graduates to fit nuclear sector needs. To do so, CIEMAT counts on a broad support from both nuclear industry and universities, some of which welcomed MINA as a part of their MASTER cycles. This paper outlines the major characteristics, the development phases and all the mechanisms set-up to brew and organize MINA-2008.

1. Introduction

CIEMAT is a Public Research Agency for excellence in energy and environment, as well as in many vanguard technologies. Since its creation in 1951, education and training in the nuclear field has been a priority, a proof of which was the creation of the Institute for Nuclear Studies in 1964. Since then a course on Nuclear Engineering has been held (nearly on a yearly basis). The first editions were focused on specific education and training on construction and development of nuclear power plants and facilities [1]. The course has been updated throughout the years according to the national trends on nuclear technology. As a result of this long “journey”, more than 600 professionals have been formed.

As consequence of the renewed interest in the nuclear energy (sometimes called “nuclear renaissance”) [2] and other national factors, like generation renewal, the Spanish nuclear sector is demanding engineers, technologists and scientists. CIEMAT has been sensitive to these changes and has implemented an ambitious and encouraging approach to face the challenge ahead: the Master in Nuclear Engineering and Applications (MINA).

2. Objectives and scope

MINA is born as a multi-academical Master defined in close collaboration with nuclear industry and Academy to fill the existing gap between graduates and nuclear professionals. This entails to provide students with an exhaustive and extensive vision of the disciplines involved in the current and future applications of the nuclear technology, without giving up fundamentals. Three specific objectives have been set:

- To review fundamentals of nuclear technology
- To deepen in subject of burning importance for present nuclear technology.
- To draw up current and near-, mid- and long-term applications of nuclear technology.

MINA is to last around 1500 hours (the first edition will extend from October 2008 to June 2009). One third of that duration (around 500 h) will be allocated to develop an individual project many of which will be supervised by the Industry. This is a major feature of MINA, usually referred to as a “project-driven” master.

3. Fundamentals

Four are the pillars of MINA: professional projection, integral approximation, sector integration and educational excellence.

3.1 Professional projection

A professional profile in terms of sound skills required in a nuclear professional has been defined by the Spanish nuclear sector. By surveying companies, utilities, agencies, etc. in the nuclear sector, several subjects have been scored as shown in Figure 1. MINA will ensure a background according to this profile, so that master graduates become attractive to any organization involved in the nuclear business.

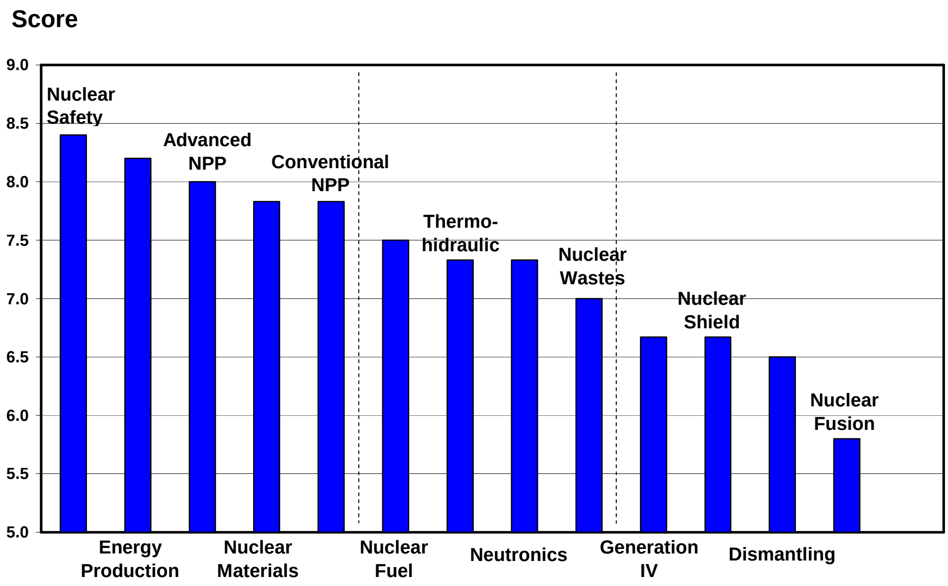

Figure 1. MINA target-profile

3.2 Integral approximation

MINA has high expectations both at the input of the education and training process (i.e., a high interest in last-year university students) and at the output (i.e., a high employment rate in the nuclear sector). To achieve it a sound and global involvement of the nuclear sector in all the elements shaping MINA (i.e., thematic structure, active participation in the training activity and logistic provision) is necessary. The final goal pursued is to turn MINA into a profitable investment for nuclear industry. The strategy followed is depicted in Figure 2 (the lines thickness indicates qualitatively the contribution weigh of industry, institutions and Academy, both in definition and in funding).

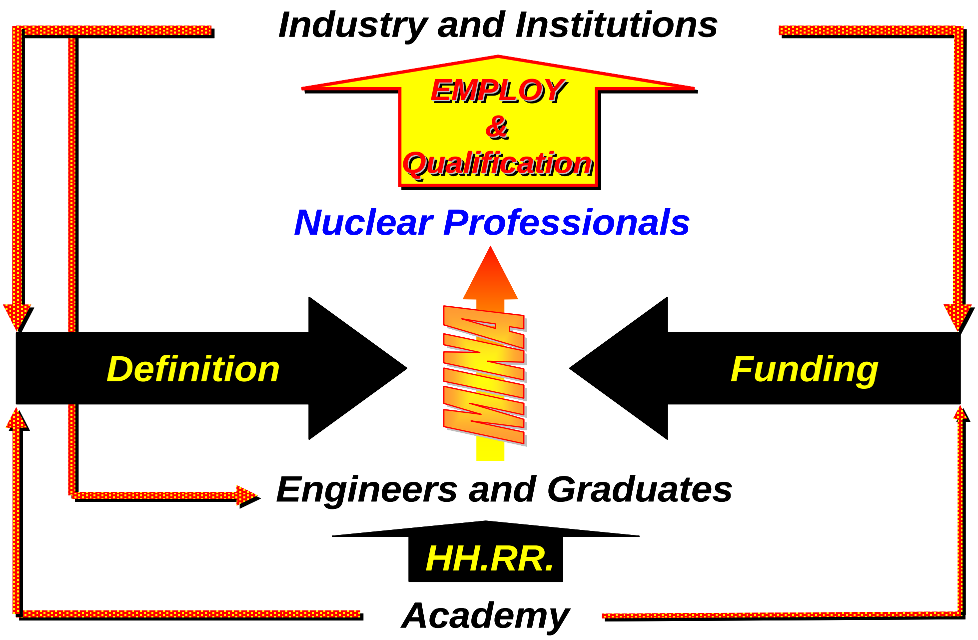

Figure 2. Integral approximation of MINA

3.3 Sector integration

An advisory committee set up by members of Academy and nuclear sector will provide recommendations and suggestions to MINA. Such an activity is to be integrated in the Spanish Technological Platform on Nuclear Fission (CEIDEN), that coordinates the different plans and national programs and the participation in the international programs of R+D. Figure 3 shows this link between CEIDEN and MINA. As shown all kind of organizations participate in the detailed definition of MINA (i.e., thematic areas).

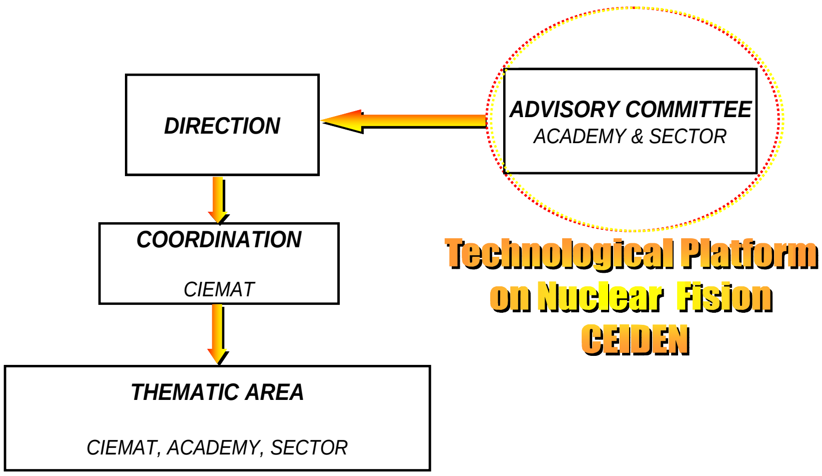

Figure 3. Relation of MINA and CEIDEN.

3.4 Excellence in education and training

Excellence is pursued by means of (Figure 4):

- Multiple participation. All kind of organizations (Academy, Industry and Institutions) will be involved in teaching.
- Distributed dedication. Institutions involvement will be selective. Thus, most of Academy weight will be linked to Fundaments and, to less extent to Technologies and Applications. On the contrary, Industry will be mostly focused on Applications. CIEMAT, as a technological research organization, will have a practically uniform contribution in all the areas, acting as a buffer between Academy and Industry.
- Thematic specialization. Each participant will highlight areas of knowledge and know-how where they have a preferential position. This has allowed identifying group leaders in the definition of subjects.

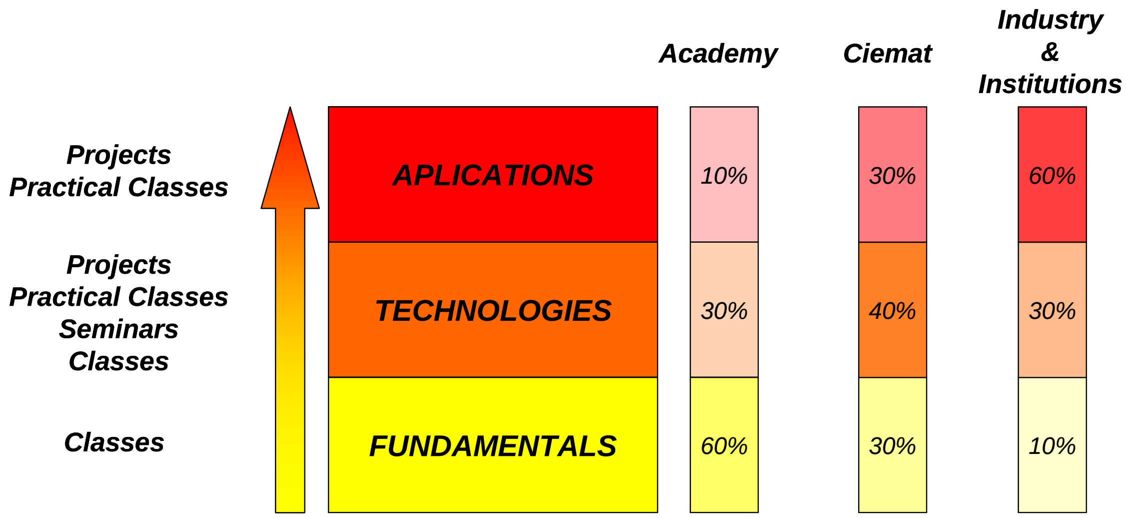

Figure 4. Organizations share in MINA.

4. Structure and approach

The MINA structure relies on three main elements:

- Theoretical lectures (750 h.). They will be focused on introducing concepts and methodologies. These classes will be supplemented with specific seminars given by acknowledged national and international specialists.
- Laboratory sessions (250 h.). Experimental technologies and/or methodologies of analysis in different areas of the Nuclear Technology will be handled. They will supplement the theoretical lectures of the main subjects.
- Final Master project (500 h.). It is the key part of MINA. A set of projects will be defined beforehand by the sector at the beginning of each MINA edition, so that contents of subjects can be adapted to enable students to face with the project challenge. All the projects will be supervised by a tutor.

According to the MINA profile outlined in Figure 1, the master subjects have been categorized as follows:

- Burning topics. Considered both fundamental and of an unquestionable relevance nowadays, they will be granted with the highest number of lecturing time (75 h).
- Fundamental topics. Essential for a sound nuclear engineering background, they will be given a high importance in the lecturing time allocation (50 h).
- Supplementary topics. Farther in the temporary horizon, their extension will be less than the above ones (25 h).

The individual contents of the subjects have been already developed. A group of experts was set up (each one integrated by Academy, nuclear sector and CIEMAT) where leadership was always given to an acknowledgeable organization on the matter. Once the individual contents defined, a review committee entrusted to guarantee avoidance of unnecessary overlapping and essential contents missing. This is sketched in Figure 5.

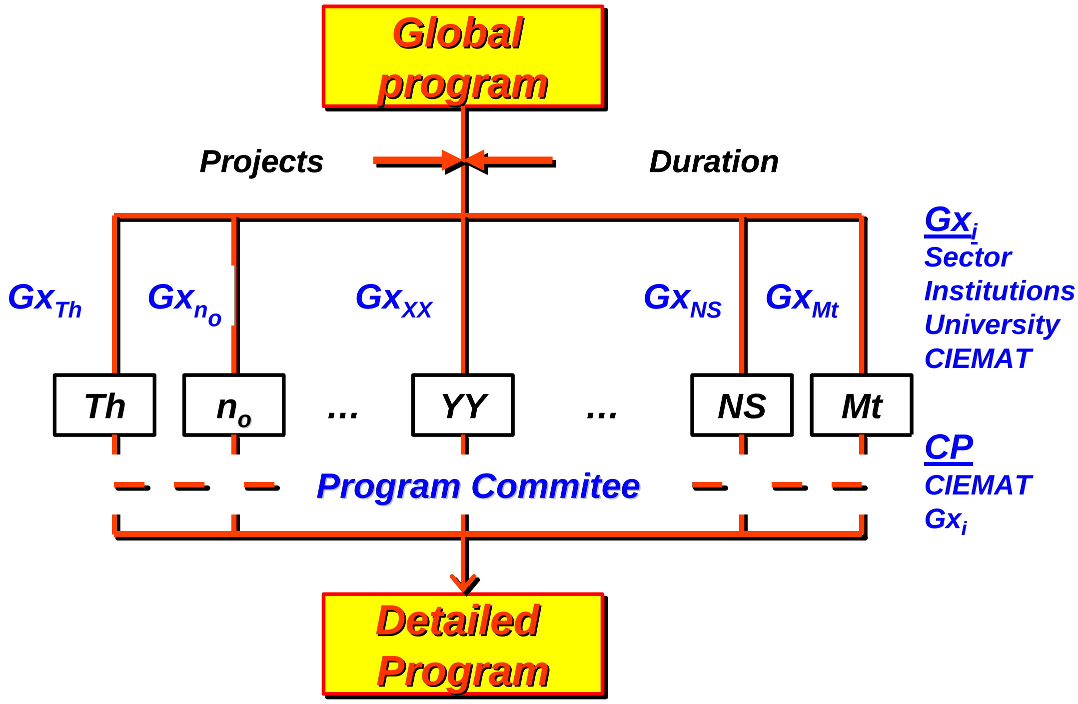

Figure 5. Protocol to define contents of the MINA subjects

5. Current status

MINA is presently ready to be submitted to several Spanish universities for their official acceptance as a master. At the same time a broad announcement campaign is about starting through different means, both in Spain and other Spanish speaking countries overseas. One of the means that will be put in place in the upcoming months is the MINA presentation to last-year students of Faculties and Polytechnic Schools with any link to nuclear technology.

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INDUSTRY-UNIVERSITY COLLABORATION: THE AECL-CRSNG-POLYTECHNIQUE COLLABORATIVE RESEARCH AGREEMENT

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ABSTRACT

The Natural Sciences and Engineering Research Council of Canada, an agency of the government of Canada, has a program of Collaborative Research and Development Grants for approved industry-university agreements. In the context of this program, application was made and a grant received for a three-year collaborative research agreement on "Advanced CANDU Reactor Computational Reactor Physics" between Atomic Energy of Canada Limited and the Institut de génie nucléaire at École Polytechnique de Montréal. Here we describe how this collaborative research and development agreement works. We also present some of the constraints both for the university and for the industrial partner, resulting from the presence of the Natural Sciences and Engineering Research Council of Canada as a major player in the agreement. Finally we discuss the major milestones achieved with this agreement that has now reached its conclusion.

1. Introduction

The Natural Sciences and Engineering Research Council of Canada (NSERC) is an agency of the government of Canada that supports university research in science and engineering through scholarships for graduate and postdoctoral students as well as research grants to university professors. Research projects involving partnerships among universities, governments and the private sector are also supported by this agency through various programmes including the "Collaborative Research and Development" (CRD) program for industry-university agreements.[1] This program is aimed at supporting financially well-defined research projects involving university researchers and their industry partners. The direct total costs of the project are shared by NSERC in the form of a research grant to the professors and the industrial partner from whom the funds may come in the form of research funds or as in-kind contribution (engineers' time for example).

Atomic Energy of Canada Limited (AECL), the designer of the CANDU family of nuclear reactors and the industrial partner in this research agreement, is currently developing the Advanced CANDU reactor (ACR).[2,3] This Generation III+ reactor that AECL is proposing to the national and international market is being designed to adhere to very strict requirements both from the point of view of safety and of performance. These requirements have a large impact on the modelling of the reactor. For example the reduction in the lattice pitch from that in the standard CANDU-6 and the use of fuel bundles containing enriched uranium and burnable poisons with light-water coolant (the CANDU-6 is fuelled with natural uranium and cooled with heavy water) all have a large impact of the neutron flux distribution inside core. The intensity of the research effort required by this new design spans many domains of nuclear engineering, including reactor physics, where the validity of the tools used for CANDU-6 design and operation can be questioned.

Recognising this research opportunity a group of professors at Institut de génie nucléaire (IGN) of École Polytechnique de Montréal and research scientists at AECL decided to set up a collaborative research and development agreement on the physics of the ACR. The first component of this agreement consisted in analysing the physics of the ACR using the reactor physics computer software developed at the IGN and comparing these results with those obtained by AECL using their own tools and methods. The second and more research-based component of the agreement was related to the development of advanced methods in the IGN software, which will provide more reliable safety analysis tools than those currently available. Work on the research program began in December 2004, and will be completed in May 2008.

The main interest for École Polytechnique is in the research and development area as well as in providing high-quality training to students. However, another important mission for École Polytechnique is the transfer of technology to the industry of advances made in research and development, in particular in the form of computer programs and mathematical methods for application to reactor physics. From the point of view of AECL, in addition to increasing its effective research efforts, bright students working on this research will eventually be the “new blood” that fuels AECL future research capabilities.

In Section 2 of this paper we provide a general description of the NSERC collaborative research and development agreement as well as the constraints for each of the partners of the agreement. A description of the ACR project can be found in Section 3, while in Section 4 we present the major achievements in research and development resulting from this agreement. Finally, in Section 5, we conclude.

2. NSERC collaborative research and development agreement

The general objectives of this NSERC grants program are set forth in this paragraph:

> “The Collaborative Research and Development (CRD) Grants program is intended to give companies that operate from a Canadian base access to the unique knowledge, expertise, and educational resources available at Canadian postsecondary institutions and to train students in essential technical skills required by industry. The mutually beneficial collaborations are expected to result in industrial and/or economic benefits to Canada.”[1]

This statement illustrates well the two main mandates of NSERC: to ensure the formation of highly qualified personnel and the transfer of knowledge and technology from the university to the industry.

These objectives are made even clearer in the grant proposal that the industry-university team must fill out. In addition to providing a detailed plan of the work to be performed based on a direct collaboration of personnel from both institutions, the number of graduate students involved in each subproject must be clearly identified. These grants are generally used to cover research agreements that last from 3 to 4 years.

The transfer of knowledge and technology to the industry is controlled by a “Policy of intellectual property” (PIP) that must be signed by all parties and accepted by NSERC. NSERC does not participate in research contracts with industrial partners that expect to gain total control of the work performed by the university personnel and their students. The PIP must include permission to publish significant advances in science and technology in the open literature. Students and professors remain free to disseminate their results, use it in their teaching, and defend theses. On the other hand, the industry is protected against unauthorized or untimely divulgation of proprietary information. A publication agreement must be included with the proposal that describes the procedure and the maximum period of time for revision of papers to be submitted for publication.

The main advantage that the industry-university partnership obtains from such a collaborative agreement is that NSERC contributes to the university an amount in cash that is equivalent to the amount invested by the industry. As a result, the industry doubles the impact of its own contribution to the research effort. The contribution in cash from the industry must represent a minimum of 50 % of the total amount requested from NSERC, the remaining contribution being provided in-kind (instruments, software, or engineers' time). Note that because of NSERC rules, the industry is also assured that both its contribution and that of NSERC are really directed towards the research effort, since these funds can only be spent on financial supports for students, travel fees for conferences and meetings, and only marginally on scientific equipment.

As with all NSERC grant applications, the quality of the proposal is evaluated by an international peer review panel that judges the grant request using six criteria: 1) the scientific merit of the proposal to generate innovative ideas; 2) the research competence of the university team to carry out the work with success; 3) industrial relevance, where the company must demonstrate the expected benefit for the Canadian economy; 4) private-sector support including the cash and in-kind contribution; 5) contribution to the training of highly qualified personnel including the number of M.Sc. and Ph.D. students and postdoctoral fellows involved in the project, as well as research associates and company personnel; and finally 6) the economic, social and environmental benefits to Canada.

Once the proposal has been accepted by NSERC, the grant is given on a yearly basis, based on the success of an annual evaluation of the progress of the work by the industrial partner. The university team also prepares an annual progress report and a final project report.

3. CRD Project for the ACR

The objective of this CRD project is to provide AECL with an alternate set of computational tools, namely the lattice code DRAGON[4] and the finite-reactor code DONJON[5], developed at École Polytechnique de Montréal, for the design and analysis of the ACR. The main goal to be achieved consists in evaluating and using these tools, and determining the biases and uncertainties in the neutronic behaviour of the core resulting from the application of the AECL standard toolset.[6,7] The project is subdivided into three main components that we now describe.

3.1 Computational schemes for the ACR core and for ZED-2 critical experiments

This part of the project is mainly devoted to the production and validation of various computational models to be used as input to the DRAGON and DONJON codes. These models are defined in terms of physical quantities and engineering data and the calculation procedure that consists in selecting the sequence of calculations to be performed, as well as the numerical methods to be used for each calculation step.

Here, the goal is to propose a series of more or less refined ACR computational schemes, to analyze the ACR core using the codes DRAGON and DONJON and to select an optimal model that can be used for safety analysis. Typical refinements in the full reactor model involved different group structures and spatial discretisation levels for the DONJON core calculation. Finite difference, finite element and nodal solutions to the diffusion equation have also been considered. Similarly, the selection of an optimal lattice model for the ACR is based on an extensive survey of the effect of lattice discretisation on resonance self shielding and flux and burnup calculations that were performed using DRAGON. These

results were compared with reference AECL calculations based on the codes WIMS-AECL[6] and RFSP[7] and differences between the AECL and IGN codes explained and resolved.
The ZED-2 facility at AECL's Chalk River Laboratories is a research reactor that is used to measure criticality and fine-mesh flux distributions in cores simulating the ACR lattice. These experiments were modeled using the codes DRAGON/DONJON, and the code biases for this type of lattice were evaluated.

3.2 ACR Physics Studies

This project deals with specific physics studies performed for the purpose of obtaining a better understanding of the physical phenomena taking place in the ACR core. These studies also serve to further refine the DRAGON/DONJON computational schemes developed in the above studies and to evaluate the domain of validity of our models and methods.

The first part of the study deals with the coolant void reactivity (CVR), which represents the change in core reactivity resulting from the removal of coolant from the core. In principle, both positive and negative values for the CVR in the ACR can be obtained depending on the fuel enrichment, burnable-poison content, lattice pitch and cell environment. A negative full-core CVR is a design requirement in the ACR, to increase the passive safety features of the reactor. Discrepancies were observed when comparing the CVR computed using WIMS-AECL and DRAGON. These were traced back to differences in the leakage and resonance self-shielding methods used by the two codes. This led to a comprehensive study of the DRAGON and WIMS cell calculations using different resonance self-shielding and leakage models. Finite-reactor sensitivity studies for the CVR are also required because changes in macroscopic leakage also play a role in establishing a negative CVR.

An important postulated accident scenario for ACR safety studies is the loss-of-coolant accident (LOCA). In the case where the CVR is negative, a loss-of-coolant accident leads to a reduction of the core reactivity and hence in a reduction in power. Nevertheless, even after this reduction in the core reactivity, there is still a considerable amount of energy produced in the fuel that is no longer extracted by the coolant. This could lead to an increase in the fuel temperature and possible fuel failures if the shutdown systems do not intervene rapidly. The main question to be answered is whether or not the reactor safety system can detect this accident sufficiently rapidly and shut the reactor down before severe consequences to the core integrity ensue.

3.3 Developments in DRAGON and DONJON

The project dealt with improvements in the codes DRAGON and DONJON to increase their ability to deal with the complex physics of the ACR core. Several new features to be implemented in these codes were considered including:

1. A multigroup analytic nodal model with discontinuity factors in DONJON/NDF.
2. A fuel-management optimization procedure that takes into account exit burnup, fuel enrichment and burnable-poison concentration.
3. A multi-parameter reactor database to store and retrieve all the nuclear data produced by the lattice code.
4. New models in DONJON including a Thomas-Raviart finite-element solution of the diffusion equation and a SPN transport-solution approach.
5. A HELIOS[8]-like subgroup approach to resonance self-shielding calculations in DRAGON.
6. 3-D modelling capabilities in DRAGON that are able to treat assemblies of clusters.

4. Major Achievements

A total of five professors and research scientists from the IGN and four engineers from AECL were involved at one time or another in this research project. In addition, the CRD was used to support three postdoctoral fellows, four Ph.D., five M.Sc. and four undergraduate students.

The scientific output of this collaboration is also important. A large number of internal reports describing the progress of the work were produced in addition to four articles published in Conference Proceedings, with three more accepted for future conferences, plus four papers (three published or accepted and one being prepared) in scientific journals.

Other benefits of this work include:

1. A more profound understanding of the ACR and indirectly of the CANDU-6 physics gained by all the participants.
2. The codes DRAGON and DONJON developed at the IGN have now been tested on very difficult reactor-physics problems and have performed very well.
3. The experience gained in using our set of codes for the simulation of physics experiments on the ZED-2, including foils-activation analysis.
4. The new models we developed in our codes were also applied to CANDU-6 analysis and are already being used in the industry for safety analysis.
5. The number of new students that were attracted in our nuclear engineering programme because of this project.
6. The number of students supported by this grant that are now pursuing their studies in the reactor-physics field or working in the industry.

This project also increased substantially the level of collaboration between AECL and École Polytechnique. Meetings with presentations in an informal setting helped the various participants understand their respective position from the point of view of simulation needs and the quality of the results generated.

5. Conclusions

We feel that the AECL/NSERC/Polytechnique collaborative research and development project for the ACR that was undertaken has been very successful and that it has achieved all of its goals. The research efforts, which are required to put on the market a new reactor, have been increased substantially by this collaboration. The goal of forming a large number of highly qualified personnel for the industry has been reached. Finally the modifications in the analysis tools that were the result of this common development effort of the industry and the university have improved the physics codes available for next-generation reactors as well as for current reactor designs.

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UNIVERSITY-BASED NUCLEAR EDUCATION AND RESEARCH IN THE UK

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ABSTRACT

The announcement in January 2008 by the UK government to encourage private operators to build a new fleet of reactor has been widely anticipated. There has been a reinvigoration of nuclear education and research in the university sector, supported by both the research councils and the nuclear industry. The recent developments in higher education and university-based research are described. This includes a description of the national NTEC university research consortium which offers Masters-level education in Nuclear Science & Technology, and the Nuclear Engineering Doctorate programme which is run in partnership with the industry.

1. Background

Before discussing the current direction of university-based nuclear education and research in the UK it is worthwhile taking a retrospective look at recent history to appreciate where we have come from.

In the 1970s the public sector investment in nuclear fission R&D was approximately £500m per year. This included expenditure on all aspects of the nuclear fuel cycle including development of the fast reactor to provide energy security for the UK which was truly at the cutting edge of nuclear development. Much of this R&D expenditure was concentrated into The UK Atomic Energy Authority (UKAEA) and with British Nuclear Fuels Ltd (BNFL) formed to take forward industrialisation of the fuel cycle.

In the 1980s the situation changed with the discovery of North Sea Gas and the Chernobyl accident. These events subsequently resulted in the UK moving away from its commitment to nuclear energy in terms of energy security. In the 1990s with the Department of Energy subsumed into the DTI, a decision was taken to split UKAEA and privatise those parts of the Authority considered appropriate for commercialisation.

This led to significant fragmentation of the skill base with many nuclear R&D facilities closed and consolidated. The “strategic blueprint” for investment in nuclear R&D was lost which subsequently led to a reduction in university based nuclear engineering and research. Private sector organisations that secured parts of the UKAEA’s nuclear capability moved into new markets and there was little investment in provision of long-term nuclear skills. Nuclear R&D was also not the remit of the UK’s Academic Research Councils and by the end of the 1990s public sector investment in nuclear fission R&D had declined to virtually zero with only roughly £1m per year invested. Effectively, there had been a year-on-year decline since the hay-day in the 1970s. At the same time, university nuclear engineering research groups were in decline and by 2000 there was not a single undergraduate degree programme in the UK with the word “nuclear” in its title.

BNFL were first to appreciate the imminent loss to the UK of expertise in some key technology areas. Towards the end of the 1990s/early 2000s BNFL established four University Research Alliances dedicated to supporting critical areas of capability needed to support its business operations. These Alliances not only performed R&D to support the industry but were also designed to have critical mass of capability. Without these centres UK nuclear capability in universities had distilled down to only singleton expertise which would disappear when individuals retired. The four centres established by BNFL to redress the situation were in Radiochemistry (Manchester University), Particle Technology (Leeds), Waste Immobilisation (Sheffield) and Materials Performance (UMIST). Manchester University and UMIST have since merged to form The University of Manchester. These centres were designed to have a critical mass size of approximately 30 people (staff and researchers) in each centre. This approach also meant BNFL was able to consolidate its vast portfolio of academic research into a few key universities and build strength where needed.

In 2002/3 BNFL worked with the Research Councils which also recognised their role in supporting the skills base in light of the Government Energy policy to keep the nuclear option open. The skills issue was also recognised by the DTI which published its Coverdale Report [1] in 2002 that concluded “the sector will require 50,000 recruits over the next 15 years, excluding potential for new build”. Of those recruits, it was estimated that about 1,000 per year would be graduates from university physical sciences and engineering degree courses.

BNFL had therefore by default assumed the role of “national champion” with responsibility for the sustainability of the skills base. In particular they were instrumental in encouraging the research councils to recognise their own responsibilities in supporting university-based postgraduate nuclear education and research, and progress in this direction in the last four years as been remarkable. However with the advent of the Nuclear Decommissioning Authority in 2005, BNFL recognised it would be under much tighter commercial pressure and therefore unable to support skills and R&D in the interest of the UK as a whole. Therefore the responsibility for the custody of the UK’s skills base was transferred to the NDA whose principal focus is the safe decommissioning and clean up of the UK’s nuclear legacy.

2. University education in the UK

Figure 1 shows a simplified nuclear education ladder for the UK. The pre-university rungs of the ladder (Schools, national vocational qualifications, foundation degrees) comes within the remit of the National Skills Academy for Nuclear (NSAN) with regional centres based near concentrations of nuclear activity. National Skills Academies are an initiative of the UK Government to enable hands-on involvement by employers in the design and delivery of skills. The NSAN aims to create, develop and promote world class skills and career pathways to support a sustainable future for the UK nuclear industry. The construction of the first regional node of the academy is underway in West Cumbria referred to as The Nuclear Academy.

The top half of the ladder belongs to the higher education institutes (universities) and covers undergraduate degrees, MSc programmes and doctoral research degrees (Ph.D., D.Phil., Eng.Doc.). The undergraduate degrees include 3-year "bachelors" degrees (B.Eng., B.Sc.) and 4-year undergraduate-masters degrees (M.Eng., M.Phys., etc.). Students on the 4-year degree have to satisfy certain academic criteria at the end of their second year to be allowed to progress. Otherwise they must transfer to the Bachelors programme. PhD students are normally recruited directly from M.Eng. and M.Phys. graduates.

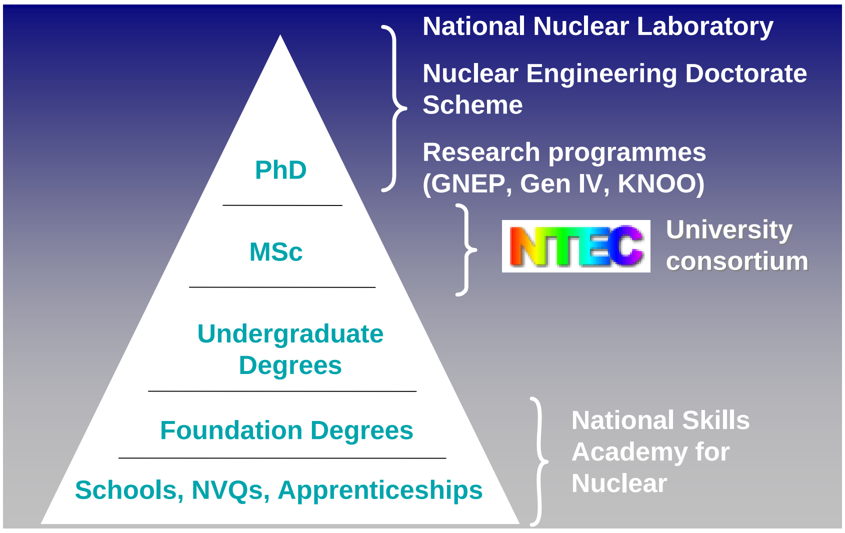

Figure 1. The educational ladder in the UK

The UK MSc degree serves a different purpose to the European Masters. It is a one-year programme (48 weeks duration rather than two semesters, and equivalent to about 75 ECTS) which can be used by students wishing to move across into a different field. Thus students from general engineering or physical science undergraduate degrees can acquire the necessary nuclear knowledge from an MSc programme to allow them a favoured route into the nuclear industry or to start PhD research in a nuclear-related area. There is little enthusiasm in the UK to make the MSc Bologna-compatible.

A recent survey of nuclear-related programmes offered by UK universities at undergraduate and postgraduate levels is available from the Dalton Nuclear Institute website [2]. It shows only one university offering undergraduate nuclear engineering (Lancaster University) although there will soon be more universities offering nuclear engineering options within their existing degree programmes. At MSc-level the choice of nuclear engineering programmes has traditionally been between courses offered by the Nuclear Department, HMS Sultan, and Birmingham University's MSc in Physics & Technology of Nuclear Reactors, a programme that has been running for over half a century.

3. New initiatives

The declining trend in university nuclear education and research has been effectively reversed in the last five years by a series of key initiatives taken by the Engineering and Physical Sciences Research Council (EPSRC). These initiatives are summarised below:

- £1m to establish the Nuclear Technology Education Consortium (NTEC) involving 11 Higher Education Institutions coordinated by the Dalton Nuclear Institute at The University of Manchester.

- £5m for an Engineering Doctorate programme in nuclear technology coordinated by the Dalton Nuclear Institute at The University of Manchester in partnership with Imperial College with support from four other universities with specialist capability.

- New research programmes: £6m for "Keeping the nuclear option open" which involves a large consortium of UK universities with Imperial College as Principal Investigator; £2.3m for "Sustainability assessment of nuclear power" involving the universities of Manchester, City and Southampton; £4m for "Nuclear waste management and decommissioning.

- £0.5m support to initiate two new Chairs in Radiation Sciences and Decommissioning Engineering at the University of Manchester.

- Establishment of the "Letter of Agreement" group which is a grouping of lead nuclear industry players (Nexia Solutions, NII, MoD, AWE, NDA) led by the EPSRC which looks for means to support and invest in nuclear R&D and skills issues common across the industry

3.1 NTEC – the Nuclear Technology Education Consortium

A single proposal was invited by EPSRC from a consortium of higher education institutes to bid for a stand-alone Collaborative Training Account. The proposal was to offer broadly-based Masters-level nuclear education in a format that could be used as part of a degree programme or taken by those already in industry for their professional development. The outputs from the various skills surveys were used to define the scope of the programme. It was much wider than a conventional nuclear engineering programme - one of the surveys had identified 18 essential skill areas across the main subjects of: Chemistry, Materials, Engineering, Physics, Earth Sciences, and Socio-economics that would be needed to support the government's nuclear power policy. The large proposed consortium of nine universities and two HEIs contained expertise across all these areas. Partners would teach to their particular strengths but would not be required to teach material they were less familiar with.

The module syllabuses were designed after extensive discussions with the nuclear industry and regulators. These involved a sector skills council survey carried out by Cogent, an Industry Day at Manchester and many follow-up one-to-one meetings with individual companies. Twenty-three letters were received from the industry to support the funding application to EPSRC. The bid was successful and the programme was launched in September 2005. The NTEC portfolio currently contains 21 modules providing for pathways in "Nuclear Technology" and "Decommissioning". Details can be found on the NTEC website [3]. The programme is accredited by the Institution of Mechanical Engineers and other learned societies. The “short-course” format of each module is designed particularly for those already in industry. They need only be away from their place of work for the one week’s intensive direct teaching. Pre-module preparation and a post-module assignment and exam are done in the students own time in evenings or week-ends. From September 2008 the core modules will be offered in an alternative “distance-learning” format with an identical syllabus and learning outcomes.

3.2 Nuclear Engineering Doctorate

The Engineering Doctorate scheme is EPSRC’s flagship scheme for doctoral training. They invited a consortium bid for a new programme in nuclear technology. This was awarded in September 2006 to a consortium led by the University of Manchester in partnership with Imperial College London which included the universities of Bristol, Leeds, Sheffield and Strathclyde [4]. The objective of the Eng.D. scheme is to provide outstanding young Research Engineers with intensive, broadly based training in collaboration with industrial companies so that they are equipped to take up senior roles within the nuclear industry. In addition to obtaining a high quality qualification, the Research Engineers gain experience of working in an industrial research and development environment. The four year programme involves the Research Engineer being based within an industrial company in the UK. The programme comprises four elements: a doctoral-level project of portfolio of projects; a Diploma in Enterprise Management; taught technical modules; and a professional development programme. The programme scope was defined by the research council to cover reactor technology, waste management, decommissioning, materials, and socio-economic aspects.

3.3 Research programmes

University-based research groups can only thrive if there are able to win funded research projects. This is looking more promising now than at any time in the last twenty years. The UK government is creating the National Nuclear Laboratory to protect the skills of Nexia Solutions. The National Laboratory and the facilities at the British Technology Centre, as well as research council funding, will provide universities with new research opportunities, and the future looks rosy. None of the new initiatives from the research council would be possible without the existence of close partnerships between university groups and the industry.

4. Acknowledgements

The author thanks Mr Warren Richards, Business Manager, Dalton Nuclear Insitute, for his help in preparing this manuscript.

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THE KARLSRUHE NUCLIDE CHART: AN EDUCATIONAL TOOL FOR THE NUCLEAR SCIENCE COMMUNITY

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ABSTRACT

A new 7th edition of the Karlsruhe Nuclide Chart was published in 2006. For almost 50 years, it has provided scientists and students with structured and accurate decay data on all known radionuclides. The Chart is of great didactic value in education and training in the nuclear sciences and provides a record of scientific progress on the discovery of new elements, nuclides, and decay modes.

1. Introduction

The Karlsruhe Nuclide Chart (KNC) is a unique tool for the nuclear science community that presents structured and accurate information on the radioactive decay of nuclides. In the 1950s, in order to meet the demand for professional training and education in developing fields of nuclear engineering and radiochemistry, the Radiochemistry Institute in the Karlsruhe Nuclear Research Centre held courses on radiochemical isotopes. The Karlsruhe Nuclide Chart was created within the scope of this teaching activity. Through the successive editions dating back to 1958, the chart has evolved to reflect scientific progress and breakthroughs. The discovery of new elements, modes of decay, and nuclides far from the stability region is reflected in the various chart editions. The latest 7th edition (2006) [1,2] contains new and updated decay data on 619 nuclides.

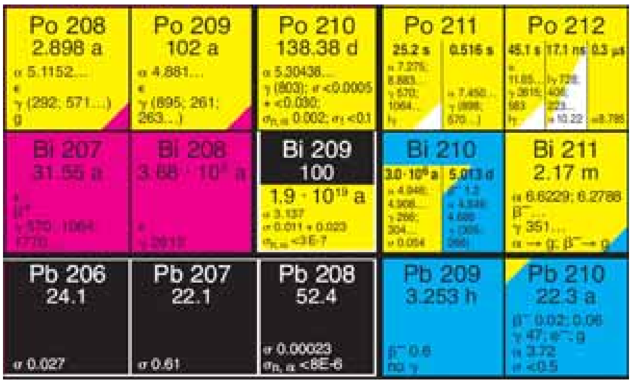

Fig 1. Section of the Karlsruhe Nuclide Chart, revised 7th edition 2007.

The Karlsruhe Nuclide Chart is based upon the proton-neutron model of the nucleus and is basically a plot of the number of protons versus the number of neutrons in stable and unstable nuclei. In contrast to many other data compilations and databases [3] which include calculated or theoretically predicted values, the data in the Karlsruhe Nuclide Chart is based primarily on experimental work. For example, nuclides are included in the chart only if the half-life or the mass has been measured or the nuclide has been clearly identified. As the chart was not developed for a specific purpose and with specific data needs (e.g. nuclear reactor community), the presented data is of general use in health physics and radiation protection, nuclear and radiochemistry, nuclear medicine, astrophysics, etc.

The current 7th edition [1,2] contains nuclear data on 2962 experimentally observed nuclides and 692 isomers. The accompanying brochure includes a history and overview of nuclear science. The multi-lingual "Explanation of the Chart of the Nuclides" has been extended from the original four languages (English, German, French, and Spanish) to include Chinese and Russian. Recently, a KNC wiki page [2] has been created to provide users with additional information. A dedicated forum is also available [1], and a FAQ page is under development.

2. Use of the Karlsruhe Nuclide Chart: some examples

Each nuclide is represented by a box containing basic nuclear data as shown in Figs.1 & 2. This data is composed of general decay data with half-life, decay modes and energies of decay radiations.

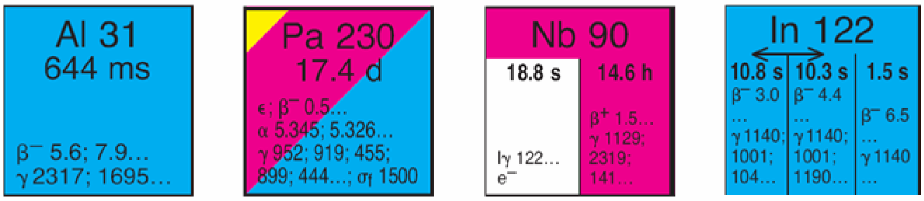

Fig 2. Nuclide representation in the Karlsruhe Nuclide Chart.

An important characteristic of the boxes is the use of colours to denote the modes of decay. There are in total 9 main decay modes, namely proton (orange), α (yellow), β^- (blue), neutron (light blue) and cluster emission (violet), β^+-emission and ε electron capture (both red), spontaneous fission (green) and isomeric transition (white). Some of these modes can have multi-particle emission. As a result of the decay process, a daughter nuclide will result. The main radioactive decay processes are shown in Fig. 3.
The branching ratios of the decay modes are not given explicitly in the chart, but are indicated by the relative sizes of the coloured areas. Pure decay modes, with a branching ratio of 100%, are indicated by a single colour. For nuclides with two decay modes, a small triangle indicates a branching ratio smaller than 5%, for example 2.5% or 10^{-7}%. The major mode has conversely a branching ratio greater than 95%. If the branching ratio of the minor mode is in the range 5 to 50%, and that of the major mode in the range 50 to 95%, the box is divided into two equally sized triangles. Three decay modes are also possible, with similar minor decay mode conventions.
The types of radiation emitted (e.g. α, β^-, etc.) are presented on the chart together with the energies of the most important emissions. The main gamma lines are presented in order of decreasing probability. Where the γ corresponds to a transition following β-delayed particle emission, the γ-energy is followed by an asterisk.
Some examples of nuclides from the KNC are shown in Fig. 2. The first nuclide shown, ^{31}Al (denoted "Al 31" in the nuclide chart), has a half-life of 644 ms. The colour blue indicates β^- decay. The fact that the box is entirely blue implies that the branching ratio for β^- decay is 100%. The β^- particle energies with the highest emission probability (5.6 MeV) and highest end-point energy (7.9 MeV) are given. These particle emissions will generally lead to daughter nuclides in excited states which de-excite through gamma emission. The resulting gamma energies are shown in order of decreasing emission probability, i.e. 2317 keV and 1695 keV. Since they result from β^- decays, these gammas are associated with the parent ^{31}Al rather than the daughter.
The second nuclide shown, ^{230}Pa, has a half-life of 17.4 d. The three colours indicate three modes of decay: yellow: α-decay, red: ε/β^+-decay, and blue: β^--decay. The small yellow triangle indicates that the α-decay branching ratio is less than 5%. The red and blue coloured regions indicate branching ratios greater than 5% for electron capture ε (red colour) and β^- emission (blue colour). The fact that electron capture has a higher branching ratio than β^--decay is indicated by the text "ε; β^-" (i.e. electron capture is first, β^- second).
The third nuclide, ^{90}Nb, shows another feature - an isomeric state of the same nuclide. The ground state (14.6 h half-life) is located on the right hand side and the isomeric metastable state (18.8 s half-life) to the left. The ground state, which is coloured red, decays by positron

emission (β^+) with a branching ratio of 100%. The metastable state ^{90m}Nb decays by isomeric transition Iγ (indicated by white) also with a branching ratio of 100%. Emission of conversion electrons, denoted by e^-, is specified only if the emission probability for electrons is higher than that of the gammas. This is the case for ^{90m}Nb. Note also that metastable states for isomeric transitions are only indicated if the half-life is greater than 1 s.
The fourth nuclide shown in Fig.2, ^{122}In, is an example of a nuclide which has more than one isomeric state. ^{122}In has two metastable states indicated by ^{122m1}In and ^{122m2}In. All three states i.e. the ground state and the two isomeric states decay by pure β^- emission indicated by the colour blue. Where there is uncertainty on the assignment of the properties to a particular metastable or ground state, this is indicated by the double arrow shown in Fig. 2.

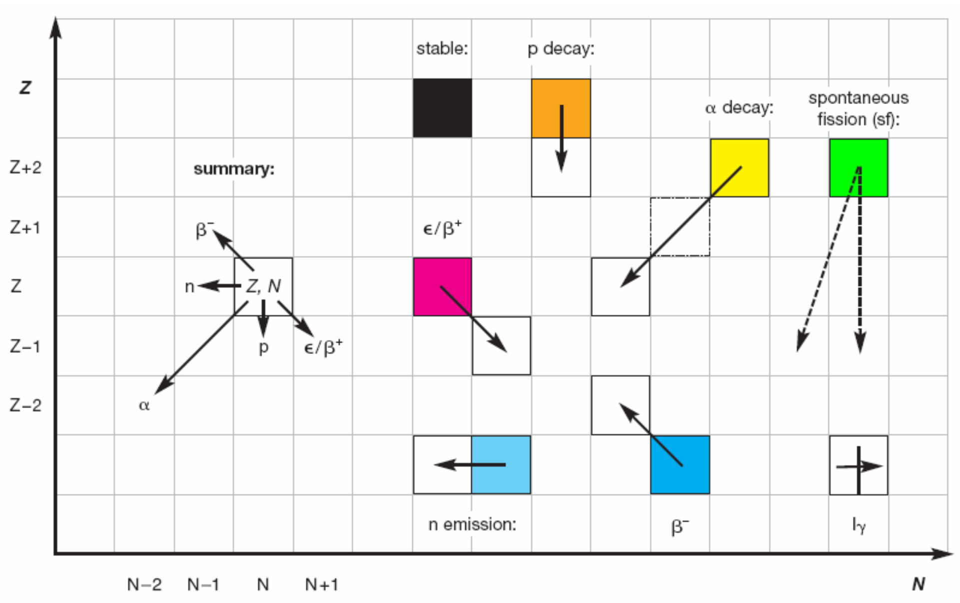

Fig 3. Radioactive decay processes on the nuclide chart. A nuclide parent with coordinates Z, N transforms to a daughter nuclide through the decay processes shown [1,2].

3. The Karlsruhe Nuclide Chart: A Record of Progress in Nuclear Science

Since the discovery of natural radioactivity by Becquerel in 1896 and isotopes by Soddy in 1913, improvements in scientific techniques have led to the discovery of artificial elements, new nuclides and decay modes. This progress has been reflected in the various editions of the KNC as shown in Fig.4. Some examples are described in the following sections.

3.1 New Elements and Nuclides

The first transuranium elements were synthesized with successive neutron capture reactions in long-term irradiation in high flux reactors [4]. Through the work of Seaborg and colleagues eight artificial elements with Z = 93 (Neptunium)-100 (Fermium) were produced in the period up to around 1955. Elements heavier than Fermium were synthesized using projectiles of ions (see below) which resulted in "hot" compound nuclei which then decay via neutron and gamma emission. In general, these "hot" compound nuclei undergo fission into two fragments - neutron emission occurs only in about 1% of the reactions. The synthesis of elements heavier than 106 (seaborgium Sg) became possible only after the discovery of the so-called "cold-fusion reactions". In these reactions, targets of "magic" nuclei, e.g. ^{208}Pb and ^{209}Bi, were bombarded by ions heavier that argon. The resulting compound nucleus, which has a much lower excitation energy, decays through the emission of one or two neutrons.
Element 101, Mendelevium, the ninth transuranium element to be discovered, was first identified in 1955 as a result of the bombardment of ^{253}Es with helium ions. Sixteen isotopes of Mendelevium are listed in the latest edition of the KNC. *Element 107*, Bohrium: In 1976

scientists at Dubna announced they had synthesized the element by bombarding ^{209}Bi with heavy nuclei of ^{54}Cr. *Element 108*: The element 108, Hassium Hs, was first synthesized in 1984. A lead target was bombarded with ^{58}Fe nuclei to produce 3 atoms of ^{265}Hs. *Element 118*: The discovery of element 118 was announced in Oct. 2006. Three nuclei were observed via collisions of ^{249}Cf and ^{48}Ca ions [4].

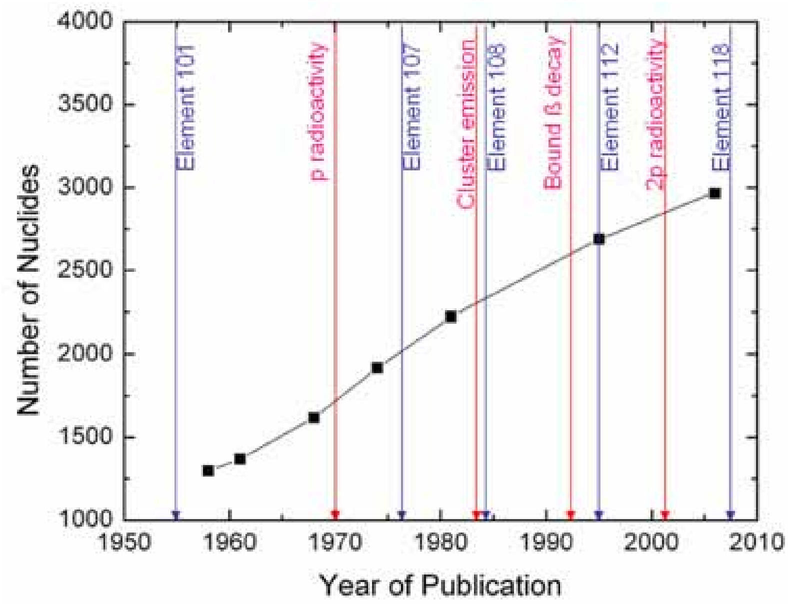

Fig 4. Number of nuclides in the various editions of the Karlsruhe Nuclide Chart. A timeline of related major discoveries is also shown.

The recent discovery of two new neutron-rich nuclides [5], ^{40}Mg and ^{42}Al, has provided additional insight into the exact location of the neutron drip-line. The drip-line is the limit of how many neutrons can bind to a given number of protons. Because of the interplay between single particle and collective quantum effects, the drip-line can only be predicted for the lightest elements.

3.2 New Decay Modes

Proton Emission: proton emission was first observed in 1970 [6] with the nuclide ^{53m}Co. There are over sixty proton emitters reported in the Karlsruhe Nuclide Chart. This is an active area of research as it provides a unique way of mapping the proton drip-line.
Cluster Emission: An intermediate decay process, between alpha decay and spontaneous fission, was discovered by Rose and Jones in 1984. This "new kind of natural radioactivity" [7], consists in the emission of a light nuclide such as: ^{14}C, ^{20}O, ^{23}F, ^{24}Ne, ^{25}Ne, ^{28}Mg, ^{34}Si. There are currently 16 cluster emission nuclides cited in the chart.
Bound Beta Decay β_b: when a stable atom is fully ionised, the resulting ion may be unstable. These nuclei give rise to a special kind of β^- emission in which an electron is liberated from the nucleus, through transformation of a neutron to a proton, and captured into one of the empty energy shells of the atom. This “bound beta decay” was observed for the first time in 1992 [8]. There are now four such isotopes known in nature: ^{163}Dy, ^{187}Re, ^{193}Ir, and ^{205}Tl. The isotope ^{187}Re is included because of its extremely long half-life (5×10^{10} y). Bound beta decay was first observed with highly charged ions of the stable nuclides ^{163}Dy and ^{187}Re provided by the synchrotron and stored in the storage cooler ring at GSI Darmstadt. The ionised $[^{163}Dy]^{66+}$ is observed to decay with a half-life of 47 d by β_b emission to ^{163}Ho. For the almost stable ^{187}Re, the fully ionised $[^{187}Re]^{75+}$ shows a decrease in the half-life of 9 orders of magnitude from 5×10^{10}y to 32.9y. In addition to the $^{163}Dy/^{163}Ho$ transmutation under extreme conditions, other such reaction pairs are $^{205}Tl/\ ^{205}Pb$ and $^{193}Ir/^{193}Pt$ and these may have an impact in stellar nucleo-synthesis where terrestrial and stellar half-lives may be different.

Two-Proton Radioactivity: Two-proton radioactivity was first observed in 2002 [9,10]. The first direct observation of two proton decay emission in the decay of ^{45}Fe was reported in 2007 [11,12] and is shown in Fig.5 (from [13]).

Beta-delayed Proton Emission: For neutron deficient nuclides, there exists the possibility of proton emission from excited states populated in the daughter nuclide via a β-decay. ß$^-$-delayed two-proton emission was first reported in 1983 in the decay of ^{22}Al and ^{26}P. The first observation of ß-delayed three proton emisison in ^{45}Fe was reported in 2007 [13] through the use of a newly developed ionisation chamber. The first photographic recording this process is shown in Fig.5. Through these new experimental observations, the information on the nuclide ^{45}Fe in the Karlsruhe Nuclide Chart will be updated in the next edition. The updated nuclide box, reflecting these discoveries, is also shown in Fig.5.

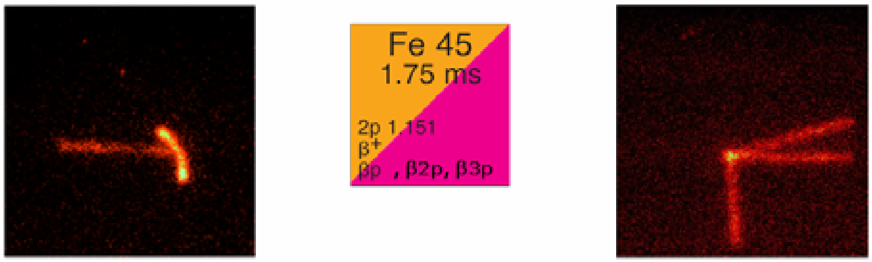

Fig 5. Camera recording of 2p and β3p decay events in ^{45}Fe [11]. *Left:* A track of a ^{45}Fe ion entering from left. The two short tracks are protons of ~0.6 MeV. (image courtesy of M. Pfützner). *Right:* three tracks of protons following the β^- decay (Reprinted with permission K. Miernik, et al., Phys. Rev. C 76, 041304 (2007). Copyright (2007) by the American Physical Society). *Centre:* updated nuclide information for ^{45}Fe shown in the nuclide chart.

4. Conclusions & Future Work

The 7th edition of the Karlsruhe Nuclide Chart has been produced by the European Commission's Joint Research Centre at the Institute for Transuranium Elements. Support for the current and future editions is ongoing to reflect scientific progress in nuclear science. In the future, new versions of the Chart will be available in electronic form (e.g. CD ROM, Web portal) in addition to the paper-based version in line with developments in information technology.

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A NETWORK TO ENHANCE COOPERATION FOR HIGHER EDUCATION ON NUCLEAR ENGINEERING

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ABSTRACT

The educational capacity of many Institutions of Higher Education in Nuclear Engineering decreased under the combined effect of a declining interest among students as well as from academic and political authorities. An increasing cooperation at the international level on educational efforts is necessary. The CHERNE network is an initiative mainly focussed on teaching and learning activities to develop a wide-scope open academic network to enhance cooperation, competence and equipment sharing between its partners. Typical activities organized within the network include workshops, intensive courses, seminars and conferences. The CHERNE network and its main objectives as well as the activities developed since its foundation are presented. Special attention is given to international intensive courses (SPERANSA, JUNCSS, ICARO, ...) organized for students of the member institutions. The common feature of these courses is a strong practical part in specialized facilities, including in some cases access to large equipment like research reactors and accelerators.

1. Introduction

The educational capacity of many Institutions of Higher Education in Nuclear Engineering has been decreasing sharply during the last decades under the combined effect of a declining interest among students as well as from the academic and political authorities. Furthermore, financial restrictions have made it increasingly difficult to maintain and develop facilities, equipment and academic staff needed for practical training of students as well as for basic research in the involved institutions.

Each university and country presents a different situation, but many departments that were initially able to propose a large panel of orientations in this field had to reduce their offer and to concentrate it on a few specialities. On the other hand, a significant number of professionals at different levels of education continue to be required for safely operating and managing the nuclear industry and all other activities involving the use of radiations.

Industry, research institutes and universities need to work together to co-ordinate more effectively their efforts to encourage the younger generation and to develop and promote a program of collaboration in nuclear education and training. Mechanisms should be set in motion for sharing best practices in promoting nuclear education. The obvious solution is an increasing cooperation at the international level on the educational efforts. For this reason, several networks have been developed, some of them focused on specific domains, others concentrated on high level professional training, some strongly structured and others not.

The CHERNE network, created in 2005 and presently involving 14 Institutions (mostly from Europe), is an initiative mainly focussed on teaching and learning activities to develop a wide-scope open academic network to enhance cooperation, competence and equipment sharing between its partners. The aims and rules of the network were established in a declaration, signed by all partners, containing specific details concerning organization, membership and activities. This declaration can be downloaded from the network web site: www.upv.es/cherne/.

Typical activities organized within the network include workshops, intensive courses, seminars and conferences on topics like radiation protection, nuclear measurements, radiochemistry, safety analysis, reactor and accelerator operation and applications, etc. In this paper, the CHERNE network and its main objectives are presented as well as activities developed since its foundation. Special attention is given to international intensive courses (SPERANSA, JUNCSS, ICARO, ...) organized for students of member institutions.

2. The CHERNE network

2.1 Members of the network in 2008

The network was created in 2005, involving now 13 European Institutions and one from United States. The list of members in alphabetic order is the following:

- Alma Mater Studiorum - Università degli Studi di Bologna (Italia)
- ČVUT, České Vysoké Učení Technické v Praze (Czech Republic)
- Dipartimento di Fisica ed Astronomia, Università di Catania (Italia)
- Dipartimento di Fisica, Università degli Studi di Messina (Italia)
- Dipartimento di Ingegneria Nucleare, Politecnico di Milano (Italia)
- DIQN-UPV, Departamento de Ingeniería Química y Nuclear, Universidad Politécnica de Valencia (Spain)
- ETSEIB - UPC, Escola Tècnica Superior d'Enginyers Industrials de Barcelona, Universitat Politècnica de Catalunya (Spain)
- ISIB, Institut Supérieur Industriel de Bruxelles (Belgique)
- ITN, Instituto Tecnológico e Nuclear, Lisboa (Portugal)
- KSU, Kansas State University (USA)
- UAS Aachen, University of Applied Sciences Aachen, Campus Jülich (Germany)
- UAS Zittau-Görlitz, University of Applied Sciences Zittau/Görlitz (Germany)
- Universidade de Coimbra (Portugal)
- XIOS, Hogeschool Limburg, Diepenbeek (Belgium)

It is a wide-scope open academic network mainly focussed on teaching and learning activities, whose objectives are to enhance cooperation, competence as well as equipment sharing between partners.
A declaration, signed by all partners, contains details concerning organisation, membership and activities. This declaration can be consulted at the web site www.upv.es/cherne/

2.2 Origin of the CHERNE network

The CHERNE network has its origin on some ERASMUS Intensive Programmes (IP) organised during last years [1] with the participation of CVUT, DIQN-UPV, ISIB, XIOS and UAS Aachen. The IP "PAN: Practical Approach to Nuclear techniques" was organised in 2002, 2003 and 2005 in Prague, and in 2004 in Mol-Brussels. A second IP (SPERANSA, Stimulation of Practical Expertise in RAdiological and Nuclear SAfety) was supported by the Erasmus programme in 2006 (Mol-Jülich), 2007 (Prague) and 2008 (Mol-Brussels).
A larger partnership was considered necessary to extend the scope of this collaboration, and it was initiated with the constitution of the CHERNE network in 2005 during a workshop organised in Valencia (Spain) by UPV [2].

2.3 CHERNE organisation and membership

CHERNE has a minimal administrative organisation, ensured by the secretary elected at the annual meeting. The secretary manages a Web page through which the activities of the network are communicated. The partners of CHERNE meet once a year to evaluate the activities of the network and discuss any proposal to extend or modify them. For the moment no fee is foreseen for CHERNE membership.
Academic institutions, research institutions, companies or individuals are accepted as members on presentation by two members, including at least one European academic member. Documents for this presentation as well as the list of partners can be found at the official Web site.

3. CHERNE activities

3.1 Description

Cooperation between the institutions should enhance the mutual support by learning from each other, by exchanging experiences, and by regular mutual reflections on what we can do to counteract the 'less interest among students' and the 'less interest among the academic and political authorities' and also on what we can learn from more successful or from less successful partners.
The scope of CHERNE is not limited and any activity related to higher education in radiological and/or nuclear engineering can be proposed.
CHERNE activities will be organised mostly for students of members, mainly at Master level. They should include at least a one-week/2 ECTS module. It's necessary to include practical training in activities for students, including when possible access to large facilities. Teaching modules are clearly seen as a possible kind of activity, but other types of cooperation may be also developed such as material for modules conveniently adapted in each university, e-learning, etc. The language used in CHERNE activities is English.
The CHERNE activities will be organised at no cost, or very low fee, for students coming from other partner institutions. The organising partner will find and propose cheap accommodation for the students coming from abroad. When possible, the organisation of CHERNE activities will be included in ERASMUS exchanges. Therefore, the partners are encouraged to sign bilateral ERASMUS agreements.
Research collaborations are not the main goal of the network. However, they are quite naturally developed as a consequence of the frequent exchanges for educational cooperation. [3, 4, 5]

3.2 CHERNE activities developed or proposed

Activities already realised or planned for the near future as well as a resume of the collaborations between the CHERNE partners can be consulted at the official Web site. They include seminars, courses, intensive courses, and research collaborations.
Activities developed at each partner institution are usually presented at the annual workshops held in Valencia (2005) [2], Valencia (2006) [6], and Prague (2007) [7], and foreseen next 26-28 May 2008 in Favignana Island (Italy). Furthermore, the activities developed by the network have been presented at previous conferences: ETRAP 2005 [1], First EUTERP Platform Workshop [8], and European Nuclear Conference 2007 [9].
In the next paragraphs a special attention is given to the international intensive courses organized. The common feature of these courses is a strong practical part in specialized facilities, including in some cases access to large equipment like research reactors and accelerators.

3.2.1 Radiation protection and nuclear measurement in non conventional sectors

Two editions (2007 and 2008) have been held of this 2-week course organised by ISIB Brussels and XIOS Diepenbeek (Belgium). Students from UAS Aachen, Bologna, UPV, ISIB and XIOS participated in these courses.
The program developed includes lectures on natural radiation, exposure of air crews to cosmic rays, indoor radon, natural radioactivity in building materials, radioactivity in the waste and recycling sector, and exposition to NORM/TENORM in the non nuclear industry. As well practical exercises are proposed on the following topics: software calculation of air crew dose, indoor radon measurements (charcoal, track-etch, continuous), soil radon measurements, radon risk evaluation (ECRS software), visit of detection portals for radioactivity in scrap or waste, simulation of intervention, measurement of NORM by gamma spectrometry, and measurements by liquid scintillation.

3.2.2 SPERANSA: Stimulation of Practical Expertise in Radiological And Nuclear SAfety.

The third edition of the IP SPERANSA, a 2-week course sponsored by EU and coordinated by CVUT Prague (Czech Republic) has been organised at SCK-CEN, Mol and ISIB Brussels from 24 February to 7 March 2008, participating 24 students from Czech Technical University of Prague, Universidad Politecnica de Valencia, Politecnico di Milano, Fachhochschule Aachen in Jülich, XIOS Diepenbeek, and ISIB Brussels.
The lectures (approx 6 h) introduced the theoretical and regulatory aspects of the practical exercises (approx. 45 h), which include: reactor operation, accelerator operation and applications, hot cell operations on radioactive material, radiation emergency (in SCK-CEN Mol and IRMM Geel); and X-rays non-medical applications, neutron measurements, decontamination, indoor and soil radon measurements, TL dosimetry, quality control and patient protection in nuclear medicine and radiotherapy, and control of environmental radioactivity (in Brussels). For some facilities such as underground radwaste laboratory, and radwaste treatment facility, where a direct operation by the students is not possible, visits with demonstrations were done. Finally, 3 round tables (approx. 6 h) were organized, on two topics: ethical aspects of radiological and nuclear safety; and nuclear/radiological techniques and safety for sustainable development; and also for synthesis and evaluation of the course.

3.2.3 JUNCSS: Jülich Nuclear Chemistry Summer School.

The success of the Summer School (2-week course) organised by UAS Aachen in Jülich from 19 to 31 August 2007 stimulated to organisers together with other CHERNE partners to submit an Erasmus IP to the EU for the 2nd edition, in fact for academic years 2008-2010. The program was approved for 2008 and the course will be held from 17 to 29 August with the participation of ISIB, XIOS, UPV, Bologna and UAS Aachen.
The contents of the course include some theoretical lectures, but mainly practical exercises to acquire skill in working techniques in the radiochemical laboratory. And this on the following topics: measurement and shielding of radioactivity, radiation safety, practical measurement of nuclear radiations (α, β, γ, n), working with open sources, production of radionuclides, radiochemical separation and radioanalytical techniques, radiolabelling techniques, applications of tracers, and chemistry of radioelements.

3.2.4 ICARO: Intensive Course on Accelerator and Reactor Operation and applications.

Another Erasmus IP project has been submitted for the 2009-2011 period, coordinated by Politecnico di Milano with a first organisation (2009) proposed to ITN Lisbon. Almost all CHERNE partners are involved in this project, as foreseen participants will be students and professors from XIOS Hogeschool Limburg, Universidad Politécnica de Valencia, Università degli Studi di Catania, Alma Mater Studiorum Università di Bologna, Ceské Vysoké Ucení Technické V Praze, Universidade de Coimbra, Universitat Politècnica de Catalunya, Institut Superieur Industriel de Bruxelles, Aachen University of Applied Sciences, and Politecnico di Milano.
The program includes lectures (about 15 hours) on radiation protection, radiation shielding, radiation safety, interaction of radiation with matter, ion beam techniques, reactor physics – statics and kinetics, and accelerator principles. Nevertheless, the major feature of the course is represented by experiments (about 32 hours) divided in three groups: accelerator-related experiments (accelerator operation and calibration, Rutherford backscattering spectrometry, and PIXE –particle induced X-ray emission); reactor-related experiments (start-up, rod calibration, and isotope production and measurement); and exercises related to radiation protection, radiation safety, radiation shielding, dosimetry, and radiation detection and measurement.

4. Conclusions

On the basis of an existing collaboration between some institutions, the creation of the CHERNE network permitted to enhance the educational cooperation among partners.
The main target of the CHERNE network is to develop teaching activities for the benefit of students of the institutions belonging to the network.
The network is still young and small, and does not yet propose many activities, but already represents a clear added value for the students, in particular with the intensification of Erasmus exchanges between the partners. Consequently, the exchange of students has been clearly increased.
A clear result obtained so far with the network, more specifically with the intensive courses already developed, is the enhancement of the interest of students and academic authorities on Nuclear Engineering.
The perspective of the network is to gradually propose more activities, while admitting new partners who can contribute to the network's life with new activities and more students benefiting of them.

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THE BELGIAN NUCLEAR HIGHER EDUCATION NETWORK A GROWING INTERNATIONAL NUCLEAR ENGINEERING PROGRAMME

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ABSTRACT

The Belgian Nuclear higher Education Network (BNEN) is a master-after-master academic programme organised through a consortium of six Belgian universities and SCK•CEN, the Belgian nuclear research centre. This paper introduces the programme, gives some statistics on the programme and discusses the problems encountered. We have seen a steady growth in the BNEN programme. However, recent indications show that we are influenced by two countering effects: the renewed interest in nuclear energy and the very high demand for engineers on the job market. The first clearly has a beneficial effect on the student numbers and the quality of the programme: industry demands well trained engineers to prepare themselves if a new nuclear wave is initiated. However, the demand from industry for "fresh" engineers is so high that it becomes very difficult to attract students who wish to postpone their career with one year to enter the BNEN programme first.

1. Introduction

In a country where a substantial part of the electricity generation is (about 58% of Belgian electricity production is of nuclear origin) and will remain of nuclear origin for a number of years, there is a need for well educated and well trained engineers in this area. However, there was no nuclear engineering programme at the engineering level (in these days, the Master level) for a long time. Some nuclear engineering related subjects where available to students taking the specialisation of physics engineering or mechanical engineering. In order to fill this gap, two interuniversity programmes, one in the Flemish speaking region and one in the French speaking region, offered a specialized one-year post-engineering degree in nuclear engineering. These programmes existed for several years but suffered from strongly reduced student numbers, mainly due to the negative connotation associated with nuclear energy at the time. Because of education decrees, demanding a certain number of students, these programmes became endangered. It is therefore, that from the worry that Belgian education could no longer "produce" knowledgeable nuclear engineers and with support from the Belgian nuclear industrial partners, that five Belgian universities and the Belgian nuclear research centre SCK•CEN signed a consortium agreement to create the BNEN [1], a Master-after-Master, one-year equivalent degree in nuclear engineering. In 2006, a sixth university joined the consortium. The universities involved are now: KUL (Leuven), UG (Ghent), VUB (Brussels), UCL (Louvain-la-neuve), ULg (Liège) and ULB (Brussels).

2. Structure and modalities of the BNEN

The BNEN academic programme is a one-year (60 ECTS) Master-after-Master programme open for holders of a five-year Master degree in engineering. Holders of master degrees in exact science or industrial sciences can be allowed to the programme if they are prepared to first do an individually drafted make-up programme: the science degree holders have to deepen their knowledge on engineering subjects while the holders of an degree in industrial sciences need to take up some science courses.

The programme (see Table 1) consists of ten courses to be followed mandatory (41 ECTS), the opportunity to select a number of advanced courses at will (up to 4 ECTS worth) and a Master thesis (15 ECTS). The advanced courses either broaden the field of education or deepen a particular subject. Topics that have been addressed are among others MOX fuel, severe accidents and radioisotope production. The Master thesis typically relates to the current professional activities of the student or the SCK•CEN, the Belgian nuclear research center provides every year a substantial list of possible thesis subjects.

	BNEN Module	ECTS	
BNEN block I	Introduction to nuclear energy	3	First semester (October to January)
	Introduction to nuclear physics	3	
	Nuclear materials Part I	3	
	Nuclear fuel cycle and applied radiochemistry	3	
	Nuclear materials Part II	3	
	Advanced/Elective courses	4	
BNEN block II (ENEN block)	Nuclear reactor theory	8	
	Nuclear thermalhydraulics	6	Second semester (February to June)
	Radioprotection and nuclear measurements	6	
BNEN block III (ENEN block)	Operation and control	3	
	Reliability and safety	3	
	Thesis/Internship	15	

Table 1: The BNEN modules

All courses are given in a modular fashion. The main advantage of this system is the easy planning for both students and professors for all lectures in a course. Also for foreign students either in an exchange programme like Erasmus or the ENEN programme, this modular system is easier to cope with. The disadvantage is clearly a heavily loaded period when a course is given (from one up to three consecutive weeks), there is little time to digest the material between two consecutive sessions in a course.

Attention is paid to the fact that most courses are not only theoretical ones, but many of them have exercise sessions and laboratory sessions associated with them. These sessions are organised and taught by the scientific staff at SCK•CEN. Many of the laboratory sessions use the infrastructure available at SCK•CEN like the BR1 reactor, the radiodosimetry laboratory and the material hot cells. These hands-on sessions clearly have an added value for the BNEN students. Many visits are organised to specialised labs at the SCK•CEN to show the students all facets of nuclear energy.

The programme, student issues and general policy is governed by the BNEN Steering Committee in which each university has one member present together with the Administration Manager of SCK•CEN and the BNEN secretary. The Steering Committee is chaired by a professor of one of the six universities for a mandate of two years. He (or in the current situation she) is supported by a vice-chair also appointed for the same time period.

The SCK•CEN, although it offers all the facilities for the programme, is not an academic institute and hence cannot deliver a degree. Students enrol at one of the six universities at their own choice and it is this university that issues the BNEN degree upon succesful passing of the exams.

3. The BNEN audience

The number of students enrolling for the BNEN has seen a serious growth since the start of the initiative as indicated in Figure 1. The programme does not serve only "full-time" students, i.e. people having just obtained their Master degree and who decide to take a one-year degree extra. Also a lot of young-professionals employed at different industrial stakeholders (nuclear power plants, regulatory body, engineering bureau …) enrol for the programme. Total numbers over the past five academic years are shown in Figure 2. They typically spread the one-year programme over two or three years to combine their job with these studies. It is clear that they need and get the full support from their employers, sometimes because they need the degree to be allowed in crucial positions in the company.

The BNEN programme is also a founding father of the ENEN programme (European Nuclear Education Network). Students are encouraged to take up courses in a foreign university to broaden their views. If a student obtains 20 ECTS or more in a different country than the one he is enrolled in, he can obtain next to his degree the ENEN certificate. The BNEN programme or some of its courses are quite popular with foreign students. This academic year we have registrations from more than ten foreign students who decided to use BNEN courses in their curriculum.

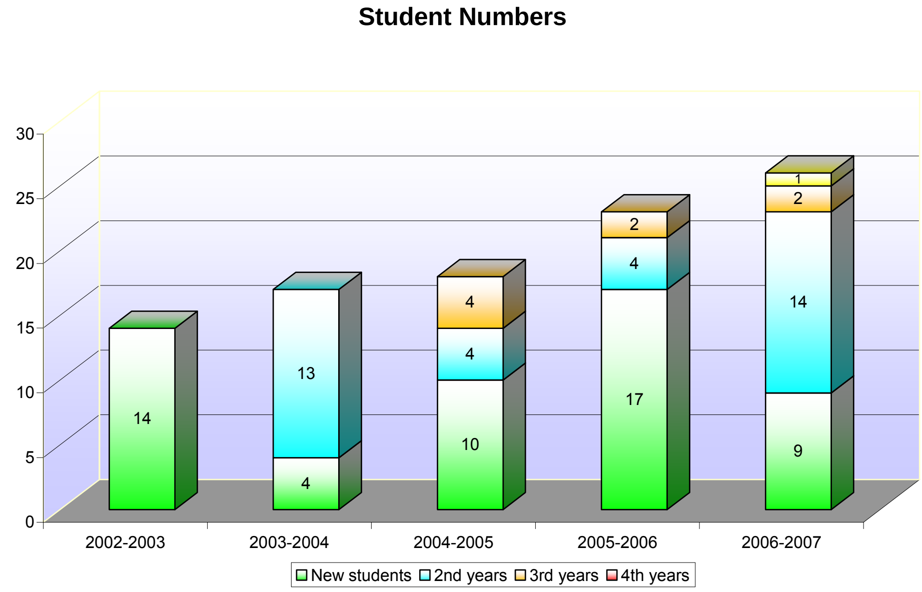

Fig 1: Student numbers registered for the full BNEN programme.

Courses are also available on a one-by-one basis. Young (but also not so young anymore) professionals are more than welcome to increase or refresh their knowledge on nuclear engineering topics. Admittance to a course is in the hands of the Steering Committee based on the credentials of the candidate.

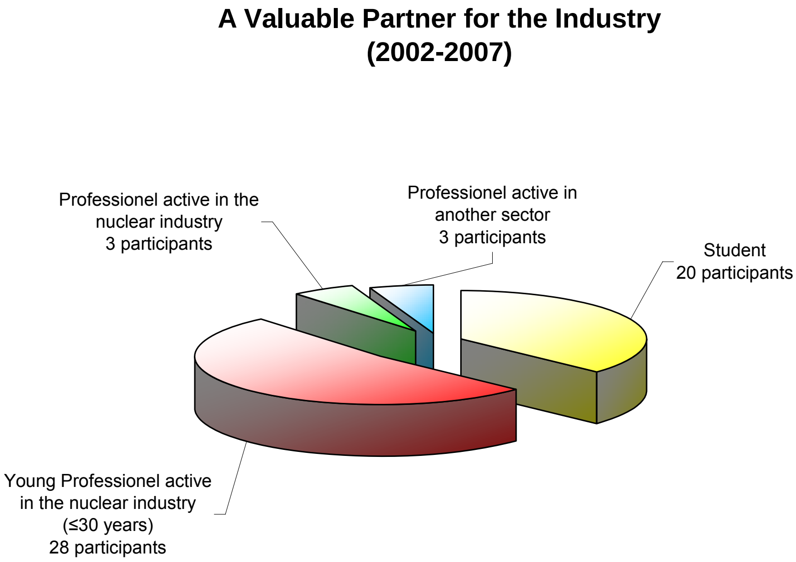

Fig. 2: The different types of students in the BNEN programme

4. Challenges for the (near) future

Over the past years, several challenges have been put to the BNEN and the Steering Committee. One of the specific issues for the federal state Belgium is the fact that education is a regional matter in which the Flanders and Walloon region can have different legislations. In a consortium with universities from both sides of the country and hence two education decrees to follow, this has posed and still poses a difficult equilibrium exercise in which specific matters like student enrolment, examination rules and recognition of previous earned ECTS credits are being resolved by a pragmatic approach of the Steering Committee. Quite recently, members of the student administration of some major Belgian universities have rung the alarm bell on the consequences of the student flexibility in the Bologna decree and the ECTS credits. A very large number of the students are off the "regular" track and they see more and more students failing due to postponing exams and mixing courses from different academic years.

A second challenge is the continuous quality assurance of the courses and the program as a whole. Within the 6th European Framework project, a Self-Assessment Report was written indicating both strong and weak points of the programme **Error! Reference source not found.**. This SAR is the result of an internal analysis of the strengths, weaknesses, opportunities and threats of the BNEN programme The evaluation methodology has been based on the well-established protocol of the Dutch Universities and has benefited from advices of a panel of international experts. To prepare this report, a large set of questions have been submitted to students, former students, BNEN professors and teachers, to the BNEN secretariat and to the BNEN Steering Committee. The SAR bundles and analyses the different answers and provides strengths, weaknesses, opportunities and threats on different aspects of the programme: the objectives of BNEN, the teaching staff, the facilities and also the students. Figure 3 gives the appreciation of the BNEN programme by the students. The BNEN also has assigned a quality coordinator who watches over the contents of all courses, the quality of the material, the coherence of the full programme and the practical matters. The Steering Committee tries to organise on a two-yearly basis a quality meeting where all professors are expected to attend to work on an improvement of their courses. All courses are evaluated by the students and these evaluations are the primary input for these meetings.

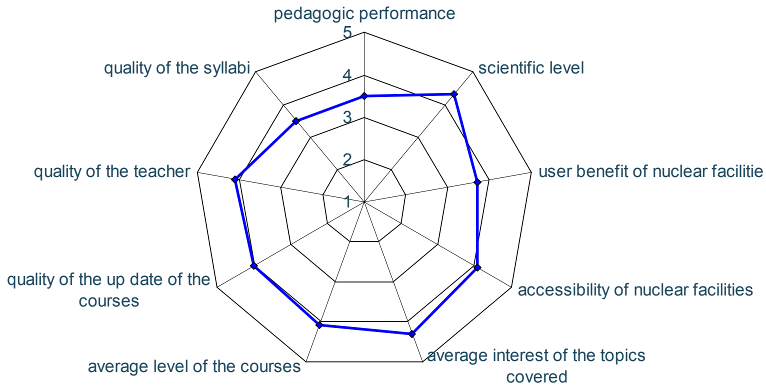

Fig. 3: Self Assessment report, student evaluations

Thirdly, the BNEN must acknowledge the support of some major industrial stakeholders who sponsor the programme financially (and sometimes in kind by allowing their specialists to give an advanced course for free). Without this support, the programme would be quite costly either for the partners in the consortium and/or in the end for the students. Of course, it is from these stakeholders that almost all young-professionals enrolled in the BNEN programme originate. Therefore, the Steering Committee guards quite strongly their academic independence and endeavours to avoid any possible hint of a conflict of interest.

Finally, a challenge that has arisen quite recently is the enormous shortage of engineering students combined with a very high demand from the industrial job market. The last and the current academic year, we have seen very little "full time" students. The dilemma between accepting a well paid job in industry or postponing this step (and risking a less favourite job market) in joining the BNEN programme is unfortunately quickly resolved, not in favour of BNEN. Those who end up in a nuclear industrial player know either from the job interview or quickly after that they, if needed for their position in the company, can be sent to the BNEN programme. This poses a problem not only to BNEN, but also to the SCK•CEN as a research centre since full time BNEN students often take a Master thesis subject at the research centre. In a second step, these Master thesis students are a perfect fishing pond for possible PhD candidates, since the SCK•CEN researchers already have a good idea of the quality of the candidate.

5. Conclusions

In Belgium, but also in Europe, we hear the words "nuclear renaissance" echoing. In some European countries (in some more than in others), the nuclear phase out is under discussion. In two European countries, new nuclear power plants are even under construction. If indeed, there will be a new wave of nuclear power plants built; there will be a high need of well-educated nuclear engineers. But the success of BNEN does not solely depend on this path. The programme also contains courses on nuclear waste treatment, nuclear safety and safeguards. In any case, nuclear engineers will be needed for a long time to ensure safe operation of the current nuclear power plants and the waste treatment and disposal facilities.

It stands without doubt that the organisation of the BNEN has had, and probably still has, to overcome hurdles created by the changing higher education landscape, the Bologna decrees, but also the peculiar Belgian situation where different universities are joined in associations and where education is not a national but regional jurisdiction. Up to now, these issues have been dealt with in a very pragmatic manner, not neglecting Belgian and/or regional educational law.

Acknowledgements

The author acknowledges the continuous drive of the BNEN Steering Committee to improve the BNEN programme and to make it attractive to engineers all over the world. He also acknowledges the support of the European Commision in the 6th Framework Programme of the project "Open Acces to the Belgian Nuclear higher Education Network".

References

[1] The BNEN programme: http://www.sckcen.be/bnen
[2] Deliverable No3 "Self Assessment Report", FP6 project "Open Access to BNEN", contract number 012564

LEADING THE RENAISSANCE – TEACHING NUCLEAR ENGINEERING TO UNDERGRADUATES IN THE UK

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ABSTRACT

In this paper we describe the origins of the only nuclear engineering degree currently to be offered in the UK. The background to the nuclear skills shortage in the UK is provided as context and then the philosophy behind the introduction of the new degree is described. The justification for the introduction of the degree, against a field of general engineering degrees, is explained and the structure of the course is described in detail. The results of a short research exercise with the students currently on the course are provided as evidence for the ambitions and perspectives of students opting for nuclear.

1. Introduction

In 2000 the Nuclear Energy Agency of the OECD (Organisation for Economic Co-operation and Development) published a report, “Nuclear Education and Training: Cause for Concern?” that confirmed what many had suspected for some time: namely, that nuclear education in the UK was in a fragile state. Two subsequent reports by the HSE-NII did nothing to dispel this view. Indeed, the leading conclusion of the second report (Nuclear Education in British Universities, February 2002) stated “If nuclear education were a patient a hospital it would be in intensive care.” At the undergraduate level, all that remained of nuclear education were a few taster modules within mainstream science degrees. At the postgraduate level, only a handful of courses with an appreciable nuclear content struggled to survive.

The concern was not so much that nuclear education had declined compared to the halcyon days of the 50s and 60s when the industry was expanding and university courses were abundant at all levels, but, rather, that it was no longer robust enough to meet the changing needs of the industry. In particular, the need for a guaranteed supply of suitably qualified technical graduates to ensure the safe operation of nuclear facilities in the UK.

A number of events had led to this situation but the two most significant were the deregulation of the energy sector and the funding of higher education. The personnel needs of the industry declined as it sought to be more competitive. With universities run on a business footing the result was that under-subscribed nuclear courses were replaced by those pertinent to other industries where there was a demand and financial support.

2. Philosophy

Paradoxically, because there was a paucity of nuclear courses there was also a need for them. Following discussions with a number of organisations, Lancaster University, Engineering Department, identified the pressing requirement for a safety related course. It was decided that this should be at the masters level as the funding at this level is more flexible than the bloc funding found at the undergraduate level. Started in 2001, the course, Safety Engineering, has run every year since its inception.

With the rapid increase in decommissioning work and the promise of new build, the profile of the nuclear industry in the UK has risen dramatically. No longer dismissed as a sunset industry, it is now an appealing prospect to undergraduate students. The time seemed ripe to attempt an undergraduate course.

The proven philosophy behind the masters course was applied to the new course. Namely, that it should balance the needs of the industry with the intellectual stimulus and challenge required by the students. Like the masters course, the undergraduate one was deliberately designed not to be 100% nuclear but, through a modular approach, to have a variable nuclear content. This allows the student to find his or her own level and it is also a way of importing expertise from other sectors into the nuclear industry.

3. Justification for introducing an undergraduate course

From a university perspective, running post graduate courses are low-risk. If the uptake does not materialise, or declines to an uneconomic level, they can be axed comparatively easily. This is not the case with undergraduate courses. By their nature they run for a longer period of time and are more deeply embedded in the university infrastructure. Before embarking on a new one, it is necessary to justify the reasons why.

Many engineering companies in the nuclear business prefer to recruit graduates from generic engineering disciplines because of the flexibility this offers them in the development of these people in directions that might be subject to change in the future. The specific ‘nuclear’ aspects of their training that are necessary, beyond the fundamentals covered in their undergraduate degree, are often covered by a combination of industry-based training and informally as a result of focussed mentoring by in-house expertise.

Despite this effective approach to nuclear specialisation on an industry basis, there is a strong justification for a dedicated nuclear engineering undergraduate course for three main reasons:

a. The level of nuclear content in many generic engineering degree schemes has become very low, and in some cases there is no nuclear content whatsoever. Furthermore, since it is not essential to have studied physics and/or chemistry at school prior to studying for an engineering degree, an engineering graduate can progress into industry with very little formal nuclear training. This can mean elementary nuclear fundamentals are absent.
b. Some companies in the high-integrity nuclear sectors, such as defence, require significant specificity in the nuclear theme. In contrast with the engineering companies requiring breadth in an engineering degree scheme, these companies require *depth* in nuclear that goes beyond generic degree schemes. These

companies represent the important minority that require nuclear engineering specialists.

c. There is a tangible demand by school leavers for a nuclear engineering degree. The potential renaissance in civil nuclear power, fusion, medical applications and nuclear decommissioning has provided high-profile publicity to the nuclear field. Nuclear engineering offers a varied career in a number of sectors and is a challenging course offering intellectual challenge. This latter issue is very important for a university department because nuclear engineering offers a means for diversifying admission opportunities without compromising the accreditation of the professional engineering institutions.

4. Structure of the undergraduate course in Nuclear Engineering at Lancaster

All students at Lancaster University study three themes in their first year. This is designed to provide them with the prerequisites to choose from a variety of potential major schemes in subsequent years. Undergraduates in Engineering at Lancaster usually study Mechanical Engineering, Electronics and Maths, with which they have the option of study for General, Mechanical or Electronic Engineering amongst a variety of other courses. Nuclear Engineering students also study a general foundation to their degree studying the same three themes in their first year. This enables students to choose ‘nuclear’ at the end of their first year, or vice versa.

The primary level of specialisation begins in the second year of the Nuclear Engineering degree scheme. In addition to further general themes such as Engineering Mathematics, Thermodynamics and Computing, students study three specific nuclear topics:

- **Nuclear Engineering:** This unit introduces the fundamental physics and engineering associated with matter, radioactivity, fission, neutron propagation and reactor systems. A historical perspective on the genesis of the nuclear sector is also included to provide students with a context as to the origin of some reactor designs.
- **Nuclear Chemistry:** This unit covers the necessary chemistry fundamentals, the periodic table, bonding and then specific issues associated with the actinides, separation chemistry and reprocessing.
- **Nuclear Decommissioning:** This unit covers the decommissioning project lifecycle, decommissioning techniques, site characterisation and monitoring techniques.

In their third year, students at Lancaster spend a significant proportion of the study on an individual project. For Nuclear Engineering students, these projects are focussed on specific nuclear topics. In many cases these are spawned from research expertise in the Engineering Department at Lancaster, such as nuclear instrumentation, control, tele-operated robotics and decommissioning challenges. The third-year project has a duration of eight months and is often a collaboration with an industrial sponsor.

In addition to the project, third-year students also study a number of units alongside which include the generic requirements of integrated systems design, engineering management, manufacturing technology and leadership in technology. In the nuclear context students study Nuclear Instrumentation and Nuclear Medicine. The former comprises all the specific instrumentation requirements of nuclear systems for the detection and measurement of radiation. Students explore a variety of practical aspects, including neutron and γ-ray monitoring systems. They also learn the fundamental concepts of efficiency, resolution and intensity. In Nuclear Medicine, students learn about the variety and justification for the use of nuclear systems in medicine, especially the applications of radiology, radiotherapy and nuclear medicine.

In the fourth year of the Nuclear Engineering MEng, students move to a scheme in which they study in intensive two-week blocks. The first week is dedicated to contact time i.e. lectures and seminar-based learning. The second week of each module is dedicated to a short project relevant to the first week of material. Interspersed between each module, students study in teams on a long project that runs for the whole of their final year. For nuclear students this would normally be a nuclear-related project, often sponsored by an industrial collaborator.

In their fourth year, Nuclear Engineering students study the generic themes of the design and modelling of systems, mechanics and actuators and intelligent system control. The nuclear specialisms at this level comprise Nuclear Safety, including the fundamental elements of the safety case and the study of major accidents, and Monte Carlo techniques, which is a practically-based module in which the students learn to design shielding for the storage of radioactive sources using Monte Carlo methods.

5. Current status and student perspectives

During the early years of the Nuclear Engineering MEng course at Lancaster, the first cohorts of students have been studied by the staff at Lancaster in order to get a better grasp on the ambitions and perspectives of young people embarking on a nuclear career for the first time. A combination of methods have been used to do this, including ad-hoc gathering of information at open days, during lectures and social events – which is forthwith termed *unstructured research*, and dedicated questionnaires sent to the students in email, forthwith termed *structured research*.

Unstructured research results

Students who have been brought up close to sites in the UK nuclear industry, such as power stations and naval installations, demonstrate significant degrees of interest in the Nuclear Engineering MEng. Their interest is a result of a long-established personal interest in nuclear technology and its future implications. They are also interested in the prospect of a career in the industry that has been part of the lives for a long time and offers them a beginning to their career that will start close to home. Students with parents or relatives in the industry are often inspired to take up academic study in it.

Structured research results

The students were asked to following questions:

- What motivated you to choose to study a nuclear topic in your degree?
- Where do you see the benefit to your careers in the nuclear aspects you have learned so far?
- In your opinion, where is the nuclear industry going?
- Which part of the nuclear industry is most attractive to you, and why?
- What are the competing industrial sectors for your skills and career?

Students responded that they were impressed by the prospect of being amongst a handful of pioneering students qualifying for nuclear engineering amongst a much bigger pool of engineering graduates. They cited the nuclear industry as being a sector that cultured personal interest in them and an example of a sector that will play a huge role in the future of the UK energy production, sooner rather then later.

Students perceive a broad impact of what they have learned so far in the nuclear engineering degree. In addition to learning about reactor systems, they value to breadth of the course which encompasses the fuel cycle – from mining through to enrichment and reprocessing. They also value the chemistry fundamentals which provide a basis to learning the nuclear fuel cycle. This breadth, they understand, will open many different avenues in the nuclear industry in their future careers.

Students' perception of the nuclear industry is that it is definitely 'on the up' and that the recent permission to build in the UK, the future of the industry looks very promising indeed. Perhaps a little naively given the current decline through shutdown of existing power plants and the replacement of this contribution through new build, students anticipate consistent growth in the proportion of UK energy that is generated by nuclear means.

Students are interested in a broad number of aspects of the nuclear business, included fuel production. However, not surprisingly, the most exciting career prospect is that of commissioning and building a new nuclear power plant. With regard to competing industrial sectors, students cite the aerospace sector, energy, construction and manufacturing.

6. Summary

The nuclear engineering degree is at present the only UK specialist route to an accredited MEng degree qualification in a nuclear specialism. As a result of the nuclear renaissance in the UK and across the world it is almost certainly to be joined by other schemes from other UK universities. The skills required to conceive, design and commission the future nuclear energy supply of the UK and indeed the world are likely to be in short supply for the foreseeable future whilst the graduates of courses such as the one at Lancaster hone their craft and develop into tomorrow's nuclear professionals. The prospects for such graduates appear to be in little doubt. The challenge is with the universities and the nuclear businesses to ensure that this resource has the tools to meet the task ahead.

Growing Fusion Education Program in Hungary

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Fusion research has a long history in Hungary. A small tokamak (major radius 0.4 m, minor radius 0.08 m) named MT-1 was installed at the Department of Plasma Physics of the KFKI Research Institute for Particle and Nuclear Physics (*KFKI- RMKI*) in 1979 and upgraded in the late 80's. Back in those years the education of diploma and PhD students was concentrated in face-to-face conversations and learning seminars given by the elder group members. Due to the shortage of financing the tokamak was shut down in 1998, but this did not mean the end of fusion research in Hungary. One year later the EURATOM Association HAS was established signing a contract between the Hungarian Academy of Sciences and the European Commission. Hungary became a full member of the EURATOM Treaty that opened new horizons and perspectives for the Hungarian fusion research. The leading force is the KFKI-RMKI (*Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Sciences*) and the following institutions are also members of the Association:

- KFKI Atomic Energy Research Institute (*KFKI - AEKI*),
- Budapest University of Technology and Economics, Institute of Nuclear Techniques (*BME - NTI*),
- Budapest University of Technology and Economics, Department of Applied Mechanics (*BME - MM*),
- Research Institute for Technical Physics and Material Science (*MFA*),
- Széchenyi István University (*SZE*),
- Institute of Nuclear Research of the Hungarian Academy of Sciences (*ATOMKI*).

Soon after the foundation of the Association, the improved financial situation, the perspective to work in an international environment and in a dynamically expanding field started to attract students in a growing number. It immediately became clear that the new students need a new educational strategy.

The Institute of Nuclear Techniques of the Budapest University of Technology and Economics seemed to be a straightforward stage for an introductory fusion course into the students' curriculum. The idea of collaboration between RMKI and NTI in the field of education of fusion students was very welcomed by the leaders of BME-NTI, and the fruitful interaction between KFKI-RMKI and NTI still prospering. This very first introductory course had covered the full field of fusion from basic plasma physics to advanced tokamak technology.

A few years later a practical course (called SUMTRAIC=SUMmer TRAIning Course) was established in collaboration with the Institute of Plasma Physics of the Czech Academy of Sciences. This course was a one week series of measurements on the Prague tokamak CASTOR. In the first year, SUMTRAIC had only Hungarian students, but thereafter participants from all across Europe and even from Africa and Asia came to Prague to learn plasma physics. Three years ago it was decided that the Prague tokamak will be replaced by a bigger device and so CASTOR was shut down. Until the new tokamak comes into operation (planned in late 2008), NTI is hosting the SUMTRAIC. Since there is no tokamak in the NTI, a glow discharge plasma source was developed on which the students can make Langmuir probe and spectroscopy measurements. This plasma source is quiet versatile and easy to use and there are plans that after the return of SUMTRAIC to Prague this plasma source will serve as a basis for establishing a set of standard students' measurement instruments in NTI. The Figure 1 shows the plasma source along with the three Langmuir probes.

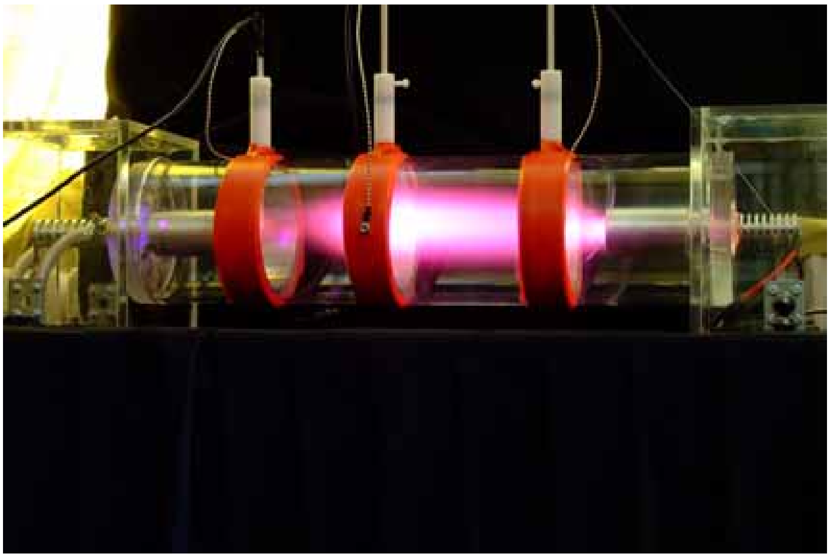

Fig.1. Glow discharge in student experiments

As the number of students interested in fusion had at least tripled in the past five years, a diversification of courses became necessary. At first the introductory course was split into two, full semester courses (one on basic plasma physics and one on fusion devices) and lately specific fusion diagnostic and technology courses have widened the palette. The summary of the available fusion related courses at BME is (as of April 2008) is summarized and visualized on the following Figure 2.

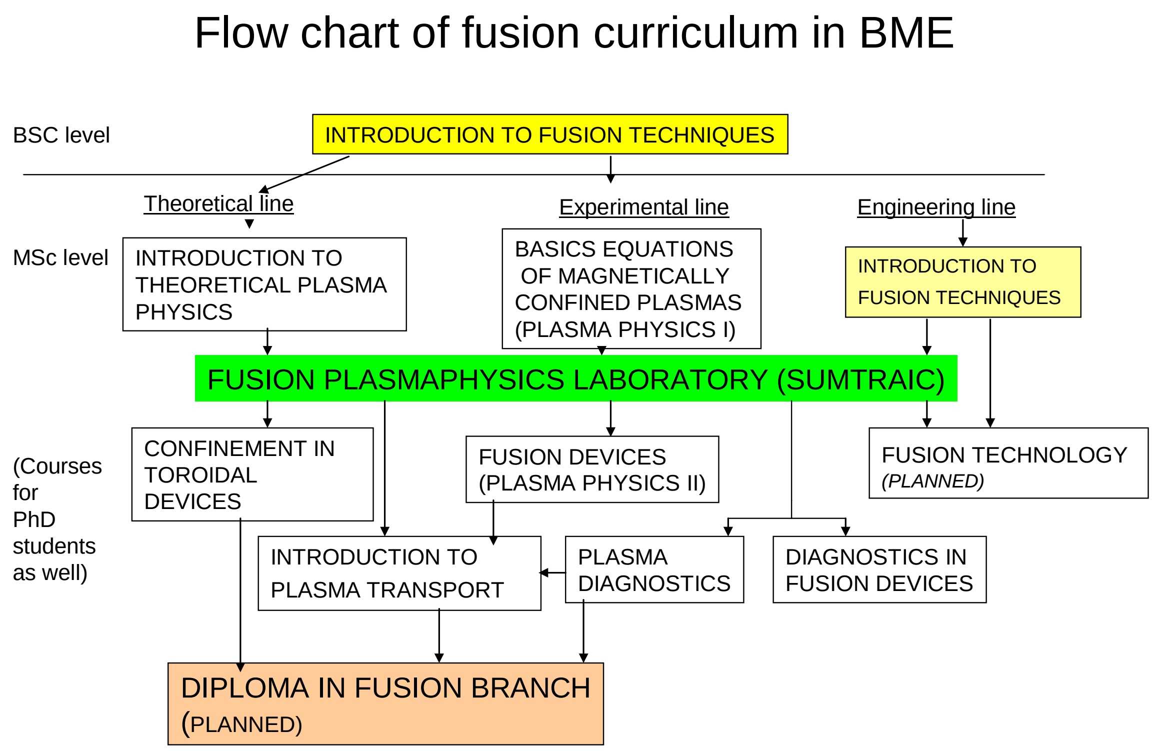

Fig.2. The structure and the courses of fusion education curriculum in BME

On the students' level, the strongest feature of our educational program is that it forms – so to say – a triangle, one side of which is the scientific work done by lower undergraduates, the second side is the diploma work of MSc students and the third one is the scientific research work and education of PhD students. Here we follow the old, Anglo-Saxon traditions. Elder researchers, mainly from KFKI-RMKI, and also from BME NTI work together with students on different research projects, teaching them in a face-to-face manner. This is a pure tutorial system, which selects the best students typically when then step from the BSc level to the MSc level. After proving their ability to work individually as well as in research groups they can publish their work in real scientific papers, which is a precondition to become a PhD student. During the years of their education, our students typically spend about 25% of their research time in research or educational establishments of foreign countries.

An excellent opportunity to increase further our activities in fusion education is the FUSENET fusion educational network to which three Hungarian institutions (RMKI, NTI and SZE) had joined. The budget of the Network had already been approved by the Commission, but the formal foundation of the FUSENET is expected to happen in mid 2008.

In summary: the education of students in the field of fusion and plasma physics is a key to the formation of a proper rising generation. In Hungary, the availability of different courses at all levels of university education from BSC to PhD fulfills the requirements of successful training of all-round future fusion experts.

NUCLEAR ENGINEERING EDUCATION PROGRAM AT UPC-BARCELONA: NUCLEAR POWER PLANT CONCEPTUAL SIMULATOR AND MULTIMEDIA NUCLEAR REACTORS.

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ABSTRACT

Since 1954 ETSEIB-UPC has an education program on Nuclear Engineering. From 1964 to 1977 the experimental education program was developed using an experimental nuclear reactor called Argos (Argonaut type reactor). UPC is providing every year about 130 ECTS on purely Nuclear Engineering oriented courses, with a PhD program on Nuclear Engineering. Nowadays, UPC has started the process to adapt these education programs to the Bologna philosophy, with a Degree and Masters Program model. Those curricula will be fully implemented in the course 2009-2010. The experimental education activities are developed with the Nuclear Power Plant Conceptual Simulator SIREP-1300, and with the experimental laboratories of nuclear physics, modern physics, radiation protection, ionization technology and some research laboratories. In collaboration with nuclear industries we organize experimental work in a full scope nuclear power plant simulator and visits to the Nuclear Power Plants of Vandellós II or Ascó I, II. Some UPC students have obtained the European Master of Science in Nuclear Engineering (EMSNE) in the frame work of ENEN.

1. Introduction

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Some UPC students have obtained the European Master of Science in Nuclear Engineering (EMSNE) in the frame work of ENEN.

2. Nuclear Power Plant Conceptual Simulator

The Nuclear Power Plant Conceptual Simulator SIREP-1300 reproduces a 1350 MWe PWR with 4 loops. In the course of Nuclear Reactor Physics (5 ECTS), the students perform 5 experiences with this simulator, and in the course of Nuclear Power Plants (5 ECTS), they also accomplish 5 experiences, each one taking two hours [1,2].

P1: Reactor kinetic parameters. Prompt neutrons and delayed neutrons. Kinetic equations. Reactor period and doubling time. Estimation of the delayed neutrons proportion. Prompt Jump.

P2: Approach to criticality from subcritical state. Reactor zero power states. Hot and cold zero power states. Subcritical multiplication factor calculation. Start-up sources. Boron dilution. Reactivity evolution after refuelling. Chemical and volume control systems.

P3: Temperature effects on Reactivity. Feedback concept. Feedback due to temperature. Doppler effect and Moderator effect. Feedback coefficients calculation. Influence on reactor stability.

P4: Isothermal coefficient and moderator coefficient. Moderation relation. Isothermal coefficient of reactivity and moderator temperature coefficient of reactivity determination. Design principle of intrinsic security. Boron limit concentration determination.

P5: Start-up and reactor load variations. Reactivity balances. Poisoning effects. Xenon-135 and Samarium-149. Negative reactivity. The poisoning effect in control. Use in relation to reactor power drop.

P6: Reactor standard states. Transition from hot full power to hot zero power.

P7: Reactor standard states. Transition from hot zero power to cold zero power.

P8: Control rods calibration.

P9: Reactor auto stabilization.

P10: Electric network disconnection and house load operation.

Figures 1 and 2: Nuclear Power plant Conceptual Simulator SIREP-1300 at ETSEIB-UPC

Figure 3: Works station for one student

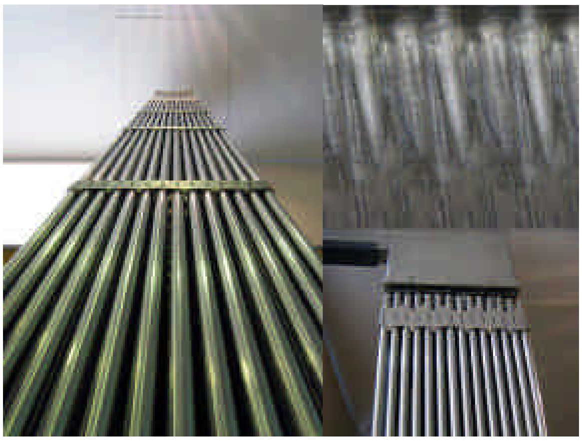
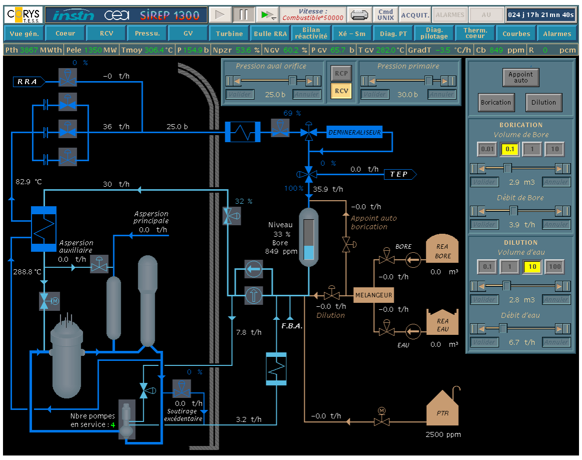
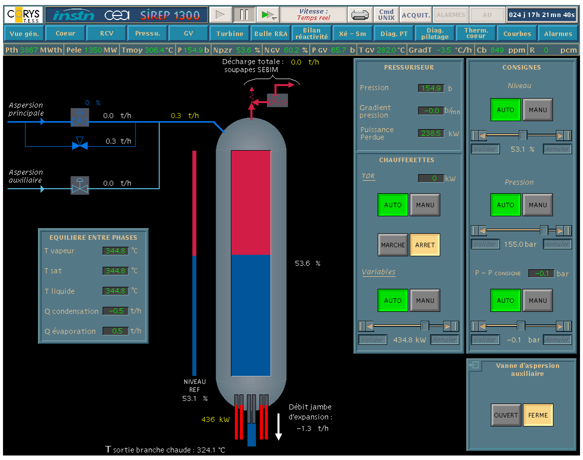


Figure 4: Fuel assembly





Figures 5, 6: Screen Simulator (Chemistry and Volumetric Control System and Pressurizer)

3. Multimedia on Nuclear Reactor

In order to improve education quality, a Multimedia on Nuclear Reactor Physics is being developed. Nowadays, this multimedia has about 770 slides and the text is in Spanish and English. The teacher uses the multimedia during his lectures and students use it at home to study this course. Part of the multimedia has been used during last courses and the students consider this material very useful.

The Multimedia on Nuclear Reactor Physics version 3.0 will be published very soon as:

-DIES, J.; PUIG, F.; PEREIRA, C.; “Nuclear Reactor Physics Multimedia” (languages: Spanish and English) “, cd-rom, v. 3.0, 770 laminas, Barcelona, 2008.

-DIES, J.; PUIG, F.; PEREIRA, C.; “Nuclear Reactor Physics Multimedia “, (language: English) v. 3.0, pag. 385, Barcelona, 2008.

-DIES, J.; PUIG, F.; PEREIRA, C.; “Multimedia de Física de Reactores Nucleares“, (language: Spanish) v. 3.0, pag. 385, Barcelona, 2008.

Samples of Nuclear Reactor Physics Multimedia (language: Spanish)

Figure 7: Main menu

Figure 8: Some nuclear power plants pictures

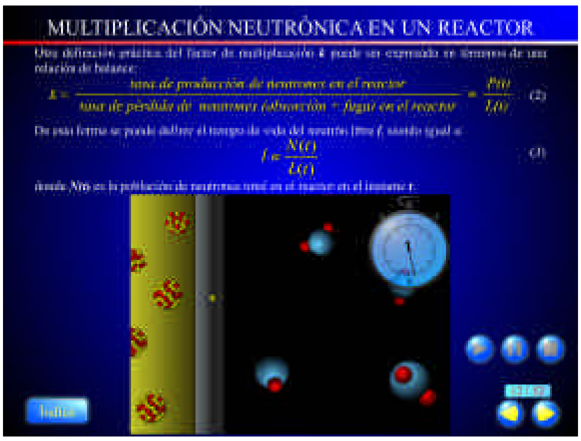


Figure 9: Animation on neutron livetime.

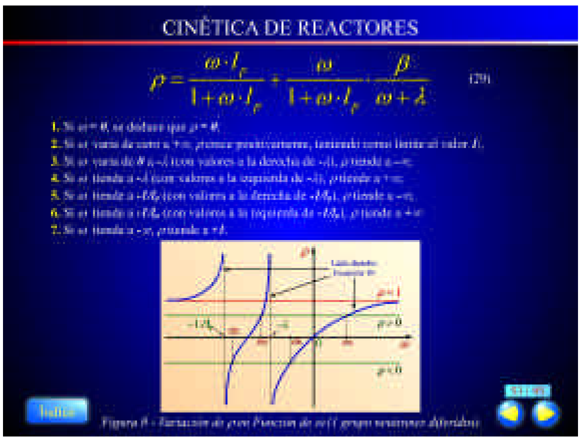


Figure 10: Reactor kinetics

Samples of Nuclear Reactor Physics Multimedia (language: English):

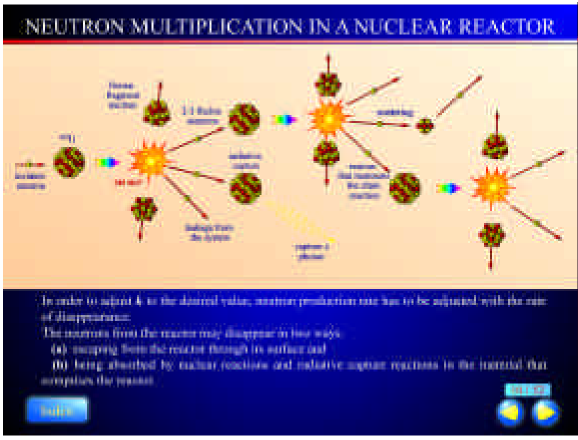


Figure 11: Neutron multiplication in a nuclear reactor

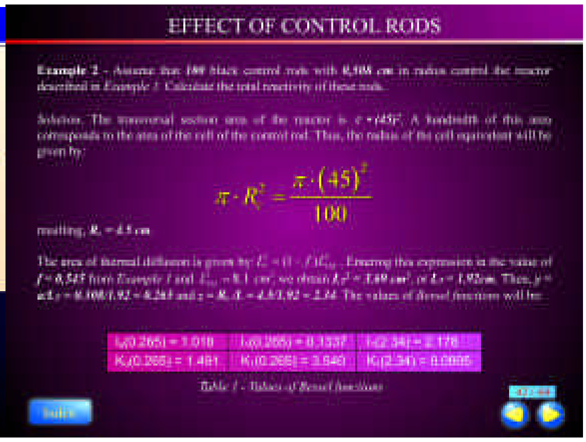


Figure 12: Effect of control rods.

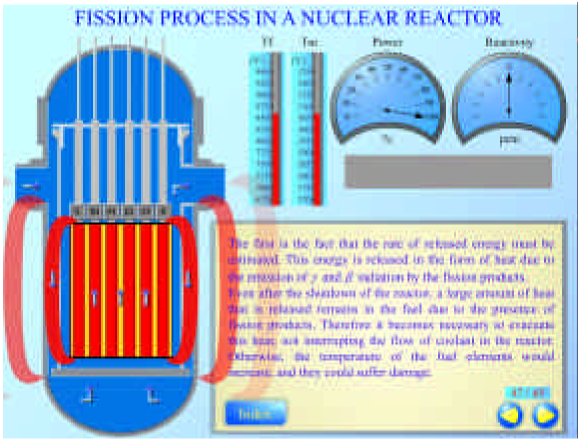


Figure 13: Fission process in a nuclear reactor

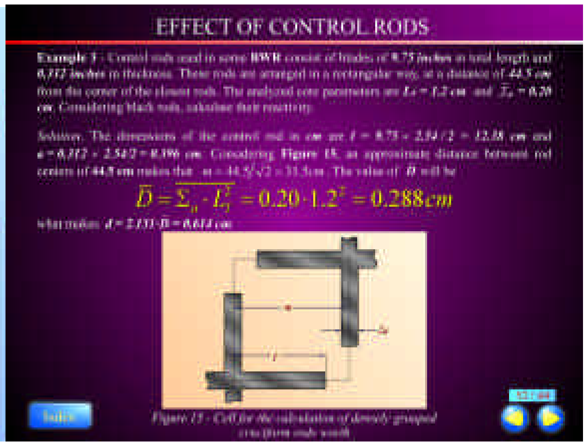


Figure 14: Effect of control rods.

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2-DIES, J.; TAPIA, C.; PUIG, F.; VILLAR, D.; "Nuclear Engineering Education Program with Nuclear Power Plant Conceptual Simulator DFEN-ETSEIB-UPC", (language: English), Ed. CPDA, pág. 206, Barcelona, 2008.

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INTERNATIONAL AND POSTGRADUATE EDUCATION AND TRAINING IN BUDAPEST

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ABSTRACT

The international and postgraduate education program of the Department of Nuclear Techniques of the Budapest University of Technology and Economics (BME) is presented. The experimental laboratory practices offered for the students at the Training Reactor of the BME are listed, and the history, background, status and curriculum of these courses are shown.

1. Introduction

The Training Reactor (TR) of the Budapest University of Technology and Education (BME) was built in 1971. It was designed and constructed in Hungary, by Hungarian nuclear experts and engineers. Only the EK-10 (10% enriched uranium oxide) fuel assemblies of the reactor were imported from the Soviet-Union. The upgrade of the active core has been made in 1981, and the maximal allowed power was raised to 100 kW.

The TR is situated in the campus of the Budapest University of Technology and Economics. The Institute of Nuclear Techniques (INT) is charged with the use and operation of the Training Reactor. The INT consists of two departments: the Department of Atomic Energy is responsible for the reactor operation, and the Department of Nuclear Techniques organises all education and training activities. The TR is declared as an inter-university institution: it accepts students not only from the BME, but also from several Hungarian universities. Bilateral and multilateral agreements assure the access for international applicants: students come now regularly from neighbouring countries in the region, and also from distant parts of the world. The level of the education extends from undergraduate practices to postgraduate education, including diploma works and PhD thesis. The Department of Nuclear Techniques also organises upgrading and vocational training courses for engineers working already in nuclear installations. Also a wide research program is carried out using the many different irradiation facilities and laboratories of the TR. In this paper we concentrate only on the international and postgraduate educational programs.

2. Cooperation with the IAEA

The cooperation with the International Atomic Energy Agency consists of

- Organising IAEA training courses in the BME
- The professors and lecturers of the BME give lectures in IAEA training courses abroad
- Staff members of the BME perform expert work – also education – in many different countries of the world

2.1 IAEA Training Courses

The first IAEA training course organised in Budapest was in 1979 about the use of research reactors. The curriculum of this course was composed of theoretical lectures and of laboratory work. A similar training course was organized also in 1983. The participants of theses courses came from Bangladesh, Colombia, Czechoslovakia, Egypt, Iran, Jamaica, Korea, Libya, Malaysia, Pakistan, Philippines, Romania, Spain, Thailand, Turkey, Uruguay, Venezuela and Viet Nam. Fig. 1. shows a hand-writing of the IAEA Director General Hans Blix after this course.

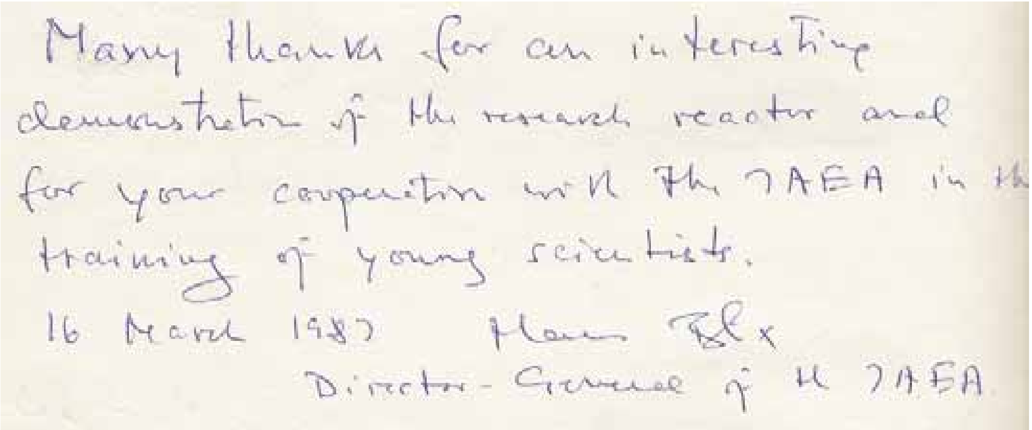

Fig. 1. Thanking words of IAEA Director General Hans Blix

A much longer IAEA Training Course was organised for reactor operators between 10th Sept. and 14th Dec. 1984. We show the list of the theoretical lectures (75 hours) and the laboratory work, since it demonstrates well the wide range of capabilities and expertise of the INT.

The theoretical lectures were the following:

- Radiation protection principles
- Radiation measurements in dosimetry
- Radiation shielding
- Reactor physics
- Heat transfer and fluid flow
- Reactor instrument and control
- Reactor protection system
- Reactor safety, accidents and hazards
- Research reactor technique and technology
- Nuclear material control
- Radioactive waste management
- Water chemistry
- Licensing procedures, regulation and codes
- Survey of reactor experiments and experimental facilities
- Reactor management, organization, commissioning, maintenance
- Emergency planning
- The training reactor of the TU Budapest

The program of this course comprised 100 hours of laboratory work:

- Radiation protection and shielding measurements in mixed *n* and γ fields
- Measurements with TLD
- Measuring activity of water and air
- Measurement of thermal utilization factor
- Measurement of resonance escape probability
- Determination of *n* dose in the core
- Determination of the reactivity worth function
- Cricital and subcritical experiments
- Thermal *n* flux measurement in the core of the reactor
- Determination of delayed *n* parameters and U content
- Control rod calibration techniques
- Measurement on the reactor simulator
- Reactor operation training
- Determination of gamma-emitting isotopes in the primary water circuits
- Determination of enrichment of ^{235}U in uranium sample by NAA
- Hot cell technology practice
- Isotope production practice

The participants of this course came from Argentina, Bangladesh, Colombia, Greece, India, Indonesia, Iran, Iraq, Libya, Malaysia, Mexico, Pakistan, Thailand, Turkey and Viet Nam.

2.2 IAEA experts' missions and IAEA fellows received

Beside the IAEA training courses the staff members of the Institute of Nuclear Techniques have performed several IAEA expert missions in developed countries (Austria, Belgium, The Netherlands, Italy, Germany, and USA) as well as in developing countries (Iran, Pakistan, Viet Nam, China etc.) In the last 20 years we accepted 25 IAEA fellows coming from 17 different countries of the world, who performed research work at the Training Reactor. The subjects of their research work included tomography, radioanalysis, environmental and radiation protection, reactor physics, reactor instrumentation etc. As an example some of the names, country and research topics are listed in Table 1.

Name	Country	Research topic
Yelena Kuyanova	Kazakhstan	Natural radioactivity
Maka Khvedeliani	Georgia	Alpha- and gamma-spectrometry
Dagmar Bursova	Slovakia	Analysing Sr and Ra content
Tahseen Alabed	Jordan	Natural radioactivity
Ibrahim Al Hamarneh	Syria	Alpha- and gamma-spectrometry
Rositza Karayvanova	Bulgaria	Sr-analysis
Hasan Mohammad	Syria	Environmental protection
Marieta del Rosario de Infante	Panama	Water chemistry
Thomas Solo	Nigeria	Neutron Activation Analysis
S. Pinam	Indonesia	Neutron-metrology
Bassem Jerby	Syria	Environmental monitoring
Frank Waiharo	Kenya	Neutron Activation Analysis
Mohamed Shhub Ballut	Libya	Sr-analysis
Lorna Palad	Philippines	Sr-analysis

Tab 1: Data of a few selected IAEA fellows

3. International Cooperation with universities

Beside the worldwide cooperation performed in the framework of the IAEA, the Institute of Nuclear Techniques has long-standing bi-lateral or multi-lateral cooperation with universities. The largest multilateral cooperation occurs within the framework of the European Nuclear Education Network (ENEN) Association [1], who has currently 45 members. In the following we concentrate on the cooperation on smaller scale.

3.1 Cooperation with the Slovak Technical University of Bratislava

The cooperation with the Department of Nuclear Energy at the Faculty of Electrical Engineering and Informatics of the Slovak Technical University of Bratislava looks back for almost three decades. We have a student exchange program, where 5-10 energy engineering students arrive to Budapest annually for laboratory exercises at the Training Reactor, and about the same number of Hungarian engineering physics students spend a week in Slovakia on a technical tour visiting power plants and other nuclear facilities. The student exercises in Budapest usually include: criticality experiment, reactor operation exercise, measurement of delayed neutron parameters, thermal neutron flux measurement, reactor-dosimetry and neutron activation analysis. The students also visit the Maintenance Performance Improvement Centre and the Simulator Centre of the Paks NPP and laboratories at the Atomic Energy Research Institute. Last year also a 4-day long neutronics computation course was held for the Slovakian students.

The technical tour in Slovakia include visits of the Gabcikovo hydro power plant, the crisis center of the Slovak nuclear authority, the Mohovce NPP and the LLW and MLW disposal site, the radioactive waste processing plant at Bohunice and the Cerny-Vah pumped storage hydro plant.

3.2 The "Eugene Wigner Course for Reactor Physics Experiments"

The Wigner Course [2] is a joint venture of the following European universities (in alphabetical order): Atominstitute of the Austrian Universities (Austria), Budapest University of Technology and Economics (Hungary), Czech Technical University Prague (Czech Republic), and Slovak Technical University Bratislava (Slovak Republic). The participants of the course perform reactor physics experiments on three different nuclear research reactors in three different countries. The *Quality Assurance Committee* of the European Nuclear Education Network Association (ENEN) assessed this course and suggested that the course uses the quality label *ENEN International Exchange Course*. The IAEA provided financial support to some of the participants of the course. Since 2003, the course is being organized annually. The participants work in groups consisting of 4-5 students. In forming the groups special care is taken to mix the students of different nationality and gender. This way the international character of the course is emphasized, and the use of English language is encouraged. The students in a group travel and work together, and they also prepare the reports together. However, they are evaluated and graded individually. The evaluation is done at each experimental site by oral evaluation of the laboratory report by the experiments' supervisor, and at a common "final evaluation" session. The course starts with a few theoretical lectures in Bratislava and continues with technical tours to a NPP and radioactive waste treatment centre near Bratislava. The experimental part consists of laboratory practices in Budapest, Vienna and Prague. Detailed information about the Wigner Courses can be found on the Internet: http://www.reak.bme.hu/Wigner_Course Here we list only the experiments at the TR of BME:

- Reactor operation exercise
- Determination of delayed neutron parameters and uranium content of a sample
- Measurement of thermal neutron diffusion length in graphite
- Reactivity worth of neutron absorbers
- Neutron activation analysis

3.3 Cooperation with 'École de Mines' Nantes (France)

The French École des Mines de Nantes and the BME INT agreed in 2000 that they organise a joint student project annually for 5 - 5 undergraduates specialised in nuclear science and engineering. From that time on these projects are being organised so that the two universities take turn in hosting the project. The work starts with a preparatory period when students study the state of the art and exchange their views in e-mail. The project itself takes 4 – 5 days that include a site visit, on-site sampling, co-operative work in evaluating the results and compiling a final presentation. The presentation is open to interested faculty members.

Topics of the recent projects:

- Sorption of boron and molybdenum on argilite used for confinement of high-level nuclear waste in France;
- Site remediation of an abandoned uranium mine in Hungary;
- Clearance and exemption levels in EU, their application in French and Hungarian nuclear regulatory practice;
- Environmental monitoring in the vicinity of the Püspökszilágy low-level radioactive waste disposal site,
- Impact of TENORM waste originating from the phosphate industry on the environment.

3.4 International summer training school SUMTRAIC

SUMTRAIC is a summer training school in the field of experimental plasma physics for controlled fusion experiments. The first SUMTRAIC was held in 2003 in Prague at the tokamak CASTOR attending only by Hungarian students. After this successful start the course became widely international and was always organized at CASTOR. The aim was to provide a hands-on experience to university and PhD. students on a small and flexible tokamak experiment. Since

CASTOR has been shutdown due to the installation works of tokamak COMPASS (where the future courses will be held), the students of this course do the measurements on a linear plasma device built in Budapest, where the basic plasma physics processes can be studied.
Students have to understand the operation of the machine, perform experiments, write their own data evaluation programs using the IDL data evaluation language, process data and finally present results on the small workshop on the last day. During the course students get a full overview how a researcher works at a real plasma experiment.

Course programme

Students are grouped into groups of 4 participants each. Each group is assigned to one of three research topics: probe measurements, spectroscopy and turbulence measurements. Each group writes data evaluation programs for its own topic and on the last day prepares a presentation of the results of their experiment. The other two topics are studied as well, but mostly using the programs and help of the responsible group [3].

4. Postgraduate education

4.1 PhD program

The INT BME takes part in the PhD school of the Faculty of Natural Sciences of BME. As an example of the wide spectrum of the research work done we show a selection from the successfully defended theses in Table 2.

Year, name	Subject of the thesis
2001: Szabolcs Czifrus	Design and realisation of a neutron field in the irradiation tunnel of the TR, suitable for BNCT
2003: Sándor Kiss	Analysis and assessment of noise diagnostic signals from NPP
2003 János Végh	Support of safe operation of NPP by use of online information systems
2004: Zoltán Hózer	Modelling leakage of fuel-elements
2004 Éva Kabai:	Investigation of behaviour of long-lived radioisotopes in the soil-plant system
2004 Tamás Pázmándi	Space-dosimetry using a 3-axis Si-detector telescope, and the 'Pille' TLD dosimeter system
2005: Márta Balla	Provenance Study of Qumran Pottery by Neutron Activation Analysis
2005 Áron Brolly	Investigation of accelerator driven actinide transmutation systems from reactor physical point of view
2005 Anikó Kerkápolyi	Study of hot particles
2005 Eszter Rétfalvi	Small angle neutron scattering study of radiation damage in steels
2006 Péter Pál Ember	Decreasing Matrix Effect in PGAA
2006 Khaled Sayed Mahmud	Numerical Modeling of Reactivity Excursion Accidents in Small Light Water Reactors
2007 Attila Bencze	Investigation of plasma fluctuations and turbulent flows in fusion plasmas
2007 László Temleitner	Structural disorder studied by neutron diffraction and computer simulations

Tab 2: Data of a few successfully defended PhD thesis

4.2 Continuing education

The INT regularly organises Training Courses for engineers working in different nuclear fields. Typically we have trainees from NPP, from nuclear authorities, sometimes also from dry storage facility. Usually those engineers are trained, who have got their MSc degree in electrical- or mechanical engineering and they do not have enough nuclear background. We organise a two year course of Continuing Education Program in Reactor Physics and Reactor Technology. The courses are in Hungarian, thus their description is only available in Hungarian language on our Hungarian WebPages [4].

The course contains the following elements:

- Applied Mathematics I, II, III
- Reactor Physics I,II,III,IV
- Reactor Technology I,II
- Radiation Protection and Dosimetry
- Environmental Protection
- Nuclear Measuring Techniques I, II
- Thermohydraulics I,II.
- Nuclear Power Plants I,II
- Operation of Nuclear Reactors
- Control Technology I,II
- Electrical Devices and Grids
- Energy Systems
- Laboratory Practices I, II, III, IV, V, VI

5. Summary

The main features of the international and postgraduate education program of the Department of Nuclear Techniques of the Budapest University of Technology and Economics was presented. The BME INT invites students interested in doing hands-on experiments and research work at a nuclear reactor, as well as students for MSc diploma and PhD work. Also applications for the annually organised Wigner Courses are encouraged.

6. References

[1] http://www.enen-assoc.org/
[2] http://www.reak.bme.hu/Wigner_Course
[3] http://www.rmki.kfki.hu/plasma/sumtraic_007/
[4] http://www.reak.bme.hu

DEVELOPMENT OF NEW NUCLEAR ENGINEERING STUDY PROGRAMS AT KAUNAS UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Taking into account the approaching start of construction of a new NPP in Lithuania and growing needs for nuclear expertise in Lithuanian energy sector, the new State National Program for preparation of highly qualified nuclear engineering specialists is prepared and being implemented. This program includes: reorganization of existing system of nuclear education, creating or updating of training facilities and methodology, modernization of pedagogical personnel's competency improvement system, creating or updating systems for re-qualifying of currently working nuclear and non-nuclear specialists, systems for nuclear competency maintenance and improvement, nuclear knowledge retention, measures for advocating of positive features of nuclear energy and improvement of public perception. The first steps for implementation of the above mentioned program – establishment of the two new Nuclear Engineering Study Programs at Kaunas University of Technology – are described in this work.

1. Introduction

A broad and deeply rooted nuclear competence is essential for proper, safe and effective operation of nuclear facilities. However, several negative indicators currently can be observed in the nuclear knowledge management area: an imbalance between the public perception of the extent of nuclear energy use and growing needs for nuclear expertise, aging of existing NPP's personnel and high retirement expectations, insufficient investments in nuclear research, education and training, lack of popularity, pre-interest and motivation of young people to study nuclear engineering. Such circumstances can cause difficulties to meet future operational and regulatory requirements and result in serious problems during construction, staffing and commissioning of a new NPP and development of entire nuclear infrastructure.

The analogous challenges are typical for the most modern and well developed countries; but they are yet more sharpened at relatively small countries with limited human and financial resources like Lithuania. Success of planned upgrading of the used nuclear technology and remaining of Lithuania in the family of nuclear states will depend on timeliness and effectiveness of organizational, technical, and managerial measures taken, including modernization of nuclear education system.

2. Forecast of needs for nuclear engineering specialists

Human resource development needs strongly depend upon the accepted approach to fill the staffing needs of new built NPP through indigenous development or purchase the required capabilities through a turn key project. Even if a turn key project is the preferred approach, consideration of developing indigenous capabilities should be considered for the long term. For each nation it is desirable to develop its own educational and training capabilities to better assure the long term availability of the crucial human resource and to provide

opportunities for its citizens. While the development of human resources requires investment, this investment brings overall benefit to the economic development of the nation [1].
Needs for nuclear engineering specialists also depend upon installed power of nuclear power plant, number of units, accepted industrial and human resources policy, level of the operator's expertise, level of subcontracting during periodic repair and maintenance and other factors.
Trying to determine quantified future needs for nuclear engineering specialists to be trained in the context of the approaching construction of a new NPP in Lithuania and developing entire nuclear infrastructure the specific study was performed at Kaunas University of Technology in 2007 [2]. The following issues were examined in this study:

- Situation in the Lithuanian job market concerning supply and demand of qualified engineering specialists for energy plants was analyzed;
- Available data about numbers and qualification of personnel working at nuclear power plants in different technologically well developed countries were explored;
- Preliminary needs for nuclear engineering specialists were determined and tentative schedule for their preparation was worked out.

Currently demand for highly qualified specialists of technology is about 1.5 times bigger than offer (for mechanical engineering specialists this ratio reaches 1.66). So, situation in the job market is not favourable for construction of a new NPP.
Numbers of personnel employed at different NPP's were compared, using generalized parameter – relative number of workers, falling to 1 MW installed electric power. Value of this parameter varies from 0.25 – 0.30 worker/ 1 MW(e) in nuclear power plants of USA, France, Switzerland and other western countries up to 1.5 – 1.6 worker/ 1 MW(e) in nuclear power plants of Russian Federation. It was observed, that type of reactor has no big impact to relative number of personnel. Much more important is organizational strategy of activities during operation and periodic maintenance – repair sessions and number of energy units. In the western-type of NPP's maintenance and repair personnel is not included in the staffing list of the plant, and the relative number of the permanent workers is low. During the period of scheduled maintenance and repair number of engaged subcontracted personnel in such plants grows up significantly (up to several times). Another strategy is used in the Russian – type NPP's: the total number of personnel here permanently includes all kinds of specialists involved in the operation, repair, maintenance, safeguard and other supporting services, and these results in a higher value of relative number of workers.
The existing best organisational practice concerned with staffing of NPP's can be summarised as follows:

- Total number of personnel of NPP during the period of normal operation should be determined on the basis of the value of relative parameter equal 0.3 worker/1 MW(e);
- During period of the scheduled maintenance and repair there should be available the subcontracted technical personnel totally resulting from the value of 0.7 worker/1 MW(e);
- The "genuine" nuclear energy specialists comprise about 30% from the total number of personnel of NPP and its supporting organizations.

On the basis of such assumptions, taking into account that the planned total installed power of a future new NPP in Lithuania with two energy units will be 3000 – 3200 MW(e), the approximate total number of permanent personnel of such plant should about 1000 (temporary subcontracted personnel not included).

3. Feasible staffing ways of a new NPP

Probably the most effective approach of staffing of a new NPP seems to be using a mix of experienced personnel in key positions, balanced with entry level positions staffed with young people from universities and technical schools.
At the end of 2007 the total staff of Ignalina NPP was approximately 3100 persons. The majority of these personnel are highly qualified, well trained and experienced specialists. According to the decommissioning programme approved in 2005 number of personnel at

Ignalina NPP is annually reduced on the average by 250 persons. After closure of Unit 2 gradual reductions of the personnel should lead to number about 1600 in 2015 specified in the final decommissioning project. Thus, a big reserve of human resources having valuable nuclear knowledge currently exists at the Ignalina NPP. However, the big part of personnel currently is of the age of 46-50 years, and in 2015 it will be the personnel approaching a retirement age. Employment of these specialists in a new NPP is problematic due to various reasons, and the possible staff contribution from the existing Ignalina NPP to the new one seems to be not more than 20-30 %. Consequently, the reminder of the staff required for a new NPP should be prepared at Kaunas University of Technology and other Lithuanian educational institutions (see Fig. 1).

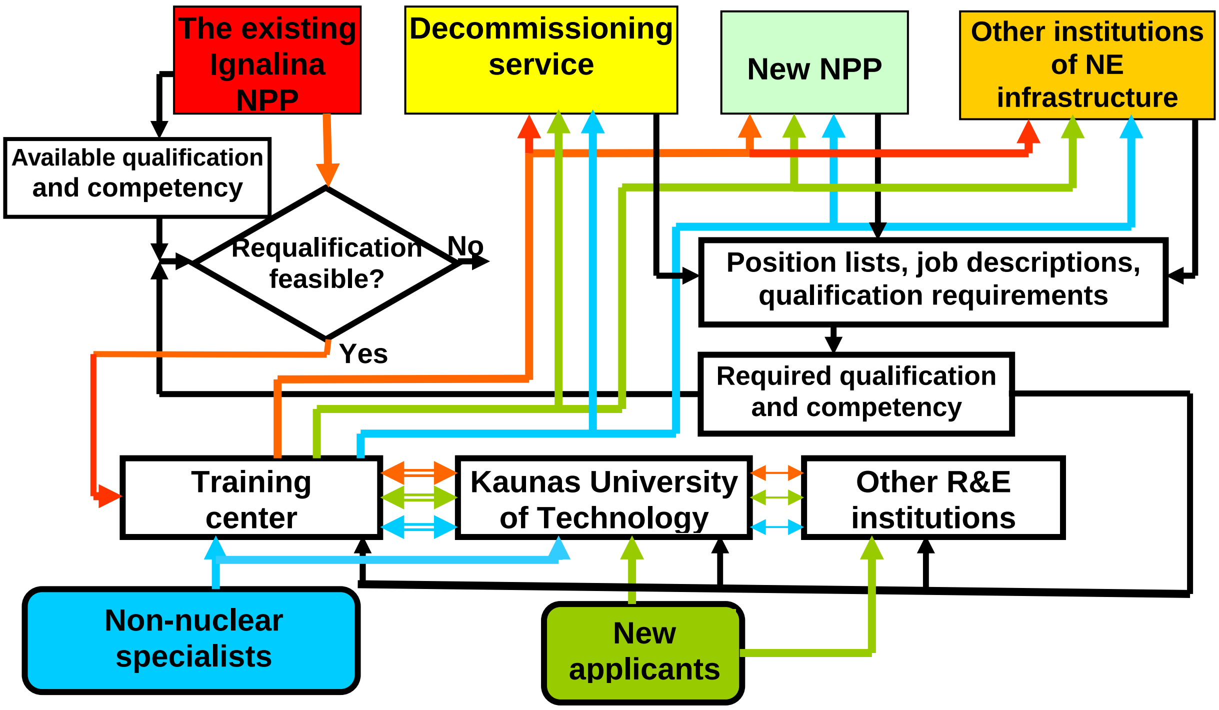

Fig. 1. Possible staffing routes of a new NPP and entire Lithuanian nuclear infrastructure

4. Methodology of the new NE study programs' curriculum development

Up to 2004 the traditional teacher-centred method of designing curriculum was used at Kaunas University of Technology. This approach is focused on the teacher's input and on the learning results assessment in terms of how well the students absorbed the material taught. Course descriptors referred mainly to the content of the course that would be covered in lectures. Such terms as aims and objectives were extensively utilized to describe modules, programs, qualifications, etc., and emphasized teaching hours, subject content and resource counting.

While developing new NE study programmes the student centred learning outcomes approach was used [3]. This approach clearly places the student at the centre of the learning process, and the emphasis moves from the teaching content to the learning outcomes, which focus attention on statements of what students learn. This approach recognizes that much learning takes place outside the classroom and includes the idea that students should be actively involved in the planning and management of their own learning.

Going by this way primarily the desired learning outcomes of the nuclear engineering study programmes were identified. The available documents and guides [4, 5] were taken into consideration and used as reference points. There were written down extensive descriptions of the learning outcomes for both the first and second level NE study programmes. The outcomes of the each study program were differentiated in terms of the following:

- Knowledge;
- Intellectual abilities;
- Practical abilities;
- Transferable abilities.

On the second stage of this process the learning outcomes of the specific modules comprising each programme were defined. It was done on the basis of the interconnection links between the learning outcomes of study programmes and study modules which were portrayed in a tabular matrix diagram. In result the list and content of modules required to achieve the desired learning outcomes were identified. The extended descriptions of the study modules were prepared, indicating the teaching and learning methods to be applied in the learning process in order to enable students to achieve the desired outcomes.
At the final stage the selected modules were comprised into blocks of general subjects, core subjects and special subjects of nuclear engineering and optional subjects according the Lithuanian General Regulations for Technological Sciences (Engineering) [6]. For the further implementation of the learning outcomes concept the following steps are foreseen in the near future:

- Differentiation between generic and subject-specific outcomes in the descriptions of study programmes;
- More precise descriptions of criteria and methods for the assessment of the learning outcomes of all study modules;
- Revision of the learning outcomes' correspondence to the threshold standards of learning.

5. Peculiarities of the developed nuclear engineering study programs

The knowledge and skills necessary to purchase or design the relevant equipment, properly construct, licence, operate, maintain a nuclear power plant and comply with normative regulations are spread across most scientific and engineering disciplines. In addition to fundamental scientific and technical education, nuclear workers typically require several years of specialized training in safety, security and radiation protection, and in the design and operation of the specific technology chosen for deployment.
'Characteristics of learning outcomes at the first (bachelor) level include:

- the acquisition of a systematic and coherent body of knowledge, the underlying principles and concepts of nuclear engineering, and the associated communication and problem-solving skills;
- development of the academic skills and attributes necessary to undertake research, comprehend and evaluate new information, concepts and evidence from a range of sources;
- development of the ability to review, consolidate, extend and apply the knowledge and techniques learnt, including in a professional context;
- a foundation for self-directed and lifelong learning; and
- interpersonal and teamwork skills appropriate to employment and/or further study.

Using these desired learning outcomes as inputs, the specific content of nuclear engineering study program was developed (Tab. 1). Although the primary focus of the four-year bachelor of nuclear engineering program is nuclear power plant engineering, the curriculum is sufficiently broad-based that graduates will be well qualified for careers in many applications of nuclear technology and energy related fields. The first two years of study provide students with a solid foundation in the fundamentals of mathematics and sciences, with years three and four concentrating on the core engineering sciences and specific nuclear engineering courses.

Tab 1: Structure of the first level (bachelor of nuclear engineering) study program

Block of modules	Extent	
	In credits	Relatively
General subjects	11	0.07
Core engineering subjects	91	0.57
Special nuclear engineering subjects	50	0.31
Optional (freely chosen) subjects	8	0.05
In total	160	1.00

A graduate of a Master's of nuclear engineering degree program should be able to:

- provide appropriate evidence of advanced knowledge about main theoretical and applied topics in the nuclear engineering field;
- demonstrate a high order of skill in analysis, critical evaluation and/or professional application through the planning and execution of project work or a piece of scholarship or research; and
- demonstrate creativity and flexibility in the application of knowledge and skills to new situations, to solve complex problems and to think rigorously and independently.'

The two-year Master's of NE study program includes four blocks of modules with total extent 80 credits. The block of theoretical studies covers 7 modules (26 credits, 32,5 % of total); block of special nuclear engineering subjects covers 5 modules (18 credits, 22,5 % of total). 10 % of the Master's study program (8 credits) are devoted for electives and 35% (28 credits) – for research.

6. Conclusions

The learning outcomes approach was employed as an effective tool for development of new Bachelor's and Master's of nuclear engineering study programmes. Hereby designed programme's curriculum seems to be corresponding to main institutional, national and international regulations and reference guides. The ensuring of adequate interconnections among learning outcomes, teaching & learning methods and results' assessment is most relevant for the quality assurance of the developed study programmes.

7. References

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THE ROLE OF UNIVERSITIES FOR THE RENAISSANCE OF NUCLEAR ENERGY IN SPAIN

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ABSTRACT

In the next two years the education at universities in Spain will be changed according to the European Space Education system, adapting the programs to a new model. In this sense and due to the construction of new NPPs in the world and in Europe, we need to consider in our programs new methodologies and advanced tools to generate new engineers with advanced knowledge. There is a good chance to coordinate the high education between universities, research centres and industry in order to create in Spain an appropriate knowledge able to attack the generation changes in human resources and the substitution of NPPs in the next coming years. In this work will be presented several ideas, schemes and actions to build the nuclear knowledge and critical mass in human resources in Spain.

1. Introduction

Spain has eight nuclear reactors operating. Six units are pressurised water reactors (PWR) and two are boiling wáter reactors (BWR), having at present a total generating capacity of 7728 MWe. The electricity generated by the nuclear capacity represented in 2007 the 20% of the total electricity generation. Spanish nuclear reactors continue to perform very efficiently, being the average load factor around 90% for over the last 10 years. This trend is also confirmed in 2007, having a load factor of 88,2% and the operating factor of 90,5 %. The nuclear capacity has additionally gained about 586 MWe since 1990 by capacity upgrades implemented in existing nuclear units. These NPP´s in operation avoid the emission of about 40 million tons of CO_2 per year.

Education and training in nuclear subjects has been tradicionally done in many Spanish universities, mainly at polytechnical universities, as in Madrid (UPM), Barcelona (UPC) and Valencia (UPV), at the research centre CIEMAT, and in the nuclear industry as

TECNATOM and Empresarios Agrupados. At present, most of the professionals working in the nuclear sector came from the aforementioned universities.

Although the nuclear sector is very active in Spain, however the current government has expressed its desire to phase out all the nuclear power units in the medium term. For tis reason, there is not a real renaissance of nuclear energy in Spain, as it has been announced in other countries. According to this political decision, nuclear education don´t need additional enhancement, and the renewal of professionals can be maintained with the present education and training programs. However, if a rainessance is planed for the next coming years, it should be necessary to stablish measures to cover new jobs. Then, new Masters and training programs should be urgently implemented in the planning of universities, research centres and industry, creating grants towards the cost of the university education for brilliant students in the next ten years, otherwise it will not be able to create new jobs with lnational human resources.

In this paper there is a view of how the UPM has considered up to now the education and training in the nuclear sector and what new trends should be considered for the coming years, assuming a renaissance of nuclear energy in a global sense, in which Spanish human resources could participate for the progress of the nuclear science.

2. Actual nuclear education at UPM

The UPM offers education programs covering in a high percentage the needs of human resources for the spanish nuclear industry, mainly for the nuclear power plants in operation and also for the rest of the nuclear sector: services, engineering companies, regulator, waste management, fuel fabrication, research and teaching. UPM provides a large list of engineers especialists in mechanic, electrical and electronic, energetic, chemist, and material science between others, with a favourable and deep background. A few porcentage of them are involved later on in NPP´s, engineering companies and in the public nuclear sector.

While the construction of new nuclear power plants may be complicated in the next coming years, the government should ensure a stable and predictable operating and regulatory framework. In this context, the UPM has a clear vision about its relationship with the society, providing a deep education in this way. If the government maintains its position of desiring a nuclear phase-out, it should conduct a quantitative analysis of the impact of a nuclear phase-out on supply security, GHG emissions mitigation and electricity prices. Such an analysis should also include the costs and benefits of extending the operating lives and increasing the capacity of nuclear plants. The result of such an analysis should ensure: a high level of safety in the operation of NPP´s, the storage of spent fuel, the disposal of low- and intermediate-level nuclear wastes, to build and operate the final disposal facility for high-level radioactive wastes, and the decommissioning of the nuclear power plants. For all these programs the government should enhance the education of young engineers for renewal positions, having as main goal that the nuclear energy is one of the energies for the future share of electricity that don´t produce GHG emission. UPM is promoting this goal as a real chance for the new titulations.

Mobility of both students and professors is one of the most importants added value to the universities and it will contribute to the coming years to increase potentially the Masters offered in competence with other universities. Every year more than 2000 students of UPM are following courses in other european universities, under the Erasmus umbrella and a similar number of foreign students are involved in different courses at UPM. In the last four years this mobility has increased with other continents as America and Asia. Due to this, UPM belives that countries with a renaissance of nuclear programs need a large number of engineers covering different fields, even with nuclear knowledge.Then the Nuclear Engineering Department of UPM offers two Master programs to cover this gap, now in spanish language and it will offered in english in the next years.

A first Master is offered in Nuclear Science and Engineering, which is a vital and exciting field, covering several facets: physics, chemistry, medicine, and engineering. This Master pretends to provide tangible benefits for the future of the spanish society and it is open to the rest of the world. Only a more broadly educated society can hope to deal effectively with a wide range of important scientific topics, including medicine and energy policy. Every year about 15 students are involved in this Master.

The offer of this Masters at UPM is estrategic for the future because consists on establish subjects that help facilitate: a first work in the nuclear energy sector or in nuclear science, and also permits the transition of early-career scientists into forefront research activities and educational opportunities. This Master is offered by the Nuclear Engineering Department and by the Institute of Nuclear Fusion. Postgraduated students have to follow two courses of 60 ECTS each, and this Master has obtained the Quality Award given by the National Agency of Quality and Acreditation (ANECA), depending of the Government. This is the unique Nuclear Engineering Department in Spain having this award. This Master gives also the opportunity to obtain the PhD in Nuclear Science and Engineering for those students that afterwards present and defend their Thesis in this field.

A branch of this Master is the Erasmus Mundus in Nuclear Fusion together to CIEMAT, and other spanish and european universities. This doctoral program has also the Quality Award. One of the adventages of obtaining this award is the possibility to invite every year to foreign professors for teaching in some of the subjects, with public funds.

A second Master is offered in collaboration with TECNATOM, and it is focused to Technologies for Electrical Power Plants. This is a 60 ECTS Master covering all technologies of electric generation. Nuclear generation is one of the main modules, in which students study basic subjects in nuclear physics, nuclear technology, nuclear safety and radiation protection and also dedicate time to work with simulators of NPP´s to know the different phases of the operation. This a good example of collaboration between industry and university. This Master is now in the seven year.

UPM is one of the partners of ENEN from the begining and participates activelly in exchanging students and offering short stages for those whising to dedicate the time to the final thesis.

3. Future nuclear education at UPM

To judge the demand for nuclear engineers in the next years, it is necessary to know that the average age demographics of the current workforce in Spain in the nuclear sector is close to 50 years. For the next 15 years there will be to substitute about 2000 engineers and 4000 technicians. So in case of a renaissance the number will increase by several factors. Several steps might be taken into account by the academic community to realize this goal:

• Shorten the time students spend in the graduation and master programs.

• Become aware of and take advantage of funding opportunities for graduate students in areas of national need.

• Encourage the best and brightest undergraduate students to take advantage of undergraduate research opportunities in nuclear science, then actively recruit these experienced undergraduates to continue their nuclear science studies and research as graduate students.

• Nuclear science faculty should identify new ways to engage graduate students in research early in their graduate careers.

In a near term, professionals in the nuclear sector will be involved in a large number of applications as: medicine, materials, industry and advanced technologies, then the education of professionals should come from the participation in several programs of education, training or research, as:

- Those offered by universities.
- Advanced courses at universities and training providers.
- Research activities done in collaboration through national and international programs.
- Networks of education.
- Summer schools.
- World Nuclear University.

UPM is enhancing the above behaviours focusing in the followings trends:

a. To maintain the high level knowledge in the nuclear science, with the masters above mentioned.
b. To know and implement advanced technologies.
c. To provide professionals in a shorter time, with a high level of knowledge.
d. To improve our master courses offering in foreign languages for increase the number of nuclear experts.
e. To offer training courses in collaboration with industry and research centres for non nuclear professionals, or advanced courses for nuclear professionals.
f. To participate in research programs as those offered by FP7.

4. Conclusions

The nuclear industry in Spain offers services and products that largely cover the needs of its nuclear power plant operators. Yet the current government has publicly expressed its willingness to phase out nuclear energy at least in the mid-term. The regulatory uncertainties caused by the government decisión should be minimised. It should also be borne in mind that a nuclear phase-out could have significant implications for Spain's future energy security and climate mitigation policies. It is essential for the government to develop an reliable estimate of short-, mid- and long-term consequences of the phase-out, including the consequences for nuclear science education at universities.

Nuclear industry demands professionals with a high education and with a broad knowledge, mainly in the nuclear topics, and also in others areas as: mechanics, chemistry, electricity and materials, which are very close matters to the nuclear science. The formation of new professionals takes a long time to universities and industry. Then it is very important to have a planification for the next twenty years to attract good students by means attractive government grants and mobility programs.

Future education in the nuclear sector requires to know advanced technologies, that should be provided by universities, and in a second phase by training proceses in collaboration with the industry. UPM provides both professionals for working in the nuclear sector just after the graduation in Master courses, and also provide appropiate tools for research to cover areas of interest for industry and future reactors in fission and fusión. Nuclear education and training should have an added value for the future, and UPM is enhancing this qualified education in close collaboration with industry, research centres around the world.

THE IMMOBILISATION SCIENCE LABORATORY - BUILDING ON PAST SUCCESS AND DEVELOPING FOR THE FUTURE

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Abstract

The Immobilisation Science Laboratory (ISL) was inaugurated within the Department of Engineering Materials at the University of Sheffield in August 2001 as the third of BNFL's four research alliances with leading UK universities. Its remit was to become a world leading centre in the science and application of waste immobilisation technology. Additional benefits were the generation of a secure skills and a knowledge base in the field of waste immobilisation that was of value to BNFL and the creation of added value to both parties through the mechanism of a university-industry collaboration. In the subsequent seven years there have been many changes to the UK nuclear industry and the ISL has adapted and developed its original remit to answer the new challenges.

Introduction

Throughout the 1970s and 1980s there was a continual decline in funding for nuclear fission research and development in the UK, possibly due to the negative publicity from the incidents at Three Mile Island in the USA and Chernobyl in the Soviet Union, now Ukraine. Historically three organisations had formed the backbone of the nuclear fission skillsbase in the UK - British Nuclear Fuels Ltd (BNFL), United Kingdom Atomic Energy Authority (UKAEA) and the Central Electricity Generating Board. With the closer of many of their laboratories throughout the 1980s and 1990s the manpower had reduced from over 8500 in 1980 to just 2000 in the year 2000. By the late 1990s BNFL decided that investment was necessary to reverse this decline. To facilitate a renaissance in UK nuclear fission research, four University Research Alliances (URAs) were established by competitive tender. Initial core funding of £2M was awarded to each of the URAs, namely -

- Centre for Radiochemistry Research, University of Manchester -1999
- Institute for Particle Science and Technology, University of Leeds - 2000
- Immobilisation Science Laboratory, University of Sheffield - 2001
- Materials Performance Centre, UMIST - 2002

Establishment of the ISL

A centre for waste immobilisation technology was awarded to the Department of Engineering Materials at The University of Sheffield in 2001 and Professor Bill Lee appointed as its first Director. Dr John Roberts was appointed Manager in February 2002 and the centre named the Immobilisation Science Laboratory, reflecting the main thrust of the ISL, to understand the underlying science involved in the immobilisation of radioactive waste. Key to the success of the ISL was the decision to utilise the majority of the £2M award for the appoint of seven new staff; two five year post-doctoral research assistants, Dr Neil Hyatt and Dr

Joanne Hill and five academic appointments. The Department of Engineering Materials at The University of Sheffield is a 5*A rated department and has a long history of research in ceramics, cements and glasses. The world's first Department of Glass Technology was established in Sheffield in 1917. The expertise of existing staff made a significant contribution to the award of the URA to Sheffield and the new academic appointments were made in research areas to compliment and enhance the expertise already present in the Department. Along with Professor Lee (ceramics) the original academic staff of the ISL comprised Professor Peter James (glasses), Professor John Sharp (cements) Professor Fergus Gibb (geological disposal of radioactive wastes) and Dr Russell Hand (glasses). The five new appointments where

- Dr Michael Ojovan - high temperature immobilisation methods and non-destructive testing of nuclear materials
- Dr Neil Milestone - cement chemistry and formulation of new cementing systems
- Dr Karl Travis - modelling over all length scales
- Dr Günter Muobus - electron spectroscopy and mapping of structure at all lengths
- Dr Hajime Kinoshita - handling of actinide materials plus high temperature synthesis and analysis of ceramics.

Professors James and Sharp have retired and Dr Neil Hyatt was appointed as a lecturer bringing the number of ISL core academic staff to nine. Associate ISL academic staff are Dr John Parker (glasses) and Professor John Harding (modelling). The ISL have also appointed Professor Neil Chapman as Visiting Professor. As well as his role as Chairman of the School of Underground Waste Storage and Disposal, Professor Chapman has many years experience as a consultant to the worldwide nuclear waste industry. The ISL currently has six post doctoral research assistants and ten postgraduate students who along with undergraduate project students brings the total number of ISL staff to approximately forty. Three Nexia Solutions staff (formerly BNFL R&T) have been appointed in a visiting capacity, Drs Ewan Madrell and Scott Owens as Visiting Lecturers and Ed Butcher as Visiting Researcher.

Development and External Collaboration

With a team established, the ISL partook in a series of visits to centres of excellence around the world to learn from best practice. These included

- Vitreous State Laboratory, Catholic University of America, Washington DC, USA
- Pacific Northwest National Laboratory, Washington State, USA
- Savannah River Site, South Carolina, USA
- CEA Laboratories in Saclay and Cadarache, France
- SCK•CEN, Mol, Belgium
- SKB Facilities including the Åspo Hard Rock Laboratory, Sweden
- Grimsel Test Site Switzerland
- Institute for Transuranium Elements, Germany.

Collaborations have continued with ISL students and postdocs spending time at these facilities and bringing new experimental techniques back to the ISL. A recent ISL postgraduate student Andrew Connelly has moved from the ISL to a research position with the CEA in Cadarache, further cementing ISL-CEA ties while Claire Utton is working at the Tokyo Institute of Technology. Overall the ISL has been very successful in training postdocs and postgraduate students that have gained employment in the nuclear industry. Of the ten postgraduates that have already obtained their PhD at the ISL, six have entered the nuclear industry with companies such as Nexia Solutions and AMEC. Another successful initiative was the establishment of an International Advisory Panel. The panel visited on a yearly basis as the ISL was being established and consisted of Ian Pegg - VSL:CUA, Etienne Vernaz - CEA, Pierre Van Iseghem - SCK•CEN, Karen Scrivener - EPFL, Pete McGrail - PNNL and Fred Glasser - University of Aberdeen

The ISL has also developed links based on a hub and spokes model with other universities in the UK. The four URAs have always worked closely together through joint supervision of students and collaboration on research projects, both research council and industry funded. The ISL have also developed close ties with Imperial College London, Queen's University Belfast and the Universities of Warwick, Reading and Birmingham. With industry funding through the URAs being so successful research council funding started to re-appear for nuclear fission funding with the ISL having a central role in many of the developments. The Nuclear Technology Education Consortium was established and co-ordinated by the Dalton Nuclear Centre at The University of Manchester as a short-fat modular system for delivery of postgraduate taught courses for Continual Professional Development all the way through to M.Sc. Qualifications. With initial funding from the Engineering and Physical Sciences Research Council (EPSRC) the ISL provide a core module (Processing, Storage and Disposal of Radioactive Waste) of the Decommissioning Stream. This course has so far being given in the last three years as a direct lecture theatre taught course. For the academic year 2008-09 it will also be available as a distance learning course, one of the first NTEC courses to be converted.

Two other major initiatives aimed at PhD level training and also funded by the EPSRC are the Keeping the Nuclear Option Open (KNOO) research programme and the Nuclear Engineering Doctorate. Whereas the KNOO provides a traditional method of PhD training with students based at universities, Engineering Doctorate programmes are run in collaboration with industry with the student based with the industrial partner and visiting the university partner for technical taught courses and supervision, as well as MBA-type courses over a four year period. By including this management aspect of the course it is envisaged that Eng Doc students will eventually gain employment as leaders in industry at the end of their four years. The ISL also has a supportive role is the Sustainable Nuclear Energy project led by the University of Manchester that researches the social and economic aspects of a future UK nuclear fission programme.

Through collaboration with European institutions it was natural that the ISL should participate in EU Framework funded projects. So far we have been successful in obtaining funding under Framework VI from the NF-Pro integrated projects and ACTINET network of excellence. The ISL is hopeful of continuing this success under Framework VII.

When the ISL was established, one of its objectives was to use the initial core funding as leverage to obtain further funding not only from public funding as described above but also from industries associated with nuclear energy. This was seen to be a key objective to ensure the success of the ISL beyond the initial five year period funded by BNFL. However, during this five year period many changes took place in the UK nuclear industry, not least of which was the separation of BNFL into separate companies and the establishment of the Nuclear Decommissioning Authority. As a result the core funding of the ISL was transferred to the NDA. In its initial phase the ISL collaborated with BNFL, UKAEA, AWE and Nirex on long term projects but was also able to work closely with BNFL Business Groups based at Sellafield on short term projects of direct relevance to the site.

A key success of the ISL has been the establishment of the Radioactive Waste Immobilisation Network (RWIN). Initially funded by the EPSRC, RWIN has so far had eight successful meetings covering the whole range of immobilisation technologies and with a membership of over 350 has continued the meetings with delegates now paying a registration fee for each meeting. The main goal of RWIN is to encourage and facilitate communication between the different sections of the UK nuclear waste industry. Government agencies, regulators, industrialists and academics all give presentations on their current work in an environment that fosters collaborative solutions to the many challenges highlighted. Several overseas speakers have also been invited to provide updates on their own national programmes. In tandem with RWIN the ISL has also established an outreach programme aimed at school children. This enables the communication of actual facts about the nuclear waste industry and is a valued contribution to both scientific and environmental aspects of the curriculum.

Research Portfolio

The success of the ISL is ultimately determined by the success of its research which is divided into the following general areas:

- Vitrification and nuclear waste glasses
- A toolbox of cement types for encapsulation
- Ceramic Immobilisation for actinide wastes
- Nanoscale Characterisation
- Non Destructive Testing
- Materials Modeliing
- Deep Geological Disposal.

To enable this research to be undertaken the ISL has access to a range of world class test facilities including

- Scanning Electron Microscopy
- Transmission Electron Microscopy
- X-ray Diffraction
- Isothermal Calorimetry
- Hydrothermal Leach Testing
- Thermal Analysis

Research in vitrification and nuclear waste glasses is focussed on investigating the relationship between wasteform production, processing, composition, structure and materials properties. New glasses are being developed to handle high halide containing wastes which are not compatible with the existing glass formulations. Using X-ray absorption spectroscopy can determine the oxidation state and co-ordination environment of key waste elements such as molybdenum. The corrosion mechanism and durability of simulants in vitrified products is also studied with an emphasis on near-field interactions. A mechanism for breakdown of the vitrified product by water has been developed.

For ILW the ISL is currently developing a toolbox of bespoke cement types for particular wastes. Research into the encapsulation of ILW originally concentrated on the waste/matrix interactions in order to estimate the long term durability. Many potentially detrimental interactions with legacy wastes have been identified such as corrosion of aluminium and uranium in cement or the reactions of zeolitic absorbents and dessicants. By developing different types of cements that use partial substitution of OPC or completely new formulations that are not based on OPC, these problems can be avoided producing a much more durable wasteform.

The ISL's ceramic immobilisation work is focussed on developing a formulation for immobilisation of PuO_2 which may be declared a waste in the UK. Research at the ISL uses Ce and U as Pu surrogates but collaboration with the Centre for Radiochemistry Research URA and the Institute for Transuranium Elements enables the use of active ^{239}Pu bearing samples. Immobilised radionuclides are stored in the immobilisation matrix via an atom by atom solid solution. The details of the atomic accommodation such as the structural units need to be identified and models of structure developed.

By using advanced electron microscopy in conjunction with complementary x-ray spectroscopy, magnetic resonance and Mossbauer Spectroscopy the ISL is conducting research into how radionuclides are held within structures. For example the use of specialised elemental mapping techniques allows the mapping of heavy elements against a light element background.

In the area of non-destructive testing the ISL has successfully developed acoustic emission as a means of monitoring nuclear wasteforms. A validated procedure for interpretation of acoustic signals from laboratory scale simulant cementitious wasteforms has been established with the procedure now ready for full scale deployment.

Most countries in the world are considering underground engineered barrier systems at a depth of 500 - 1000 m for the final disposal of their radioactive waste. The ISL is developing an innovative system of deep borehole disposal that would place the waste in a borehole with a diameter of 60 - 80 cm at a depth of greater than 4 km. One of the key aspects of this type of disposal is that it depends on geology rather than engineering to isolate the waste from the biosphere. Laboratory based tests have proved the viability of such a system which is now at the developmental stage for full scale deployment.

The Future

The establishment of the NDA in April 2005 has created many changes in the nuclear industry in the UK, some of which have affected the ISL. The NDA now owns the liability for all the civil nuclear licensed sites in the UK. The R&T division of BNFL renamed Nexia Solutions have managed the university contracts on behalf of the NDA. Management of NDA-University contracts has recently been put out to tender but the ISL is still working closely with Nexia Solutions as a preferred partner on many of the other tender actions issued by the NDA for work. The UK Magnox stations previously operated by the British Nuclear Group are now clustered together into two Site Licence Companies, Magnox North and Magnox South. As they enter a decommissioning phase the ISL will broaden its focus from Sellafield site challenges to include projects that are specific to these sites. A contract has recently been signed for work to support the decommissioning of Hinkley Point A. In parallel to these initiatives the EPSRC has issued a call for proposals specifically in the area of radioactive waste management. In response, it is hoped that the ISL can provide appropriate training and develop new research projects.

With the UK government issuing statements on the need for new build in the UK, with possibilities of exceeding the current 20% nuclear fission contribution to the electrical grid, it is envisaged that the research and training provided by the ISL will be required for many years to come.

REUSING LEGACY SIMULATION CODES FOR EDUCATION IN DISTRIBUTED SIMULATION ENVIRONMENTS

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ABSTRACT

This paper describes the use of DiSiF (Disitributed Simulation Framework) in the context of education and training in the domain of nuclear sciences. It gives an overview of the underlying framework architecture and focuses on the advantages of DiSiF in reusing and preserving existing knowledge stored in legacy simulation codes. Therefore an example is given that shows how a complex workflow is designed with Graphplan [9] and Kepler [8] using the aspect oriented modelling paradigm. It also covers how new knowledge can be created by deploying these legacy simulation codes using the role-based access and view control for academic education and training.

1 Introduction

In the domain of nuclear sciences, many simulation systems have been developed over the past decades. A lot of effort, knowledge, and experience have been put into place for developing and validating these codes. At the time the codes were developed there were technical limitations, therefore handling them successfully requires a lot of experience and learning time. To overcome this obstacle, and to preserve the knowledge contained in these codes, an architecture based on modern software technologies is required. Therefore the Institute of Nuclear Energy and Energy Systems (IKE) is developing a distributed simulation framework (DiSiF), which makes it easy even for non-programmers to integrate those legacy codes into applications and to provide a new infrastructure in which these codes can be used.

The architecture of DiSiF is based on the separation of concerns paradigm [1] and employs web services and grid computing as implementation technologies. DiSiF also includes the possibility of extended user and access control using the role-based view control (RBVC) model. This role-based access and view control supports an easy adaptation for different aspects of education and training without disregarding the mandatory security needs for the domain of nuclear sciences.

Besides the extended learning effort for understanding the mostly complex input of the codes, the user performs the simulation workflow manually or by manually operated batch processing. DiSiF offers actor based workflow modelling using Kepler which is an extensible system for the design and execution of scientific workflows. This allows non-programmers to model and design workflows without needing to know any programming languages. Once a workflow has been designed by experts using legacy simulation codes they can be used for education and training in different contexts.

2 The System Architecture of DiSiF

The system architecture of DiSiF is divided in two parts (see figure 1): *i. the Client Component (DiSiF-CLI)* and *ii. the Simulation Component (DiSiF-SIM)*. DiSiF-SIM offers secured web service interfaces for DiSiF-CLI. The system architecture defines rules for this interface as follows:

1. DiSiF-SIM fully trusts a DiSiF-CLI that uses the secured web service interface.
2. DiSiF-SIM makes neither authentication nor authorization of users.

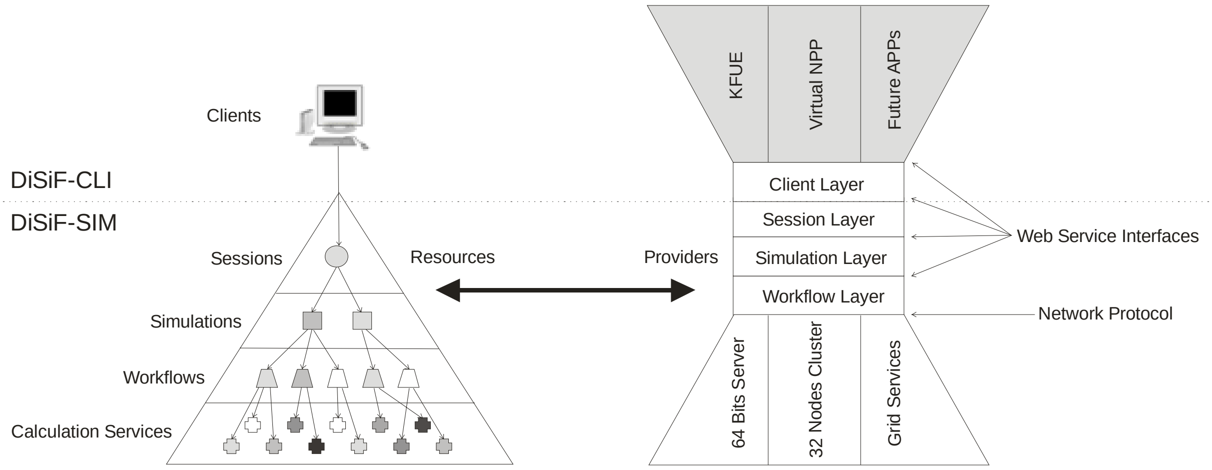


Fig. 1 The hourglass architecture of DiSiF

DiSiF-CLI. The standard implementation of the DiSiF-CLI middleware is a Java Servlet that implements the RBVC user and access control model which extends the role-based access control (RBAC) reference model. RBAC was introduced in 1992 by Ferraiolo and Kuhn [2]. In 2004 RBAC was standardized by ANSI [3] [4]. The ANSI Core RBAC model includes sets of the basic RBAC elements called users (USERS), roles (ROLES), sessions (SESSIONS), and permissions (PRMS). The latter consists of permitted operations (OPS) on objects (OBS). If a role has a specific permission assigned and a user is assigned to this role, he is allowed to perform the operation on the object. In this context the term role represents duties in an organization where users and permissions are assigned to (many-to-many relations).

RBVC extends the RBAC in a way that roles are also used for view control duties. Therefore an extended control model, based on RBAC, was developed, which offers characteristic views on common simulation tool functions. The resulting model is called role-based view control (RBVC) [5]. Fig. 2 shows the view extension made for the new RBVC model. The term view in this context is used for a special shape of a function and includes the behaviour of the presentation and the controller of the application. As a result views can offer optimized functions for the duties in a special role. The figure also shows the standardized role hierarchy (RH) which is a many-to-many relation between roles. In difference to the ANSI RBAC model the inheritance of the RBVC can be controlled by role types. The novelty of this approach is the possibility to use more than one role hierarchy scheme at the same time depending on the role type. This offers more flexibility in using the RBVC model for self administrated and integrating systems.

The standard client is a web browser which communicates with the Java Servlet via Asynchronous JavaScript and XML (AJAX) [6]. This approach allows better graphical user interfaces using AJAX technologies to compensate the benefits given by normal applications compared to normal web applications. But generally the system is not limited to a web browser. The support of other clients is possible but it depends on the specific client if the middleware has to be adapted or changed.

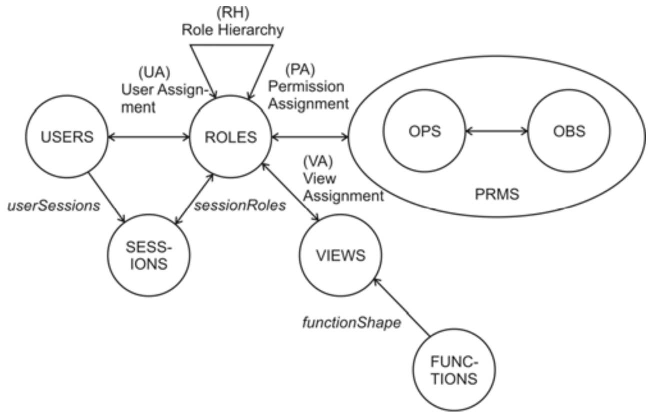


Fig. 2: View extension of the role-based view control model [5]

DiSiF-SIM. The classic simulation scenario in nuclear engineering is the one where a user has to perform a simulation in order to obtain certain results that can be used for further work. The entire simulation is used as a simulation tool or resource by this user, who, most of the time, is unaware of the inherent algorithms and technicalities that make the simulation possible. The user employs the simulation resource and must make a decision based solely on the result of the complete underlying chain of operations. The simulation is composed of one or several workflows which play the role of algorithmic resources for the simulation. Finally, every workflow is composed of computational operations, that can be executed in parallel mode or sequentially and finally provide a result. In DiSiF these computational operations are regarded as the workflow's resources. We called this a hierarchy of autonomous resources and represented it as a layered pyramid (see figure 1). The relations between hierarchical autonomous resources have the following properties: *i. Resources can exchange information with their neighbour's only (i.e. upper, lower, and same level layer);*
ii. A resource from layer n is the owner of the resources it has instantiated at layer n-1;
iii. Information can only be exchanged between a resource and its owner or a resource and it's owned resources.

Figure 1 also shows the layered hourglass software architecture supporting the abstract resource oriented model. Layered software models have been proven to be very efficient in the fields of networking and communication but also in almost all other software development fields, including embedded software or the n-tier model. Each layer corresponds to a resource provider and can run on different machines. Objects that are instantiated at different levels in the stack are the actual resources.

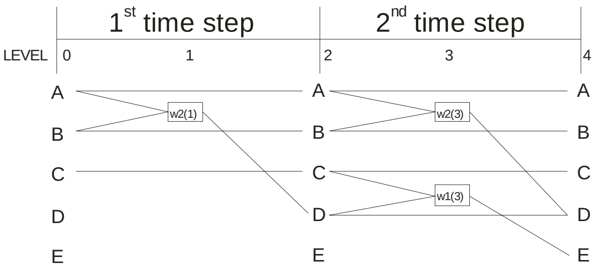
3 Designing Workflows

Workflows are the key components of any simulation system, regardless of whether they are employed in education and training, research or industry. They provide consistency and reliability for the entire system and therefore good workflows should always be a major design goal of any simulation system. Unfortunately in the field of nuclear engineering there is a huge gap between today's software techniques and how workflows are actually assembled by scientists, students and professionals. A typical computer code for the domain of nuclear sciences is composed of scattered computational modules (CMs), usually implemented using the Fortran programming language communicating with each other through input and output files. There are two major issues here:

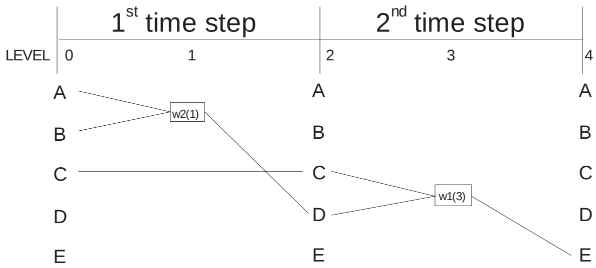
1. If somebody wishes to make an actual computation which involves more than one such CM there appears the natural need of a workflow and currently this is done by hand, i.e. the user has to manually run the modules one by one in a specific order.
2. The input/output files consumed/produced by the CMs are subject to compatibility restrictions, e.g. the output parameters of module 1 must be among the input parameters of module 2.

Overcoming these issues takes an enormous amount of time for each experiment that one has to undertake. Our approach of designing workflows is based on the actor oriented modelling (AOM) paradigm [8] and a Kepler based implementation. The paradigm states that workflows are composed of actors with different functions that are supervised by a director. The director dictates the way in which actors interact and synchronizes their communication. The actors communicate through input and output ports which are interconnected through relations (see figure 4). The action of an actor is fired when all input conditions are satisfied, i.e. all mandatory input parameters are provided through the input ports. After the actor finishes the action it outputs the results through the output ports and the next actor(s) that are in relation with it can be fired.

Before proceeding to the actual implementation of the workflow, an execution and concurrency plan for the workflow has to be developed. Primarily the plan describes the firing order of the actors and the parameter dependencies but it also provides an overview of all possible interconnection schemes, given a set of CMs (actors) and their associated input and output parameters and variables (actor parameters and ports).



(a)



(b)

Fig. 3 – A Graphplan based workflow planning example

Figure 1 shows an example of a workflow plan [10] using the Graphplan formalism [9]. Graphplanning is done in two steps. The first step is called the *expantion step* (figure 3.a) and the second one the *backward search step* (figure 3.b). The parameter sets A, B, and C are available right from the start (level 0), whereas D and E are computed by the two involved modules, w1 and w2. During the first time step, the module action w2(1) is performed and parameter D is output so that at level 2 the prerequisites for module w1 are satisfied. In time step 2 both modules can perform their actions because the required input parameters are available. Module w1 produces the output E which, for this example could be the result of the workflow. Through backwards searching the actual workflow is identified and we can proceed to the Kepler implementation.

The workflow implementation consists of wrapping up the CMs into actor classes and then designing the actual workflow in Kepler. A Kepler actor is a Java class with specialized methods, e.g. *initialize, fire, prefire*, etc., that are called by the workflow engine at different points in time. These classes can be added to Kepler's actor library for future use. Then the job of the workflow designer is to interconnect the actors such that the resulting workflow respects the plan. Furthermore, the execution of the workflow must take place in a specific domain of computation [8] which must also be chosen by the workflow designer. Figure 2 shows an example workflow used in the ABR system [7]. Each computational module is represented by an actor. The model controls the information flow and synchronizes the firing of the different actors, thus, allowing automatic parallel or sequential execution of different branches of the workflow. The SDF (Synchronous Data Flow) director fires the open end actors, i.e. it creates the required number of tokens in order to execute the workflow. The synchronizer actor waits for all the branches to complete. When an actor is fired, the corresponding CM is executed as an operating system process or a Condor [11] grid job.

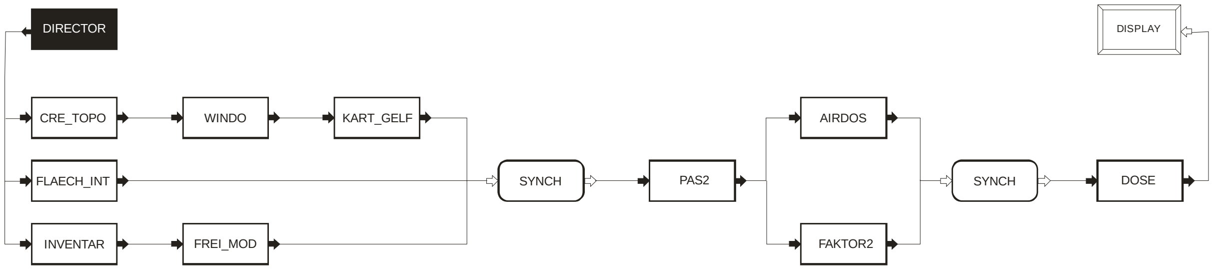


Fig. 4 – The ABR workflow

Kepler workflows can be run from Vergil (Kepler's GUI) or from another Java application by employing and controlling the workflow manager (WM) object. The WM is the same one used by Vergil and it is this feature of Kepler that allows us to define the following two main use case categories: *i. Experimental / educational use* – a researcher / student develops or modifies a workflow using Vergil and the actors in the Kepler library for testing a new concept or *ii. Production use* – the workflow is embedded inside a more complex simulation system like, for example the ABR system.

4 Conclusions

We have presented a method of integrating legacy computer codes into modern software architecture and also showed how to build and use workflows in different contexts. This is an important achievement for the domain of nuclear sciences where researchers, students and professionals must spend much time manually interconnecting scattered computer codes in order to develop a workflow. The presented architecture is secured, scalable and reliable.

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NUCLEONICA Web Portal

NUCLEONICA:
A WEB PORTAL FOR THE NUCLEAR SCIENCES

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ABSTRACT

NUCLEONICA (www.nucleonica.net) is a new nuclear science web portal from the European Commission's Joint Research Centre. The portal provides a customisable, integrated environment and collaboration platform for the nuclear sciences using the latest internet "Web 2.0" technology. NUCLEONICA is aimed at professionals, academics and students working in fields as diverse as the life and earth sciences, and the more traditional disciplines such as nuclear power, health physics and radiation protection, nuclear and radio-chemistry, and astrophysics. It is also used as a knowledge management tool to preserve nuclear knowledge built up over many decades by creating modern web-based versions of so-called "legacy" computer codes. All NUCLEONICA's web applications are browser and operating system independent and can be accessed by a variety of mobile devices.

1. Introduction

Education, training and knowledge management in the nuclear field require the renaissance of sophisticated computational skills and tools which support recent developments on issues such as energy security and protection of the environment, advanced nuclear fuel cycles, qualitative and quantitative analyses of future nuclear power growth scenarios etc. The new nuclear science web portal NUCLEONICA contributes to this skill renaissance by offering many features which encompass the knowledge of generations of nuclear scientists.
NUCLEONICA is the latest development in a family of information systems for the nuclear science community. From the software technical point of view the history began with Nuclides 2000 [1] (a classical client side database application), developed further to Nuclides.net which was a combination of local client side database connected with web-based application modules. The most recent member of the family, NUCLEONICA [2], is fully web-based requiring, on the client side, only a web browser and internet access [3]. The NUCLEONICA portal (Fig 1) consists of four main "Centres" (Fig 2): Data Centre, Application Centre, Knowledge Centre, and Networking Centre.

2. Data Centre

Nuclear data can be accessed through online interactive nuclide charts [4] (based on decay modes, half-lives, binding energy, spin, parity, etc.), reference data (datasheets, derived data, cross sections, spectral data, fission yields, etc.) and searchable databases for internationally evaluated nuclear data. The NUCLEONICA database [1], which is based on the Joint Evaluated Fission and Fusion (JEFF3.1) radioactive decay datafile, contains decay data on 3896 nuclides in ground and isomeric states. In addition, spectral data with a total of approximately 54000 energies and emission probabilities is available. Additional databases include the 8th Table of Isotopes, prompt gamma neutron activation data, and effective dose coefficients.

Fig 1. NUCLEONICA nuclear science portal.

3. Applications Centre

NUCLEONICA applications are designed to be user friendly, intuitive, and require a minimum of learning time. These powerful applications, which form the "backbone" of the nuclear science portal, can be used by professionals and students for everyday calculations. For advanced users, NUCLEONICA provides a more "hands-on" approach with its advanced scripting interface [5].

The application modules include radioactive decay, dosimetry & shielding [6], fission yields, transport and packaging, library creation for spectroscopy, nuclide mixtures, webGraphics. Recently added applications include a range and stopping power module for charged particle interaction with matter (collaboration with Ondokuz Mayis University) [7] and a radiological dispersion module for collective dose estimates following a radiological dispersion event (restricted access). Currently a new gamma spectrum simulator for a wide range of NaI and HPGe detectors is under development [8].

Through a collaboration between the Karlsruhe Research Centre and the Institute for Transuranium Elements, a web-based version of KORIGEN called webKORIGEN [9] has been developed for use in NUCLEONICA. For users, webKORIGEN overcomes the necessity of installation, input preparation and processing, compilation and debugging by offering an intuitive user-friendly web-based application – ideal for training purposes. With webKORIGEN, the user can concentrate on science rather than on the technicalities of large Fortran computer codes. WebKORIGEN supports calculations for a set of standardized problems, trimmed to three major classes of nuclear plants: the thermal power plants deployed worldwide as Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR) and a future extension to the current industrial technology the European Fast Reactor (EFR). This is discussed in more detail in section 6 in the context of preservation of nuclear knowledge and as an example of the development of a web application from a legacy computer code.

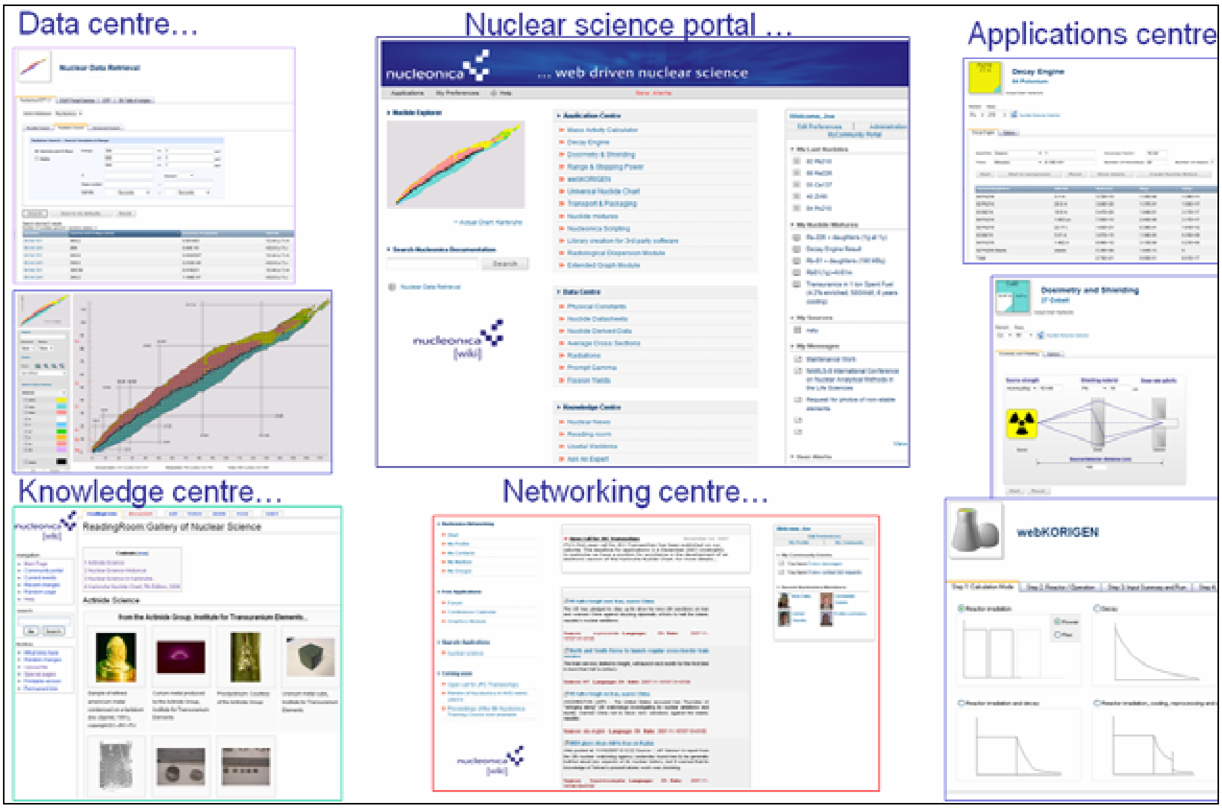

Fig 2. NUCLEONICA's main "Centres" for Data, Applications, Knowledge and Networking.

4. Knowledge Centre

The *Knowledge Centre*, or NucleonicaWiki [10], is the content management system (CMS) used for NUCLEONICA documentation. It is based on the same MediaWiki "engine" as used in Wikipedia. The NucleonicaWiki is used for online Help, ReadingRoom (for articles, and presentations), weblinks, element information, ask an expert Q & A etc.
The NucleonicaWiki is also used for training course organisation. To date, nine nuclear science training courses based on Nucleonica have taken place both at ITU and in external training centres. All training course announcements [11], agendas, full presentations, exercises, case studies, photo galleries etc., are available online in the NucleonicaWiki. NUCLEONICA training courses introduce the basic concepts of nuclear science and technology and are suitable for participants from the nuclear industry, nuclear research organizations, universities, regulatory authorities etc. Lectures are followed by “hands-on” case studies on the use of the NUCLEONICA web-based applications.
In addition to the above described nuclear science training courses, in 2008 we plan to initiate a number of short-stay training activities on NUCLEONICA at ITU. These short-stay training courses will provide PhD students, research fellows and trainees with a more extensive training in the use of NUCLEONICA through "mini-projects". Calls for proposals for such "mini-projects" will be announced on the NUCLEONICA website.

5. Networking Centre

The *Networking Centre* allows users to stay in contact with colleagues from workshops or conferences, meet scientists from similar areas of interest and build up an international contact list. The users can represent themselves (personal page) and their Institute/Organisation in the international science community. The nuclear news aggregation

service provides latest news and information on nuclear issues - the JRC’s web crawlers scan hundreds of newspapers every few minutes.
NUCLEONICA's Conference Calendar can be used to enter information on forthcoming events, meetings, conferences etc. The user can decide if he wishes to share this information with other users. In this way a user-generated calendar of events is generated. Alternatively, the user can decide to keep the information in his personal diary.

6. Preservation of Nuclear Knowledge: Web-based Fuel Cycle Calculations with webKORIGEN

WebKORIGEN is a web-based user-friendly version of the KORIGEN code. KORIGEN, developed in the Karlsruhe Research Centre, constitutes a standalone package supporting the fuel depletion, reprocessing, and decay calculations. KORIGEN, originating from the ORNL ORIGEN code, is used in the German nuclear industry and by German licensing authorities for application to German light-water reactors. It enables reliable assessments of decay energy release from actinides, fission products and activated impurities in irradiated fuel and is routinely applied for purposes related to the safe handling, reprocessing and storage of spent fuel.

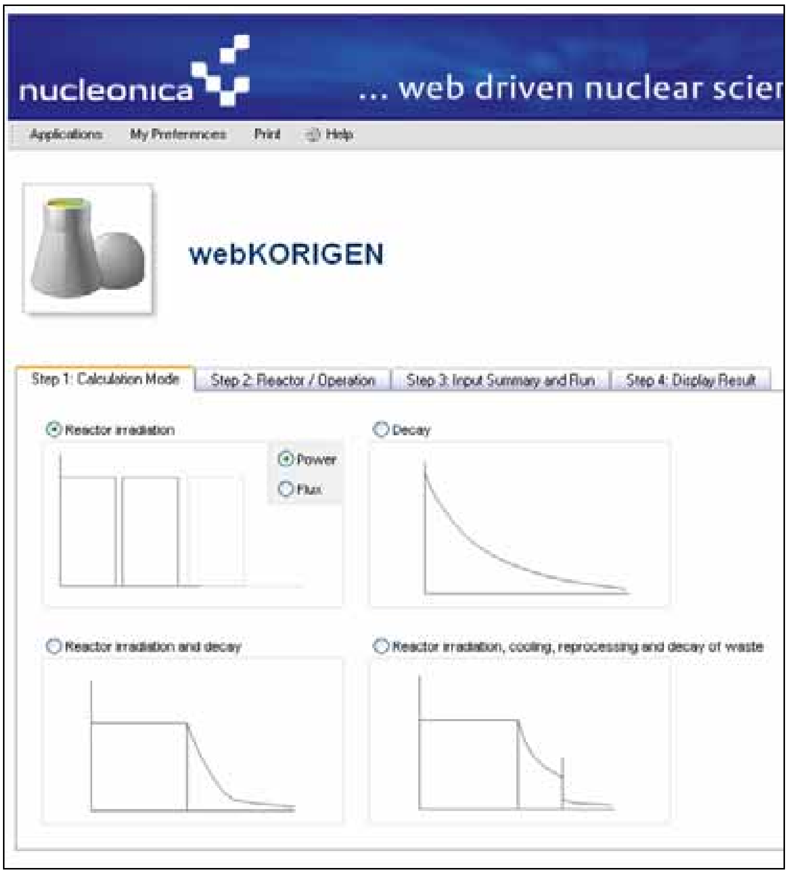

Fig 3. The webKORIGEN interface for fuel cycle calculations in NUCLEONICA.

By using webKORIGEN, advanced performance-based assessments of selected integral nuclear fuel cycle (NFC) characteristics can be done. It is applicable to both industrially practised, current and future advanced NFCs implementing the partitioning and transmutation (P&T) processes. The fuel cycle options in webKORIGEN cover “once-through “ uranium-oxide NFC and “conventional reprocessing“ NFC, the latter based on plutonium separation and single recycling in the form of uranium-plutonium mixed-oxide fuel. The webKORIGEN depletion engine uses facility data for thermal and fast systems; among them the Pressurized and Boiling Water Reactors, and the European Fast Reactor. WebKORIGEN belongs to the isotopic summation codes which explicitly calculate, for a large set of isotopes, time dependent mass concentrations, radioactivities, decay heat and radiotoxicities of the nuclear material irradiated in a reactor core. Thus for the depletion calculations the complete nuclear databases must be supplied and managed. These data, prepared in advance, are transferred on demand to webKORIGEN from linked dedicated libraries. Their accuracy, benchmarked with experiments, warrants the reliable performance of the code.

7. Conclusions

NUCLEONICA is a web portal specifically dedicated to education, training and knowledge management in the nuclear sciences. In addition to providing internationally evaluated nuclear data, the portal provides access to a variety of nuclear science applications ranging from dosimetry and shielding to detailed fuel cycle calculations. NUCLEONICA's networking features allow users to stay in contact with colleagues, meet scientists with similar interests and build up an international contact list. The NucleonicaWiki provides a powerful content management system for online Help, ReadingRoom (for articles, and presentations), weblinks, element information, "ask an expert", etc., and in addition for information on the Karlsuhe Nuclide Chart [12].
With NUCLEONICA, there is no need to install software - all data and software is server-based. The development team takes care of maintaining the datasets and software and can add user options in response to customer demand. Further Information on registration [13] is available on the NucleonicaWiki.

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AN INTERACTIVE WEB ACCESSIBLE GAMMA-SPECTRUM SIMULATOR

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ABSTRACT

A versatile γ-spectrum simulation tool has been developed to allow the generation of accurate γ-spectra for a wide range of NaI and HPGe detectors and for any mixture of γ-emitting radionuclides. The simulator provides full interactive control of a virtual γ-spectrometer for modeling various geometries with shielded and unshielded sources. The output consists of an interactive graph, containing cumulative and nuclide specific spectral distributions. More detailed spectral information and a detection efficiency graph are available as advanced options. The simulator, which can be accessed through the NUCLEONICA nuclear science and data portal, is a powerful tool for providing basic and advanced training in various areas of nuclear science and applications.

1. Introduction

Nowadays the γ-spectrometry is used on a daily basis in different basic and applied fields of nuclear science and technology. A variety of instruments and measurement techniques, involving γ-spectrometry measurements, are employed routinely by nuclear and radio-chemists, health physicists, nuclear facility operators, radiation protection staff, safeguards inspectors, border police, customs and low-enforcement officers. Needs for education and training in these areas are high and, obviously, they will be increasing in the future as new challenges, such as strengthening nuclear safeguards and security, nuclear terrorism prevention and implementation of new standards in radiation safety and protection, arise. Contemporary web technologies coupled with advanced mathematical simulation can offer unique possibilities to address these growing demands by providing realistic visual interactive web-accessible teaching aids and tools. This paper reports on the first stage of the development of such a realistic web-based simulation tool, the Gamma Spectrum Generator, which can be accessed through the NUCLEONICA [1] nuclear science and data portal at www.nucleonica.net.

2. Basics of the simulation approach

The current implementation of a virtual measurement setup is based on a point-like γ-ray source located on the axis of a cylindrically symmetric NaI or High-Pure Ge (HPGe) crystal (the sensitive volume of a γ-spectrometer) and separated from it by a number of absorbing layers, as shown in Fig.1. The γ-spectrum for such measurement setups is constructed by summing appropriately normalized detector response profiles, generated for individual γ-rays emitted by a source.

The response profiles consist of peak and continuum components. The former includes the full energy peak (FEP), single and double escape peaks (SEP and DEP), X-ray escape peaks (XEP), and the 511 keV annihilation peak. The continuum component contains two contributions, both coming from Compton scattering events, which occur either inside a detector crystal or its surroundings. Although it is continuous in nature, the latter is often referred as a backscatter peak.

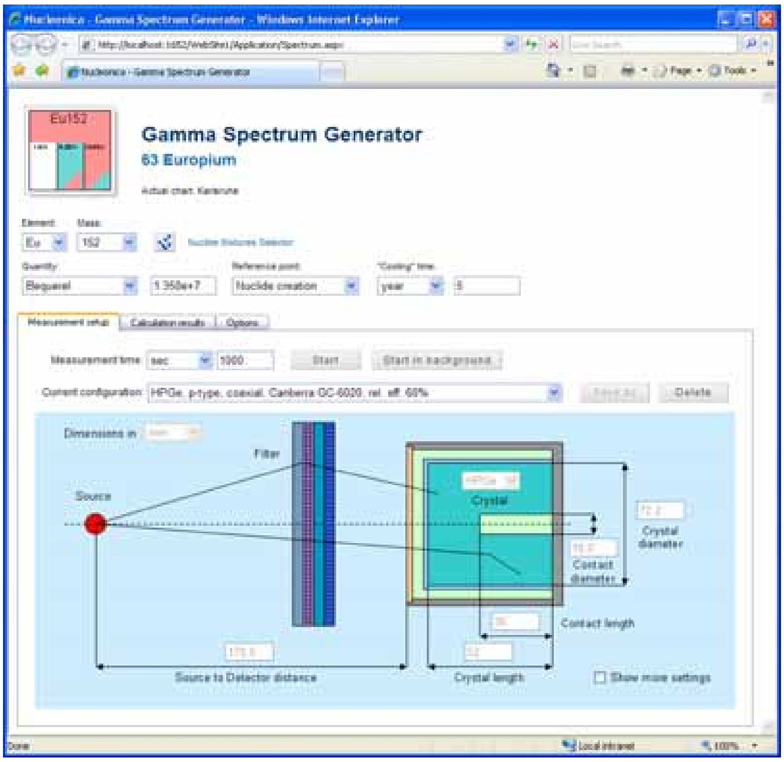

Fig 1. A screen capture of NUCLEONICA's Gamma Spectrum Generator web-page showing a tab with basic measurement geometry setup controls.

The relative contributions of the spectrum components are evaluated using an extensive detector response database, which has been created with help of a specially developed and validated Monte Carlo program. The database contains a large set of the peak-to-total and continuum-to-total efficiency ratios, and parameterized continuum shapes, calculated on grids of detector crystal dimensions, γ-ray energies and source-to-detector distances. In the course of modeling, a set of special interpolation techniques [2] is applied to calculate the efficiency ratios and continuum profiles for an arbitrary measurement setup and photon energy. Gaussian and Voigt distributions are used to model shapes of γ- and X-ray peaks, respectively. The peak widths represent actual energy resolution of a detector with additional contributions from Doppler broadening and natural line widths.
Once the relative response profile is constructed, it is converted to absolute values by performing normalization to the total detection efficiency. This efficiency is calculated by numerical integration over a detector crystal volume for the specified location of a source. The final response normalization is performed to account for the emission probability of particular γ-ray and actual number of decays of a respective nuclide, occurred during spectrum measurement. The latter is calculated based on the extended Bateman's analytical solution [3] of the system of differential equations governing radionuclide buildup and decay during source cooling and spectrum measurement time intervals.
Evaluated reference nuclear decay and photon attenuation data available in NUCLEONICA are used throughout spectrum modeling.

3. Features implemented

Fig.1 shows main features implemented in Gamma Spectrum Generator web-page. Using respective controls, an arbitrary individual nuclide or a pre-defined mixture of nuclides can be selected as a radiation source. A nuclide or a mixture of interest may be chosen also from NUCLEONICA's Nuclide Explorer or Nuclide Mixtures pages, which can be reached using corresponding links. Once a source nuclide is selected, the box at the top left of the page shows an image with its basic properties (decay modes, half-live, existing isomers) indicated. The nuclide's name to the right of the image provides a link to a part of the NUCLEONICA

Wiki, which describes in detail properties of the chemical element. The quantity (activity, mass or number of atoms) of a nuclide or a mixture can be specified either at the moment of its production/certification or at the spectrum measurement starting point of time. In the former case controls for specifying duration of a source cooling time interval become available.

The spectrum measurement time and γ-spectrometer parameters can be specified on "Measurement setup" tab. Using the "Current configuration" dropdown list, one can choose a suitable γ-spectrometer from 6 pre-defined configurations, which include 2 coaxial HPGe detectors with 50% and 150% relative efficiency, low-energy (LEGe) and broad-energy (BEGe) HPGe detectors, and 2 scintillation detectors with standard $\varnothing 3'' \times 3''$ and $\varnothing 2'' \times 1''$ NaI crystals. The last entry ("Edit") in the drop-down list switches controls on the underlying measurement setup to the edit mode, whereby one can configure his own γ-spectrometer. The configurable parameters include the source-to-detector distance, as well as dimensions and materials of the detector construction elements, such as the detector crystal, crystal reflector, crystal packaging, crystal inactive layer, and the detector input window. All dimensions can be entered in "mm", "cm" or "inch" units. In addition to the crystal length and diameter, the dimensions of a cylindrical contact at the rear side of the crystal (a construction feature of conventional coaxial HPGe detectors) can be specified. Up to 6 additional absorbing filters made of Al, Cu, Fe, Pb, Sn, or polyethylene can be placed between source and detector, if one wants to reduce unwanted contribution to the simulated spectrum from the intense low-energy γ-radiation. The user can also add these filters to his virtual spectrometer configuration to simulate γ-spectra from containerized sources. Additional controls for specifying the detector energy resolution properties, number of spectrum channels and channel-to-energy conversion coefficient appear when "Show more settings" checkbox at the bottom right of the measurement setup drawing is selected. Once the user-specific γ-spectrometer is created, it can be saved in user's personal account in NUCLEONICA for future reference and use.

One can start calculations either in an on-line or background mode. In the latter case a notification will be sent via email and a respective alert will be raised in one's NUCLEONICA account, once the task has been completed. There are more settings on the "Options" tab, which provide additional control over the spectrum simulation. For instance, one can enable or disable decay calculations that will or will not allow contributions from decay products, being accumulated during source cooling and spectrum measurement time intervals. The backscatter peak simulation can be also switched on and off, and its contribution to the total detection efficiency can be adjusted using a special scaling factor.

The standard output, which appears in "Calculation results" tab, consists of a stacked graph displaying cumulative and nuclide specific spectra, as well as peak, continuum and backscatter photon contributions to the full spectrum (see Fig.2). One can easily switch between types of spectral information presented on the graph, which include probability density functions for the detector input count rate at start or end of the measurement, as well as mean or statistical (Poisson) number of counts accumulated in spectrum channels. The graph is accompanied by brief numerical information on the total and nuclide specific count rates and number of spectrum counts. Additionally, a graph displaying total detection efficiency for the current spectrometer setup, as well as FEP, SEP, DEP and XEP efficiencies as functions of the incident photon energy can be activated. For both, spectrum and efficiency graphs, a set of controls are provided to tailor their appearance to one's needs and requirements and to download the final image in different graphics formats. A detailed report, containing the complete collection of spectral and efficiency numerical data, is generated also and can be downloaded as a text or Excel spreadsheet file.

4. Some examples

A number of graphs, demonstrating the capabilities of the Gamma Spectrum Generator, are shown in Fig.2. All graphs were created using the generator's tools and downloaded directly from its web-page.

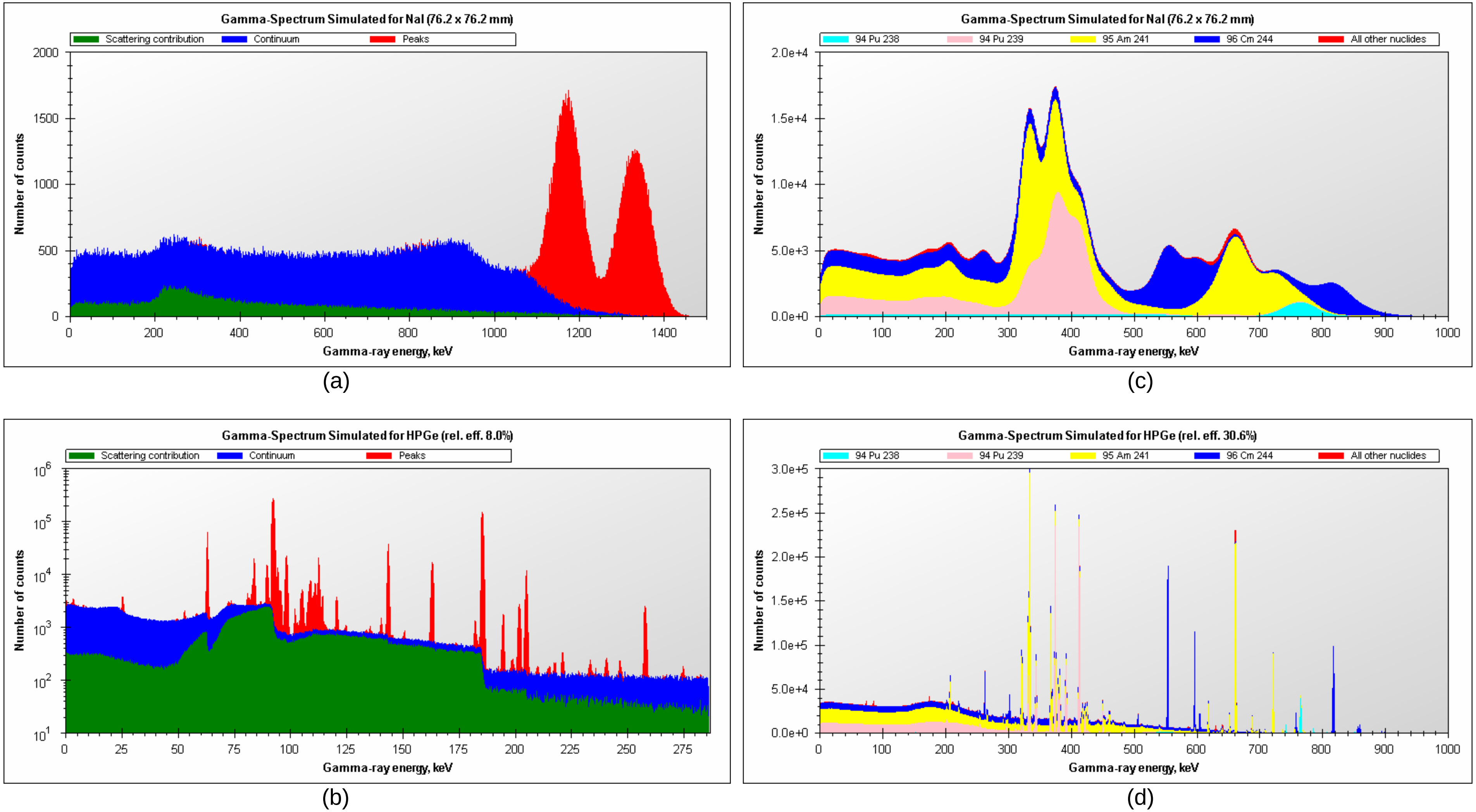

Fig 3. γ-spectra simulated for: (a) ^{60}Co 100 kBq source and NaI (∅3″×3″) detector, (b) 1 g natural U sample shielded with 0.5 mm Sn and LEGe (20 mm × 2800 mm^2) detector, (c) actinides in 1 kg PWR spent fuel shielded with 5 mm Pb and NaI (∅3″×3″) detector, and (d) actinides in 1 kg PWR spent fuel shielded with 5 mm Pb and BEGe (30% rel. eff.) detector.

Fig.2a shows γ-spectrum simulated for a 100 kBq ^{60}Co source and NaI (∅3″×3″) detector. The source is assumed to be positioned at 25 cm distance from the detector and measured for 1000 s. The graph demonstrates a powerful feature of the generator, which allows to visualize peak and continuum components of the spectrum. In addition, a backscatter peak contribution is shown as a separate continuum component in the graph.

The backscatter photon contribution looks more complicated in the γ-spectrum in Fig.2b. The spectrum was simulated for a 1 g U sample located at 2.5 cm distance from LEGe detector (crystal length 20 mm, active area 2800 mm^2) and shielded with 0.5 mm Sn filter. It was assumed that U had been separated from the ore 2 years before the measurement and had natural abundances of ^{234}U, ^{235}U and ^{238}U at the date of the separation. The spectrum includes contributions from all decay products, which have been accumulated since this date. To obtain better statistics of counts, the spectrum measurement time was 10^5 s.

Fig.2c and Fig.2d show low- and high-resolution γ-spectra for a 5.25 TBq source, which represents actinides extracted from a 1 kg sample of 6-year-aged PWR spent fuel. The isotopic composition of the fuel was calculated using NUCLEONICA's webKORIGEN [4], assuming 4.2% for the original enrichment and 50 GWd/t for the final burnup of the fuel. The low- and high-resolution spectra correspond to NaI (∅3″×3″) and BEGe (30% rel. eff.) detectors, respectively. In both cases the source was assumed to be shielded with a 5 mm Pb filter and located at 25 cm distance from the detectors. The measurement time is 1000 s. From the spectra shown one can see easily the advantages of the high-resolution γ-spectrometry when accurate characterization of the sample is required.

5. Future work

The capabilities of the Gamma Spectrum Generator are planned to be further extended to include simulation of the spectrum distortion effects (e.g. due to coincidence summing and energy resolution deterioration), which may appear in measurements involving elevated count rates and small source-to-detector distances. It is also foreseen to extent the detector response profile database to include $LaBr_3$ scintillators that, because of their much superior energy resolution, start to replace traditional NaI crystals in many applications. Inclusion of self-attenuation effects is another challenging task, which would allow more realistic simulation of γ-spectra from voluminous sources.

6. Conclusions

A versatile web-accessible γ-spectrum simulation tool has been developed to allow generation of accurate γ-spectra for a wide range of NaI and HPGe detectors and for any mixture of known γ-emitting radionuclides. The simulator is a useful visual teaching aid in providing basic and advanced training for members of nuclear and non-nuclear communities working in various areas of science and technology. The simulator tool is especially useful in training facilities, which have restrictions on the use of radioactive substances, or when sources of special interest (e.g. spent fuel, enriched U, weapon grade Pu or other highly radiotoxic materials) are not readily available.

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WEB-BASED DOSIMETRY AND SHIELDING CALCULATIONS IN NUCLEONICA

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ABSTRACT

The dosimetry and shielding module in Nucleonica allows the user to calculate gamma dose rates from point sources of either single nuclides or composite mixtures. The intuitive interface allows quick and accurate calculations. The present paper provides a detailed description of the module, in addition to discussing potential applications, particularly for education and training purposes.

1. Introduction

The new nuclear science web portal Nucleonica [1] has been developed at the Institute for Transuranium Elements. Nucleonica offers a suite of applications ranging from a powerful user-friendly Nuclide Explorer, which allows the user to navigate the nuclide chart and explore the properties of nuclides, to various computational and networking modules. One of the first modules developed was for dosimetry and shielding calculations for radioactive point sources and nuclide mixtures. The formalism for the dosimetry and shielding calculations is given in the Nucleonica wiki together with a detailed description [2] of the interaction of radiation with matter which provides the underlying physical basis.

2. The Dosimetry & Shielding Module

The dosimetry and shielding module allows the user to calculate gamma dose rates from point sources of either single nuclides or composite mixtures. It is possible to obtain the corresponding dose rate given a specific shield material and thickness. Alternatively, it is possible to calculate the material shielding thickness required to obtain a desired dose rate. More than 3000 nuclides and excited states with more than 53,000 gamma and x-rays are available in the Nucleonica database for dosimetry calculations, together with a choice of ten different materials for shielding purposes. The intuitive interface allows quick and accurate calculations and has been specifically designed to be suitable for use by professionals and students in nuclear science and technology.

2.1 Interface

The main interface, shown in Fig. 1 allows the users to select the nuclide, the source strength, the source/detector distance, the shield material and shield material thickness. In the example shown in Fig. 1, Co-60 ground state has been selected using the drop down menus. In the upper left hand corner, a graphic of the selected nuclide shows the half-life of the selected nuclide, 5.27 y, and information on the metastable state Co60m. The source strength can be set in different units, namely Activity (Bq), Activity (Ci), Mass (g) or number of atoms. The default value shown in Fig. 1 is 1 MBq. In addition, the user has the choice of 10 shield materials: lead, concrete (dry), tin, tungsten, uranium, water, aluminium, air (dry air at sea level) and tissue. The calculation is initiated by clicking in the Start button. The detailed results, shown in Fig. 2 in tabular form below the main interface, include the half-value layer (HVL) and the tenth value layer (TVL) thicknesses required to reduce the gamma dose rate to 50% and 10% respectively of the initial value, and the specific gamma dose rate constant for the given nuclide.

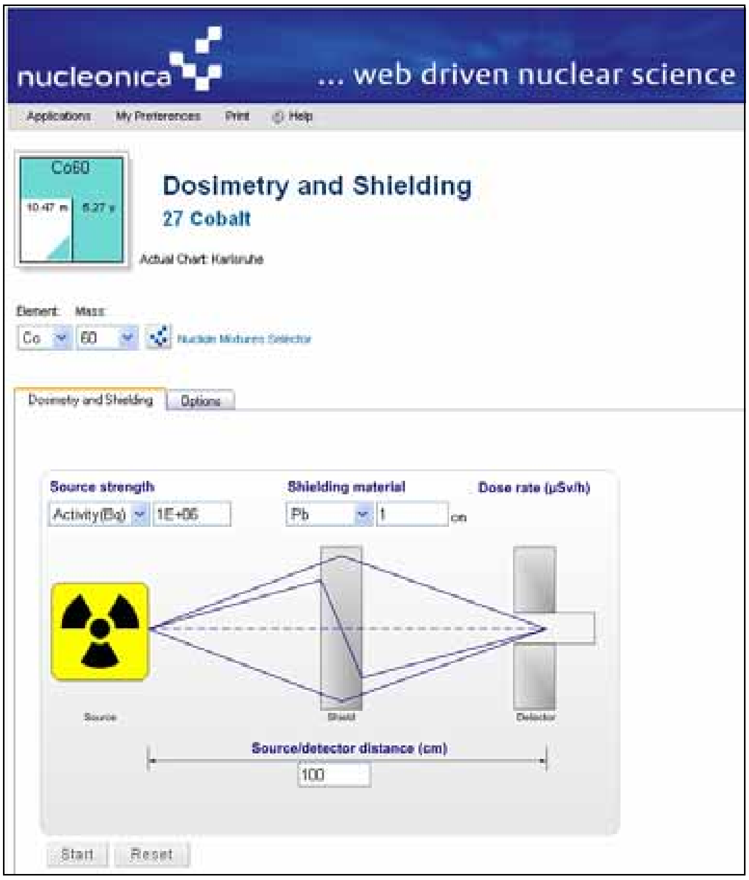

Fig 1. Dosimetry & shielding module interface.

Half-Value Shield Thickness(cm)	1.88E+00
Tenth-Value Shield Thickness(cm)	4.90E+00
Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h)	3.37E-01
Gamma Dose Rate (µSv/h)	2.52E-01

Download ⦿Excel ○CSV Separator: Semicolon (";") ☑Use field qualifier (")

Number of lines (γ):	6	ΣE.P.(γ):	2.50E+06
Number of lines (X):	4	ΣE.P.(X):	8.35E-01
Number of lines (γ+X):	10	ΣE.P.(total):	2.50E+06

Download ⦿Excel ○CSV Separator: Semicolon (";") ☑Use field qualifier (")

Nuclide	Gamma Energy (MeV)	Emission Probability P (per disintegration)	Mass Attenuation Coefficient (shielding)(cm²/g)	Number of Mean Free Path(µd)	Build-up Factor	Mass Absortion Coefficient (tissue)(cm²/g)	Gamma Dose Rate(µSv/h)
27 Co 60	1.33E+00	1.00E+00	5.64E-02	6.40E-01	1.46E+00	2.89E-02	1.36E-01
27 Co 60	1.17E+00	9.99E-01	6.20E-02	7.04E-01	1.46E+00	2.98E-02	1.16E-01
27 Co 60	8.26E-01	7.60E-05	8.59E-02	9.75E-01	1.43E+00	3.16E-02	4.92E-06
27 Co 60	3.47E-01	7.50E-05	3.05E-01	3.46E+00	1.67E+00	3.21E-02	2.02E-07
27 Co 60	7.48E-03	6.44E-05	2.71E+02	3.07E+03	1	1.22E+01	0
27 Co 60	7.46E-03	3.27E-05	2.72E+02	3.09E+03	1	1.23E+01	0
27 Co 60	8.26E-03	1.31E-05	2.11E+02	2.40E+03	1	9.01E+00	0
27 Co 60	2.16E+00	1.20E-05	4.54E-02	5.15E-01	1.48E+00	2.52E-02	2.65E-06
27 Co 60	8.50E-04	1.49E-06	7.16E+03	8.12E+04	1	5.38E+03	0
27 Co 60	2.51E+00	2.00E-08	4.39E-02	4.99E-01	1.24E+00	2.40E-02	4.15E-09

Download ⦿Excel ○CSV Separator: Semicolon (";") ☑Use field qualifier (")

Fig 2. Detailed results for a 1 MBq Co-60 source.

This information is followed by the number of gamma and X-ray energies used in the calculation together with the quantity $\Sigma_i E_i \cdot P_i$ which is the sum of the energies multiplied by their emission probabilities. In the table in Fig. 2, the results include the contribution of each gamma-line or X-ray to the total dose rate, the mass absorption coefficients for tissue, the build-up factors, and the mass attenuation coefficients for the shield material (for refs. see [2]). The information can be re-arranged by clicking on the column headers. In the example shown in Fig. 2, clicking on the column header "Gamma Dose Rate (µSv/h)" re-arranges the table to show the main contributions to the gamma dose rate. In the case of Co-60 this is from the 1.33 and 1.17 MeV gamma lines. The information given in Fig. 2 can also be downloaded for further processing.

2.2 Basis of the Calculation

The dose rate is calculated using the point source kernel approach and is given by [3]:

$$\frac{dH(r)}{dt} = \frac{A}{4\pi r^2} \cdot \sum_i \left[E_i \cdot P_i \cdot \left(\frac{\mu}{\rho} \right)_i^{tissue} \cdot B_i \cdot \exp\left[-\left(\frac{\mu}{\rho} \right)_i^{shield} \cdot \rho d \right] \right]$$

where H(r) is the equivalent dose at distance r, A is the source activity and d is the shield thickness. The summation is over all lines i: E_i and P_i are the gamma energies and emission probabilities per disintegration, $(\mu/\rho)^{shield}$ is the mass attenuation coefficient in the shield material, $(\mu/\rho)^{tissue}$ is the mass absorption coefficient in tissue, and B_i is the dose build-up factor. In Figs 1 and 2, the calculated dose rate is 0.25 µSv/h at 1m with 1 cm Pb shielding.

2.3 Options

The Options window can be access from the appropriate tab in Fig. 1. There are two modes of operation. The user can obtain a dose rate with a given shield material and thickness. Alternatively, the thickness of shield material required to obtain a given dose rate can be calculated. The user can choose to include only gammas, X-rays, or both in the calculations. In addition, the threshold energy for contributions to the dose rate can be set by the user. The default value is 15 keV – photons with lower energy are absorbed by the outer layers of human tissue and do not contribute to the whole body dose.

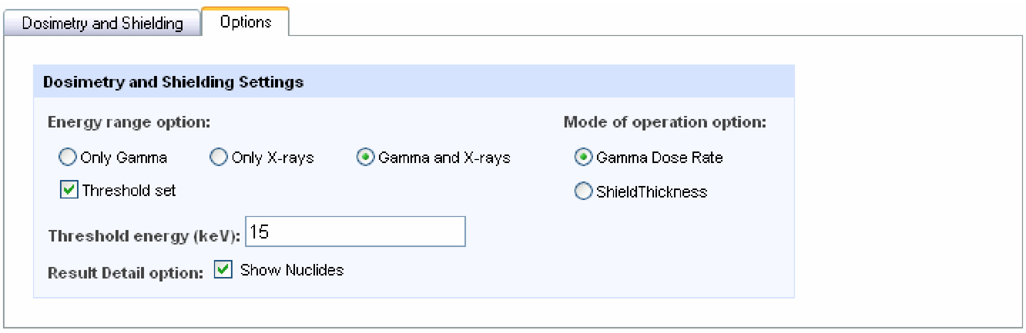

Fig 3. The Options window

3. Some Examples

3.1 Example: Occupational Exposure in Nuclear Medicine Departments

Tc-99m is a commonly used isotope in nuclear cardiology as a "tracer" for high image quality visualisation of organs. It is well suited to the role because it emits readily detectable 140 keV gamma rays, and has a short half-life of 6.01 hours. After approximately 10 half-lives, Tc-99m has almost completely decayed to its long-lived daughter Tc-99. The biological half-life of Tc-99, however, results in earlier removal from the body. A patient is injected with typically 30 mCi of Tc-99m. The treated patient must, therefore, be considered as an unshielded source of radiation. During this time the radioactivity is present in the body, the medical staff - nurses, physicians and operators - will be exposed to radiation from the patient. It is thus interesting to estimate the dose rate received from a patient treated with 30 mCi of Tc-99m and to calculate how much shielding does a patient's body provides to protect his family and the medical staff. For this study we consider that the radioactivity is concentrated in the middle of the body (studies have shown, for example, that the technetium has tendency to concentrate in the kidneys) as a point source and shielded below 1 cm of human tissue. Calculations can then be performed with the dosimetry and shielding module of Nucleonica. The resulting gamma dose rate is 16.5 µSv/h, 65.9 µSv/h and 1.65×10^5 µSv/h at distances from the patient of 1 meter, 50 cm and 1 cm respectively. These figures are comparable with previous medical studies, see ref. [4]. If one considers that a typical procedure lasts for about 40 min, the exposure due to the patient requires the medical staff to be protected. The use of lead apron is compulsory for medical nuclear operators. From the dosimetry & shielding module, the dose rate behind a 0.5 mm lead apron at 1 m distance from the patient is reduced from 16.5 to 8 µSv/h.

3.2 Example 2: Handling of Spent Fuel in a "Hot-Cell"

The aim of this example is to demonstrate a shielding calculation with a mixture of nuclides, and to show the module working in the “shield thickness” mode. A "Hot-Cell" provides facilities for performing operations on highly radioactive material with minimal radiation exposure to the personnel involved. Most hot cells are designed to accept fuel rods for post irradiation investigations. To protect the user against gamma radiation, the different cells are shielded with lead bricks and can be operated through a lead glass window.
For this study we create a nuclide mixture, using the mixture option in Nucleonica, based on the main contributors to the gamma heat calculated using a webKORIGEN calculation of a spent fuel rod 4.2% enriched from a standard PWR reactor (50GWd/t) and after 6 years of cooling. The total mass of the 20 most important contributors to the total activity is 3.4 g per kg of spent fuel. The maximum mass load of spend fuel introduced into the hot cell is typically about 500g.

Top Nuclides	Results	Top Elements	Results	Totals	Results
Cs137	5.110E+15	Cesium	6.398E+15	Actinides:	5.153E+15
Ba137m	4.834E+15	Plutonium	4.904E+15	Fission Prod	2.198E+16
Pu241	4.651E+15	Barium	4.834E+15	Total	2.713E+16
Sr90	3.505E+15	Strontium	3.505E+15		
Y90	3.505E+15	Yttrium	3.505E+15		
Pm147	1.474E+15	Promethium	1.474E+15		
Cs134	1.288E+15	Europium	5.176E+14		
Eu154	4.108E+14	Ruthenium	3.963E+14		
Rh106	3.963E+14	Rhodium	3.963E+14		
Ru106	3.963E+14	Krypton	3.503E+14		
Kr85	3.503E+14	Praseodymium	1.893E+14		
Pu238	2.168E+14	Cerium	1.870E+14		
Pr144	1.871E+14	Curium	1.854E+14		
Ce144	1.870E+14	Antimony	1.560E+14		
Cm244	1.837E+14	Americium	6.181E+13		
Sb125	1.560E+14	Tellurium	3.806E+13		
Eu155	1.065E+14	Neptunium	1.429E+12		
Am241	5.968E+13				
Te125m	3.804E+13				
Pu240	2.289E+13				

Neutron and gamma rates
Neutron rate: 7.32E+08 n/s
Gamma rate from Actinides: 2.679E+12 MeV/s
Gamma rate from FPs: 6.230E+15 MeV/s

Fig 4. Results of a webKORIGEN calculation for the most important contributors to the gamma heat from spent fuel.

German regulations give a limit for occupationally exposed workers (category A) of 20 mSv/year assuming 2000 working hours (i.e. 2000 h of exposure). This leads to an hourly dose rate of 10 µSv/h for a regular worker working. The limit for occupationally exposed workers (category B) is 6 mSv/year assuming 2000 working hours (2000 h of exposure) hence equivalent to 3 µSv/h. We can then use the dosimetry and shielding module and using the "shield thickness" mode calculate the thickness of lead required to obtain 3 µSv/h at 1 m of distance for 1.7 g of the calculated mixture obtained with webKORIGEN. The calculation gives a lead thickness of 14.8 cm. In most of the existing hot cells, reinforced concrete walls provide the main shielding used for construction. The module has dry concrete as a shield option. This can then be used as an approximation for the concrete walls. The calculation gives a required thickness of 92.8 cm of concrete, as shown in Fig. 5. Typically, hot-cells have wall thickness of approximately 1 m of reinforced concrete and 1 m thick lead glass windows.

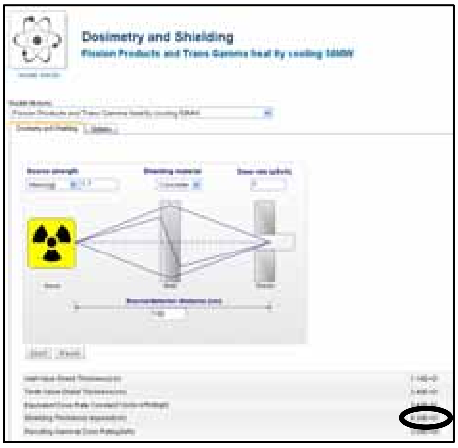

Fig 5. Calculation for the concrete shielding requirement for 1.7 g of the main transuranics elements and fission products, corresponding to 500g spent fuel.

4. Future developments

The Dosimetry & Shielding module in Nucleonica is under continuous development driven in particular by user demand. Future upgrades will include additional shielding materials, multilayer shielding options, and volumetric source dosimetry based on Monte Carlo calculations.

5. Conclusion

The dosimetry and shielding module in Nucleonica is a versatile tool for quick and accurate dosimetry and shielding calculations. It allows the user to calculate gamma dose rates from point sources of single nuclide and mixtures, through a choice of 10 different shield materials. Over 3000 nuclides with more than 53000 gamma lines are available in the database. The examples described provide an overview of the features available and the flexibility of the module for education and training purposes in nuclear science.

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RANGE AND STOPPING POWER CALCULATIONS IN NUCLEONICA

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ABSTRACT

In the interaction between charged particles and matter, the stopping power or the average energy loss per unit path length plays an important role in many fields. Because of the great interest in this phenomenon, a web-based application has been developed in the Nucleonica portal to calculate the range and stopping power of electrons, positrons, protons, alphas, muons and heavy ions in a variety of different targets. The target materials can be selected from a variety of pre-defined elements and compounds. Alternatively, user-defined compounds can be created and stored for later use. The present paper provides a detailed description the range and stopping power calculations in Nucleonica. Agreement between the results and other well-known computer codes and experimental results shows that the module gives very reliable results. The application is suitable for professional use and for education and training purposes by educators and students in nuclear science.

1. Introduction

Stopping power, i.e. energy loss of energetic particles per unit length in matter, has been studied experimentally and theoretically since the beginning of the 20th century because of its wide application area, such as ion implantation, fundamental particle physics, nuclear physics, radiation damage, radiology, structure analysis of solid target by Rutherford backscattering spectroscopy, and plasma-first wall interaction in a nuclear-fusion reactor. Stopping power can be considered in two parts: first is the interaction of incident particle with target electrons (called electronic stopping power), and second is the interaction with target nuclei (called nuclear stopping power).

The first (classical) calculation of the energy loss of energetic particles was made by Bohr [1], while the first quantum mechanical treatment was done by Bethe [2]. This latter theory of stopping power is particularly accurate when the projectile's velocity is sufficiently high. Another important quantity is the range of the charged particle in matter. The range is defined as the mean path length of the particle in the target matter before coming to rest. Generally, analytic transport theory and Monte Carlo calculations are used for the range calculations.

Because of its importance, we have developed a web-based application for Range and Stopping Power (R&SP) calculations. One can easily calculate Range and Stopping Power for many types of projectile in various targets through the user-friendly interface in NUCLEONICA [3]. Full documentation of this module is given in the Nucleonica Wiki [4].

2. Projectile-Target Compositions

The user interface of the R&SP module is shown in Fig. 1. All pre-defined parts of module can be selected through the appropriate combo boxes in the main menu. Electrons, positrons, alphas, protons, muons, and ions with atom numbers from 1 to 92 can be selected from the "projectile" combo box shown in Fig. 1.

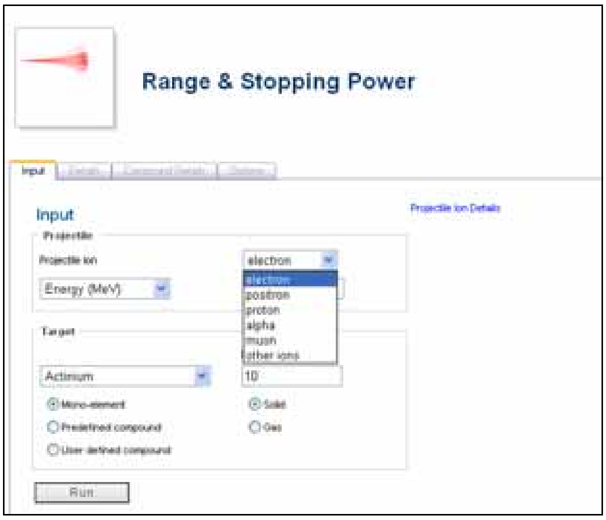


Fig 1. The RANGE module interface showing the types of projectiles available.

If the user selects "other ions", two new combo boxes appear. The first allows the user to choose an element from Z=1 to 92 and second allows selection of the isotopes. There are some limitations with regard to setting the energy of projectile. The module does not calculate stopping power and range if the projectile's energy is less than 10 keV or more than 1GeV for electrons and positrons, and less than 1 MeV or more than 1GeV for muons, and less than 1 keV or more than 2 GeV for alphas, protons and other ions.
For targets, the user can choose predefined mono-element from Z=1 to 92, predefined compounds, or user defined compounds. Pre-defined mono elements and compounds can be selected by using the corresponding radio buttons and combo box. Moreover, the target densities are taken form the Nucleonica database. By selecting the corresponding radio button, gas or solid state atomic density of the target is taken from the database. These values can, however, be changed in the density TextBox in main menu.
Users can create their own compounds by clicking the appropriate radio button and then "Compound Details" menu. In the compound details menu, one can add elements and their corresponding stoichiometry. User defined compounds can be given a name and saved for later use (Fig.2).

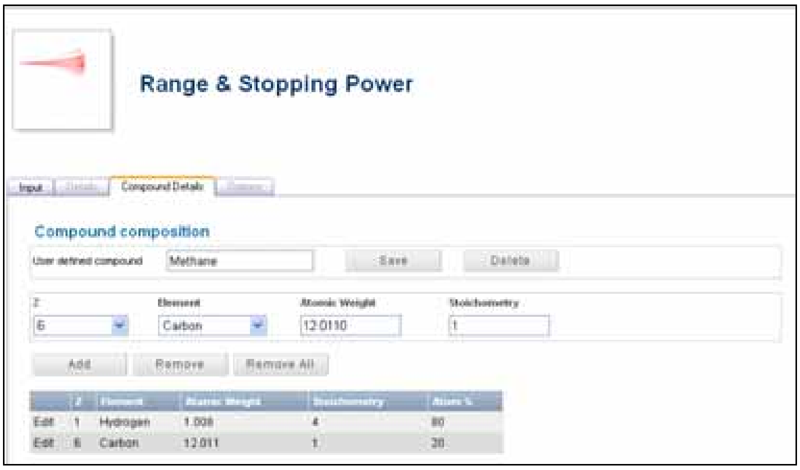


Fig 2. Interface for the creation of user-defined compounds.

Once the projectile and target have been selected/created, the calculations can be initiated by clicking the "Run" button. The results are then shown at the bottom of the page (see Fig.3).

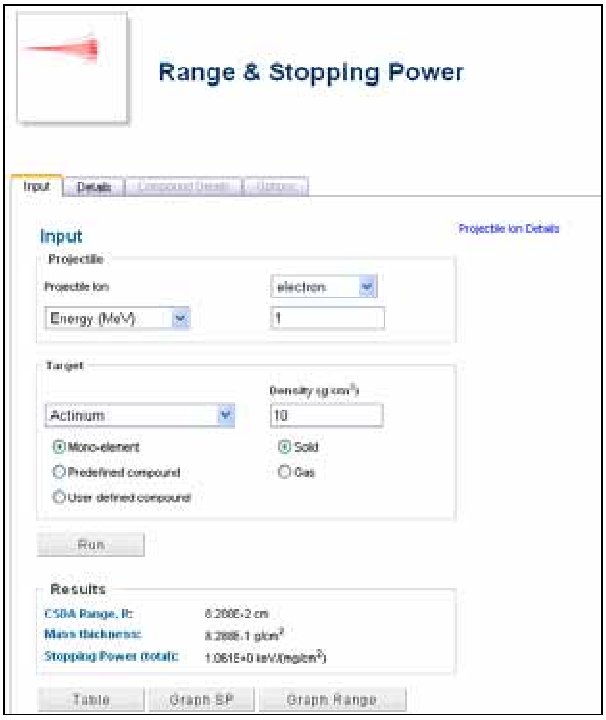


Fig 3. Main page of the Range module showing the input and summary results.

In addition to the summary results shown in Fig. 3 for a particular energy, the Range module creates a table of results for a wide energy range. This Table (button is shown at the bottom of Fig.3) contains projectile energy, electronic and nuclear stopping powers, the range, and the longitudinal and lateral straggling. Additional information is given in the results "Details" shown in Fig. 3. User can also see the graph of stopping power (Graph SP) and range (Graph Range) for the calculation. More details of the Range module can be found in Nucleonica Wiki [4].

3. Calculation Method and Theories Behind Range Module

The Range module uses different calculation methods depending on the type of the projectile. Mainly the SRIM [5] "engine" is used for heavy ions as well as alphas and protons. SRIM is a well known computer program developed by J.F. Ziegler and Biersack for the calculation of stopping power and range. This program includes many different methods including fitting to the experimental results. A detailed description of the calculation method can be found in *The Stopping and Ranges of Ions in Solids* [6].
In addition, we have used our codes for the calculations for electron, positron and muon projectiles. These calculations depend on previously developed and published methods. For electrons and positrons our codes are based on the work of H. Gümüş et al. [7,8]. Because the positron has the same mass and a charge opposite that of the electron, the structure of a positron track in matter is frequently assumed to be similar to that of an electron, so stopping power is calculated in a similar way to that of the electron. The Stopping Power calculation for electrons (or positrons) which are traversing through matter is similar to that of heavy charged particles. The interaction of incident particles with target electrons can be calculated from Bethe’s theory, and this gives rise to the “Collisional Stopping Power”. The interaction between incident particles (electrons or positrons) and target nucleus results in Bremsstrahlung, and this gives rise to the “Radiative Stopping Power”. The collisional stopping power of matter is calculated by considering the effective charge approximation. When charged particles are accelerated or decelerated, they radiate and the energy of this

radiation can be any value from 0 to the energy of incident particles. This is the source of the radiative stopping power or Bremsstrahlung. This is more important especially for fast electrons (or positrons), since the mass of electron is much lower than that of nucleus it is accelerated more rapidly when it is in the coulomb field of nucleus. The strength of Bremsstrahlung depends on the target's atomic number (Z), and it is proportional to Z^2 and also proportional to incident energies. On the other hand, the collisional stopping power is proportional to Z. So, the ratio of the radiative stopping power to the collisional stopping power is approximately given by

$$\frac{S_{rad}}{S_{coll}} = \frac{ZE}{800} \qquad (1)$$

at high energies (more than 10 MeV), and E is the energy of the incident electrons in units of MeV. At high energies, this ratio can be used to calculate the radiative stopping power. The RANGE module uses this ratio to calculate radiative stopping power.

The muon is an elementary particle whose charge (-1 e) and spin (1/2) are equal to that of the electron. It is sometimes regarded as a "heavy" electron, because its mass is 207 times the electron mass and its interactions with matter are very similar to those of electrons. Muon interactions with matter differ significantly from electron interactions purely as a result of its much greater mass. For example the stopping power for electrons, particularly in the high energy regime, is dominated by the bremsstrahlung process, which is not the case for muons unless the energies are in the multi-GeV range. On the other hand, in this multi-GeV regime, radiative processes are more pronounced than for other heavy charged particles and ions. The Range module uses Bethe-Bloch equation for muons [9] for the calculation of stopping power.

Most of the transport calculations and Monte Carlo simulations for the calculation of Range are based on the so-called **C**ontinuous **S**lowing **D**own **A**pproximation (CSDA). In this approximation, it is assumed that the particle loses its energy in a continuous way and at a rate equal to the stopping power. Since the stopping power is the energy loss of projectile per unit path, CSDA range (or Bethe range) is calculated by

$$R(E) = \int_{E_{abs}}^{E} \frac{dE'}{S(E')}$$

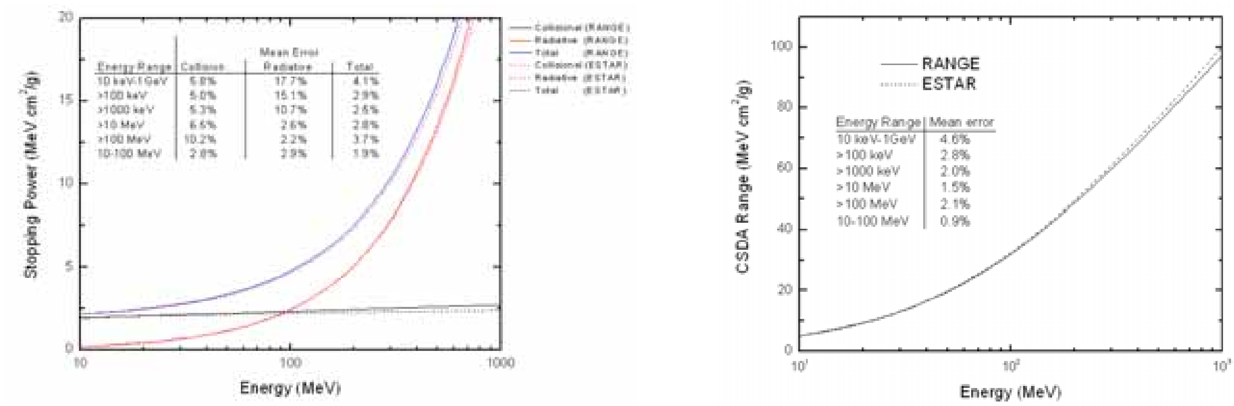
where E_{abs} is the energy where particle is effectively absorbed. The CSDA range is the path length travelled by the particle and since energy-loss fluctuations are not considered, the CSDA range is always higher than projected range (R_p) which is the distance between the point where particle enters the stopping medium and the point where particle is absorbed (or comes to rest). It becomes important when the projectile's energy is low enough. For electrons, positrons and muons, the Range module uses this approximation to calculate the range of the projectile in the matter.

4. Accuracy of the Range Module

To determine the accuracy of the Range module results, we have compared our results with various results in the literature. For electrons, protons and alphas in gas, solid and liquid phases for mono element and compound targets, we compared our results with the results obtained from the STAR program groups [10]. STAR program groups include three different stopping power and range calculation programs: ESTAR for electrons, PSTAR for protons and ASTAR for alphas. These programs were developed at the NIST. For positrons, we compared our results with the results given in ICRU 37 report [11]. For muons, we compared our results with the results given in Ref. [9]. The Range module uses SRIM for heavy particles with a known accuracy of less than 5%.

Test results show that agreements are less than 5% for protons and alphas, less than 10% for electrons and positrons, and less than 7% for muons. These results show the mean error and are for the total stopping powers and the CSDA Ranges.

For electrons and positrons, agreement is better than these results for collisional stopping power, however, for radiative stopping power mean error is higher because we use the simple ratio (Equation 1) to calculate the radiative stopping power.
For muons, the Range module uses the formulation which is indicated at the work of Groom et al. [9]. Because we calculate the stopping power at the energies below 1 GeV, we have calculated only collisional stopping power. However, the radiative stopping becomes important at high energies, so one must calculate also radiative stopping power. On the other hand, radiative stopping power is important above 100 GeV in almost all matter. This shows that our calculation can be also used at the energies above 1 GeV for muons.
Below, we give the graphs of the results of Range module for electrons in water as an example. The graphs include mean errors in Range module. Results for other projectiles and targets are given in the Nucleonica wiki [4].



(a) (b)

Fig 4. Range module results for electrons in water (liquid):
(a) the stopping power of water (liquid) (b) the range of electrons

5. Conclusions

The Range module in Nucleonica provides a user-friendly interface for quick and accurate calculations on the range and stopping powers of charged particles - electrons, positrons, protons, alphas, muons and heavy ions - in matter. Target materials include the natural elements, pre-defined and user-defined compounds. In addition, the user can also select the energy and stopping power units, etc. Range and stopping power results can be displayed in high quality graphs. The Range module can be used in the Nucleonica scripting language [12]. A detailed description of the Range module and the underlying theory is given in online Help in the NucleonicaWiki.

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NUCLEONICA – SOFTWARE DESIGN PATTERNS

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ABSTRACT

NUCLEONICA is the latest development in a family of information systems for the nuclear science community. Throughout this contribution some aspects of the internal structure of NUCLEONICA are described, in order to show the flexibility of the software architecture. In a typical 3-tier architecture it combines efficient databases with modern rich internet presentation techniques and a modular structure. Based on the Microsoft .NET framework it is well-suited to provide the ease of use today's computer users have come to expect. It is shown how web server, webservices, application libraries and the database repository are smoothly integrating with third party applications like MediaWiki that is used as a general help facility and as an interactive Q&A discussion forum.

1. Introduction

The evolution from the first predecessor through to NUCLEONICA reflects the software technical paradigm change from fat clients to a modern web application using latest Web 2.0 technology. NUCLEONICA's modular structure with the idea of *Software as a Service* in mind is well suited for integrating newly developed application modules such as the radiological dispersion module as well as well-known legacy codes such as KORIGEN [1] for nuclide depletion calculations in nuclear reactors. It was even possible to integrate an open-source framework like Mediawiki [2], being built on Apache, PHP and a mySQL database. Despite totally different code bases and database requirements a common single-sign-on for all applications could be realized.

The idea of providing an electronic knowledge base of physical nuclide data has a long history. There are two predecessor applications of NUCLEONICA each using a unique software technical approach – due to the technical possibilities and habits existing at the time, Nuclides 2000 [3] was a fat client Visual Basic application that installed on Windows PC's and was distributed on CD-ROM. It consisted of a database of nuclear data (Microsoft Access) and several applications, e.g. Nuclide Explorer (with far less functionality than in NUCLEONICA) and a decay engine. In that approach, updates weren't easily possible (new CD-ROMs had to be produced) and the platform was restricted to Windows based PCs. All algorithms were frozen to the scientific state when the CD-ROM was produced.

The next step towards web technology came with Nuclides.net in 2003 [4]. Still produced on CD-ROM with similar a design approach as that of Nuclides 2000, it shifted the applications part such as Decay Engine to a web application server at ITU in Karlsruhe, thus providing the possibility to keep step with the improving scientific models.

NUCLEONICA [5] now broke completely with the CD-ROM based approach through being accessible completely from the World Wide Web. Since there is no need to install software,, the applications open up also to Mac and UNIX users. The database information is always up to date and there's no longer need to support users with installation problems or to distribute updates in case of program flaws. A major challenge however was the need to provide the necessary performance, because all concurrent users share the same central systems.

2. Modular architecture based on .NET

NUCLEONICA consists of four layers. The website itself is an ASP.NET 2.0 web application. It uses an SQL Server 2005 database, several DLLs (green) and services (red) that run on the same machine.

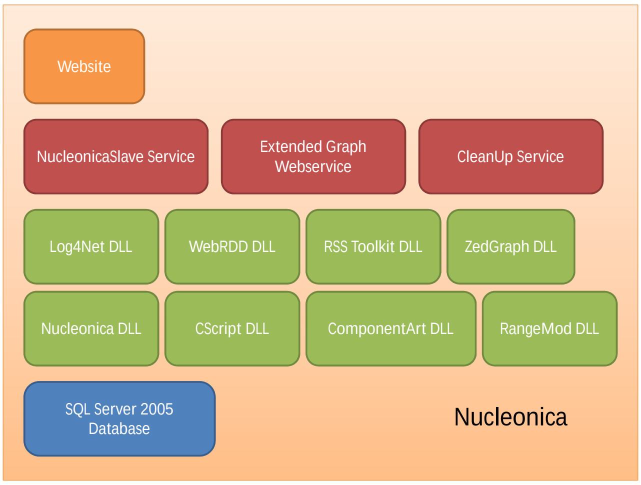

Fig. 1: NUCLEONICA Modular Architecture

Website	The ASP.NET pages the NUCLEONICA website consists of.
NucleonicaSlave	Long running asynchronous background executions
Extended Graph Webservice	Customizable generation of graphs, wraps ZedGraph.DLL
CleanUp Service	Housekeeping of temporary files
Log4Net DLL	Library for writing to the Windows event log (Error Handling)
WebRDD DLL	Library for computations in the RDD module
RSS Toolkit DLL	Library for RSS syndication
ZedGraph DLL	Library for graph generation (e.g. common graphics control)
Nucleonica DLL	Library for computations in most application pages. Common functionality like database access and collection types.
CScript DLL	Library for the NUCLEONICA Scripting Language components
ComponentArt DLL	3rd party library with enhanced user interface controls
RangeMod DLL	Library for Range & Stopping Power application
SQL Server 2005	Database server

Tab 1: NUCLEONICA modules and functionalities

The NUCLEONICA website shares a common look and feel on almost every web page. This is implemented via separate files, such as for a header and footer. Master pages are flexible page-templates allowing to "skin" and control the layout of the entire website by modifying a single template. This "visual inheritance" reduces maintenance and the overall complexity of the entire website.

NUCLEONICA uses a set of third party AJAX controls by ComponentArt [6], a vendor specializing in the creation of user interface and data visualization software for Microsoft's .NET platform. AJAX (**A**synchronous **J**avaScript **a**nd **X**ML) is a way of including content in a web page in which JavaScript code in the web page fetches some data from a server and displays it without re-fetching the entire page. The data fetched is often in XML format.

The Microsoft .NET Framework uses a managed code programming model. It consists of two main components, the common language runtime (CLR) and the .NET Framework class library. The evolution process from Nuclides 2000 to NUCLEONICA includes a variety of grown, highly complex, nuclear scientific class libraries and applications. These had to be made accessible for the fully web-based NUCLEONICA. The challenge of integrating libraries written in various programming languages into NUCLEONICA while ensuring the security, robustness and stability of the legacy code reinforced the decision for the .NET Framework. Another essential point was the cross-language compatibility of Microsoft .NET. A multitude of developers contribute to the steady evolving progress of NUCLEONICA, each of them using the programming environment best suited to his task.

3. Web 2.0 – a gimmick or a vision?

Web 2.0, far from being merely a buzz-word of modern information technology, comprises some highly interactive, individually tailorable design patterns that aim at providing an interlinked computing platform by making use of the internet not only as an information resource but also as a scientific networking platform. *"…Web 2.0 is of course a piece of jargon, nobody even knows what it means*". Tim O'Reilly, known as the founder of O'Reilly Media, coined the term Web 2.0 in 2004 encompassing a new generation of web based services – such as wikis, communication, social networking and collaborative tagging. Seeing the internet as a participation platform he understands Web 2.0 as a new way of collaborating, collecting, constructing and experiencing in the World Wide Web. The constantly emerging techniques and features of modern web applications range from content syndication to interactive rich user interfaces. The evolution from Nuclides.net to NUCLEONICA, a fully web based portal service, opened the chance to involve the user more into the application. The following approaches are realized in NUCLEONICA:

Feature / Technique♣	Example
Rich Internet Application	- Nuclide Selector - Nuclide Explorer - Alerting Service - NUCLEONICA Portal
Content Syndication and Collaboration	- NUCLEONICA [Wiki] - ITU Nuclear News - NUCLEONICA Hot Topics - Conference Calendar
Social Networking	- NUCLEONICA Community Portal

Tab. 2: Web 2.0 Features of NUCLEONICA

The main goal was to combine rich and user-friendly interfaces with the approach of a web based scientific application suite, as well as an embedded social network for nuclear science experts.

Rich Internet Application

The combination of AJAX driven controls, customizable services and user-friendly user interfaces grants a highly flexible browser-based application. One of the frequently used controls - the "Nuclide Selector" - offers an AJAX-based way of selecting the nuclides for further processing.

Fig 2: Nuclide Selector Control

In the first step the element is selected. This causes an AJAX *callback* to retrieve the mass numbers according to the element directly from the database. The selection of the desired mass number then initializes the *postback* to the server. Another usage of AJAX (on the server side) is the alerting control. This control notifies the logged in user about finished calculations, recent postings and messages. In these examples AJAX technology inconspicuously enhances the user interface without overloading and complicating it.

Content Syndication and Collaboration

The modern internet user not only acts as a consumer, but also as a contributor and/or producer. Therefore it was crucial to be aware of the relevance of user generated content (UGC). NUCLEONICA meets these requirements by offering the NUCLEONICA [Wiki] and the Conference Calendar. Users can exchange knowledge, information, support and events, resulting in a constantly growing mine of information – a benefit to all users. Beyond that NUCLEONICA provides a wide variety of nuclear news that can be accessed from the application or via the ITU Nuclear News Feed. The ITU nuclear news and the NUCLEONICA Hot Topics are distributed via Real Simple Syndication (RSS). RSS allows a user to subscribe to a page, not just to be linked to it. So, one is notified every time the pages changes or news are added. This makes NUCLEONICA a “live” application.

Social Networking

Another part of NUCLEONICA is the social network. Inside NUCLEONICA users can link and communicate with each other based on their common interests or scientific experiences. The network enables users to keep track of their contacts, groups and events.

4. Software as a service

Performance being an important issue with server based computing, it was necessary to have NUCLEONICA as modular as possible. The design goal bears in mind the possibility to distribute different parts of the application to different servers for load sharing and high availability issues.

The database (Microsoft SQL Server) runs totally independently and can easily be moved to another server without any code change due to the use of the .NET database interface.

Images such as graphs produced by the particular applications (Decay engine, Dosimetry and Shielding, etc.) have to be rendered in formats suitable to web browsers on one side. On the other hand it was also a design goal to support scientists with graphs of a quality appropriate for further uses such as in presentations or publications. For this purpose NUCLEONICA developers chose the freeware package ZedGraph [7] that was natively designed for Microsoft .NET and turned out to be extremely fast and produces graphs of convenient quality. It fits smoothly into the interfacing model of multi-instance applications without user interface that are typical running on a back-end server. As a consequence NUCLEONICA offers the ability to produce nice graphics not only as part of the nuclear applications but as a service for any type of data through the Extended Graph module. Moreover, in a next step this service will be offered as a webservice enabling scientists to make use of NUCLEONICA as part of their own local applications. As a proof of concept there’s already a plug-in for Microsoft Excel calling NUCLEONICA webservice for generating graphs (see Fig. 3). In future versions it is planned to provide more applications through webservice interfaces.

Long-running applications are tedious to the user especially in a web environment where one tends to consider everything that lasts longer than a few seconds as ”stuck“. The possibility of running complex computations asynchronously in the background and informing the user about results through email alerts underlines this service character of NUCLEONICA.

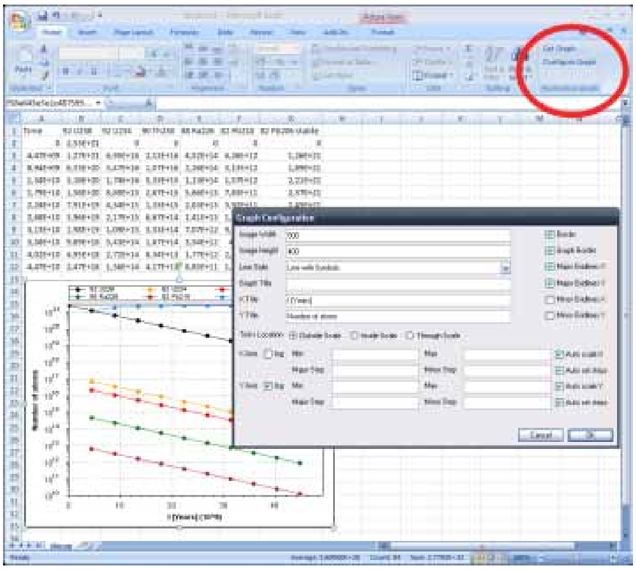

Fig. 3: Excel Plug-In for NUCLEONICA

5. Legacy Applications – don't re-invent the wheel!

Implementing NUCLEONICA as a web application was a major issue that should be made easier by re-using as much existing code as possible – both as far as system modules and libraries are concerned, and on the other hand as for nuclear and physical application modules.

As an example NUCLEONICA [Wiki] relies on the existing and well-proven technology of MediaWiki (itself built on the components of the freeware meta-package XAMPP Lite [8]). However extensions were implemented to realise for example the Single-Sign-On capability between NUCLEONICA (a .NET application) and MediaWiki, a PHP application. The NUCLEONICA user profits by not having to log in to the Wiki when coming from NUCLEONICA. Another example is the ZedGraph package (see above).

Scientific legacy code is built into the integrated nuclear software models. The webKorigen module for example is a piece of software developed over many decades. This module was integrated and combined with a modern web user interface.

Keeping in mind flexibility NUCLEONICA users are encouraged to integrate their own legacy algorithms. The integrated scripting language NUCLEONICA script, a dynamically parsed C like programming language offers access to all necessary database fields of the integrated nuclear knowledge base. It comprises all necessary language elements to write own code making use of the data and also of the integrated applications up to presenting textual and graphical results.

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[5] http://www.nucleonica.net
[6] http://www.componentart.com/webui/
[7] http://zedgraph.org/
[8] http://www.apachefriends.org/en/xampp.html

International Developments in Nuclear Education and Training

CHALLENGES FOR EURATOM RESEARCH AND TRAINING IN THE FRAME OF THE EUROPEAN "HIGHER EDUCATION" AND "RESEARCH" AREAS

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ABSTRACT

In this key note lecture, the following questions will be addressed (see Figure 1):

1)*What are the challenges for Euratom Research and Training in the frame of the European "Higher Education" and "Research" Areas ?*
and who are the main stakeholders ? (end-users with common needs, decision makers with a common vision, institutions with implementation instruments)

2)What kind of response is offered by the Euratom RD&DD and E&T programmes in nuclear fission and radiation protection ?
and what is their scientific and societal impact ?
- RD&DD or RD3 for short = Research, technological Development, and engineering Demonstration, industrial Deployment (also called *Innovation Cycle*)
- E&T = Education and Training

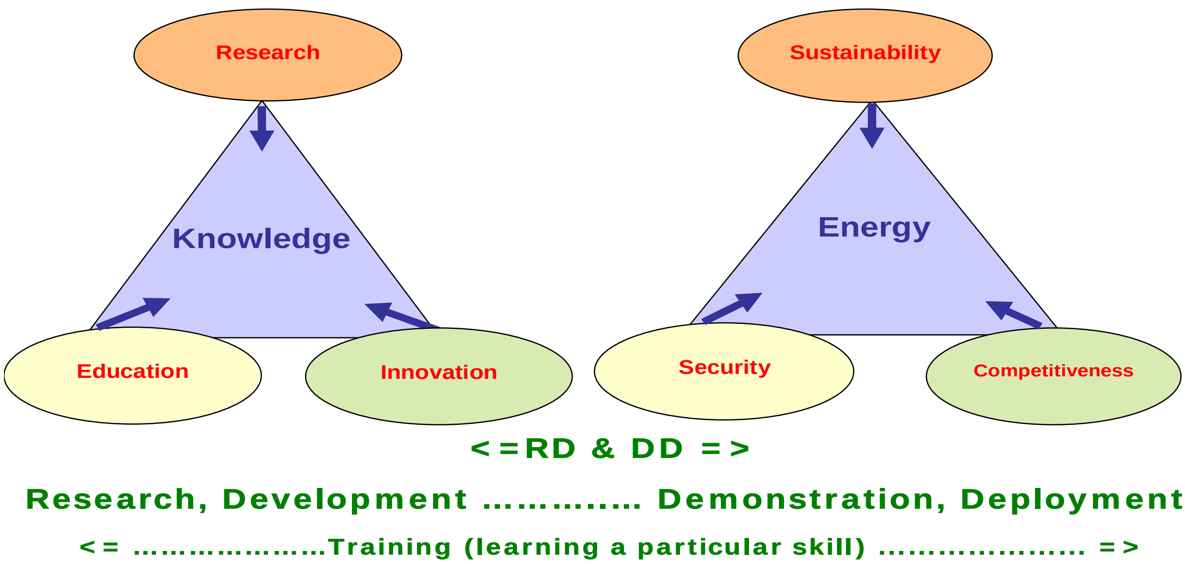

Figure 1 - “Knowledge Triangle” (*research & development*) and "Energy Triangle" (*demonstration & deployment*) + Education and Training (learning a particular skill)

1. INTRODUCTION / INNOVATION CYCLE / HOLISTIC APPROACH FOR RESEARCH-DEVELOPMENT AND DEMONSTRATION-DEPLOYMENT (RD&DD) AND EDUCATION AND TRAINING (E&T)

The globalization that has swept away the barriers to the movement of goods, ideas and people affects naturally the development of research and training. A new approach is required for programmes at both national and EU level. In this context, the concept of sustainability plays a major role. The EU definition of sustainability is very close to that of Mrs Gro Harlem Brundtland, the former Prime Minister of Norway. This definition was proposed in 1987 at the World Commission on Environment and Development (also called the *Brundtland Commission*). It describes sustainable development as: "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*.

Sustainable Development Strategies are implemented world-wide. At the EU level, it is worth recalling the recent first "*Progress Report on the Sustainable Development Strategy (SDS) 2007*" – see EC Communication COM(2007) 642 [1]. The related EU policy has identified seven key sustainability challenges, which will be the subject of annual progress assessment reports [2], namely:

1. *Climate Change and Clean Energy* (including nuclear, the main subject of this lecture)
2. Sustainable Transport
3. Sustainable Consumption and Production
4. Conservation and Management of Natural resources
5. Public Health
6. Social Inclusion, Demography and Migration
7. Global poverty.

In the general debate in the EU-27 about innovative technologies for *Climate Change and Clean Energy*, there are two types of challenges:

- scientific and technological (S/T) *challenges* related to *research* and technological *development:* the main instrument provided by the EU is the Framework Programme
- economic and political (E/P) *challenges* related to engineering *demonstration* and industrial *deployment*: the main instruments are economic and regulatory incentives.

To implement innovative technologies for *Climate Change and Clean Energy* in Europe, the governments, in collaboration with the EC and the main stakeholders, should develop, in particular, a common research and training strategy, that is:

(a) identify the end-users and their common needs (bottom up action)
(b) converge to a common vision amongst the main stakeholders (top down action)
(c) develop and apply implementation instruments at both EU and national level.

As a result, the governments and the EC are expected to act as:

- *initiator* of ambitious *research and development* programmes: e.g. to orient public funding to visionary research and training programmes (basic as well as applied) on well targeted issues with potential breakthroughs, based, in particular, on large research infrastructures of common interest

  (S/T challenges related to *research* and technological *development /RD/*)

- *financial investor* for *demonstration and deployment* programmes: e.g. to support and facilitate large financial investments, especially during the transition period between two

[1] http://ec.europa.eu/sustainable/docs/com_2007_642_en.pdf

[2] http://ec.europa.eu/environment/eussd/

technological steps (in particular, when going from the current traditional economy to the future "*clean, clever and competitive*" economy)

(E/P challenges related to engineering *demonstration* and industrial *deployment /DD/*)

- *regulator* to ensure that the *citizens' interests* are defended and that the *industrial competition* is fair (level playing field at both national and international level): e.g. establish a common European framework for the mutual recognition of best practices for safety culture, risk governance, codes and standards.

RD&DD programmes have the most chances of success if they can take advantage of a working environment that meets the following conditions (examples are given between brackets for the specific case of *innovation in nuclear fission technologi*es):

- *objective* (i.e. clear allocation of responsibilities between industry and regulators; between promoters of innovation, RTD performers and potential customers, etc)
- *consistent* (i.e. level playing field for all nuclear actors across the Community, convergence or mutual recognition of technical and radiological safety practices, etc)
- *predictable* (i.e. no unexpected requirements from the authorities or from the market, reasonably favourable public opinion, stable international political climate, etc).

In the EU, the RD&DD programmes, tackling the above challenges, are naturally related to the policies for Research and Energy. Community Research, however, is not conducted for the sake of research for research, but as a support to EU policies, in particular, to the Energy policy. This is illustrated in Figure 1 in the form of two policy triangles:

- the "*Knowledge Triangle*" (EU policy for research, innovation and education, with emphasis on RD, that is: Research and technological Development) - see FP-7 strategy in "*Building the ERA of knowledge for growth"* [3] COM(2005) 118 and FP-7 budget in "*Financial perspectives 2007 – 2013*" [4]
  (ERA = "*European Research Area*", launched in the context of the *Lisbon Strategy*, European Council of 23-24 March 2000)

- the "*Energy Triangle*" (EU policy for security of supply, sustainable development and competitiveness of energy, with emphasis on DD, that is: engineering Demonstration and industrial Deployment) - see the Energy Package announced in the EC Communication "*An Energy Policy for Europe*" [5] (EPE, 10 January 2007), subsequently endorsed by the European Council of 8-9 March 2007 .[6]

2. TOWARDS THE "EUROPEAN HIGHER EDUCATION AREA": A SINGLE UMBRELLA FOR EDUCATION AND TRAINING PROGRAMMES (2007 – 2013) / "ERASMUS" FOR HIGHER EDUCATION (DG EAC)

In the EU, education is in principle an exclusive competence of the Member States. Therefore the role of the EU is "limited" to develop the European dimension in education, in particular, by encouraging mobility of students and teachers (e.g. academic recognition of diplomas - see ERASMUS below) and by promoting co-operation between educational establishments.

Education is mentioned in a general social clause in the recent "*EU Reform Treaty*" of Lisbon (signed on 13 December 2007 by the representatives of the 27 Member States and ratified

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[3] http://ec.europa.eu/research/era/index_en.html

[4] http://ec.europa.eu/financial_perspective/index_en.htm

[5] http://ec.europa.eu/energy/energy_policy/doc/01_energy_policy_for_europe_en.pdf

[6] http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/93135.pdf

by 5 Member States as of 8 February 2008, namely: Hungary, Slovenia, Malta, Romania and France). Here is an excerpt of Article 5a:
"In defining and implementing its policies and activities, the Union shall take into account requirements linked to the promotion of a high level of employment, the guarantee of adequate social protection, the fight against social exclusion, and a high level of education and training as well as protection of human health."

In this context, the EU launched in 2007 the *Lifelong Learning Programme* (LLP), as a single umbrella to integrate all educational and training initiatives that were originally organised by DG Education and Training (EAC) through the SOCRATES Programme 2000 - 2006. The budget is nearly EUR 7 billion for 2007 to 2013. This new EU programme replaces the existing education, vocational training and e-Learning programmes, which ended in 2006 [7].

The LLP enables individuals at all stages of their lives to pursue learning opportunities across Europe. It consists of four "sectoral" sub-programmes:

- **Comenius** addresses the teaching and learning needs of all those in pre-school and school education
- **Erasmus** addresses the teaching and learning needs of staff and students in Higher Education. It also provides support for institutions across Europe to work on shared projects, including curriculum development and other areas
- **Leonardo da Vinci** enables people who are involved in vocational education and training to benefit from work experience placements and career development opportunities in another country
- **Grundtvig** focuses on adult education and funds small-scale, community-based activities.

A transversal programme complements these four sub-programmes in order to ensure that they achieve the best results. Finally, the **Jean Monnet programme** stimulates teaching and reflection on the European integration process at higher education institutions worldwide.

As regards the four sectoral programmes, quantified targets have been set in order to ensure a significant, identifiable and measurable impact for the programme, namely:

- For **Comenius** (school education): to involve at least three million pupils in joint educational activities, over the period of the programme
- For **Erasmus** [8] (higher education): to contribute to the achievement by 2012 of three million individual participants in student mobility under the present programme and its predecessors (reminder: the first ERASMUS programme started in 1987)
- For **Leonardo da Vinci** [9] (vocational training): to increase placements in enterprises to 80 000 per year by the end of the programme
- For **Grundtvig** (adult education): to support the mobility of 7 000 individuals involved in adult education per year, by 2013.

Certain parts of the above EU's programmes are treated by *executive agencies*. The Education, Audiovisual and Culture Executive Agency (EACEA [10]) is responsible for centralised actions: *Multilateral Projects and Networks, Observation and Analysis, Operating grants, Unilateral and National Projects (Transversal Programme & Jean Monnet) and Accompanying Measures*. Fully operational from the 1st of January 2006, this Executive Agency operates under supervision from its three parent Directorates-General: *Education*

[7] http://ec.europa.eu/education/programmes/llp/index_en.html

[8] http://ec.europa.eu/education/programmes/llp/erasmus/index_en.html

[9] http://ec.europa.eu/education/programmes/llp/leonardo/index_en.html

[10] http://eacea.ec.europa.eu/index.htm

and Culture (DG EAC), *Information Society and Media* (DG INFSO) and the *EuropeAid Cooperation Office* (DG AIDCO). National agencies have also been created in 31 countries: they are responsible for decentralised actions, such as Partnerships and individual Mobility [11].

As a way of reminder, the aim of the ERASMUS programme (started in 1987, first discussions on ECTS) was to encourage transnational cooperation between universities, to boost European mobility and to improve the recognition of studies and qualifications throughout the Union. The ECTS is the "*European Credit Transfer and accumulation System*" that underlies the mutual recognition mechanism of ERASMUS: it is actually based on the student work load required to achieve the objectives of the programme. More ambitious goals were then fixed in the Bologna declaration, signed in 1999 by the Ministers of Education from 29 European countries in the Italian city of Bologna (actually the current EU-27 countries – Cyprus + Switzerland, Norway and Iceland).

The purpose of the Bologna process (or Bologna accords) is to create the *European higher education area* (EHEA) by making academic degree standards and quality assurance standards compatible throughout Europe. It has gained in popularity year on year - from a modest number (3000) of undergraduate students in 1987 to 150 000 in 2006 (cumulating in a total of more than 1.2 million students over the period 1987 – 2006). The scheme in 2006 covered 2200 higher education establishments (that is: 90 % of their total) in 31 countries. The EU budget of ERASMUS for 2000-2006 amounts to around EUR 950 Mio (of which EUR 750 Mio for students grants). As of May 2007, the ERASMUS programme is targeted at the students and staff of the higher education institutions in all 27 Member States of the European Union, Switzerland, the three countries of the European Economic Area (Iceland, Liechtenstein and Norway), as well as Turkey, Cyprus and Croatia since 2001, plus another 12 countries (including Albania, Andorra, Bosnia and Herzegovina, Holy See, Macedonia, Russia, Serbia and Montenegro since 2003).

Of particular relevance to Erasmus is the Erasmus Mundus (EM for short) programme, with more ambitious objectives, especially regarding cooperation with Third Countries. As a way of reminder, a "Third Country" means a State other than an EU Member State and other than Associated Countries to the relevant Community Programme. Both Erasmus and EM programmes contribute to the realisation of the Bologna aims, in particular by promoting student mobility and through the development of the ECTS credits system. This facilitates mobility through the accreditation and mutual recognition of study periods abroad. Erasmus can be undertaken at undergraduate, Masters and PhD levels. However, there are clear distinctions between Erasmus and EM. While Erasmus is a mass mobility programme which has supported over 1 million students since 1987, EM has been designed as an excellence programme with scholarships available on a more competitive basis. The percentage of successful applications to EM over the period 2004 – 2006 was approximately 14 %.

The Erasmus Mundus programme is actually a co-operation and mobility programme in the field of higher education which promotes the EU as a centre of excellence in learning around the world. The Erasmus Mundus programme was launched in 2004 and has since supported 80 joint master courses with over 4 000 students from approximately 60 third countries (in particular, China, Brazil and Russia), gaining a scholarship to obtain a Masters degree in Europe. A further 23 Masters Courses will become operational in 2008. The Erasmus Mundus programme provides a response to the challenges of globalisation faced by European higher education today, in particular the need to adapt education systems to the demands of the knowledge society, to enhance the attractiveness and visibility of European higher education world-wide and to stimulate the process of convergence of degree structures across Europe. These themes are central to current national reform processes in higher education taking place in Member States.

[11] http://ec.europa.eu/education/programmes/llp/national_en.html#benl

The Erasmus Mundus programme comprises four Actions:

- *Erasmus Mundus Masters Course* (that is: top-quality Masters Courses of between one and two years offered by a group of higher education institutions, leading to a master degree - selected Masters Courses must be attended by European graduate students as well as by a specific number of third-country graduate students and scholars)
- *Scholarships* (that is: funds to the selected Erasmus Mundus Masters consortia)
- *Partnerships* (that is: partnerships between Erasmus Mundus Masters consortia and third-country higher education institutions)
- *Enhancing attractiveness* (that is: dealing with the mutual recognition of qualifications with third countries).

The current Erasmus Mundus programme covers the period 2004 - 2008 and has an overall budget of EUR 230 million. After three successful academic years (2004-2006), the EC adopted in 2007 a proposal to launch the new generation of the Erasmus Mundus programme for the period 2009-2013: just over EUR 950 million will be available for European and third-country universities to join forces in joint programmes and to grant scholarships to European and third-country students for an international study experience [12]. An interim evaluation report was published in June 2007 [13]

As far as third-country assistance is concerned, the Erasmus Mundus External Co-operation Window (EM ECW) [14].should be mentioned. It is a co-operation and mobility scheme in the area of higher education co-operation launched by Europe Aid cooperation Office and implemented by the above mentioned EACEA. Its objective is to exchange persons, knowledge and skills at higher education level between the EU and third countries such as Belarus, Moldova and Ukraine.

Linkages with other EU programmes in the field of higher education

In addition to the above-mentioned Lifelong Learning Programme 2007-2013 (including Erasmus and EM), there are a number of other EU-financed programmes that seek to foster closer cooperation with third countries in the field of higher education. A summary overview of some of the most relevant programmes is provided below:

- the Atlantis (formerly known as the EU-US co-operation programme) and EU-Canada cooperation programmes in the field of higher education and vocational training as well as pilot co-operation projects in higher education with Japan and Australia, which aim to improve the quality of human resource development.
- the ALBAN programme (a programme of high-level scholarships in Europe for Latin America) provides scholarships for postgraduate studies for Latin America professionals/future decision-makers in EU institutions. Between 2003 and 2007, more than 3 300 applicants from 18 Latin American countries were selected to receive an Alban scholarship. This programme will now be merged within EM.
- ALFA (América Latina - Formación Académica) is a programme of co-operation between higher education institutions (HEI) of the EU and Latin America to develop systematic and lasting partnerships including a mobility component.
- the Asia-Link programme helps develop partnerships and sustainable links between higher education institutions in Europe and specific Asian countries to promote regional and multilateral networking.

[12] http://ec.europa.eu/education/programmes/mundus/projects/index_en.html

[13] http://ec.europa.eu/education/programmes/mundus/doc/evalreport_en.pdf

[13] http://eacea.ec.europa.eu/extcoop/call/index.htm

- the Tempus [15] programme (a Trans-European Mobility scheme for University Studies) enables universities from EU Member States to co-operate with 26 partner countries from the Western Balkans, Eastern Europe and Central Asia, and the Mediterranean partner countries in higher education modernisation projects. In the past 17 years, Tempus has funded 6 500 projects, involving 2 000 universities from the EU and its partner countries. Currently, the budget over 2007 - 2013 is EUR 50 million.
- Directorate-General for Research (DG RTD) manages various programmes which support co-operation between higher education institutions at the doctoral and research level, such as the PEOPLE programme (ex-Marie Curie) – Section 3.

Many of the above EU third country oriented programmes in the field of higher education use the new Instruments of the EU (in particular, DG Europe Aid). For example, the Tempus IV programme for the Western Balkan countries is a part of the *Instrument for Pre accession Assistance* (IPA). Countries of Eastern Europe (e.g. Russia, Ukraine), North Africa (e.g. Morocco) and the Middle East are covered by the *European Neighbourhood and Partnership Instrument* (ENPI). Countries from the Central Asian region receive assistance from the *Development and Cooperation Instrument* (DCI).

Nuclear Education and Training projects under ERASMUS (overview 2005-2007) [16]

(1) EMRP - *European Master in Radiation Protection* [17]
(Erasmus Curriculum Development project, coordinated by UJF Grenoble)
- partners = UK, CZ and FR / grant amount = EUR 180 K / approved budget = 310 K

(2) SPERANSA [18]- *Stimulation of Practical Expertise in Radiation and Nuclear Safety*
(Erasmus Intensive Programme, coordinated by Czech University in Prague)
- partners = DE, ES and BE / grant amount = EUR 18 K / approved budget = 25 K
= CHERNE "*Cooperation in Higher Education on Radiological and Nuclear Eng*."

(3) EMNT [19]- *European Master in Nuclear Technology : Decommissioning Waste Management and Non-Power Applications*
(Erasmus Curriculum Development, coordinated by UJF Grenoble)
- partners = 2 x IT, LT and UK / grant amount = EUR 146 K / appr. budget = 220 K)

(4) FUSION-EP [20]– *European Master in Nuclear Fusion Science and Engineering Physics*
(Erasmus Mundus Masters Course by Ghent University / part of Action 1 [21])
- partners (EU + non-EU) = FR, SE, DE and 3x ES plus 2x USA, 2x Russia and China
/ Grant 2006 = 894 000 € (15 000 € consortium + 879 000 € scholarships)
/ Grant 2007 = 852 000 € (15 000 € consortium + 837 000 € scholarships)
/ Application (2008-2009) for non-EU students was open until 1st February 2008/

A list of *National Information and Contact Points* [22] exists for Erasmus Mundus.

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[15] http://ec.europa.eu/tempus

[16] http://eacea.ec.europa.eu/static/en/overview/erasmus_overview.htm

[17] http://eacea.ec.europa.eu/static/en/erasmus/documents/compendium-CD-2005.pdf

[18] http://eacea.ec.europa.eu/static/en/erasmus/documents/Compendium_2005.pdf

[19] http://eacea.ec.europa.eu/static/Bots/docbots/ERASMUS/IC%202006/cd_coord_2004.pdf

[20] http://www.em-master-fusion.org

[21] http://ec.europa.eu/education/programmes/mundus/projects/index_en.html

[22] http://ec.europa.eu/education/programmes/mundus/doc/national.pdf

3. TOWARDS THE "EUROPEAN RESEARCH AREA": A SINGLE UMBRELLA FOR RESEARCH AND TRAINING PROGRAMMES (2007 – 2013) / "PEOPLE" EX – MARIE CURIE ACTIONS (DG RTD)

In the EU, the year 2000 was marked by the launch of the above mentioned *European Research Area* (ERA) [3]. The related EC Communication "*Towards a European Research Area*" proposed ways in which research in Europe could be more effectively organised and coordinated. It is generally accepted that research and training go naturally together.

The Seventh Framework Programme (FP-7, EC research over the period 2007 - 2013) has a total worth of EUR 50 521 million and includes the following specific programmes:

- *Cooperation* – fostering collaboration between industry and academia to gain leadership in key technology areas - EUR 32 413 million (64.2 %)
- *Ideas* – supporting basic research at the scientific frontiers (implemented by the *European Research Council* / ERC) - EUR 7 510 million (14.9 %)
- *People* – supporting mobility and career development for researchers both within and outside Europe (follow-up of Marie Curie actions) - EUR 4 750 million (9.1 %)
- *Capacities* – helping develop the capacities that Europe needs to be a thriving knowledge-based economy (support to infrastructures) - EUR 4 097 million (8.3 %)
- *JRC (non-nuclear)* - EUR 1 751 million (3.5 %).

The 7-th Euratom Framework Programme (FP-7, Euratom research over the period 2007 – 2011, five years duration imposed by the Euratom Treaty) consists in:

- *Nuclear research (Euratom programme)* – developing Europe's nuclear fission and fusion capabilities (RTD and JRC) - EUR 2 751 million (see Table 1 in Section 5).

The FP-7 has three major new elements, as compared with FP-6 (2003 – 2006):

(1) First, the «border» research has its own programme (*Ideas*). The *European Research Council* [23] (ERC) will fund investigator-led, frontier research. It consists of two grant schemes, the *Starting Independent Researcher Grant* and the *Advanced Investigator Grant*. A Scientific Committee was set up in 2005 and the management will be in the hands of a Commission's *executive agency* that should become operational in 2008. Projects submitted to the ERC are proposed by individual teams of researchers and evaluated according to the sole criteria of excellence by high-level panels.

There are several reasons why "basic" or frontier science (as opposed to "applied" science, as in RD&DD) is necessary. Generally, four classes of benefits can be distinguished:

- contributions to culture: e.g. from particle physics to environmental chemistry
- the possibility of discoveries of big economic and practical importance
- spin-offs of industry: e.g. ionising radiations for medical applications
- education and training: e.g. to excite the interest of the younger generations.

Focussing on nuclear fission and/or radiation protection, one could think of "basic" research at EU level, for example, in the following areas:

- basic science tools to improve experimental research (e.g. laboratory testing)
- participation in the NSF driven programme NBIC (nano-, bio-, info- and cognitive)
- basic actinide sciences to optimise the management of long-lived radioactive waste
- mathematical modelling / optimisation of electrochemical processes (radiochemistry)
- multi-scale numerical simulation of irradiation damage effects on fuels and materials
- quantification of the risks associated with low and protracted exposures of radiation.

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[23] http://erc.europa.eu/

(2) Secondly, the number of *European Technology Platforms (ETP)* [24] has increased and at the end of 2007 there were 31 of them. Technology Platforms bring together stakeholders of a strategic area. Their development process is in three stages:

- stakeholders, led by industry, come together to agree on a *common vision* for the technology (over the long term)
- stakeholders define a *Strategic Research Agenda* (SRA) setting out the necessary medium- to long-term objectives for the technology (orientation towards innovation)
- stakeholders mobilise significant human and financial resources (*Deployment Strategy* - DS) to implement the above Strategic Research Agenda.

The more "mature" platforms may propose *Joint Technology Initiatives* (JTI). These are very big projects made of public-private partnership, with a great autonomy, which should be implemented through bodies created under article 171 of the Treaty (that is: requiring a Council's decision). The EU budget of such a project could reach hundreds of million EUR. The pioneering JTIs are *ARTEMIS* (embedded computing systems, budget of EUR 3 billion over 10 years) and *ENIAC* (nano-electronics, budget of EUR 2.5 billion over 10 years): both of them are supported by the DG Information Society and Media and had their first governing board meetings in Brussels on 22 February 2008. They are expected to launch their first calls for proposals by mid-2008. Two other JTIs, the *IMI* (Innovative Medicines Initiative), which will support the development of new medicines, and *Clean Sky*, which will seek to increase the competitiveness of the European aeronautics industry while reducing emissions and noise, are due to be launched soon.

(3) Thirdly, a new *Risk-sharing finance* facility is proposed with the aim to enhance backing for private investors in research projects, improving access to loans from the European Investment Bank (EIB) for large European research actions. In December 2005 a decision was taken to allocate up to EUR 10 billion to this end.

The "Marie Curie Actions", managed by DG Research (RTD), have long been one of the most popular and appreciated features of the Community Framework Programmes for Research and Technological Development. They have developed significantly in orientation over time, from a pure mobility fellowships programme to a programme dedicated to stimulating researchers' career development. The "Marie Curie Actions" have been particularly successful in responding to the needs of Europe's scientific community in terms of training, mobility and career development. This has been demonstrated by a demand in terms of highly ranked applications that in most actions extensively surpassed the available financial support.

In the Seventh Framework Programme, the "Marie Curie Actions" have been regrouped and reinforced in the "PEOPLE" Specific Programme[25]. Entirely dedicated to human resources in research, this Specific Programme has a significant overall budget of more than EUR 4.7 billion over a seven year period until 2013, which represents a 50% average annual increase over FP6. This Programme acknowledges that one of the main competitive edges in science and technology is the quantity and quality of its human resources. To support the further development and consolidation of the European Research Area, this Programme's overall objective is to make Europe more attractive for the best researchers.

The "PEOPLE" Specific Programme will be implemented through actions under five headings:

[24] http://cordis.europa.eu/technology-platforms/home_en.html

[25] http://cordis.europa.eu/fp7/people/home_en.html

- "**Initial training of researchers to improve mostly young researchers**" career perspectives in both public and private sectors, by broadening their scientific and generic skills, including those related to technology transfer and entrepreneurship.

  Funding schemes: *Initial Training Networks* (that is: grants to networks of young researchers, bringing together academia and industry, thereby facilitating the access to facilities, people and potential future employers)

- "**Life-long training and career development**" to support experienced researchers in complementing or acquiring new skills and competencies or in enhancing inter/multidisciplinarity and/or intersectoral mobility, in resuming a research career after a break and in (re)integrating into a longer term research position in Europe after a trans-national mobility experience.

  Funding schemes: *Intra-European Fellowships for Career Development; European Reintegration Grants; Co-funding of Regional, National, and International Programmes*

- "**Industry-academia partnerships and pathways** " to stimulate intersectoral mobility and increase knowledge sharing through joint research partnerships in longer term co-operation programmes between organisations from academia and industry, in particular SMEs and including traditional manufacturing industries.

  Funding scheme: *Industry-Academia Partnerships and Pathways* (that is: exchange of personnel, from post-graduate to "captains of industry", between the private and the public sector, in the context of common research projects)

- "**International dimension**", to contribute to the life-long training and career development of EU-researchers, to attract research talent from outside Europe and to foster mutually beneficial research collaboration with researchers from outside Europe.

  Funding schemes**:** *International Outgoing / Incoming / Reintegration / Fellowships for Career Development; International Staff Exchange Scheme* (that is: individual fellowships for Europeans in the EU or abroad, or for non-Europeans in the EU)

- "**Specific actions**" to support removing obstacles to mobility and enhancing the career perspectives of researchers (e.g. *Marie Curie Awards* and *National Contact Points*).

The *National Contact Points* (NCP [26]) network is the main provider of advice and individual assistance in all Member States and Associated States. As the NCPs are national structures, the type and level of services offered may differ from country to country. In general, the following basic services will be available in accordance with the Guiding Principles agreed by all countries:

- guidance on choosing thematic priorities and instruments
- advice on administrative procedures and contractual issues
- training and assistance on proposal writing
- distribution of documentation (forms, guidelines, manuals etc.)
- assistance in partner search.

4. EUROPEAN "STRATEGIC ENERGY TECHNOLOGY" (SET) PLAN AND "SUSTAINABLE NUCLEAR ENERGY TECHNOLOGY PLATFORM" (SNE-TP): KEEP THE NUCLEAR OPTION OPEN

In response to the conclusions of the European Council of March 2006 (document 7775/06), the Commission adopted the so-called *Energy Package* on 10 January 2007, as it has been already mentioned in Section 1. It was the subject of the Communication *An Energy Policy for Europe* (EPE) [5]. This Energy Package comprises the first *Strategic European Energy Review* (SEER) and a draft Action Plan for the Energy Policy for Europe. The SEER is complemented by in-depth reports on all the main issues concerning climate change and

[26] http://cordis.europa.eu/fp7/ncp_en.html

clean energy, including Renewable Energy, the Internal Gas and Electricity Market, Sustainable Power Generation from Fossil Fuels, Nuclear, Technology, and Infrastructures.

Climate Change and Clean Energy is the first of seven key sustainability challenges identified by the EU (Section 1). Climate change is discussed in the Communication "*Limiting Global Climate Change to 2° Celsius: The way ahead for 2020 and beyond*". The objective is to limit global warming to no more than 2°C (to be compared to 0.76 °C as of today) above pre-industrial temperatures. This means that global emissions of greenhouse gases will have to be stabilised by around 2020 and then reduced by up to 50% of 1990 levels by 2050. Nuclear fission (that can be considered as a "clean energy") is discussed in the PINC Communication "*Illustrative Nuclear Programme for the Community*" [27].

Of particular importance is the Communication *Towards* a *European Strategic Energy Technology Plan*, also dated 10 January 2007 (SET plan) [28] .The aim of the SET plan is to provide an objective perspective on the different energy technologies which will or might become available between now and 2050 to tackle the "energy supply issue" while respecting the environment (CO_2 and GHG free sources) and being competitive. The prospects for market penetration of a series of low carbon technologies will be analysed, be it for electricity/heat conversion or for transport technology. As a result one has a better picture of what are the real chances of the different technologies and what is needed to support their development. This will also contribute to providing the long-term framework that investors need for the deployment of new technologies in the energy market, that is: a working environment that is objective, consistent and predictable (Section 1).

The response of the European Council (in particular, all EU Energy Ministers) to the Energy Package tabled by the Commission is summarized in the conclusions of the Spring European Council of 8 – 9 March 2007 (document 7224/07 "*Europe – succeeding together"*). This new European policy contains clear commitments on GHG emissions, on energy efficiency, on renewable energies and on bio-fuels. Two key targets (of interest for this discussion) were set by the European Council - see Communication *"20 20 by 2020 / Europe's climate change opportunity*", COM(2008) 30 (dated 23 January 2008):

- a reduction of at least 20% in greenhouse gases (GHG) by 2020 – and more (30 %) if other countries go with
- a 20% share of renewable energies in overall EU energy consumption by 2020 (binding target).

At the above March 2007 European Council, the role of nuclear energy was one of the main debating points. The Presidency Conclusions reiterated the established position that it is for each EU nation to decide whether to use nuclear power. As a consequence, nuclear energy is naturally part of the SET Plan. The EU Energy Ministers actually reaffirmed that the EPE should contribute in a balanced way to the following three objectives:

- *increasing security of supply* (nicknamed "Moscow")
- *ensuring the competitiveness of European energy industry so as to provide energy at the best possible prices for citizens and companies and stimulate investments* (nicknamed "Lisbon")
- *promoting environmental sustainability (with emphasis on the objective to limit the rise in global temperatures to 2°C)* (nicknamed "Kyoto").

[27] http://eur-lex.europa.eu/LexUriServ/site/en/com/2006/com2006_0844en01.pdf

[28] http://ec.europa.eu/energy/energy_policy/doc/19_strategic_energy_technolgy_plan_en.pdf

As far as research is concerned, discussions about a long-term RD&DD strategy in nuclear fission and radiation protection started in the Euratom FP-5 (1998 – 2002) project MICANET (Michelangelo network, coordinator AREVA NP) and continued in three Euratom FP-6 (2003 – 2006) projects:

- *SNF-TP (Sustainable Nuclear Fission, 2 years, from October 2006, coordinator CEA)*
- *PATEROS (Partitioning and Transmutation European Roadmap for Sustainable nuclear energy, 2 years, from September 2006, coordinator SCK-CEN)*
- *CARD (Coordination of research, development and demonstration priorities and strategies for geological disposal, 1 year, from Sept. 2006, coordinator NIREX).*

As a result of the above Euratom FP-5 and FP-6 projects, a European Technology Platform (ETP – Section 3) was launched in 2007 to bring together all stakeholders in the area of nuclear fission, focussing on research and development (RD), namely:

(1) Sustainable Nuclear Energy Technology Platform (SNE-TP [29])
- launch event in Brussels on 21 September 2007, platform composed principally of research organisations from both the public and private sectors
- the SNE-TP consists of a General Assembly (biennial meetings), a Governing Board and an Executive Committee that supervises 3 main activities:
    * *Strategic Research Agenda* (SRA)
    * *Deployment Strategy* (DS), including policy framework
    * Knowledge Management and Education & Training (+ scientific evaluation), led by ENEN
- two additional bodies provide input and recommendations to the governing board: the mirror group, providing information to ensure the effective coordination with national programmes, and the technical safety organisations (TSO) group
- the SNE-TP will provide valuable input to the nuclear fission part of the SET Plan
- the SNE-TP could become a *Joint Technology Initiative* (Section 3) if a sufficiently strong private-public partnership is developed and if the proposed *European Research Agenda* and *Deployment Strategy* are endorsed by the main stakeholders in Europe.

In parallel, as a result of the previously discussed EU policies (*Sustainable Development Strategy* and *Energy Policy for Europe*), two other European actions were launched in nuclear fission, focussing on demonstration and deployment (DD):

(2) European Nuclear Energy Forum (ENEF [30])
- launch event in Bratislava on 26 -27 November 2007, forum composed principally of industrial stakeholders and non-governmental organisations (NGOs)
- the ENEF consists of three Working Groups:
    * Opportunities
    * Risks of nuclear energy, including education and training, which is led by EoN ("European Nuclear Trainee Academy" / ENTA proposal) in collaboration with ENEN wherever appropriate
    * Information and transparency issues.

(3) High Level Group (HLG)
- launch event in Brussels on 12 October 2007, group composed principally of senior officials from national regulatory or nuclear safety authorities.

[29] www.snetp.eu

[30] http://ec.europa.eu/energy/nuclear/forum/index_en.htm

To launch the Sustainable Nuclear Energy Technology Platform, a "*Vision Report*" (a kind of "Chart") was produced. It proposes a vision for the near, medium and long term development of nuclear fission energy technologies, with the aim of achieving a sustainable production of nuclear energy, a significant progress in economic performance and the highest level of safety as well as resistance to proliferation. Nuclear fission energy can deliver safe, sustainable, practically carbon-free and competitive energy to Europe's citizens and industries. In particular, this document proposes roadmaps for the development and deployment of potentially sustainable nuclear technologies, as well as actions to harmonize Europe's training and education, while renewing its research infrastructures. Public acceptance is also an important issue for the development of nuclear energy. Therefore, research in the fields of safety of nuclear installations, protection of workers and populations against radiations, management of all types of waste and governance methodologies with public participation will be promoted. The proposed roadmaps provide the backbone for a *Strategic Research Agenda* to maintain Europe's leadership in the nuclear energy sector, in both research and industry. By emphasizing the key role of nuclear energy within Europe's energy mix, this document also contributes to the European Commission's SET Plan, by calling on Europe to mobilise the resources needed to fulfil the vision of sustainable nuclear energy.

A number of recommendations are given in conclusion of the above Vision Report, e.g.:
"to effectively combat climate change, the cost of greenhouse-gas emissions must be taken into account at a worldwide level. Nuclear power must be included in the post-Kyoto international negotiations, as a part of clean development mechanisms, contributing to sustainable development".

5. EURATOM STRATEGY FOR RESEARCH AND TRAINING IN NUCLEAR FISSION AND RADIATION PROTECTION (COMMON NEEDS; TOWARDS ONE VISION; IMPLEMENTATION AT NATIONAL AND EU LEVEL)

As it was discussed in Section 1, the governments, in collaboration with the EC and the main stakeholders, should develop a common research and training strategy, that is:

(a) identify the end-users and their common needs (bottom up action)
(b) converge to a common vision amongst the main stakeholders (top down action)
(c) develop and apply implementation instruments at both EU and national level.

(a) Identification of end-users and common needs

As a result of the new *Energy Policy for Europe* [5] (10 January 2007), the European Commission proposed on 22 November 2007 a STRATEGIC ENERGY TECHNOLOGY (SET) Plan. For the preparation of this SET Plan, a wide consultation was organised across the EU about the need for "*European Industrial Initiatives*". On that basis, the EC proposed to launch six priority initiatives, starting in 2008, one of them being a *Sustainable nuclear fission initiative* (with focus on the development of Generation-IV). This EC proposal (based on the SET plan) was endorsed by the European Council of 13 – 14 March 2008 (Brussels) [31].

As a way of reminder, the history of nuclear fission power production is divided in four technological Generations (called I, II, III and IV), with timescales extending from around 1950 to 2040. To each of these generations, S/T and E/P challenges are associated, as follows:

- Generation II (1970 - 2000): reliability (in particular, security of supply & safety), and sustainability (in particular, waste management and resource utilization)

[31] http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressData/en/ec/99410.pdf

- Generation III (2015): competitiveness (a.o. increased plant performances, like 60 years lifetime and 90 % plant availability), and enhanced reliability and safety

- Generation IV (2040): enhanced sustainability (a.o. better utilisation of resources and full actinide recycling) and enhanced competitiveness (a.o. cogeneration).

Generation IV systems are meant to be a technological breakthrough, with a major impact on the following fields (four technology goals agreed upon in 2002 – see GIF below):

- Sustainability (e.g. better fuel utilisation and waste management)
- Economics (e.g. competitive life cycle and minimum financial risk)
- Safety and reliability (e.g. plant management and investment protection)
- Proliferation Resistance and Physical Protection (e.g. safeguarding facilities).

A number of strategic studies were launched, in particular, under Euratom FP-6 (2003 – 2006), to identify the needs in all areas, that is: reactor systems (including the above GIF technology goals) and safety design (including plant modernisation), waste management (including Partitioning and Transmutation /P&T/ and geological disposal) and radiation protection (including applications of ionising radiations) – Section 7.

(b) Towards a common vision amongst the main stakeholders

Nuclear research and training requires in fact broad and extended geographical, disciplinary and time horizons, that is:

- the nuclear research community extends to all 27 EU Member States and beyond
- a variety of scientific disciplines (both applied and fundamental) are concerned
- four generations of nuclear power technologies are involved (period 1950-2040).

As far as the main stakeholders are concerned, one can distinguish 6 categories (they are usually all involved in the large Euratom research and training programmes):

- the nuclear research organisations (public and private)
- the systems suppliers (e.g. nuclear vendors, engineering companies, etc)
- the energy providers (e.g. electric utilities, heat and/or hydrogen vendors, etc)
- the regulatory bodies and associated technical safety organisations (TSO)
- the education and training (E&T) institutions, and, in particular, the universities
- the civil society and the international institutional framework (IAEA and OECD).

Regarding the development of innovative reactor systems and fuel cycles, there is a world-wide common vision amongst 12 countries and Euratom. This subject is at the heart of a large international research programme, led by the Generation IV International Forum (GIF). In July 2002, six innovative reactor systems were selected: 4 fast reactors /SFR, GFR, LFR, SCWR / and 2 thermal reactors /VHTR, MSR/. Within the EU-27, however, there is not yet a common vision on the future of nuclear fission (Generations III and IV). Actually there is consensus only on Generation II issues (e.g. "*Convergence of Technical Nuclear Safety Practices in Europe*" developed by WENRA) and on the need to maintain an adequate skills base in nuclear fission across the EU (therefore the Euratom effort on education and training).

(c) Implementation instruments at both EU and national level (such as FP-7)

At the EU level, nuclear research and training (Euratom programmes) is principally under the responsibility of two Directorates Generals (DG):

- DG Research (RTD, located in Brussels), which organises the “indirect actions”, i.e. multi-partner projects undertaken by consortia made up of national laboratories, industrial groups and research organisations (both private and public) in the EU, usually on a shared cost basis, such as in the seventh Framework Programme [32].

- DG Joint Research Centre [33] (JRC, headquarters in Brussels) which carries out “direct actions” in their own research laboratories (7 scientific institutes in 5 Member States). Nuclear training actions at DG JRC focus on neutron measurements, nuclear materials and non-proliferation issues (safeguards) in collaboration with ESARDA and IAEA.

In this key note lecture, the emphasis is on the indirect actions, organised by DG Research under the 6th (FP-6 / 2003-2006) and under the 7th Euratom research framework programme (FP-7 / 2007 – 2011)[34].

Table 1 - Euratom framework programmes for fusion and fission (FP-4 till FP-7)

	FP-4 (1994-98)	FP-5 (1998-02)	FP-6 (2003-06)	FP-7 (2007-11)
Fusion Energy	**840**	**788**	**824**	**1 947**
Nuclear Fission and Radiation Protection *(indirect actions)*	**170**	**191**	**209**	**287**
JRC’s EURATOM activities (*direct actions*)	**271**	**281**	**319**	**517**
Total	**1 281**	**1 260**	**1 352**	**2 751**

Euratom Budgets since 1994 are given in Table 1. As it was mentioned in Section 1, research and training should be viewed in the context of the synergy between the two Policies:

- Research ("research – development" in the context of the knowledge triangle)
- Energy ("demonstration – deployment" in the context of the energy triangle).

At the national level within the EU Member States, the largest part of nuclear research and training activities is traditionally under the responsibility of Ministries (e.g. Education, Science, Research, Industry, etc). Some States – especially those with a significant number of nuclear installations - have large programmes, associated with universities and funded by both government and industry (e.g. CEA in France, FZK in Germany, etc). Other States have developed less expensive programmes that are more appropriate to their specific needs (e.g. with emphasis on radiation protection and on applications of ionising radiations).

A number of *National Networks for Nuclear Research and Training* (most of them set up quite recently) play also an important role in the overall implementation process, such as:

- **NTEC** [35] (*Nuclear Technology Education Consortium* of 11 establishments – lead by the Dalton Nuclear Institute in the UK (of particular interest is also the UK initiative "*Keeping the Nuclear Option Open*" [36])

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[32] http://cordis.europa.eu/FP-7/euratom/home_en.html

[33] http://www.jrc.cec.eu.int/

[34] http://cordis.europa.eu/fp7/euratom-fission/home_en.html

[35] http://www.ntec.ac.uk/

- **Kompetenzverbund Kerntechnik** [37] (*Alliance for Nuclear Competence*, under BMWi) in Germany

- **INSTN** [38] **(**Institut National des Sciences et Techniques Nucléaires), as a of CEA, INSTN is a higher education institution under the joint supervision of the Ministries in charge of Education and Industry in France

- BNEN [39] (Belgian Nuclear Education Network, hosted at SCK-CEN Mol), cosponsored by the national nuclear industry, containing all six “nuclear” universities of Belgium

- CIRTEN [40] ("Consorzio Interuniversitario per la Ricerca Tecnologica sull' Energia Nucleare”) in Italy

- REFIN [41] (Romanian Nuclear Education Network – "Retea Educationala in Fizica si Ingineria Nucleara")

- FINNEN [42] (Finnish Nuclear Education Network, Helsinki University of Technology /TKK/)

- NKS [43] (Nordic Nuclear Safety Research = Denmark, Finland, Iceland, Norway and Sweden)

- CENEN (Czech Nuclear Education Network)

- KINT (Dutch Knowledge Infrastructure on Nuclear Technology).

Also worth mentioning is the co-operation of EU and National nuclear training programmes with international organisations, such as:

- the *World Nuclear University* (WNU[44]), an initiative of the World Nuclear Association under the umbrella of IAEA, launched in September 2003 with a secretariat in London

- the *Asian Network for Education in Nuclear Technology /* ANENT [45] (IAEA initiative in 2004), 28 participating organisations from 12 countries as of Sept 2006 (namely: Australia, China, India, Indonesia, Malaysia, Mongolia, Pakistan, Republic of Korea, Sri Lanka, Thailand, Philippines and Vietnam).

Assessment of Euratom research programmes (achievements versus objectives)

Euratom RD&DD addresses most of the above common needs and is in line with the common vision that is emerging amongst the main stakeholders. As far as Research and

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[36] www.wun.ac.uk/nuclearsci/research_themes/pubpolicy/pdfs/KNOO.pdf

[37] http://www.grs.de/products/data/3/pe_460_20_1_pe_434_20_1_kv03endg.pdf

[38] http://www-instn.cea.fr/

[39] http://www.sckcen.be/bnen/courses.html

[40] http://www.cirten.it/

[41] http://www.refin.pub.ro/

[42] http://www.tkk.fi/fi/

[43] http://www.nks.org/english/About_NKS/About_NKS.htm

[44] http://www.world-nuclear-university.org/

[45] http://www.anent-iaea.org/

Development (RD) are concerned, two new instruments were introduced under FP-6 and are further proposed under FP-7 [46] :

"*Networks of excellence*" *(NoE)*: the aim is to promote EU excellence while generating a process of "long term commitment" amongst the contractors. Here are the objectives of NoEs (also used as EC internal assessment criteria in programme monitoring):

- *Co-programming of research at the level of organisations :* 1. building up of strengths and shrinking of weaknesses / 2. long-term joint planning of research projects / 3. knowledge management (within and outside the Community project) / 4. horizontal integration (S/T multi-disciplinarity)
- *Vertical Integration :* 1. universities / 2. research organisations / 3. systems suppliers / 4. energy providers and waste agencies / 5. TSOs or regulators / 6. decision-makers
- *Sharing of personnel and facilities :* 1. mobility and mutual recognition of scientists / 2. sharing of equipment and (soft- and hardware) tools / 3. e-management of the project and applications of e-science / 4. "irreversible links" in the consortium (long-term vision).

"Collaborative projects" (CP): the aim is develop new knowledge, new technology, products, demonstration activities or common resources for research during the contractual period. Here are the objectives of CPs (also used as EC internal assessment criteria in monitoring):

- *Vertical Integration : see NoE above*
- *Horizontal Integration : 1. nuclear physics (nano-scale) / 2. chemistry (meso-) / 3. continuum mechanics (macro-) / 4. mathematics and informatics / 5. electronics / electricity / 6. health / environmental sciences*
- *Knowledge Management : (cf. the "Knowledge Triangle" in Figure 1) 1. research (i.e. identification, creation and development of knowledge) / 2. education (i.e. preservation, dissemination and transmission of knowledge) / 3. innovation (i.e. use and exploitation* of knowledge for research and/or industrial/regulatory purposes).

On the contractors' side, a number of external assessment exercises were conducted. Some participating organisations carried out, for example, a SWOT analysis (*Strengths – Weaknesses – Opportunities – Threats*) of their participation in Euratom research actions. Other participants went for a cost/benefit analysis (*what is the "value for money"?)* of their participation. It is worth reporting the conclusion of a large European utility: *"To give an idea of the quantitative benefits which can be obtained from sharing costs in the framework of European programmes, we can mention a few illustrative figures: in the nuclear field, in 2002, we brought about 3,5 M€ and got access to R&D results worth 36 M€. This factor of 10 is obviously a strong incentive for a utility to get actively involved in the European Research Area !"* (introductory lecture at FISA-2003 / Luxembourg, November 2003 [47]).

6. ENEN OBJECTIVES FOR EDUCATION AND TRAINING: MODULARITY AND COMMON QUALIFICATION APPROACH; MUTUAL RECOGNITION; EUROPEAN MOBILITY; FEEDBACK FROM STAKEHOLDERS

Keeping the nuclear option open means also maintaining an adequate skills base to ensure sufficient personnel in research organisations as well as in nuclear installations. This is a concern shared not only by the EU but also by OECD/NEA [48] and by IAEA [49].

[46] http://cordis.europa.eu/FP-7/what_en.html#funding

[47] http://cordis.europa.eu/fp5-euratom/src/ev-fisa2003.htm

[48] http://www.nea.fr/html/ndd/reports/2000/nea2428-education.pdf

[49] www.iaea.org/km/

In 2000 Mr. M. El Baradei, Director General of the IAEA declared in a speech:
"As the nuclear workforce ages and retires, and support decreases for university programmes in nuclear science and engineering, knowledge management is becoming critical to ensuring safety and security, encouraging innovation, and making certain that the benefits of nuclear energy - related to human health, food and agriculture, water management, electricity supply, and a host of other applications - remain available for future generations."

Also in 2000, Euratom decided to fund a number of strategic studies and to strengthen training in all sectors of nuclear fission and radiation protection.

It is worth recalling that nuclear training is an obligation in the Euratom Treaty (signed in Rome in 1957) [50]. Here are two excerpts:

- Under "Provisions for the encouragement of progress in the field of nuclear energy" CHAPTER 1 / PROMOTION OF RESEARCH / Article 4

1. The Commission shall be responsible for promoting and facilitating nuclear research in the Member States and for complementing it by carrying out a Community research and training programme.

- Under "Provisions for the initial application of this Treaty" / Article 215

1. An initial research and training programme, which is set out in Annex V to this Treaty and the cost of which shall not …exceed … units of account, shall be carried out within five years of the entry into force of this Treaty.

For the sake of clarification, education and training (E&T) are defined as follows:

- Education is a basic or life-long learning process: education is broader than training and encompasses the need to maintain completeness and continuity of competences across generations (it is essentially a knowledge-driven process, involving academic institutions as suppliers, and students as customers).
- Training is learning a particular skill required to deliver a particular outcome: training is about schooling activities other than regular academic education schemes (it is essentially an application-driven process, involving industrial/regulatory training organisations as suppliers, and professionals as customers).

The goal of the Euratom education programme is actually to offer a number of instruments that help produce top-quality teaching modules that can be assembled into Masters programmes or higher level training packages that are jointly qualified and mutually recognised across the EU. This is done in collaboration with the DG EAC *Lifelong Learning Programme* (Section 2) and the DG RTD programme FP-7 *PEOPLE* (Section 3).

The Euratom approach is naturally in line with the Bologna process (ERASMUS). More specifically, its strategy for nuclear E&T is based on the following four objectives:

- MODULAR COURSES AND COMMON QUALIFICATION APPROACH
(offer a coherent E&T framework and ensure top-quality for each module)
- ONE MUTUAL RECOGNITION SYSTEM ACROSS THE EUROPEAN UNION
(e.g. European Credit Transfer and accumulation System of ERASMUS /ECTS/)
- MOBILITY FOR TEACHERS AND STUDENTS ACROSS THE EU
(prepare the "internal market" for free circulation of nuclear experts)
- FEEDBACK FROM "STAKEHOLDERS" (BOTH SCIENTIFIC AND FINANCIAL)
(involve the "future employers" in the process, thereby getting additional funding).

[50] http://eur-lex.europa.eu/en/treaties/index.htm

In order to achieve the above objectives, a non-profit making association (*under French law of 1901*) was formed in September 2003: this is the "*European Nuclear Education Network*" (ENEN) [51], a spin-off of the homonymous FP-5 project. As of December 2007, the membership of the ENEN Association consisted of 44 members, namely: 37 universities (effective members), and 6 research centres and 1 multinational company (associated members), located in 17 European Countries. The current aim is to cover 29 countries, namely: the 27 Member States of the EU and two neighbouring countries (Switzerland and Norway). Supported by the 5th and 6th Euratom Framework Programmes, the ENEN Association developed, in particular, education and training courses in a European exchange structure, based on core curricula and optional fields of study. Of particular interest is the list of 295 ENEN courses (modules) that were produced in 25 nuclear fission disciplines. ENEN can be considered as an important step towards the harmonisation of training activities in nuclear fission and radiation protection in the EU-27.

The ENEN association consists of five Committees. The Training and Academic Affairs Committee and the Advanced Courses and Research Committee develop and implement non-overlapping schemes covering one full academic year (60 ECTS) of courses in nuclear disciplines leading to Master degrees. The latter Committee also promotes interactions between research conducted at European universities and nuclear research centres, and end users such as utilities, power plants, regulatory bodies, industries, etc. It organises exchanges and meetings between doctoral and post-doctoral students in the framework of seminars, workshops and courses on topics at the edge of current scientific research. The Training and Industrial Projects Committee facilitates interactions between training organisations and professionals in nuclear industries to provide pertinent and harmonised training programmes for continual training on new topics as well as to refresh and update capabilities and qualifications. The Knowledge Management Committee operates the ENEN web site, advertises courses and events of interest, develops and disseminates E-learning tools, courses and training packages on a variety of media, maintains data banks and communication systems. The quality of the ENEN products and the project deliverables, the reports, courses, training packages, certificates, and the reliability of the information is continuously monitored by the Quality Assurance Committee.

The central issue of the ENEN association was originally the elaboration of a concept to establish a *European Master of Science in Nuclear Engineering* (EMSNE). The concept envisaged should be compatible with the European educational road map for higher education defining Bachelors and Masters Degrees as agreed to in the Bologna declaration. Clearly, the scheme should be practicable in that it takes into account the realities of European education. The basic goal is to offer interesting programs with exciting subjects to attract bright students and to guarantee a high quality nuclear education in Europe by means of stimulating student and instructor exchanges, through mutual quality assurance checks of the courses offered, by close collaboration with renowned nuclear research groups at universities or laboratories. The nuclear master program should consist of a solid basket of basic nuclear science and engineering courses but should also contain some advanced nuclear courses.

The full curriculum leading to the original degree of *Master of Science in Nuclear Engineering* (MSNE) is composed of *course units* formally recognized by ENEN and characterized by a number of ECTS credits, reflecting their load. These credits can be collected from all "ENEN-recognized" institutions. A minimum of 60 ECTS credits (that is: the equivalent of one academic year) are needed to be granted the degree of MSNE. The home institution will grant the formal degree of Master of Science in Nuclear Engineering, based upon the formal recognition of the ECTS credits, in line with the ERASMUS mechanism. The quality label *European Master of Science in Nuclear Engineering* (EMSNE) is granted by ENEN, on

[51] www.enen-assoc.org.

behalf of its members, only if at least 20 ECTS credits (including project work or thesis) have been followed at an ENEN-member institution other than the home institution.

Although the concept envisaged is applicable to a variety of speciality domains, in a first phase, ENEN concentrated on establishing a degree in *nuclear engineering* mainly related to nuclear electric power generation. Nowadays, the original ENEN objectives are extended. The result could be a nuclear fission *European Master* degree with different "options" like

- *waste management (including P&T and geological disposal)*
- *nuclear medicine*
- *radiation protection*
- *radiochemistry & nuclear chemistry*
- *nuclear applied sciences (including accelerators, instrumentation, etc).*

As the concept strives to offer the students the "best quality" higher education in Nuclear Engineering in Europe, ENEN has focused on a *realistic* concept that enables to interact and take courses from typical centers of excellence with a sole or major nuclear focus. The model developed does not intend to establish one single elite school that offers the degree of European Master, but rather takes advantage of exchange schemes and mutual recognition. The scheme does not intend to do away with existing programs but tries to strengthen them by offering exchange modules. The regional and national spread of the program is thought to be important to allow graduated students to interact with local safety and other authorities (language and cultural aspects). The concept is designed to fit full-time as well as part-time students. The part-time scheme is supposed to better accommodate the schedule of professionally active students.

The four above ENEN objectives apply naturally across all sectors of nuclear fission, in particular: nuclear engineering (including Generations II, III and IV), radioactive waste management (including geological storage) and radiation protection (including applications of ionising radiations). The implementation of nuclear E&T, however, can be sector specific.

7. EDUCATION AND TRAINING UNDER EURATOM FP-6 (2003 – 2006): STRATEGIC STUDIES IN ALL NUCLEAR AREAS AND TRAINING ACTIONS EMBEDDED IN LARGE RESEARCH PROJECTS

In line with the four above objectives of ENEN, Euratom FP-6 (2003 – 2006) launched a number of strategic studies in specific areas of reactor engineering and safety design, waste management (including Partitioning and Transmutation /P&T/ and geological disposal) and radiation protection (including applications of ionising radiations), namely:

1 - *Nuclear European Platform for Training and University Organisations (**NEPTUNO** [52]),* coordination action funded for 1.5 years with a total budget of 830 kEUR from EC, initiated in January 2004 and coordinated by CEA/INSTN

2 - *Coordination Action on Education and Training in Radiation Protection and Radioactive Waste Management (**CETRAD** [53]),* coordination action funded for 1.25 years with a total budget of 300 kEUR including 250 kEUR from EC, initiated in January 2004 and coordinated by University of Wales (UWC) – Cardiff School of Engineering

3 - *Securing European Radiological Protection and Radioecology Competence to meet the Future Needs of Stakeholders (**EURAC**),* coordination action funded for 1 year with a

[52] http://www.sckcen.be/neptuno/)

[53] http://www.grc.cf.ac.uk/cetrad/

total budget of 168 kEUR including 100 kEUR from EC, initiated in October 2004 and coordinated by Middlesex University (list of FP-6 Euratom projects [54])

4 - European Master of Science Course in Radiation Biology (MSCRB [55]), specific support action funded for 3 years with a total budget of 400 kEUR from EC, initiated in October 2003 and coordinated by Gray Cancer Institute / Middlesex

5 - European Network on Education and Training in Radiological Protection (ENETRAP [56]), coordination action funded for 2 years with a total budget of 450 kEUR including 400 kEUR from EC, initiated in April 2005 and coordinated by SCK-CEN Mol (Section 9)

6 – Belgian Nuclear Education Network (BNEN [57]), specific support action funded for 1.5 years with a total budget of 100 kEUR from EC, initiated in April 2005 and coordinated by SCK-CEN Mol

7 - Consolidation of European Nuclear Education, Training and Knowledge Management (ENEN II [58]), coordination action funded for 2 years with a total budget of 1240 kEUR including 1150 kEUR from EC, initiated in October 2006 and coordinated by the ENEN association – see below.

The above strategic studies (NEPTUNO, CETRAD, EURAC, MSCRB, ENETRAP, BNEN and ENEN II) dealt essentially with <u>education</u> (with a strong participation of academia). As far as <u>training</u> is concerned, it is worth mentioning the training activities "embedded" (that is: proposed as work packages) in some large FP-6 projects (with a strong participation of scientists from public and private laboratories).

In the integrated project, **PERFECT** [59], resources are assigned for training in advanced numerical simulation tools for irradiation damage. A total of 13 PhD students and as many Post Docs are funded by the project. The proposed numerical tools allow students to perform “virtual irradiations” on “virtual reactors”, with the aim to analyse the resulting evolution of mechanical properties and microstructure.

In the network of excellence, **SARNET** [60], an education and training programme is foreseen directed at young scientists. The aim is to consolidate European excellence in the long-term in the areas of experimental and numerical simulation as well as in level 2 probabilistic safety assessment methods and in mitigation techniques related to severe accident management.

In the integrated project, **RAPHAEL** [61], a number of major industrial issues are discussed in connection with future industrial needs and energy policies (e.g. high temperature heat and electricity supply, natural resource preservation). Special attention is paid to education in innovative nuclear hydrogen production technologies and in communication.

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[54] http://cordis.europa.eu/FP-6-euratom/projects.htm

[55] http://www.gci.ac.uk/education/index.htm

[56] http://www.sckcen.be/enetrap/

[57] www.sckcen.be/BNEN

[58] http://www.enen-assoc.org

[59] https://www.FP-6perfect.net/site/index.htm

[60] http://www.sar-net.org/

[61] http://www.raphael-project.org/index.html

In the integrated project **EUROTRANS** [62]**,** there are 17 universities, represented by the ENEN Association. At least 5% of the budget is assigned to PhD students, whereas an additional 300 k EUR is reserved for E&T (detailed course programme in www.enen-assoc.org). It is also worth mentioning the launch of a doctoral school on P&T by the ENEN association in this EUROTRANS project.

In the integrated project **ESDRED** [63] ("**E**ngineering **S**tudies and **D**emonstration of **Re**pository **D**esigns"), the partners (waste management agencies and technological R&D organisations) organise training sessions of broad interest. One of their general aims is to fabricate and test prototypes of technologies for deep geological disposal of high level radioactive waste (such as spent fuel or vitrified waste), for backfilling and for sealing disposal cells or drifts.

As far as radiation protection goes, in the integrated project **RISC-RAD**[64] (**"R**adiosensitivity of **I**ndividuals and **S**usceptibility to **C**ancer induced by ionizing **RAD**iations"), there are courses on "quantitative radiation risk modelling" and on "ethics in biological experiments".

In the integrated project **EURANOS**[65] ("**EUR**opean **A**pproach to **N**uclear and radi**O**logical emergency management and rehabilitation **S**trategies"), training is organised in connection with "real time on-line decision support (RODOS)" for emergency management and rehabilitation strategies.

FP-6 project ENEN II (covering all areas of nuclear fission and radiation protection)

This FP-6 Coordination Action (October 2006 – September 2008) consolidates and expands the achievements of the *European Nuclear Education Network* association in the previous framework programmes. The ENEN-II project is aiming at developing the ENEN Association in a sustainable way in the areas of nuclear engineering, radiation protection and waste management. Nuclear education and training networks are developed at the national level to provide a solid basis for networking at the European dimension (Section 5). Advisory groups and discussion forums are established to strengthen guidance, interaction and feedback from end-users and stakeholders regarding higher level training needs. In addition to EC funding, third-party funding will be attracted to support mobility of teachers and students at masters', doctoral and post-doctoral level. The approach (four ENEN objectives – Section 6) used so far successfully for education are developed and extended to training activities.

The ENEN II project activities are structured around the five committees of the ENEN Association in close collaboration with selected consortium partners (Section 6). The project also develops a "Think Tank" function with reviews on nuclear energy and applications in various fields, evaluating performance, achievements, expectations, potential, and costs including also public perception and social aspects.

8. EDUCATION AND TRAINING UNDER EURATOM FP-7 (2007 – 2011): TRAINING ACTIONS EMBEDDED IN LARGE RESEARCH PROJECTS AND "EURATOM FISSION TRAINING SCHEMES" (EFTS)

Similarly to what was done under Euratom FP-6, the current Euratom FP-7 programme launched nuclear E&T actions "embedded" in all large projects, that is: reactor systems, waste management (including P&T and geological disposal) and radiation protection.

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[62] http://nuklear-server.ka.fzk.de/eurotrans/

[63] http://www.esdred.info/

[64] see http://www.riscrad.org/

[65] http://www.euranos.fzk.de

Here is a (non-exhaustive) list of seven training actions embedded in large FP-7 projects related to innovation in (1) reactor systems and (2) radiation protection.

Reactor systems (P&T as well as materials and fuels for Generation IV)

1 - ACSEPT / Actinide reCycling by SEParation and Transmutation
Starting date: (most likely) = 01/02/2008 (duration = 48 months)
Coordinator: Commissariat à l'Energie Atomique CEA, France (34 partners in total)
Total costs = 23 789 000, containing the EU grant of 8 999 000 EUR.

The overall goal is to advance the European integration in the fields of separation techniques, and actinide chemistry in particular, to combat the decline in student numbers, teaching establishments and young researchers. Of course strong links will be established with the direct or derived actions of the FP-6 Network of Excellence ACTINET. Summer schools will be organised at least twice during the 4 years lifetime of the project. Efforts will also be devoted to preserving, retaining, and archiving nuclear chemistry knowledge from current as well as from past Euratom RTD projects, using an ad-hoc Communication System. Funds are also foreseen to promote knowledge transfer from people retiring or already retired.

2 - GETMAT / **Gen IV and Transmutation MATerials**
Starting date: 01/02/2008 (duration = 60 months)
Coordinator: Forschungszentrum Karlsruhe GmbH FZK, Germany (24 partners in total)
Total costs = 13 959 123, containing the EU grant of 7 500 000 EUR.

The overall goal is to motivate a new generation of material scientists to study and deepen the open challenges in the materials science for nuclear applications. In addition to workshops in collaboration with OECD/NEA and IAEA, the following training activities have been foreseen:

- Training Course 1: Correlation between the material microstructure and its mechanical integrity (inter-relationship between the microstructure and mechanical performance including modeling of microstructure evolution and mechanics)
- Training Course 2: Influence of the environment on the material performance (platform for discussion of different concept under the materials point of view).

3 - CARBOWASTE / Treatment and Disposal of Irradiated Graphite and Other Carbonaceous Waste
Starting date (most likely) = 01/04/2008 (duration = 48 months)
Coordinator : Forschungszentrum Juelich GmbH, Germany (29 partners in total)
Total costs =11 500 000 EUR, containing the EU grant of 6 000 000 EUR.

The overall goal is to develop the scientific competence and human capacity that will guarantee the availability of suitably qualified researchers, engineers and employees in this specific field of legacy waste management. For spreading excellence, this project will engage PhD students and/or post-doctoral fellows throughout Europe, working alongside the industrial partners. The students will get training at partner institutions so that they can make use of analytical equipments, modelling techniques and other resources of high quality. Universities working with the ECTS system will exchange information on their nuclear chemistry and physics teaching curricula, and will invite industrial partners to give lectures on waste management options.

4 - F-BRIDGE / Basic Research for Innovative Fuel Design for GEN IV
Coordinator: Commissariat à l'Energie Atomique CEA, France (20 Partners in total)
Starting date: 01/03/2008 (duration = 48 months)
Total costs =10 234 318 EUR, containing the EU grant of 5 467 808 EUR.

The overall goal is to share the modelling and experimental methodologies in fuel materials sciences that will be developed during the project. The project will organise two summer schools demonstrating to young scientists and engineers how basic research in material science can contribute to the understanding of fuel behaviour under irradiation and to the selection and development of advanced fuels. F-BRIDGE is putting together researchers from different communities: physics and chemistry, academics and nuclear organisations, modellers and experimentalists, research scientists, irradiation experiments engineers, designers, and manufacturers. Therefore, thematic workshops will be organised to ensure communication and knowledge dissemination inside the consortium.

Radiation protection (medical applications of ionising radiations)

5 - SEDENTEXCT - Safety and Efficacy of a New and Emerging Dental X-ray Modality
Starting date: 01/01/2008; duration 42 months
Coordinator: School of Dentistry, Univ. Manchester, UK (7 Partners)
Total costs: 3 070 361, containing the EU Grant of 2 449 461 EUR.

The aim is the acquisition of key information for sound & scientifically based clinical use of Cone Beam Computed Tomography (CBCT) & to use them to develop guidelines dealing with justification, optimisation & referral criteria and to conduct dissemination and training for users of CBCT. A dedicated WP on training and valorisation will perform a need analysis amongst the professional community (dentists, manufactures and dental suppliers,...) and public to establish an agreed list of training needs and contents. A particular priority of the website development will be a "Training on Demand" web server, with materials handled by a special Image Database and by an original user-friendly HTML shell. As a result, the user can learn directly from his/her online, without the need of external software.

6 - MADEIRA - Minimizing Activity and Dose with Enhanced Image quality by Radiopharmaceutical Administration
Starting date: 01/01/2008; duration 36 months
Coordinator: Helmholz Zentrum München (HMGU former GSF), DE (7 Partners incl. USA)
Total costs: 3 948 824, including the EU-Grant of 2 820 000 EUR.

The goal is to improve 3D nuclear medicine and molecular imaging technologies and with this the quality of the diagnostic information obtained & to reduce the amount of radioactive material to be administered. A dedicated WP on training and dissemination has been set up and training courses will be organised on radiation physics (months 6), radiation protection in nuclear medicine (month 18) and imaging in nuclear medicine (month 30). Moreover it is foreseen to organise a public workshop on "Innovations in Nuclear Medicine" (months 33) targeting stakeholders in science and industry beside to set up a project web site and respective project flyers.

7 - ORAMED - Optimization of Radiation Protection of Medical Staff
Starting date: 01/02/2008; duration 36 months
Coordinator: SCK-CEN, BE (12 Partners including 1 from CH)
Total costs: 2 445285; containing the EU Grant of 1 839 999 EUR.

The goal is to improve standards of protection for medical staff for procedures resulting in potentially high exposures and to develop methodologies for better assessing and reducing exposures to medical staff in interventional radiology (IR). A dedicated WP on training and dissemination is set up aiming among others to develop an information package, such as presentations and e-learning modules for distribution through professional organisations and to organize a workshop where the main results of the project could be presented and disseminated among stakeholders.

Towards "*Euratom Fission Training Schemes*" involving academia and stakeholders

Nuclear training activities at higher education level do exist since long time, not only at academic but also at industrial/regulatory level. The industry (in particular, systems suppliers and energy providers) organises lifelong training activities for their staff, for example, in the framework of so-called "*training passports*". This is called CPD (*Continuing Professional Development*) and covers a variety of activities, such as: theory (e.g. advanced science and technology) and practice (e.g. internships in different departments) as well as business and communication.

To support CPD at the EU level, Euratom FP-7 in its Work Programme 2008 [66] proposed a number of "*Euratom Fission Training Schemes*" /EFTS/, to be coordinated by teams of academia and "stakeholders". The coordinating team should deliver a kind of "*European quality label*" that comes on top of any national certificate and demonstrates the top-quality of the scheme followed by the students or trainees. Stakeholders could be nuclear industry (case of reactor systems), regulators (case of radiation protection), agencies (case of waste management) or any other private or public organisation that needs new skills in the nuclear arena. The EFTS is a new scheme, leading to a significant development from a pure training and mobility programme to one dedicated rather to structuring training across the EU, taking advantage of synergies between the main stakeholders (in particular, public and private sector). The target audience consists of research workers and professional experts at least at post-graduate or equivalent level, i.e. from nuclear scientist to "captains of industry".

The proposed FP-7 funding scheme is a "*Coordination and Support Action*", that is: the duration should be several years (not a one-week spot action !). For each selected theme, the EU funding will be provided principally for the coordination and networking aspects of the EFTS, i.e. scientific secretariat, implementation of joint training programmes, organisation of training events, mobility of teachers and students, exchange of scientific staff (internships) and/or training facilities, contacts with national authorities to discuss European qualification, etc. Other funding sources should be used to pay the grants for individual fellowships, such as national programmes (both private and public) or EU programmes (e.g. *Lifelong Learning Programme* and *PEOPLE / ex – Marie Curie /* Sections 2 and 3).

A number of pilot sessions should be organised with the following objectives:

* address life-long learning and career development in areas of Nuclear Fission and Radiation Protection, adapting wherever possible the four ENEN principles (modularity and qualification, mutual recognition, mobility and feedback from stakeholders)

* maximise transfer of higher level knowledge and technology (preferably in close connection with research and innovation) with emphasis on multi-disciplinarity and/or inter-sectoral mobility (in particular, internships in the stakeholders' organisations) across the EU

* develop an evaluation methodology, for example, following the IAEA *Systematic Approach to higher level Training* /SAT/ ("*Systematic Approach to Human Performance Improvement in Nuclear Power Plants: Training Solutions*", IAEA-TECDOC-1204, March 2001) [67]

* ultimate objective = develop *European passports for* Continuous Professional Development that will enable high-level nuclear experts to perform their job across Europe, without any administrative or other barrier, and will be a quality label for potential employers.

[66] http://cordis.europa.eu/fp7/dc/index.cfm?fuseaction=UserSite.EuratomDetailsCallPage&call_id=88

[67] http://www-pub.iaea.org/MTCD/publications/PDF/te_1204_prn.pdf

9. TOWARDS A COMMON VISION OF NUCLEAR TRAINING BEYOND ERASMUS: EU INSTRUMENTS FOR MUTUAL RECOGNITION OF CERTIFICATES AND QUALIFICATIONS AMONGST STAKEHOLDERS

Besides the scientific contents of academic curricula, the FP-6 strategic studies (Section 7) discussed also practical problems related to mutual recognition and accreditation across the EU Member States. In the area of education (in particular, universities), ERASMUS provides a series of well tested tools (based on "Bologna"). In the area of training (in particular, continuous professional development), where a great variety of stakeholders are involved, the problem is more complex, because there is no such mechanism as "Bologna". The Radiation Protection community, in particular, examined the problem of mutual recognition of *Qualified Experts* in *Radiation Protection,* in connection with the Euratom *Basic Safety Standards* (ENETRAP project). The appropriate EU instruments could be the European Qualifications Framework (EQF) or/and the Community Directive 2005/36/EC (see below).

Mutual recognition of certificates for lifelong learning in the EHEA

If mobility between EU countries is to be promoted, a European Qualifications Framework [68] is needed for higher education as well as for lifelong learning. This is the scope of the European Qualifications Framework (EQF), adopted by the EP in October 2007 (to be formally adopted by the Council in 2008). The EQF will provide a common language to describe qualifications which will help Member States, employers and individuals compare qualifications across the EU's diverse education and training systems. It is foreseen that Member States relate their national qualifications systems to the EQF by 2010, and that individual certificates or diplomas should bear an EQF reference by 2012 .

Mutual recognition of professional qualifications in the Internal Market

The rights of EU citizens to establish themselves or to provide services anywhere in the EU are fundamental freedoms in the Single Market. National regulations which only recognise professional qualifications of a particular jurisdiction present obstacles to these fundamental freedoms[69]. This fact was recognised by the Internal Market Commissioner who proposed the Community Directive 2005/36/EC, which came into effect on 20 October 2007. In line with the Lisbon strategy of 2000 (Section 1), the purpose of this Directive is to ensure the free movement of qualified persons, thereby contributing to the development of the knowledge-based economy, the flexibility of labour markets and improved public services.

This Directive lays down mechanisms according to which fully qualified professionals in one Member State (MS) will benefit from the recognition of their professional qualifications when willing to exercise the same regulated profession in another Member State. The Directive replaces fifteen existing Directives in the field of the recognition of professional qualifications. A number of changes are proposed compared with the existing rules, including greater liberalisation of the provision of services, more automatic recognition of qualifications and increased flexibility in the procedures for updating the directive.

Automatic recognition is possible only in "Specific Sectors" (mainly in the health sector) where there is clear agreement on harmonised minimum training requirements or on professional experience. Otherwise, the "General System" applies, that is: the host MS compares the qualifications held by the migrant with the qualifications required in the host MS. This Directive applies whenever the profession at stake is regulated in the host MS, which is the case, in particular, of the *"qualified experts" in radiation protection* (see below).

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[68] http://ec.europa.eu/education/policies/educ/eqf/index_en.html

[69] http://ec.europa.eu/internal_market/qualifications/index_en.htm.

A practical example: mutual recognition of "qualified experts" in radiation protection

In the Euratom legislation on *Basic Safety Standards*, the Council Directive "96/29/EURATOM" of 13 May 1996 is of particular interest for nuclear training actions. It layed down *basic safety standards for the health protection of the general public and workers against the dangers of ionizing radiation* (OJ L-159 of 29/06/96). Two years later in the same context, a European syllabus was proposed concerning the training requirements for the recognition of *"qualified experts" in radiation protection*. This syllabus was laid down in Annex I of Communication 98/C 133/03 (OJ L-133 of 30/04/98) from the Commission concerning the implementation of the above Council Directive 96/29/Euratom. Once the International Commission on Radiological Protection (ICRP) will have issued new recommendations, the above Directive 96/29/Euratom will be revised taking into account operational experience and consolidating the existing *acquis*. This revision of the basic safety standards, however, will not affect the definition of *qualified experts*.

As a consequence, the CEA-INSTN (Saclay, France), in collaboration with other European partners, launched in 2000 the *European Radiation Protection Course* (ERPC) to deliver the theoretical knowledge needed to be recognised as a *qualified expert* on the basis of the above Euratom legislation and of the related IAEA Standard Syllabus. There were, however, strong barriers for the attendance of this ERPC course: in particular, the lack of recognition by the national competent authorities across the EU, the use of rather traditional educational tools and the total costs for participants. This is actually the challenge facing the above mentioned DG RTD project *European Network on Education and Training in Radiological Protection* (FP-6 / ENETRAP, consisting mainly of research organisations – Section 7) in collaboration with the DG TREN platform *European Training and Education in Radiation Protection* (EUTERP, consisting of representatives of the national safety authorities). One of the objectives of the EUTERP Platform is to gather knowledge of the different national criteria for recognition of radiation protection experts and to come to agreement on these criteria, thereby facilitating the free movement of these experts in the EU.

10. CONCLUSION / SCIENTIFIC AND SOCIETAL IMPACT OF EURATOM PROGRAMMES FOR RD&DD AND E&T (DIRECT AND INDIRECT ACTIONS)

In this key note lecture, the following questions were addressed (see also Figure 1):

1) *What are the challenges for Euratom Research and Training in the frame of the European "Higher Education" and "Research" Areas ?*
and who are the main stakeholders ? (end-users with common needs, decision makers with a common vision, institutions with implementation instruments)

2) *What kind of response is offered by the Euratom RD&DD and E&T programmes in nuclear fission and radiation protection ?*
and what is their scientific and societal impact ?
- RD&DD or RD3 for short = Research, technological Development, and engineering Demonstration, industrial Deployment (also called *Innovation Cycle*)
- E&T = Education and Training

The following categories of stakeholders were identified (actually, most of them are present in the large Euratom research and training programmes):

- the nuclear research organisations (public and private)
- the systems suppliers (e.g. nuclear vendors, engineering companies, etc)
- the energy providers (e.g. electric utilities, heat and/or hydrogen vendors, etc)
- the regulatory bodies and associated technical safety organisations (TSO)
- the education and training (E&T) institutions, and, in particular, the universities
- the civil society and the international institutional framework (IAEA and OECD).

Actually, Euratom research and training should be considered in the wider context of EU Policies, in particular those related to sustainability. *Climate Change and Clean Energy* is the first of seven key sustainability challenges identified by the EU. Nuclear fission is part of the solution and is discussed in various European platforms (SNE-TP, ENEF and HLG).

The Euratom strategy developed by the EU and the main stakeholders is based on an analysis of the common needs (end-users' point of view) and a possible consensus on a European vision (decision makers' point of view). Implementation instruments should then be developed and applied at both EU and national level. At the EU level, the implementation is usually carried out through "indirect Euratom actions" (organised by DG RTD) in synergy with "direct Euratom actions" (conducted by DG JRC). At the national level, the nuclear laboratories and a number of *National Networks for Nuclear Research and Training* are working towards the same objectives (naturally with national nuances).

The following preliminary conclusions can be drawn regarding, in particular, the nuclear training strategy of Euratom:

(a) Identification of end-users and common needs

- to <u>make nuclear (again) attractive amongst the younger generation</u>, training should be maintained as close as possible to RD&DD (*Innovation Cycle*) – Section 1
- to <u>set up lifelong learning programmes at EU level</u>, while optimising international cooperation (third countries), the ERASMUS approach should be followed – Section 2
- to <u>strengthen the synergy between private and public sectors</u>, exchanges of staff across the stakeholders' organisations should be promoted (inter/multi-disciplinarity) – Section 3

(b) Towards a common vision amongst the main stakeholders

- contribute to the Energy Policy for Europe by providing valuable input to the European Strategic Energy Technology (SET) Plan through participation in SNE-TP – Section 4
- optimise Euratom research and training actions by better integration (both vertically and horizontally), sharing of facilities, and policy for knowledge management – Section 5
- develop the European Nuclear Education Network (ENEN) towards all areas of nuclear fission and radiation protection ("young" students and "old" professionals) – Section 6

(c) Implementation instruments at both EU and national level (such as FP-7)

- promote training actions to be embedded in large research projects in all areas, thereby satisfying the needs of research organisations and universities – Section 7
- promote training actions through the synergy between stakeholders' organisations (e.g. EFTS), thereby satisfying the needs of industry as well as regulators – Sections 8 and 9.

Challenges for Euratom Research and Training in the frame of the European "Higher Education" and "Research" Areas

TABLE OF CONTENT

The Role of Education in Knowledge Management

TRAINING AS A TOOL FOR IMPROVING MOTIVATION AND EFFICIENCY IN NUCLEAR SAFEGUARDS

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This paper argues that in order to bridge the existing and future skills-gap in nuclear safeguards training focus must shift from the traditional provision of technical training to professionals to a more global approach, in which the organisation itself and the transfer of knowledge is viewed as the focal point for the establishment and the development of safeguards training.

It puts forward that the transfer of knowledge between generations of nuclear Safeguard workers in order to bridge the lack of formal skills is possible but it depends on a sound analysis of the situation which combines new analytical methods and a new framework approach.

Finally, the paper gives some examples of measures already undertaken in Euratom Safeguard training which can be taken as an embryo for further development.

1. Introduction

In terms of knowledge based management, nuclear safeguards training has always taken a techno-centric approach focusing on technology-based training to enhance knowledge sharing and growth. In the past, this has been sufficient to cater for training needs given the rather homogeneous population whose needs it has catered for.

Taking into account two major factors of change, one demographic and one linked to the difficulty of finding staff with necessary background qualifications, this paper advocates the need to switch our focus to a more organisational-based training that comprises of the organisation as a catalyst for facilitating knowledge, with the transfer of knowledge between peers as the key element.

The first part will therefore focus on the current situation and the challenges ahead. The second part will discuss conclusions and suggested solutions to solve these composite issues.

2. Current Situation

Nuclear Safeguards training has a more than 20 year old long tradition. It is the oldest training cell within the European Commission under the same framework. Traditionally, the focus has been on providing technical specialised training covering the needs of specialists in the field. This type of training has served well during its existence aiding above all new inspectors to acquire the necessary skills relatively quickly.

However, for the past 5 years, this form of institutionalised technical training has not met current demands and needs for the following number of reasons;

The first cause for concern is a demographic determinant. The European Commission has in its communication on the demographic future of Europe estimated that the European labour market will lose almost 50 million people up until 2050.

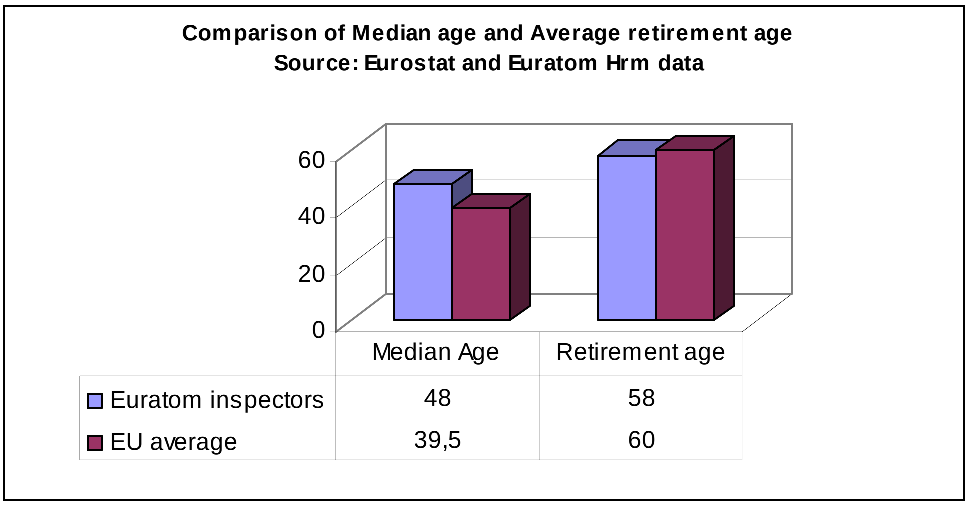
Another demographic effect is the ageing of the available work force. The final factor to take into account is the decline in nuclear literacy as a result of the low priority this topic is given in many European universities.

It should also be noted that performing nuclear Safeguards as defined in the Euratom Treaty is a very complex task ranging from verifying operators´ declarations, executing complicated measurements and representing the Commission (often alone) in relationships with member states and the IAEA. All these roles require technical skills, numerical skills, diplomatic skills, negotiation skills, social skills and other behaviouristic skills to ensure maximised efficiency with the lowest possible level of friction.

If you apply these factors to our concrete topic it soon becomes clear that we can no longer ensure that we will have nuclear expertise to recruit from, especially since salaries will probably increase in the nuclear industry depending on the scarcity of getting qualified staff, while the salaries within the EC are not business cycle related and remains less competitive.

Therefore, the main concern for training will be above all to focus on the transfer of knowledge (Argote, Ingram, Levine and Richard L. Moreland: Knowledge Transfer in Organizations) between experienced and less experienced inspectors. A second challenge will then be to adapt training to a cadre of people who do not necessarily possess background knowledge of the nuclear industry and, finally, safeguards training will also have to be adapted to meet the requirements of experienced inspectors and to train them as proficient mentors.

Graph 1: Average age and average exit rate of employees in Euratom and the EU



As seen from the above graph, the median age of a nuclear inspector (permanent officials working as nuclear Safeguards inspectors) in Euratom is 48 years of age (internal data). This is a very high median age compared to the workforce as a whole in the EU which stands at 39.5 years of age at present (Eurostat, 2001 fig,). Furthermore a final factor is the average exit age into retirement which currently in the EU is 59.9 years of age (Eurostat, 2001 fig,) a figure similar to that of Euratom although our inspectors tend to retire somewhat earlier. Although these figures are not directly comparable, broader conclusions can still be drawn. It is likely, given that the current safeguard policy prevails, that during the next 10 years considerable investment is needed in human resources, ranging from competitions, recruitment and provision of introductory training for new inspectors.

In conclusion and as a result of the above factors it is clear that although the overall problem is complex and involves numerous factors, the main focus of change can be centred on three major areas, formulated as questions:

- How do we guarantee qualified, competent and well trained staff for future Safeguards?
- How do we solve the knowledge gap and ensure a system which allows for a good natural transfer of knowledge between our inspectors?
- How do we meet new demands if more fundamental background training is required?

2.1 The starting point

A switch from a techno-centric approach to training to an organisational-based training taking into account social networks and lifelong learning strategies would first of all require a very sound analysis of the current situation.

This analysis would cover three major initiatives. Firstly a sound analysis of the actual skills of the current inspectors is needed. This should be done by interviews in combination with statistical data gathering. This should give us supporting data on the current skill levels of our clients (Tomas Olsson: Larande organisationer)

Secondly, there would be a need to review the current formalised training system. Is it adapted to the present and future needs? What do we need to change in order to better meet the demands?

Finally an analysis of the organisation itself would need to be performed. Such an analysis covering the directorate of nuclear Safeguards inspectors would facilitate and enhance our knowledge about the communication networks of our clients. This kind of analysis is a key element in introducing an organisational based learning: instead of focusing on **what** we learn, our assumption here is instead **how** we learn (Bandura, Social learning theory).

How well does the process of informal learning work? How useful is the current network to its individuals? Is the present network stimulating and encouraging exchange of knowledge between peers?

2.2 Interpreting the initial results - basic assumptions

Although premature, some preliminary results gathered from the initial set of statistical fact finding and skill-assessment can be extracted.

Firstly it is clear that Safeguards training in Euratom has not evolved with time since its inauguration more than 20 years ago. This is particularly true for the technical training which has remained static both in pedagogical terms as well as in a relative content term.

The result is that technical training for experienced inspectors is not adapted to their needs. Another interpretation of the data also suggests a very rigid learning culture based on traditional theoretical and practical exercises not taking into account the need of the individual or the organisation.

Secondly, preliminary results also indicate that basic training is increasing in importance. As discussed above, the low priority of nuclear training in Europe combined with demographic changes make it evident that the new inspectors recruited for Nuclear Safeguards do not necessarily possess a relevant background for their position. Therefore induction training courses, rudimentary tuition and guidance is needed to a much larger extent that before (OECD study in 2000, ‘Nuclear Education and Training: Cause for Concern).

The third main finding is that there is a need to develop new training, reflecting on more non technical competences. Given the complexities of nuclear Safeguards inspections and the necessity for the individual inspector to represent Euratom in conjunction with both Member States and the IAEA more competences are required than just technical skills.

On the final point covering the organisation and its networks, the basic assumption would be that the shape of the social network helps determine the networks´ usefulness to its individuals. Smaller tighter networks tend to be less useful and efficient than larger more open networks with many weak ties to individuals outside this network (Wasserman, Stanley, & Faust, Katherine. (1994). Social Networks Analysis: Methods and Applications. Cambridge: Cambridge University Press).

Such larger social connections are more likely to introduce new ideas and becoming more efficient than the other form of network. Tight-knit groups on the other hand have rather homogeneous opinions and share common traits which in fact can hinder both creativity and efficiency.

This kind of analysis is very important in order to improve informal learning structures and this type of learning. In concrete terms, an older experienced inspector will feel motivated, if his experience is recognised as an incremental part of learning while the new inspector will have a day-to-day training of high quality.

3. Conclusions

As seen from above argumentation and discussions our work has yet to be finalised. Nevertheless, tentative conclusions have been drawn and basic measures have already been taken in order to revitalise our training along the lines discussed above

First of all we have adapted and strengthened the introductory training for nuclear safeguards inspectors. In order to facilitate the transfer of knowledge most of these training sessions are given by very experienced inspectors. Discussions are actively encouraged via the use of case studies and the creation of an open informal environment. The structure of the training is also modular, meaning that primarily 1 day sessions are mixed with introductory work via a mentor in each unit.

This pedagogical process also ensures that each new employee is given the time to absorb and consolidate each theoretical workshop before he takes part in the next one. Usually these modules are also actively inviting more experienced inspectors who for one reason or another might need a refresher. Their active contribution further enhances and facilitates this transfer of knowledge.

In addition to the above, the length and level of detail of our basic training has increased from traditionally a two week basic course to its present length of almost 7 full time weeks, spread over the first 20-30 weeks of employment.

Secondly and in order to further develop the technical training we are developing in-house competences which provide technical training at a facility. This type of basic training is essential for our work and will entail a theoretical framework given at HQ followed by real inspection work training in various nuclear facilities across Europe. At the date of writing one such training session has been given and two more are planned for this year.

Thirdly in order to cater for the more experienced inspector, transfer of knowledge is ensured via ad-hoc related in house training courses. These courses cover most fields relating to nuclear Safeguards and reflect upon new tasks, additional tasks and changed responsibilities. At present around 10-15 courses a year are run on this basis.

In addition to the above, new types of training are envisaged taking into account other aspects of the qualified inspector's work. This training mainly focuses on relationships with operators and third parties in order to ensure increased efficiency while maintaining the lowest possible level of friction. For example this training is related to basic human behaviour like negotiation and communication techniques just to name a few topics. The first set of courses is running during the month of March and more are to be added for autumn 2008.

Finally and lastly a note on the last steps of development towards an organisational based training system. When we have our final results, we will be in a position to better identify global and individual training needs. Moreover such an analysis will give us access to information needed in order to identify and professionalise a cadre of trainers willing to work on further improving the quality of the delivery. These identified lecturers will be trained in pedagogies and other skills in order to facilitate this transfer of knowledge.

This would form an embryonary approach towards the long term goal of creating a Safeguards Training Academy. Such an academy would bridge the gap between formal and informal learning. The scope of Safeguards training however needs to be broadened and additional services and training provided should be offered to other international actors, Member States and nuclear operators.

An overall framework would be the final step towards a training organisation where the transfer of knowledge is done both informally and formally with all actors involved in nuclear safeguards. Such a body could or perhaps should be semi-dependant from its origin and would also work conceptually on issues such as quality assurance, accreditation and vocational training support structures (vocational guidance, training advice, skills mapping etc.). This would also make sense in relation to costs. The nuclear safeguard community is small, training is costly and specialised. A common effort from all actors and the pooling of resources would free funds and make them available for other urgent needs.

It is obvious that the above mentioned development requires experience to work. This means that the experienced Safeguards worker regardless of his position and origin remains a core feature as the main deliverer of training. This is a fundamental switch of focus and requires above all patience and a long-term strategy.

In addition, the positive side-effects of such a longer term strategy and conceptual change should not be neglected. Transfer of knowledge in a correct manner also helps actors to understand their independent roles and their overall situation in the Safeguards framework. A mutual understanding would facilitate and increase the efficiency of inspection work.

Moreover, on a detailed level, since training is based on transfer of knowledge rather than having a technical formalistic approach, it is likely that the status and motivation of the experienced safeguards worker will increase. This would subsequently have a secondary impact on work performance and output.

Given the demographic changes and the low priority of nuclear training described under part 2, the median age will increase even further during the coming 10-15 years. The present nuclear Safeguards worker will work longer than before and his experience should not be underestimated as a source of know-how.

It is our belief that in order to bridge the knowledge gap and to ensure competent future nuclear safeguard workers this is the only feasible way forward until nuclear training is restored as a part of the curriculum of European universities.

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DEFINING QUALIFICATIONS AND COMPETENCE FOR PERSONNEL IN A SMALL WASTE MANAGEMENT ORGANISATION THE CASE OF POSIVA

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ABSTRACT

In 2000, the Finnish Parliament ratified a Decision-in Principle enabling Posiva to carry out confirming site investigations at Olkiluoto in Eurajoki. Posiva became the first organisation in Europe to select the site for a spent fuel repository. The construction of an underground rock characterisation facility, ONKALO, started in 2004 on the chosen site. This facility is constructed according to the safety requirements of a repository. Posiva's aim is to include ONKALO as a part of the deep repository in the licensing application, which is scheduled for submission by the end of 2012. Becoming a license holder and an operator of a nuclear facility requires qualified and competent personnel. Posiva, like many other organisations in the industry, needs to cross the generation gap, as its experienced specialists will retire before the disposal operations start. Since the licensing process will be one of the first of its kind, also new competencies of personnel are required. Posiva's systematic approach to develop the competence of Posiva's personnel to meet the requirements of the next stages of the disposal project is described.

1. Introduction to POSIVA

The first studies for the management of spent fuel started in Finland at the end of the 1970's. The government decided as early as in 1983 on the goal of disposing of the spent fuel starting 2020. In 1995, the national legislation, which bans the import or export of spent fuel, came into force. The same year Posiva Oy (Posiva) was established to carry out the RTD work and implementation of the spent fuel disposal programme for its owner's Teollisuuden Voima and Fortum Power and Heat. In 2000, the Finnish Parliament ratified a Decision-in Principle enabling Posiva to carry out confirming site investigations at Olkiluoto in Eurajoki municipality. Thus, Posiva became the first organisation in Europe to select the site for a high-level nuclear waste repository. The construction of an underground rock characterisation facility, ONKALO, started in 2004 on the final disposal site. The facility is constructed according to the safety requirements of a repository, because the aim is to include it as a part of the non-controlled area of the deep repository in the licensing application. The submission of the application is scheduled to take place by the end of 2012.

2. Need to define and develop competencies required for a repository licensing process

Becoming a license holder and an operator of a nuclear facility requires qualified and competent personnel. New competence is required from the personnel for the licensing process of a disposal facility, since the process will be one of the first of its kind. At the current project stage, the competencies needed for the licensing and also for operations' start are at the focal point of Posiva's competence development.

Posiva's personnel has been steadily growing over the years from about 20 persons employed by the company in the beginning to today's 70 employees. The resource planning for the disposal facility operations has defined a need of about 110-120 employees in total for the year 2020 and onwards when the disposal operations are scheduled to begin. In addition, Posiva uses many researchers, consultants and contractors from various universities, research organisations, and companies in carrying out the RD&D work and construction.

Posiva's organisation can be defined in organisational terms as encompassing the features of a professional bureaucracy (according to Minzberg in Karlöf 1995, 310-311) and also as a focal point of a subcontracting network (Anttila & al. 2002, 2) or a virtual project organisation. This influences the description of Posiva's current business processes, where a key core process is the overall steering of the RD&D work aiming at the license application in 2012 and the start of disposal operations in 2020.

Posiva, too, like many other organisations in the industry, needs to cross the generation gap, as its experienced specialists will retire before the disposal operations start. The company's employees' age structure resembles the overall age structure in the industry (CETRAD 2005, 27): 54% of the personnel are between the age of 20-39 and 33% are over 50 years of age (Posiva 2007).

3. Setting up internal training courses and networking with training providers

In 2002, the company's domicile was moved from Helsinki to Eurajoki municipality and the company's personnel rapidly doubled. As gaining high-level expertise in geological disposal takes tens of years, systematic approaches to define competence and needs for personnel's training are a must.

In 2003, Posiva contracted VTT (State Research Centre) to carry out a course for the new personnel in the scientific fundamentals of safety in geological disposal of spent fuel. The training course was five days long and was rerun in 2004 and 2005 with further development in 2005. From 2006 onwards, the course was now carried out in two course modules each four days long (Palmu & Hansen 2006, 20-21). The latter course module gives a more in-depth view into the specific areas of Posiva's safety case. The training is carried out in Finnish and Posiva's consultants are able to participate the course, too, when there are vacant seats.

Over the years Posiva's own personnel's role in addition to other experts from other research institutions and consultants has increased in the implementation of the course. The course is continuously improved based on a detailed participant feedback and this feedback is a vital source of further training needs, too. In 2008, Posiva's consultants formed the majority of one course module for the first time.

During 2006-2008 further tailored training courses were designed either internally, with our cooperation partners, or subcontracted. Such training courses included fundamentals in both geosciences (2 days) and groundwater chemistry and hydrology (2 days) for personnel without prior basic training these topics; an advanced six day workshop in Safety Case methodology in cooperation with NAGRA from Switzerland and ONDRAF/NIRAS from Belgium, and a 4-day course in microbiology in deep disposal with Micans from Sweden.

Since the training needs are currently not defined using a formal competence management system, several other means are used. These include open e-mail questions to the personnel on their perceived training needs and internal course feedback including questions about the next stage of development needs of participants. In 2006, an internal training group was established and the members now provide input from different units and departments about their training needs. The individual training plan was structured according to the chosen competence categories to ensure that a wider scope of training areas would be included as a part of the annual development talks. In 2007, the average number of training days for a Posiva employee was 10.5 days.

Further actions to strengthen the personnel's learning opportunities include Posiva joining the ITC-School Association in 2003; working together with the ITC-School to implement a course on *Cement and Cementitious Materials in Geological Disposal* in 2008; participating in 6th framework programme's E&T projects like CETRAD and ENEN II; and in the preparation of a new training scheme proposal for the FP7 framework call to continue the work of the CETRAD project and PETRUS group in geological disposal.

4. Developing a competence management system

4.1 Defining competencies

Competence as a term has many meanings (Viitala 2005, 31-36), which can be confusing, if the term is not defined. In this context, the competence of an individual is understood as being a part of human capital (according to Seeman, De Long, Stucky & Guthrie in Viitala 2005, 36). The competence can be either explicit or tacit and it consists of the individual's specific experience, knowledge, skills, mastery of procedures, or of a combination of all of these.

Our case treats competence as encompassing of wider areas professional capabilities that in a combination define the professional mastery or expertise needed to carry out a certain job. In addition to the competence for a certain professional mastery, a person may possess several other areas of competence, which are not currently required for a job. Also these competencies are taken into consideration, since they can guide e.g. in stand-in arrangements and in horizontal or vertical career development in the organisation.

The term competence management means a systematic management work with the purpose of securing the competence required to meet the company objectives and goals now and in the future (Viitala 2005, 38).

We differentiate between competence and a qualification. We consider a qualification as a legal or other requirements that an individual needs to meet or demonstrate formally either by acquiring a national academic degree or vocational accreditation given by an institute or examiner authorized to give the accreditation. Also the submission of an application to a professional organisation for quality assurance to meet a set of predetermined criteria and/or undertake and pass an examination can produce a qualification. We use this distinction, since in some theoretical discussions the term qualification (e.g. Toikka 1984) is also used in a similar meaning as competence. In our case, the qualification requirements at a minimum level include a basic radiation protection examination prior working in the nuclear facilities or passing an examination for a worker safety pass.

4.2 Towards a formal competence management system and training needs defined by competence requirements

Posiva carries out development work to develop a formal competence management system. The system is used to define the training and development needs by analysing existing competencies and identifying competence gaps in the development talks with the assistance of the competence management system. Thus the training needs would be more strategically derived and could focus also on the needs of the future.

In 2005, the first internal group interviews of selected personnel were carried out to define what type of special competence the existing personnel possesses and what type of competence is deemed to be missing that is needed. The same year in a planning meeting, the management set an objective to define the job competence profiles of Posiva's employees and this work continued during 2007. It resulted in a step-wise project to develop a strategy-driven competence and training analysis aiming at a systematic competence development system by the end of 2009 (Figure 1).

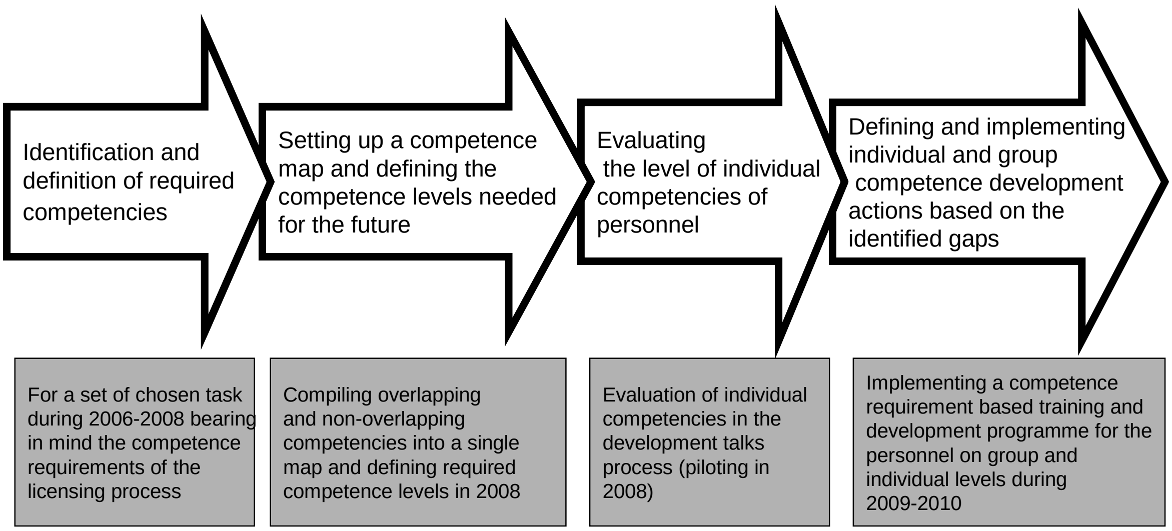

Fig 1. The development process of Posiva's systematic competence management

As a starting point of the project, we set up a categorization to facilitate the identification of competencies and training needs. The categories were adapted into Posiva's context from the work introduced by Hätönen (e.g. in Hätönen 1999).

The competence categories selected we selected are as follows:
1. General competencies needed to enter and function in working life like reading, writing, use of mother tongue, basic IT-skills, information acquisition skills, worker safety,
2. Communication and cooperation competencies like foreign language skills, presentation skills, negotiation skills, intercultural, team and project group working skills,
3. Organisational competencies like knowledge of the management and quality system, organisational procedures and information systems, and reporting systems,
4. Professional competencies like professional knowledge of a specific scientific or technical discipline (e.g. geosciences, chemistry) or administrative area like accounting, communications or quality management,
5. Competencies in geological disposal like knowledge of the disposal concept, safety case, nuclear requirements, interactions and interrelations between the different parts of the disposal system.

Competence profiles and a competence map of the existing jobs are compiled as a result of the work. In 2008, this map is stored into a database and the next steps of the competence management system development will be carried out with an aim to include this system as a part of Posiva's support process in competence development and resource planning during 2009. The level of competence can vary from a beginner (0-1) to a top expert (4-5) in each area. The required level of mastery should result in level 3 equalling a competent person in the specified competence (e.g. Viitala 2005, 157). Tools like Biggs' and Collis' Solo-taxonomy (in Tynjälä 1999, 182-183) assist in defining the competence levels.

The authorities continue to develop new requirements and modify the existing nuclear power plant personnel's qualifications for personnel operating in nuclear facilities. The Radiation and Nuclear Safety Authority (STUK) is reviewing and updating all of its safety guides by the end of 2011. Therefore flexibility to accommodate future changes is an important feature of the system.

4.3 Limitations of formal competence management systems

According to Virkkunen and Ahonen (2007, 16-19) a prerequisite for mapping competencies is that the jobs and the knowledge and skills are known in advance. However, this is not the case in industries where technology, products and business concepts are renewed fast.

We could also consider that the research and development nature towards deep geological disposal and toward the realization of the disposal concept includes similar uncertainties related to the needed competencies as a fast changing business environment. In an environment that is constantly changing or partly unknown, the personnel need to identify problems and develop solutions related to their work instead of following a given set of task definitions. If the training and development of personnel is based merely on the competence mappings, it is not sufficient to keep the personnel abreast of needed future developments. The learning processes in the organisation need to support continuous renewal according to the company strategy, too. There is a need to develop competence collectively and the challenge for the management is to lead the emergence of new competencies for the future, which do not exist yet (ibid).

In Posiva, we have chosen to develop the system collectively in internal group discussion with the current position holders and to use tools that could enable us to change the content of the system in a flexible and light way. This enables us to upgrade the established routines according to the changing future needs. Future will tell us how we have succeeded in taking into account the limitations of the formal competence management systems.

5. Conclusions

A formal competence management system is widely used in several industries. The nuclear utilities in Finland have applied a formal competence management system for about 20 years now. As demonstrated by the CETRAD project study in 2005 (CETRAD 2005), in the waste management organisations, only preliminary steps towards formally defining competencies required in developing and implementing waste management programmes were taken. Posiva started working towards this goal in 2006.

A lesson learned from the utilities' experience is that a formal system should look at the competencies as broader areas of professional mastery instead of individual detailed skills to be mastered. This enables setting up an efficient system also from the information maintenance point of view and allows for sufficient flexibility to update the content of the competence areas as the program advances and new competence needs emerge. A computerized system/database is also essential in the maintenance and update of the personnel's competencies.

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HOW KNOWLEDGE MANAGEMENT CAN HELP NUCLEAR COMPANIES TO FIGHT THE AGING WORKFORCE ISSUE?

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ABSTRACT

Aging of the workforce represent a major challenge for developed nations, especially for non-attractive industries – including nuclear companies. Organizations will lose a significant amount of institutional knowledge as their most experienced employees leave the workforce. The high costs associated with knowledge loss can be seen both on and off the balance sheet, affecting the entire enterprise. Formal knowledge transfer mechanisms supported by leading technology solutions can capture critical workforce knowledge and experience within retiring populations to pass on to future employees. Accenture's Enterprise Knowledge Retention and Transfer offering provides a holistic approach to help companies maintain critical knowledge.

1. The Aging Workforce Issue

Companies and governments in developed nations face a major workforce-related challenge that could evolve into a crisis situation:

- A large percentage of their workforces will be eligible for retirement in the next five to 10 years, resulting in a major exodus of talent and experience.
- This challenge is compounded by the fact that there's a much smaller talent pool coming up behind retiring "Baby Boomers."
- With workers aging and fewer people in succeeding generations, companies and governments will experience a significant exodus of talent in the next two decades and a dearth of new employees to step into those roles.
- Efforts to respond to this crisis to date have addressed some targeted knowledge and talent needs, but few if any organizations have addressed the problem in a way that will yield lasting benefits.

Accenture's Aging Workforce study[1] revealed four key findings:
1. <u>The workforce in many countries is aging</u>, and companies will begin to feel the impact of this aging in as little as 5 to 10 years.

- Globally, the elderly account for 15 percent of the population in the developed world, compared with 2 percent to 3 percent 150 years ago.
- By 2010, more than 25% of the US working age population will reach retirement age, resulting in a potential shortage of 10 million workers.

2. The impact of workforce aging is compounded by the fact that <u>people in many countries are leaving the workforce at a younger age</u>.

- In the US, the average retirement age has fallen from 67 in 1950 to 61 today.

- Europeans overall are exiting the workforce at a younger age than ever, and much younger than those in the United States. The average retirement age of European workers fell from 66.2 in 1950 to 59.8 in 2000. Reflecting that drop are the figures of employment rates for people in Europe aged 50 to 64 (as of 2000): 40 percent in Italy; 42 percent in Belgium; 52.7 percent in France; 54.6 percent in Germany; and 63.4 percent in the UK and Finland. These compare with 67.9 percent in the US.

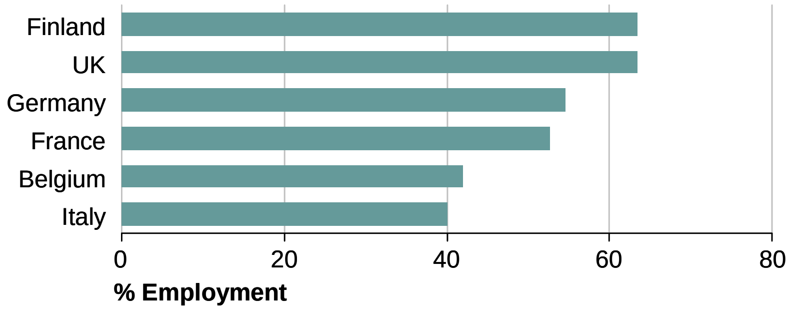

Fig 1. 2000 employment rate in people aged 50 to 64 in selected European nations

3. The aging workforce is a long-term issue. This trend will last for several decades because people are living longer and producing fewer offspring.

- At the turn of the 21st century, there were approximately 600 million older people globally—a figure that's anticipated to rise to 2 billion by 2050. At that time, when the median age globally is projected to be 36 (compared with 26 today), the number of older people is expected to exceed the number of young for the first time in history.
- From a country perspective, Italy, Japan and Spain will have as many people aged 60 or more as people between the ages of 15 and 59 by 2040. By 2030, 28 percent of Germany's population, and 20 percent of the United States', will be older than 65—and 19 million people in the UK will be over 60. In Canada, one in five people will be 65 or older by 2026—a major jump from one in eight in 2001. In Europe as a whole, the over-65 population is anticipated to rise from 15.4 percent of the EU population in 1995 to 22.4 percent by 2025.
- The aging trend will last for several decades because, quite simply, people are living longer and producing fewer offspring. For instance, life expectancy has reached 80 in Japan and 83 in the US. By 2075, at today's rates, US life expectancy is projected to reach 87. Globally, life expectancy has increased from 45 to 65 since World War II and shows no signs of slowing. Continuing advances in medicine and science likely will push life expectancy to 100 and possibly higher in the next few decades.
- Decreasing fertility rates also is a major factor. In the past 30 years, the worldwide fertility rate has been nearly halved—from 5.0 children per woman to 2.7. In the developed world, it's even lower—1.6—which is lower than the 2.1 replacement rate needed to maintain stationary population. In Canada, where the rate was three or more children per woman until the mid-1960s, the fertility rate has dropped to 1.5. The situation is particularly dire in Japan (1.5), Germany (1.3) and Italy (1.2).

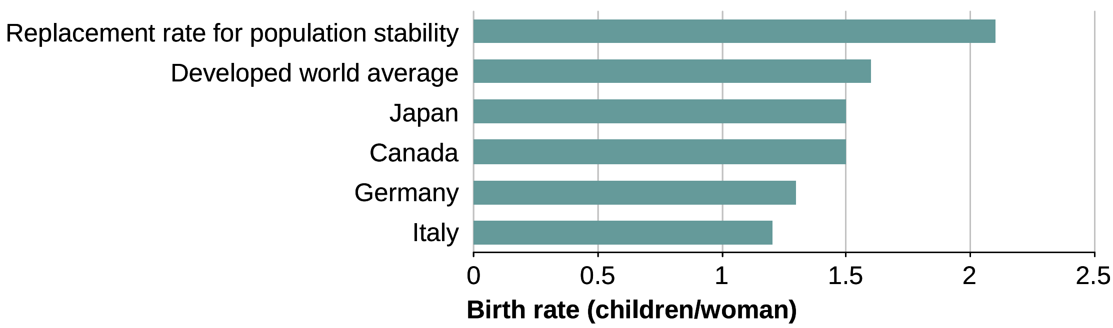

Fig 2. Birth rate in selected nations

4. Some sectors will be harder hit than others. Utilities, energy, mining and manufacturing, and government are viewed as 'unglamorous industries' by many people in their 20s and 30s. This mindset, if not altered, will further shrink the talent pool from which organizations can draw in the future. Newer employees tend to reject the notion of a "cradle to grave" career with the same employer.

2. Implications to Business

As current workers retire and a new - but smaller - generation of employees enter, organizations will need to understand the implications to their business:

Increased Costs

- Recruiting costs of 70-200% of annual salary
- Training up to 40% of employees is a multi-million dollar expense, typically $3,000 - $5,000 per employee
- Additional 5-10% contractor cost to have retirees come back and coach/train new employees

Decreased Productivity

- Supervisors incur at least 10-20% additional overhead overseeing new hires vs. experienced personnel
- Training effectiveness: 40% of new hires do not meet expectations or gain the right amount of experience in the first 18 months
- Bottom line impact of 3-5% due to lost productivity

Increased Safety Risk

- Less experienced workers could increase the number of workplace fires and explosions that kill 200 and injure more than 5,000 workers each year and cause billions of dollars in losses

Human Capital / Workforce Impacts

- If they don't act now, organizations will lose a significant amount of institutional knowledge as their most experienced employees leave the workforce. Important, sometimes critical, information and expertise may literally walk out the door.
- Organizations will find themselves locked in a battle for a shrinking pool of talent and confronting the escalating salaries that will accompany a limited supply of workers.
- Organizations will face the prospect of having to do the same amount of work with much fewer employees.

3. Knowledge Management solutions for fighting the battle against knowledge loss

Many organisations do not have a formal knowledge transfer mechanisms in place to capture critical workforce knowledge and experience within retiring populations to pass on to future employees. Both explicit and tacit knowledge needs saving and knowledge retention is a critical, yet challenging issue, especially in industries involving tacit knowledge. The high costs associated with knowledge loss can be seen both on and off the balance sheet, affecting the entire enterprise. The most forward-thinking organizations minimize the effects of knowledge loss by leveraging strategies such as phased retirements, re-hiring retirees to dissipate knowledge, job shadowing and succession planning.

For many organizations, the first order of business will be to implement a formal way to ensure that the experience and expertise of retiring workers are captured and transferred to their successors. Employees can be enabled to capture and communicate critical knowledge by providing them with technology solutions such as:

- Web-based collaboration tools that collect and distribute knowledge
- Mobile devices to capture knowledge in new ways
- Experts distributing knowledge across the company, not only within their team
- Ability to add context to knowledge
- Business simulation techniques that propagate important information
- An intelligent repository to facilitate and manage knowledge sharing

Accenture has worked with organizations in both the public and private sectors on such projects, using an approach called Enterprise Knowledge Retention and Transfer. This approach encompasses the tools and methods necessary to capture critical knowledge—both explicit and tacit—from experienced employees, and make this knowledge available to less-experience employees on an ongoing basis at the point of need.

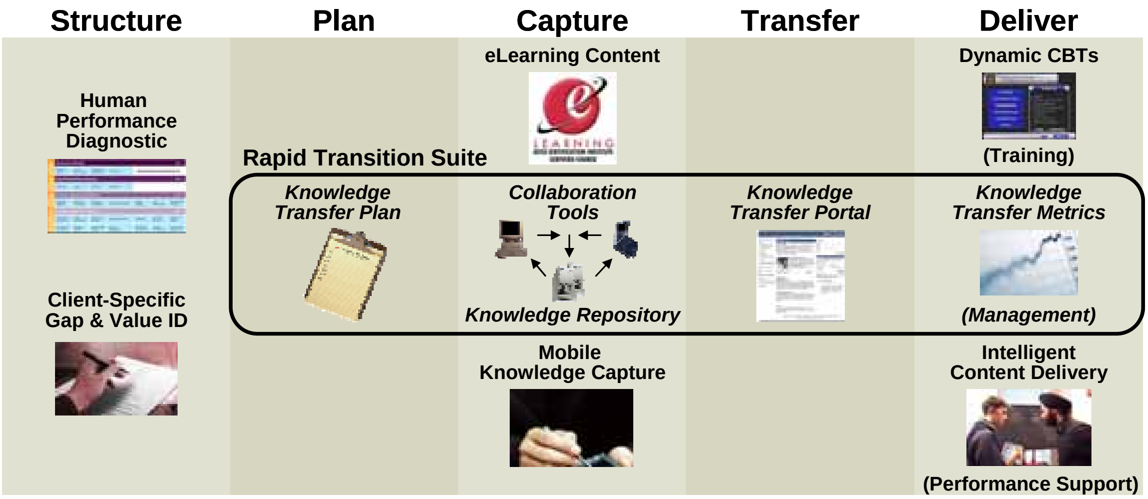

Fig 3. Accenture's Enterprise Knowledge Retention and Transfer offering

Enterprise Knowledge Retention is both a tool and a methodology. The methodology specifies how to determine the roles, responsibilities and skills that are to be transferred as well as how to manage the transfer process. This approach begins with the development of a knowledge transfer plan, assists with documenting processes through interviews, capturing contextual information about a project or system, and helping employees learn specific tasks through synchronous and asynchronous collaborative tools.

Accenture Technology Labs' Enterprise Knowledge Retention (EKR) tool is an integrated suite of applications designed to ease the transfer of knowledge from worker to worker. It was originally designed for outsourcing engagements (where it's had great success under the name Rapid Transition Suite), but has recently been helpful in facilitating knowledge transfer for mergers & acquisitions as well as situations in which a workforce is heading rapidly for retirement.

- At the heart of the offering is a Web-based suite of tools—based on proprietary, patent-pending software developed by Accenture—that intuitively guides teams through a successful knowledge capture and transfer program. The suite captures knowledge from experienced employees (the "instructors") by digitally capturing video of instructors and recording their narration as they perform key tasks (for example, closing an organization's financial books). These recorded sessions then are turned into digital "knowledge objects" that are stored in a knowledge repository that is accessible by “learners” whenever necessary through a Web portal customized to each employee. The benefits of the suite include reducing the time, cost and risk factors that organizations may face during knowledge transfer—especially the capture of valuable knowledge to be transferred between employees across a variety of different scenarios.

- Another tool that plays an important role in Accenture’s knowledge management approach—specifically, in knowledge capture—is the Personal Awareness Assistant that can be used by mobile workforces to passively capture and store key information with context. Using a scrolling audio/video buffer, PAA recognizes and records relevant phrases, names, requests, or faces. Field force employees can perform their daily interactions without interference.
- On the knowledge delivery side, Accenture has developed technology that enables knowledge to be intelligently delivered to employees at the point of need. This technology could apply to any setting in which workers’ interactions with people involve asking questions in an attempt to resolve an issue—such as a safety or environmental “auditor” who visits nuclear sites to ensure that they are meeting regulatory guidelines. Professionals could be prompted during conversations to ensure that they are using the correct terminology and approach.
- Also playing a key role in knowledge delivery is what Accenture calls a dynamic CBT. Because of how knowledge objects are captured and stored in the knowledge repository, we’re able to present insights from a variety of different experts—and update these insights continuously to keep the content fresh and relevant.

Overall, Enterprise Knowledge Retention helps companies to overcome the most common knowledge retention barriers such as:

- Time & distance: retiring employees leave before new hires arrive, or employees in multiple, disparate locations
- Capturing and planning challenges: upfront planning to address impacts of employee loss, identifying network of relevant contacts/experts
- Ineffective knowledge transfer and deployment: employees don’t know how to train and don’t have time for the extra burden, not enough motivation or incentives provided; knowledge not leveraged due to lack of organization and formalized progress monitoring.

4. References

[1] Accenture’s Aging Workforce Study: based on a survey of full-time employed adults, aged 40-50, with 1,407 respondents in U.S. & overseas. Conducted by ICR / International Communications Research for Accenture.

A NATIONAL APPROACH TO UNDERSTANDING SKILLS REQUIREMENTS IN THE NUCLEAR DECOMMISSIONING INDUSTRY

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ABSTRACT

This paper details the NDA Skills and Capability Strategy and highlights how it is working with others[1] to define skills demands across the UK and make investments where necessary to ensure that the infrastructure is in place to meet its Mission. It will detail how, working with Site License Companies, a national picture of resource demand has been identified and illustrate how the substantial progress to date in major projects such as the National Skills Academy for Nuclear, a Nuclear Institute, the Energy Foresight teacher training programme and others are making a difference to meeting current and anticipated demand for skills in the nuclear industry.

1. Introduction

1.1 The Nuclear Decommissioning Authority (NDA) is a non-departmental public body, set up in April 2005 by the UK Government under the Energy Act 2004 to take strategic responsibility for the UK's nuclear legacy.

1.2 The NDA mission is clear: 'To deliver a world class programme of safe, cost-effective, accelerated and environmentally responsible decommissioning of the UK's civil nuclear legacy in an open and transparent manner and with due regard to the socio-economic impacts on our communities'. In line with the mission, the NDA's main objective is to decommission and clean-up the civil public sector nuclear legacy safely, securely, cost effectively and in ways that protect the environment for this and future generations. The NDA does not carry out clean-up work itself but has in place contracts with site licensee companies[2] (SLCs), who are responsible for the day-to-day decommissioning and clean-up activity on each UK site. Individual sites develop Lifetime Plans that set out the short, medium and long-term skills and resource requirements for the decommissioning and clean-up of each site.

1.3 The Energy Act 2004 sets out the responsibility for the NDA to ensure there is *"an appropriately skilled workforce available to carry out decommissioning and clean up"* (Ref.1).

1.4 The key drivers for NDA investment in skills include the clear link to improved business performance and the availability of key skills in a diminishing and competitive environment.

[1] Others include such bodies as The National Skills Academy for Nuclear, Cogent Sector Skills Council, Higher and Further Education institutions, Training Providers and Trade Unions
[2] NDA Site Licence Companies are: Sellafield Ltd, Magnox North Ltd, Magnox South Ltd, Springfields Fuels Ltd, Dounreay Site Restoration Ltd, Reactor Sites Restoration Ltd and the Low Level Waste Repository Ltd.

2. The NDA Skills and Capability Strategy

2.1 The NDA Skills and Capability Strategy:

- sets out progress against the NDA Strategy 2005 with respect to Skills;
- consolidates progress to date;
- shares success stories and good practices; and
- outlines a Strategic Skills Action Plan to cover the next three to five years.

2.2 The Strategy demonstrates how the NDA is meeting its obligations within the Energy Act 2004 by *"developing world class skills"* through *"excellent people, skills and facilities."* It summarises current progress and future challenges.

2.3 Strategic Objectives are defined which capture activities, processes and investments made by the NDA, partners and stakeholders highlighting the mode of operation used to achieve success to date. Delivery of the Skills and Capability Strategy is defined through a robust Skills Programme (Fig 1), linked to the NDA Mission, reflected in Key Strategic Themes with "SMART" Objectives (Tab 1) leading to multiple Skills Projects managed in-house and through strong partnerships – all of which is underpinned by the "Skills Action Plan".

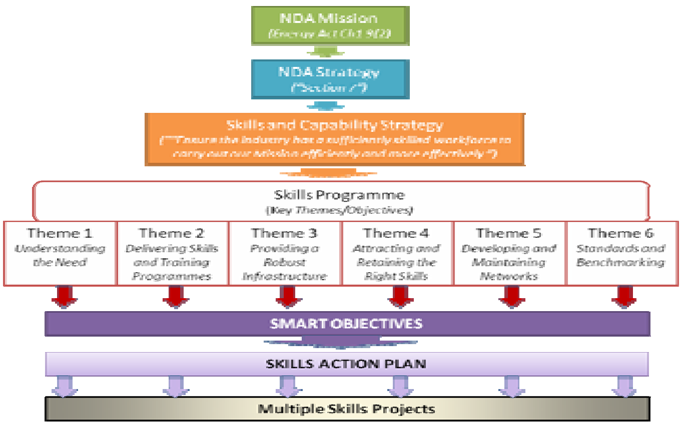

Fig 1. The NDA Skills Programme

1. Understanding the Need Identification of a series of cross-sector initiatives which promote an employer led approach to the demand for skills and training and development of world class skills which supports demand in the short, medium and long term	Establish and manage a National NDA skills resource
	Through appropriate Supply Chain organisations identify skills demand and shortages
	Produce a national statement of skills issues, demands, risks and opportunities for the NDA
	Work with national, regional and local bodies to plan provision to meet demand
	Liaise with sectors outside the NDA to understand the wider demand for transferable skills
	Support the NDA IT Strategy
2. Delivering Skills and Training Programmes Working with the sector employers, skills and training providers at all levels to develop skills and training initiatives and pro-actively engaging with universities and research providers to support the development of world class skills and technical capability for the nuclear sector.	Address identified skill shortage areas with appropriate frameworks
	Support the approval and take up of higher level qualifications to meet NDA needs
	Support the approval and take up of vocational qualifications to meet NDA needs
	Support the approval and take up of other training programmes to meet NDA needs
3. Providing a Robust Infrastructure Working with key stakeholders to identify, develop and promote excellent facilities to support delivery of world class nuclear skills programmes	Play a leading role in the development of new organisations and facilities to respond to national and local skills needs for the nuclear industry
	Review and develop where necessary training and education facilities near to NDA sites
4. Attracting and Retaining the Right Skills Encouraging collaboration across the sector, working with employers, schools, colleges and universities to raise awareness and develop the supporting framework which ensures the attraction and retention of key skills for the future	Invest in and support the STEM agenda in schools
	Support and participate in educational activities near to NDA sites
	Engage Graduates and Under-graduates to participate in developing career opportunities in the nuclear industry
	Work with Professional Institutes
5. Developing and Maintaining Networks Encouraging collaboration and partnership across the sector to develop solutions and raise awareness and share understanding of the skills agenda	Participate in and lead where appropriate skills networks related to the nuclear industry
6. Standards and Benchmarking Using recognised national and international standards, business improvement methodologies and tools related to skills performance to measure, compare and work towards become recognised as one of the leading world class industries	Implement the use of nationally and internationally recognised Standards related to skills
	Determine a methodology for measuring and improving business performance linked to skills

Tab 1. Themes and Objectives

3. Major Achievements to Date

3.1 SLC Skills Strategies – all of the NDA Site Licence Companies produce comprehensive documents which set out skills and resource requirements in the short, medium and long term.

Fig 2. Example Site Skills Strategies

3.2 National Standard Resource Codes – all of the NDA Site Licence Companies have agreed a common set of Resource Codes and are working to define associated "Dictionaries". This will allow the collation of data and resource planning on local, regional and national basis to support better management of available resources, skills and opportunities for employees within the industry. These will also be aligned to the Sector Skills Council (Ref.2) definitions and roles profiles to aid opportunities for cross-sector resourcing and analysis as well feeding into their "Career Pathways" programme.

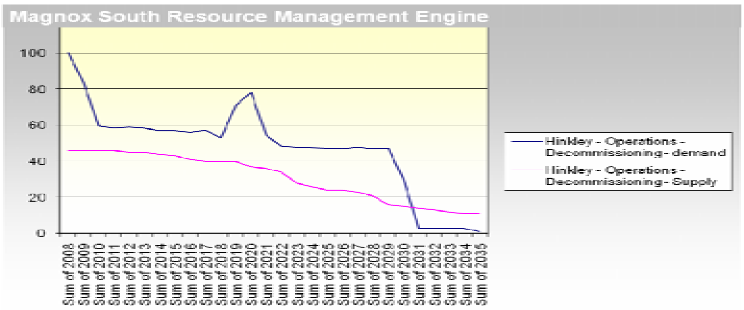

Fig 3. Example Skills Profile

3.3 A PhD sponsorship[3] and bursary programme[4] is in place to support individuals in targeted areas of research which supports the NDA mission.

3.4 Foundation Degrees – available in England, these are new qualifications which are designed with employers, and combine academic study with work place learning to equip people with relevant knowledge and skills to improve performance and productivity. Foundation degrees are awarded by universities and require equivalent standards of academic attainment as the second year of an honours degree. To date, working with Sellafield Ltd, Lakes College West Cumbria and GenII, Foundation degrees in Nuclear Decommissioning[5] and Nuclear Related Technologies[6] have been developed and are now being delivered to employees to provide new skills for the changing work environment.

3.5 A Community Apprenticeship Programme has been established by the NDA to fund 100 Apprentices in the nuclear decommissioning supply chain.

[3] http://www.nexiasolutions.com/content.php?pageID=229
[4] http://www.nuclear.nsacademy.co.uk/Bursary%20award%20scheme.html
[5] http://www.uclan.ac.uk/courses/ug/fdsc_nd.htm
[6] Awaiting validation

3.6 National Skills Academy for Nuclear[7] – a founder member and principle funder, the NDA has supported and assisted the development and successful establishment of the National Skills Academy for Nuclear and its operating arms particularly in West Cumbria, Scotland and North Wales.

Fig 4. Initial design for the Nuclear Academy in West Cumbria

3.7 Dalton Cumbria Facility – a partnership with the University of Manchester to establish a nuclear research and skills facility aimed at post graduate level with world class research areas in Radiation Sciences and Decommissioning Engineering linked with the British Technology Centre (and emerging National Nuclear Laboratory) at Sellafield. Chairs and students have been appointed in the research areas and plans for additional infrastructure facilities are well advanced.

3.8 The Energy Foresight Programme[8] aimed at 14-16 year olds to encourage the take up of Science, Technology, Engineering and Mathematics (STEM) has been updated to include a module on “Managing Nuclear Waste” and delivered to 400 schools across the UK. Plans and funding are now in place to roll out to some 50% of all secondary schools over the next 2 years.

3.9 The NDA National Graduate Scheme[9] has been a huge success to date with over 1500 applicants for the first 10 places. 13 offers have been made to graduates who will start a 2 year programme in April 2008 and carry out projects in the NDA, Site Licence Companies, the nuclear supply chain or Regulators, abroad in nuclear related organisations and a period of work with “corporate social responsibility”.

4. Mode of Operation

4.1 The NDA recognises that it cannot work alone in developing and implementing its approach to skills but has a key role to play in acting as the catalyst to lead the development of sustainable world class nuclear skills by developing excellent people, skills and facilities operating to the highest quality standards in order to fulfil its mission.

4.2 The NDA mode of operation in delivering its obligations with respect to skills is through a strong and well established network of partners and stakeholders (Fig 5.).

[7] http://www.nuclear.nsacademy.co.uk
[8] http://www.energyforesight.org
[9] http://www.nda.gov.uk/recruitment/nucleargraduates

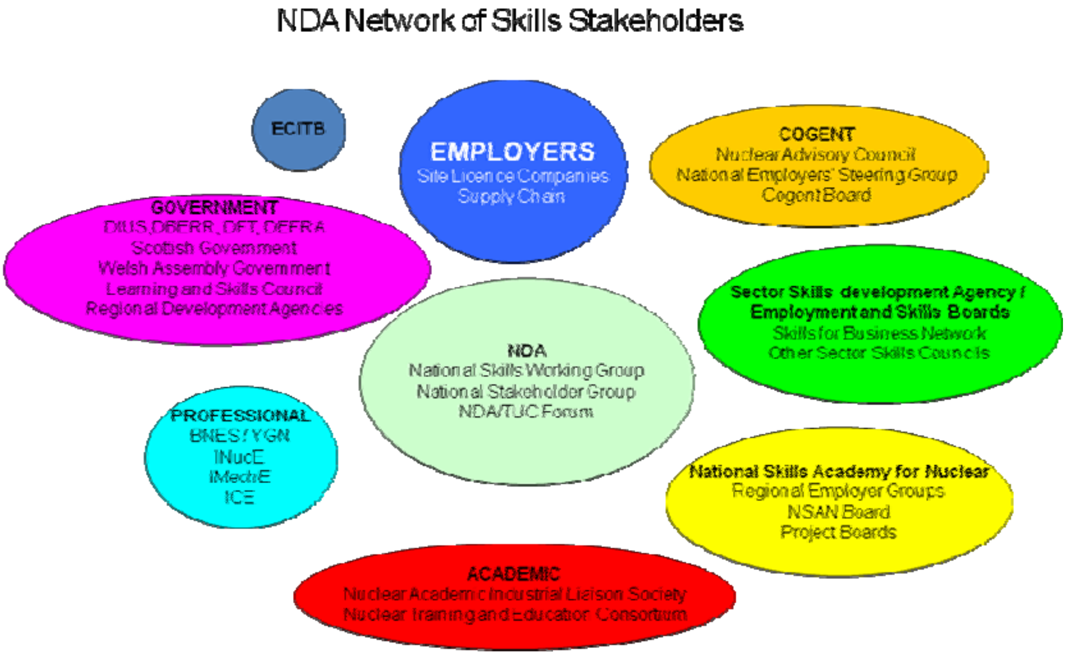

Fig 5. "Examples of NDA Partners and Stakeholders"

4.3 With the support of partners and stakeholders, the NDA is committed to taking a strong leadership role where appropriate in developing and delivering skills solutions using the following principles:

- strong partnerships with SLCs;
- delivering skills solutions collaboratively;
- networking to the best advantage;
- leading and influencing where appropriate;
- leverage and sustainability of investments;
- sharing good practice; and
- defining "World Class" and benchmarking the industry.

5. Conclusion

5.1 The challenges facing the nuclear decommissioning sector are substantial:

- a diminishing skills base and low uptake of key subjects such as Science, Technology, Engineering and Maths. This is in part due to demographics but also competition from other industries;
- the ability to meet regional and national requirements;
- a diversified contractor base;
- a lack of clarity on the long term needs;
- perceptions of the industry; and
- mobility and transferability of resources

5.2 The work by the NDA so far is the start to understanding and addressing the skills requirement for the nuclear decommissioning sector. There is still much more to do but with support from stakeholders and partners it can act as an enabler to make real and substantial changes to "*develop world class skills*" through *"excellent people, skills and facilities."*

References

1. Energy Act 2004 Chapter 1 section 9 (2) "General duties when carrying out functions."
2. Cogent – the Sector Skills Council for Chemical, Nuclear, Oil and Gas, Petroleum and Polymers

ENSURING KNOWLEDGE AND SKILLS IN DEEP GEOLOGICAL DISPOSAL: PROGRESS OF THE ITC-SCHOOL INITIATIVE

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ABSTRACT

The ITC School of Underground Waste Storage and Disposal is an independent, non-profit Association, based in Switzerland. It has more than 50 member organisations worldwide and was established in 2003 with the specific objective of responding to the clear need for continued training in radioactive waste management over the coming decade. Many national repository programmes were in difficulties and expertise was dwindling internationally. The ITC School has filled this gap by providing an average of four or five training courses a year in Europe, Japan and the USA, often with large practical elements. This short paper outlines the work that has been undertaken by the Association over its first five years of operations.

1 Introduction

At the beginning of the 21st century, national organisations and programmes developing safe approaches to deal with the back-end of the nuclear fuel cycle were faced with concerns that were common across the nuclear industry in general: how to ensure the availability of professional skills and knowledge in the field. These concerns were acknowledged by international organisations such as the IAEA, the OECD Nuclear Energy Agency and the European Commission.

In 2003, several initiatives started in Europe and worldwide to ensure the propagation of knowledge and skills in deep geological disposal over the generation gap. One of the key initiatives was the founding of the non-profit association, ITC School of Underground Waste Storage and Disposal, initially by five organisations from Switzerland, Spain, and Japan. Today, the ITC School, with its currently 57 members from 16 countries, has matured into an organisation that can be considered as the leading professional training provider in deep geological disposal in Europe. By the end of 2007, ITC-School had provided high quality professional training, benefiting from its position as a focal point in relation to the experts in its member organisations, for around 350 participants from 38 countries in 20 specialised courses and other activities.

2 The looming skills gap

The growing need for permanent solutions for the management of long-lived radioactive wastes is both a societal and technical challenge for the different actors and stakeholders in the industry. One of the main factors adding to the complexity of the management of long-lived radioactive wastes is its multidisciplinary nature.

At the beginning of 2004, the European Commission funded a 15-month programme called CETRAD, to identify the training needs, capabilities and resources available in the EU in the field. The findings of the project confirmed the existence of the generation gap in deep geological disposal, the lack of formal post-graduate level education, and the scarcity of professional training providers in the field. In addition, specific legal qualification or competence requirements on the training of personnel working with deep geological disposal do not exist yet.

Gaining high-level expertise in geological disposal takes tens of years. Last year was a significant turning point in the industry, because the industry experienced the retirement of many internationally acknowledged top experts and this will continue for at least the next 10 years.

The findings of the CETRAD project supported the need for both the ITC School and the IAEA supported project that established the Network of Centres of Excellence in Training and Demonstration of Waste Disposal Technologies in Underground Research Facilities and led to new European initiatives such as the EC sixth framework programme's PETRUS initiative, within the ENEN II project, initiation of the European Nuclear Training Network and the ESF supported underground training facility (USF) Josef Gallery in the Czech Republic.

3 Some ITC history

The concept of providing continued training with a high practical content and access to laboratory facilities arose in late 2001, at the time when Nagra, Switzerland, was designing the 6th Phase of activities at the Grimsel Test Site (GTS). The initial idea was to have a 'school' component within the future GTS activities. Over the next few months Nagra explored the idea with other organisations and the concept of the ITC ('International Training Centre') was born. Nagra provided resources to establish the School and set it on its feet for the first critical years of its existence.

The ITC School was established as an Association (*Verein*, under Swiss law) in April 2003 after a one-year period of exploratory discussions. For the first 12 months or so, Nagra provided the secretariat and offices for the new Association. However, the ITC Executive and Members agreed with Nagra that ITC should become independent as soon as possible, not least because this was considered to be in the better interests of Members and of overall transparency – too close a link to one Member or one sector being undesirable once ITC was able to stand on its own feet.

By the middle of 2004 the financial situation, although difficult, looked stable enough to make this move and ITC formally moved out of Nagra's offices to Dättwil, near Baden, although the domicile of the Association remains in Innertkirchen, in the Kanton of Bern, close to the GTS. Indeed, may of the courses provided by ITC are given in this region, using the excellent facilities of the nearby tourist village of Meiringen as a base.

ITC is run with a small secretariat of part-time staff and makes considerable use of support from its Member organisations in setting up and running training courses. For example, the majority of course tutors are provided by the Members. Nevertheless, many course users are actually from outside the Association, largely as a result of the close link between ITC and the IAEA Network of Centres of Excellence entitled 'Training in and Demonstration of Waste Disposal Technologies in Underground Research Facilities' (see next Section). Apart from fully open courses, ITC has also organized a number of tailored training activities for specific Members and is also involved in a number of European Commission RD&D projects as the partner responsible for running project training activities (e.g. OBRA, TIMODAZ and the initial training in FUNMIG).

ITC membership is open to any organisation supporting the broad concept of providing training and education in waste disposal. As and association, new Members have to be elected by the existing Members. Membership growth was rapid over the first few years, reaching 50 by early 2005, and has been relatively stable since that time. As a non-profit Association, the ITC School exists solely to serve the needs of its Members. As noted above, the original intention in establishing ITC was that it should be representative of all sectors with a working interest in radioactive waste disposal and this has certainly been the case, as can be seen in Figure 1. There is strong representation from organisations in every sector associated with underground disposal of radioactive wastes.

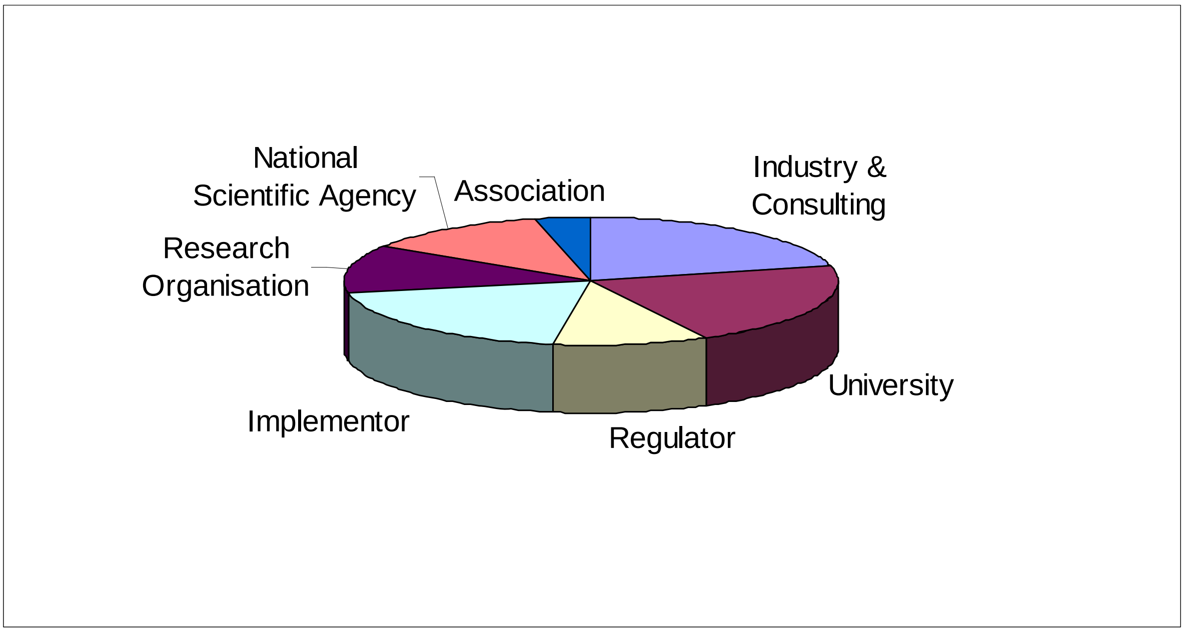

Figure 1: Current (early 2008) ITC membership, by sector.

4 The IAEA Network of Centres of Excellence

The birth of ITC School coincided with, and developed in close association with, a major training initiative organised by the IAEA. At around the same time that the concept of the ITC was being discussed, the IAEA also recognised the need for propagation of experience and dissemination of knowledge to newer waste management programmes worldwide. In particular, it saw the value of using existing underground laboratories to help provide practical, hands on training to those scientists and technologists just entering the field. In 2001 it established a Network of Centres of Excellence on 'Training in and Demonstration of Waste Disposal Technologies in Underground Research Facilities'. The objective of the Network is to assist in the transfer of knowledge and technology from IAEA member States with advanced research and development programmes in underground research facilities to Member States with less well-developed repository implementation programmes and/or having no direct access to underground research laboratories.

The project is led from the IAEA's Department of Energy, Division of Waste Technology (NEFW). Primarily, the project is funded and managed through Agency Project L.402/11 (Building Confidence in Geological Disposal of Radioactive Waste). Significant support to the project is provided by the Department of Technical Co-operation and indirectly through extra-budgetary contributions from some Member States that own Underground Research Facilities.

Through various pathways such as classroom and underground instruction, scientific visits, fellowships, coordinated research programs and on-site group training, the Network provides opportunities to increase levels of competence in nuclear waste management among countries having spent nuclear fuel and highly radioactive waste to be disposed of.

The core Members of the Network are radioactive waste management organisations and universities from Belgium, Canada, Sweden, Switzerland the UK and the USA. Member countries participating in the programme are:

IAEA Network Recipient Countries		
Argentina	Czech Republic	Philippines
Armenia	India	Romania
Brazil	Lithuania	Russian Federation
Bulgaria	Kazakhstan	Slovakia
Chile	Republic of Korea	Slovenia
China	Mexico	South Africa
Croatia	Pakistan	Ukraine

Classroom and underground instruction began in 2003, with courses offered in Europe through the ITC and in North America through a cooperative effort between the USA's Department of Energy and Lawrence Berkeley National Laboratory, and Canada's Atomic Energy Canada Limited (AECL).

Since the inaugural ITC course (the first IAEA Network course in Europe), ITC has facilitated 9 out of the 16 courses in the Network programme and is expected to continue in its 'facilitator' role during the next three years of the programme (2009-2011). Facilitation means that ITC works closely with the host organisation, which provides facilities such as a access to URLs, with ITC structuring the course and developing the course materials and exercises.

5 Course programme

Training in radioactive waste management needs to tackle a range of requirements, and focus both on new professionals in waste management who have just started a career and experienced professionals who may have changed or broadened their responsibilities. There are also other users, including decision-makers who are not professionals but who need to be aware of the issues surrounding waste management. Consequently, ITC organises courses and training ranging from the generalist – covering all key aspects across the broad spectrum from waste arisings to societal and decision-making issues – to intensive, specialist courses. Since the foundation of ITC, the following courses have been organised or are scheduled for 2008 (the location and main collaborating partners are identified):

1. 2003: The Fundamentals of Geological Disposal & The Theory and Practice of Underground Rock Facilities (IAEA, Nagra and SCK.CEN; Switzerland and Belgium).
2. 2004: Geochemical Modelling of Natural and Contaminated Groundwaters (University of Bern, Switzerland).
3. 2004: Workshop on Case Studies of Subsurface Radionuclide Migration (EAWAG, Switzerland).
4. 2004: Siting of Deep Geological Repositories (IAEA and RAWRA; Czech Republic).
5. 2004: Fundamentals of Geological Disposal (IAEA and Nagra; Switzerland).
6. 2004: The Role of the Safety Case in Planning and the Implementation of a Repository Programme (RWMC; Tokyo, Japan).
7. 2005: Decision-Making and Stakeholder Involvement (IAEA and PURAM; Hungary).
8. 2005: Deep Repository Design (IAEA and Nagra; Switzerland).
9. 2005: Multicomponent Reactive Flow and Transport (University of Bern; Switzerland).
10. 2005: Fundamentals of Radionuclide Migration (FUNMIG), Barcelona, Spain.
11. 2006: Geologic Disposal of High-Level Waste (USDOE, USA).
12. 2006: Interface between Geology & Safety Assessment (HSK; Switzerland).
13. 2006: Planning Preliminary Site Investigations (NUMO and SKB; Switzerland & Sweden).
14. 2006: Fundamentals of Geological Disposal (IAEA and Nagra; Switzerland).

15. 2007: Natural and Archaeological Analogues in Waste Disposal (Switzerland).
16. 2007 Practical Environmental Radiochemistry (PSI; Switzerland).
17. 2007: Geologic Disposal of High-Level Waste (USDOE; USA)
18. 2007: Deep Geological Repositories in Sedimentary Environments (IAEA and DBE Technology; Germany).
19. 2007: Transport and Retardation Processes in Fractured Rocks (IAEA and Nagra; Switzerland).
20. 2008: OBRA Project Workshop: Providing information for local communities (European Commission; Switzerland).
21. 2008: Geological Disposal: The Methodology of Safety Assessment (HSK; Switzerland).
22. 2008: Cement & Cementitious Materials in the Geological Disposal of Radioactive Waste (Posiva; Finland).
23. 2008: TIMODAZ training course: THMC properties of clays and claystones (EPF Lausanne, Switzerland).
24. 2008: Geologic Disposal of High-Level Waste (USDOE; USA).
25. 2008: Fundamentals of Geological Disposal (IAEA and JAEA; Japan).

An area that ITC intends to engage in over the next few years is provision of training for university students, especially at postgraduate (Masters) level. ITC has many universities as members and is becoming more closely involved with them and with separate programmes that they are organising (e.g. PETRUS – which aims to develop a European Masters degree in geological disposal) to fill the training gap at the academic level. For example, and avenue being explored is that ITC courses might be accredited and incorporated into academic modules to provide both a valuable network link between students and professionals and practical access to underground training facilities.

6 Conclusions

A few years ago, ITC observed that the future outlook for training in radioactive waste management was mixed. Despite the need, the funding of training was apparently widely regarded as of low priority and seemed often to be regarded as a marginal organisational expenditure, with training activities sometimes being opportunistic, rather than well planned and structured. It was not well appreciated that the provision of high quality training requires much preparation, access to large facilities and the input of the best expertise – and is consequently expensive.

The extent to which this situation has improved is currently hard to gauge, but there is certainly a renewed will to improve matters. This is most likely driven more by the perceived requirements of a nuclear power renaissance than the specific needs for managing the 'back end' of the nuclear fuel cycle. Without the present political drivers of reducing carbon emissions and improving the security of electricity supply that are pushing nuclear energy forward again after decades in the doldrums, it is arguable whether the impetus would exist to fill the skills gap in waste management. But the outlook today is really encouraging – and certainly much brighter than it was when ITC was being established five years ago.

For further information on the activities of the ITC School, visit: www.itc-school.org.

NUCLEAR KNOWLEDGE PRESERVATION, CONSOLIDATION, VALIDATION, DISSEMINATION AND TRANSFER ACTIVITIES AT THE JOINT RESEARCH CENTRE

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ABSTRACT

Nuclear knowledge had been build up continuously since the beginning of the last century. After Chernobyl in 1986 the acceptance of nuclear energy decreased in many Member States. The interest of younger generations for nuclear studies dramatically decreased and nuclear education was abandoned by many engineering faculties. In the meantime the generation of senior nuclear experts is retiring. On the other hand a renaissance of nuclear power is ongoing. In order to avoid a possible loss of capability and knowledge in the EU action should be taken now preserving and disseminating it to the new generation.
Following several recommendations the JRC has formulated 3 actions in its Work programme dealing with Nuclear Knowledge Preservation, Training and Education, each of them covering a different area of competence. This paper describes the JRC activities foreseen for 2008 but concentrates on nuclear knowledge preservation activities.

1. Introduction

After the Chernobyl accident in 1986 a trend at universities and in industry was observed of a decrease in students choosing nuclear related studies. Now the generation of senior nuclear experts is retiring. On the other hand, due to security supply and climate change issues (green house mitigation measures) receiving more importance lately, a renaissance of nuclear power is ongoing. In order to avoid a possible loss of capability and knowledge in the EU action should be taken now preserving and disseminating it to the new generation.
There is a huge amount of information and knowledge available, either published or easily available, but also publications difficult to trace. Especially those are at risk of being dispersed or lost due to a series of factors.
Considering that

- the European Commission in its Green Paper, in the 7th Framework Programme (FP7) and in a Communication recognises the need to efficiently disseminate research results [1,2,3],

- the International Atomic Energy Agency (IAEA) has adopted in 2002 a resolution on "Nuclear Knowledge" emphasizing the importance of nuclear knowledge management, which was reiterated in subsequent years [4],
- the Working Party on Nuclear Safety (WPNS) recommends the improvement of exchange of nuclear safety information [5],
- the Council of the European Union recommends in its conclusion regarding nuclear safety the compilation and exchange of any information regarding nuclear safety research [6],
- the European Atomic Energy Community recommends that the expected fading out of nuclear knowledge qualifies for a potential European solution [7],
- the OECD Nuclear Energy Agency adopts a statement about qualified human resources in the nuclear field due to the tremendous decline in students for nuclear studies in the last decades [8],
- the European Nuclear Energy Forum (ENEF) raised the idea of a European Nuclear Academy directly co-ordinated with the European Nuclear Education Network (ENEN) at its inaugural meeting [9],

nuclear knowledge preservation and consolidation activities will be carried out with a strong political support. Also from the IT industry signals are pointing into the same direction. IBM's Nuclear Power Advisory Council recommends strongly knowledge management in nuclear technology [10].

2. Initiative

Following the above political recommendations and due to its experience in Education and Training the JRC has formulated 3 actions in its 2008 Work programme dealing with Nuclear Knowledge Preservation, Consolidation, Validation, Dissemination and Transfer, namely "Capture", "KTE" and "TENS". Each of them covers a different area of competence in the nuclear domain. Additionally, some horizontal activities are taking place throughout the JRC.
"Capture" stands for "Consolidation and Preservation of Nuclear Technology Knowledge and Reference Data for Education and Training of Experts for Plant Life Management and Future Plant Designers". "KTE" covers the knowledge management, education and training field regarding the nuclear fuel cycle. The objective is to create a management system which will allow collection, dissemination, use and organization of the scientific information. Such system is founded on different pillars, e.g. documentation archiving, knowledge transfer, education and training, project management and scientific and public communication. "TENS" deals in priority with nuclear training and education aspects in the area of nuclear safeguards, non-proliferation and nuclear security but owns also a specific Safeguards knowledge management.

3 Knowledge Collection, Preservation and Consolidation

Lately, many stakeholders, such as Institutes, R&D Organisations, Regulators, Utilities, Governmental Organisations, have recognised the need for collecting, preserving, consolidating (validating), and disseminating nuclear knowledge (documents, competences and data), in order to make it easily accessible to future generations through modern informatics tools and training and education measures.
In the nuclear safety area it needs to cover an as wide as possible range of reactor designs, systems, components, materials and technologies, including PWR, WWER, BWR, CANDU, MAGNOX, MTR, etc.. A broad spectrum of components and technologies will be considered, i.e. reactor pressure vessel (RPV), piping, internals, steam generator, etc. regarding knowledge, material data and practices. In the long run, this will also support future decommissioning exercises of nuclear installations as a valuable knowledge source.
The urgency of such activity is valid in particular for Russian designed Nuclear Power Plants in the new Member States, facing a serious issue in terms of losing fundamental knowledge which is furthermore scattered in many countries and in different languages.
In addition to the knowledge available in each Member State, JRC produced a long standing record of results from its own institutional activities and even more through the participation

to a large number of European Network partnership projects. In particular, substantial knowledge is available at JRC-IE on plant-life-management (PLIM) topics as well as structural design, nuclear science, structural safety analysis, thermo-fluid dynamic, reactor dosimetry, safety management systems, decision making and human factors, design criteria, super critical water, etc. in most cases relevant for supporting the development of advanced reactor systems as GEN IV applications.
It is important, besides preservation, to consolidate the enormous amount of scientific results produced since. This can be effectively done utilising a dedicated method developed at the IE for consolidation of knowledge. The method is based on the active involvement of those senior experts who participated since the beginning of the nuclear era and are still active and available. It makes extensive use of well focused consolidation workshops and has been tested in recent years achieving encouraging results.
Training and education material can be developed in this way very effectively for the use in academic organisations such as the European Nuclear Education Network (ENEN), National Universities, etc..
GEN IV cannot afford to fall into the same shortcoming in the future. A systematic approach needs to be developed to start knowledge preservation and slowly entering into consolidation exercises. It has to be noted that the development of GEN IV is also based on knowledge created along several decades already and in many cases spin offs of previous generation R&D. The same could be said for Fusion, Accelerator Driven Systems and other applications.
Based on the experience of the JRC with its “Online Data & Information Network for Energy” (ODIN) web portal (http://odin.jrc.ec.europa.eu) and the pilot project on WWER RPV knowledge collection, multi-lingual reports (e.g. Russian, Ukrainian, Slovakian documents in original language, articles in local magazines, proceedings from national events, etc.) will be collected and organized into prior defined subjects. Experts will be proposing summaries of related publications and after “Consolidation Workshops” State-of-the-Art will be produced and published as open EUR Reports (with references to the original papers). In this way the EUR Reports will have no restriction for further distribution (while Intellectual Property Rights [IPRs] might still be part of the original documents).
The below figure illustrates the proposed way forward for consolidation.

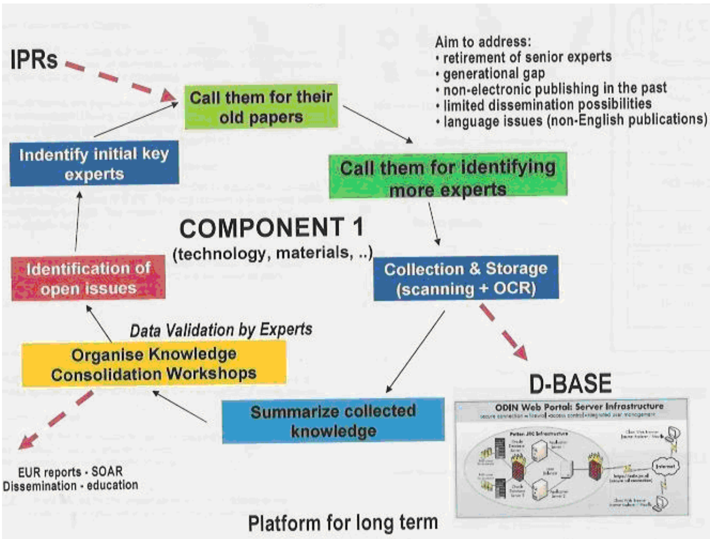

Figure 1: Nuclear Knowledge Consolidation Circle

Besides hard knowledge it is crucial to construct a Network of EU experts, who are available for consultation in case of crisis situations (EC-FP7 priority). The leading experts (including those already retired) need to be traced and their coordinates should be kept in a central database. The EUR Reports and the results from the Workshops are the bases for dissemination and developing training material mainly for younger staff entering the field. Collaboration with ENEN is also envisaged.

4. Data Validation

In the past several International projects have produced large amounts of relevant data which are dispersed in a number of d-bases or only available on paper; mainly the IAEA, EC Round–Robin exercises, etc. Such data need to be re-examined and validated for further use. For example, in 2005 the IAEA has transferred its International Reactor Pressure Vessel Database, which is one of the largest of irradiated materials databases in the world, to the JRC for further management. The change was necessary due to outdated users interface software; whereas JRC had implemented already Java based data retrieval software, which can be developed further according to the future requirements.

A modern and useful database should have the three following functions:

1. Data collection, processing, storage
2. Data validation, and
3. Data evaluation

The first function is fulfilled by a JRC databank in ODIN. The second requires the continuous work of specialists to fit trend curves and check outliners. The third is also the task of specialists, as new trend curves have to be established after validation of the data.

This data validation could become a follow-up activity, in case the knowledge consolidation methodology proves to be successful on a wider scale. It would support designers, safety authorities, modellers and also upgrade C&S.

5. Web Portals

One of today's activities of the IE concerns data management and dissemination in nuclear safety. An Online Data & Information Network (ODIN) is set-up, which maintains one document database and four engineering databases. These databases aim to deploy networks for energy related research & development, specifically for nuclear energy and to provide the public experimental data of European projects on mechanical and thermo-physical material properties in comparison with international standards and recommendations. Moreover ODIN manages six nuclear databases, which have restricted access. They cover: (i) data on High Temperature Reactor (HTR) Fuel Elements, (ii) HTR graphite element data, (iii) data on safety of Eastern European Type Nuclear facilities, (iv) information on current research reactor safety assessment approaches, (v) data on hydrogen incidents and accidents, (vi) information on long term radioactive waste management, to enable co-operation and technology transfer for member states with small nuclear programmes.

Nucleonica is a new science web portal from the ITU. It provides a customisable, integrated environment and collaboration platform in fields as diverse as the life and earth science, and more traditional disciplines such as nuclear power, health physics and radiation protection, nuclear and radiochemistry. It is also used as a knowledge management tool to preserve the nuclear knowledge built up over many decades by creating a modern web-based version of so-called "legacy" computer codes.

6. Knowledge management in Safeguards

The JRC is part of the European Safeguards Research and Development Association (ESARDA) created in 1969 to assist the European safeguards community with the advancement of safeguards, enhancing the efficiency of systems and measures, as well as investigating how new techniques can be developed and implemented.

As such, the JRC provides the secretariat of the association and has developed a specific website (http://www.jrc.cec.eu.int/esarda/) to provide the latest issues of the Bulletin, as well as scientific and practical information about the working groups and symposia. It also contains a comprehensive database with associated search tools gathering all the reference materials relating to safeguards since its origin (treaties, a safeguards glossary, technical sheets, modules of courses and key publications).

7 Education

Education is commonly defined as a basic, knowledge-driven, learning process, involving academic institutions as suppliers and students as customers, which encompasses the need to maintain completeness and continuity of competences across generations.

The implementation of the second part of Article 9 of the EURATOM Treaty, “to establish an institution of university status”, became only possible almost 40 years later when European universities started a mutual recognition process. A transparent exchange mechanism between the different national higher education systems had to be agreed between leading universities in Europe. This was obtained within the Sorbonne-Bologna process in 1998, which formalized a European Credit Transfer System (ECTS) for studying at those European universities [11]. With the decreasing number of nuclear engineering and nuclear physics students, the number of nuclear courses offered today is more limited than 30 years ago, but they are therefore, with the ECTS internationally recognized, more accessible for foreign students.

The temporary European Nuclear Engineering Network, established through the RTD FP5, was given a permanent character by the foundation of the European Nuclear Education Network (ENEN) Association in 2003, pursuing a pedagogic and scientific aim. [12]

The ENEN is approached by JRC to extend its programme into nuclear safeguards and security. A Memorandum of Understanding between the JRC and the ENEN, associating JRC to the ENEN which is under establishment, is a first step in this direction.

The JRC is contributing mainly to education by offering R&D projects for graduate students towards a PhD degree. In very limited scientific domains in which universities are not involved the JRC is providing academic courses of short duration for a limited audience. On the other hand, it is clear that the JRC is a research centre and has no vocation to play the role assigned to universities.

7.1 Academic Courses

With the support of the European Safeguards Research and Development Association (ESARDA), in particular the ESARDA Working Group on Training and Knowledge Management, the IPSC is organizing yearly a Nuclear Safeguards and Non Proliferation course. This course will be organized this year for the fourth time from April 14 to April 18. The BNEN/ENEN has recognized the course as a standard academic one semester course of 3 ECTS. To formalize and maintain this recognition, the course syllabus is being finalized with all presentation materials for the so-called “mandatory” section. Both the lecturers and ESARDA WG’s have been called upon for contribution/collaboration to this.

At the GELINA facility in the IRMM yearly two courses are given on neutron measurements (incl. time-of-flight experiments and accelerator experiments). One is recognised as an elective course in the ENEN programme. The other has been organized twice for the academic network for co-operation in Higher Education on Radiological and Nuclear Engineering (CHERNE).

Some JRC courses are covered under a Collaboration Agreement (CA) between JRC and Universities. As most recent example, such a CA has been drafted upon request of the University of Florence for contributing with teaching in the master “Nuclear Materials and the control of the Non-Proliferation Regime”. This master, which was opened with the explicit support of Dr. El Baradei, will be started in 2008 and JRC is offering a one week course of 3 ECTS points.

In addition, some experts of JRC are teaching academic courses in the nuclear field at universities (e.g. Universities of Ghent, of Leuven, of Brussels, of Delft, of Heidelberg).

7.2 Traineeships

The JRC traineeship scheme provides trainees with experience of working in a research environment and a better awareness of the operation of JRC and the Commission. It benefits the JRC by providing extra resources, an influx of fresh ideas and closer links to the academic community.

There are three categories of trainee – (1.) industrial placement (or pre-graduate work experience), (2.) preparing a thesis and (3.) post-graduate work experience.
JRC is also reinforcing its collaboration with universities by providing university students access to its research facilities. In this way ITU was one of the founding members of the "Association for research and lecturing in nuclear engineering in Southwest Germany" together with the Forschungszentrum Karlsruhe, Energie Baden-Württemberg, the Ruprecht-Karls University of Heidelberg, the University of Karlsruhe (TH), the University of Stuttgart and the Universities of Furtwangen and Ulm.

7.3 PhD and Post-doctoral Fellowships

The JRC offers PhDs and post-doctoral fellowships to encourage young scientists to enhance their experience in an international, multicultural and multidisciplinary environment. JRC hosts PhD students with internal grants (in close collaboration with the university surveying that at the end of the research a PhD title can be awarded) and with external grants, such as e.g. the Marie-Curie Fellowships for pre- and post-doctoral researchers, or national fellowships (e.g. from the German Alexander von Humboldt Stiftung).

8 Conclusion

The JRC has a longstanding experience in nuclear training and education, mainly in the field of nuclear safeguards and the nuclear fuel cycle. Recently, also knowledge management issues are tackled more systematically by the different Institutes, mainly by creating a management system, which allows the collection, dissemination, use and organization of the scientific in-house information and by applying a new methodology to collect, preserve, consolidate and disseminate external nuclear safety knowledge. The need for this, expressed from different international institutions and committees, may lead to an increase of efforts in the nuclear knowledge management area.

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ACTIVE LEARNING - A NEW METHODOLOGY? APPLICATION TO EDUCATION ON NUCLEAR ENGINEERING

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ABSTRACT

One of the objectives of European Higher Education Institutions in order to improve the formation of their graduates is to promote the use of active learning methodologies. A new methodology as old as the teaching activity. Remember Socrates, Plato and the Ancient Greek Academy. Students should be the active subject of their own learning. Teachers should supervise and direct this learning process in order to optimise teaching results. It is thus necessary to involve students in the development of lessons being indispensable their personal motivation. The issue is to invite students to actively participate in the class by discussing each lesson whose objectives are proposed by means of questions in order to stimulate the participation of students in the discussion. Some experiences developed at the Polytechnic University of Valencia are presented. Results obtained over the last years have demonstrated that the application of this methodology enhances the student learning performance.

1. Introduction

One of the objectives of European Higher Education Institutions in order to improve the formation of their graduates is to promote the use of active learning methodologies. Many people refer to this as a new methodology. However, it is as old as the teaching activity. Just remember Socrates, Plato and the Ancient Greek Academy.

The student should be the active subject of his own learning. Teachers should supervise and direct this learning process in order to optimise teaching results. It is thus necessary to involve students in the development of lessons being indispensable their personal motivation.

The issue is to invite students to actively participate in the class by discussing each lesson, although they have no background in the field. The objectives of every lesson are proposed by means of questions in order to stimulate the participation of students in the discussion.

Obviously, students must be previously provided with the information necessary to prepare the discussion. Sometimes this information is put in a web page from where it can be downloaded by the students. It can include notes about the matter, bibliography, practical exercises and questions. Students can also use different books, journals or websites to complete the study of the lesson.

In particular, a textbook [1], has been published for a course on Radioactive Contamination, which includes Fundamentals and Applications, that is, basic concepts on radiations and radiation protection as well as contamination features and decontamination techniques. The active learning methodology developed for this course was presented at a previous conference, ETRAP 2005 [2].

Active learning methodology usually implies that students are evaluated by means of a continuous evaluation [3]. It takes into account the comprehension of basic concepts and their application to practical cases, verifying the accomplishment of objectives. It is stressed the development of personal works with an oral presentation. Results obtained over the last years have demonstrated that the application of active learning methodology enhances the student learning performance.

Some experiences developed at the Polytechnic University of Valencia are presented. They refer to courses given by the author related to Radioprotection and Nuclear Engineering.

2. Methodology

The teaching methodology must be focused on an active participation of students in their own learning. They will learn –if they want!– and the role of their teachers is leading their learning and preparing and providing the material necessary to help them to achieve learning objectives [3].

The student should be then the active subject of his own learning. Teachers should supervise and direct this learning process in order to optimise results. It is thus necessary to involve students in the development of lessons being indispensable their personal motivation.

One of the strategies used with this goal is to present a short list of questions the first day of the course, so that students can express their expectations for the course and the professor could know about gaps in their knowledge. Another way to motivate the students is to carry out without announcement an exercise at the middle of the term, so that they could realise about the concepts well learnt so far.

The main component of this active methodology is the development of each lesson at the classroom. Lessons are not exposed in a traditional way but they are discussed in the classroom following some guidelines with several objectives in mind. It is necessary that students prepare the lesson previously and obviously they need some guidelines as well as a reference text. A web page linked to each course is very helpful to provide information to the students.

During the development of the class, different questions are proposed to the students in order to perform an analysis of the lesson achieving the objectives previously established. These objectives shall include, if possible, the following points:

- what must be learnt by the student;
- trying to find out why must he learn it; and
- maintaining a connection between the different matters.

During the discussion the students shall present their own points of view as well as their doubts and problems of understanding. The professor shall lead the discussion directing it to fix and understand the objectives proposed for each theme. After clearly understanding the concepts of the lesson, it will finish with a summary of the most important points to underline them and stress its comprehension. This development should be complemented with practical exercises.

The participation of students in the development of the lesson is first timid, but increasing with time. They carry out many exercises and works proposed at the classroom and this contributes clearly to their formation. Besides exercises proposed during the class, a list of questions for self-evaluation is provided at the end of each lesson.

In the next paragraphs a review is done to specific aspects of two courses given by the author at the Polytechnic University of Valencia.

2.1 Radioactive Contamination

Students in the 5th year of Industrial Engineering (branch Environment) have a course on Radioactive Contamination. They arrive to this course with scarce or no background about radiation or radioactivity. Therefore, some basic concepts on radiations and radiation protection should be learnt before starting the study of radiation applications, contamination features and decontamination techniques. One can say that they start from scratch. Nevertheless, they are invited to actively participate in the class by discussing each lesson. To stimulate their participation the objectives of the lesson are proposed by means of questions. Of course, students have been previously provided with the information necessary to prepare the discussion. During several years this information was included in a web page, but finally a textbook was published [1].

The development of the class is centred on basic concepts and practical applications, being complemented with works in group and practical exercises in the laboratory. A booklet for laboratory practical exercises was also published [4].

Practical exercises include laboratory and computer calculations (shielding and doses) but one of the most innovative tasks –very appreciated by students– was the analysis of a real situation, usually a radiological accident. Students should prepare their work reading the available information and preparing in small group a presentation of their analysis in a public session at the seminar. They are provided with a summary of the accident and some guidelines to develop their work [5].

2.2 Nuclear Materials and Fuel Cycle

It is a course also given in the 5th year of Industrial Engineering (branch Energy in this case). It belongs to the master course on Nuclear Engineering so students have already a background on radiations and nuclear applications. Nevertheless, they are likewise invited to actively participate in the class by discussing each lesson. Their participation in the class is also stimulated by proposing the objectives of the lesson by means of questions. Once more, students should be previously provided with the information necessary to prepare the discussion. A web page linked to the course is very useful to give them information. Planning of the course and proposed questions and exercises are also uploaded on this web page. An extensive bibliography is also provided and the works developed by students of previous courses are complementary information quite useful for preparing the discussion. Some textbooks are also used [6,7].

It is very important for this course to perform visits to the installations of the fuel cycle. It is done when possible. Otherwise, some virtual visit should replace it, for instance with videos. Another important issue for this course is a practical exercise whose goal is the partial assembling at the laboratory of PWR and BWR fuel elements. This exercise permits to the students the handling of pieces of fuel elements and helps them to understand the function of each piece.

3. Evaluation

The learning process of all students is actively conditioned by the evaluation method applied. For an active learning methodology the best evaluation method should be the continuous evaluation of the student participation in classes. Of course, it may be complemented with other traditional evaluation methods such as written or oral exams. Also, for each exercise (numerical, computer, laboratory reports, other works…) performed and presented during the course a mark should be given.

The participation in the class and the presentation of exercises are a free decision taken by students. Therefore, in those cases when students do not actively participate in the activities of the course, they must pass an exam, written or oral.

Nevertheless, whenever it is possible the final evaluation is carried out by means of an oral presentation of a work developed by a group of 2 students. The mark obtained with this work will complement the continuous evaluation taking also into account all notes obtained from voluntary individual exercises and works.

The final written exam, when it is done, has a non-traditional structure. For the course on Radioactive Contamination it is usually divided into three parts. In the first one, students should demonstrate their good knowledge of basic concepts and solve some single numerical exercises. In the second part, a practical analysis of some situation (usually an accident, real or imaginary) is proposed and the student should summarise some guidelines for a possible solution. The third part contains free questions. For instance, the student has to choose a theme and underline its main objectives with a clear justification of them. Whenever these free questions are proposed, students show an initial surprise, but usually results obtained can be considered good.

In the case of the course on Nuclear Materials and Fuel Cycle, the continuous evaluation obtained from the student participation in classes is complemented with a personal contribution to one of the themes of the course. When this activity is proposed, each student must present a short resume of the theme previously to its discussion in class.

4. Results

The number of students in the group never exceeded 30 students over the last eight years and this is an advantage to apply an active learning methodology.

Results (final marks) obtained by students in the last eight years are listed in Table 1. Marks in Spain range from 0 to 10. It is necessary a mark greater than 5 to pass the course and the students passing the course are classified into 4 groups: Approved (5-6), Notable (7-8), Excellent (9) and Honour (10) the highest mark. Presently there are legal restrictions so that only a maximum of 1-2 honours (depending on the number of registered students) per course may be given.

Table 1. Marks obtained by students when an active methodology was applied.

Year	Students	Presented	Refused	Approved	Notable	Excellent	Honour
2000/01	29	23	0	12	8	2	1
2001/02	29	28	3	7	14	3	1
2002/03	23	18	2	4	7	3	2
2003/04	15	14	0	3	6	3	2
2004/05	21	17	0	5	6	4	2
2005/06	20	19	1	3	12	1	2
2006/07	13	12	3	5	2	2	0
2007/08	8	8	0	0	5	2	1

Marks obtained by students in previous years, when master classes were given with greater groups, are listed in Table 2, where it can be seen that final marks were not so good.

Table 2. Marks obtained when master classes were given without an active methodology.

Year	Students	Presented	Refused	Approved	Notable	Excellent	Honour
1996/97	29	21	7	10	1	2	1
1997/98	73 (#)	53	6	23	18	4	2
1998/99	33	30	8	11	10	0	1
1999/2000	32	24	4	8	7	2	3

(#) There were a greater number of students because students from Chemical Engineering joined the group.

Differences observed between tables 1 and 2 can be attributed to the methodology. The main differences in favour of the active methodology are the lower number of students refused, the increase in the number of students participating in all activities, so that they are fully evaluated, and finally the increasing number of students with higher marks. Nevertheless, the main difference is the satisfaction shown by students although they have more work and the knowledge by the professor that the learning level is increased.

5. Conclusions

The active participation of students in the class permits them to improve their learning. To achieve this goal, the class should not be a master class but it is necessary to maintain a discussion with questions addressed to the comprehension of concepts as well as to fix objectives for each lesson, checking out that they have been completely achieved.
It is indispensable to obtain an adequate motivation of students. A possible strategy for this is to permit them to express their expectations in the course and to adjust the development of the classes in terms of the feedback obtained from their attitude and work.
It is necessary to provide students with documents so that they can prepare lessons before attending the class. It is useful to upload the information in a web page but the best solution is to provide them with an appropriate textbook.
All activities proposed in the class should stimulate the participation of the students. They must be not compulsory but with positive repercussion, if any, in the final mark.
The elaboration of the lesson objectives by the students themselves is an exercise very useful to enhance their learning process.

The continuous evaluation seems to be the best method when this active learning methodology is applied. On the other hand, an evaluation taking into account the understanding of basic concepts, its application to practical cases and the free exposition of the objectives of the course by the student has been shown, in general, very positive.
The marks obtained by the students as well as their satisfaction seem to confirm this point.

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EDUCATIONAL KNOWLEDGE RETENTION IN NUCLEAR RESEARCH INSTITUTES IN JAPAN, THE U. S. AND EUROPE

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ABSTRACT

Bibliometric analysis was carried out for champion data comparisons among prestigious nuclear research institutes (PNRI) existed in Japan, the U. S., France and Germany. The analysis was relied on database INIS (IAEA), ECD (DOE) and WOS (Thomson). INIS is advanced, key ex-post evaluating tool for champion data comparisons. The world champion among 11 PNRI is ORNL, confirmed by INIS, ECD and WOS. Over the 25-year time span of research paper publication, JAERI is the 3rd ranked institutes following ORNL and ANL. INIS database results revealed that CEA/Saclay is the French domestic champion regarding research paper publication. The research knowledge within the present scope is retained successfully and is available elsewhere. The retained knowledge (some over 50 years old) could and should be utilized for educational and training purposes for younger generation.

1. INTRODUCTION

Valuable and retention-worthy knowledge is born as a result of research activities in nuclear institutes. Such knowledge should be provided explicitly in the form of research papers to facilitate more usage for educational purposes and nuclear knowledge management. Using research papers provided by JAERI-Japan and 10 prestigious international nuclear research institutes (PNRI), an institutional comparison by bibliometric method was performed for this study from the view point of educational knowledge retention. This comparison is aimed at learning the volume of intellectual assets produced by each institute and also looking from the view point of knowledge management for the benefit of taxpayers in order to explain an accountability or a transparency of national institutes funded mainly by the government [1]. It is the principal author's hope that the results will be encouraging to younger generations who wish to become nuclear researchers in the near future.

2. ANALYTICAL METHOD

2.1 Prestigious institutes chosen

The following PNRIs (JAERI plus 10 other international institutes) were chosen for the present study. They are all well-renowned national institutes (laboratories) with historical nuclear research programs.

JAPAN:	Japan Atomic Energy Research Institute (JAERI)[1]
The U.S.:	Oak Ridge National Laboratory (ORNL), Sandia National Laboratory (SNL), Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL) and Idaho National Laboratory (INL)

[1] JAERI was reorganized in 2005 and renamed as the Japan Atomic Energy Agency (JAEA). The present study addresses intellectual assets created by JAERI. Hence, JAERI is used in the text.

EUROPE: Karlsruhe (FZK) and Jeulich (FZJ) in Germany. CEA/Saclay, CEA/Grenoble, and CEA/Cadarache in France

2.2 Research tools

As the principal research tool, the International Nuclear Information System (INIS), owned and operated by International Atomic Energy Agency (IAEA) was used [2]. INIS has been in existence since the year 1970 and today 118 countries and 23 international organizations co-operate for managing nuclear information resources. Research outputs from JAERI and the other international research institutes chosen for the study are provided into the system regularly.

Additionally, the U.S. Department of Energy (DOE) Office of Scientific and Technical Information (OSTI) builds the Energy Citation Database (ECD), operating since 1948 [3]. Research outputs of JAERI and other renowned international research institutes are also included in this database. The subject scope includes all energy-related topics. ECD includes international information published through the mid-1970’s. Since that period, ECD is populated primarily with U.S.-published research results due to dissemination limitations placed on internationally-exchanged information. ECD in the present study was used as a reference. Further, the Web of Science (WOS) from ISI-Thomson [４] was also used as a reference because managers interviewed indicated it to be a more familiar tool to many of the major nuclear research institutes located in Europe.

2.3 Time span

From CD-ROM or the Website, INIS provides published papers with a time span of 25 years (1978-2002) and for 5-year periods, that is, present (1998-2002), past 5 (1993-1997), past 10 (1988-1992), past 15 (1983-1987) and past 20 (1978-1982). In comparison, ECD can provide submitted papers with a time span of 50 years (1953-2002), 25 years (1978-2002) and 5-year periods. WOS has a similar functionality as that of ECD.

3. RESULTS

3.1 Trials to determine the representative institutes for France

France is a very advanced country in applications for the peaceful use of nuclear energy. At the moment, a total of 58 nuclear power plants (PWR) are in operation. The share of nuclear was about 78% of the gross electricity totals. As far as the principal author’s knowledge is concerned, there existed 9 CEA (Commissariat à l’Energie Atomique) research institutes covering the country. They are Fontenay-aux-Roses (since about 2000 main interest in life sciences), Saclay (main interest in physical sciences and fundamental research), DAM Ile de France (defence sector), Valduc (defence sector), Grenoble (technological research, electronics, instrumentation, etc), Cadarache and Valrho (nuclear sector), Cestra and Le Ripault (defense sector). In accordance with the purpose of this study, a domestic comparison to gain a few French representative institutes was carried out. Using the INIS database, the papers published by the prestigious French nuclear research institutes during past 25 years are studied. Results shown in **Figure 1** revealed that the papers are ranked in the following order:

Saclay > Grenoble> Cadarache > Fontenay-aux-Roses > other institutes・・・・・・・/1/

In the Saclay and Grenoble institutes alone, more than 15,000 papers were published during the 25-year period and they are still available for reference. The retained knowledge in the form of these papers will be of much benefit to many younger French and international students or researchers. For the wider bibliometric comparison used in this study, the top three institutes, CEA/Saclay, CEA/Grenoble, and CEA/Cadarache, were selected.

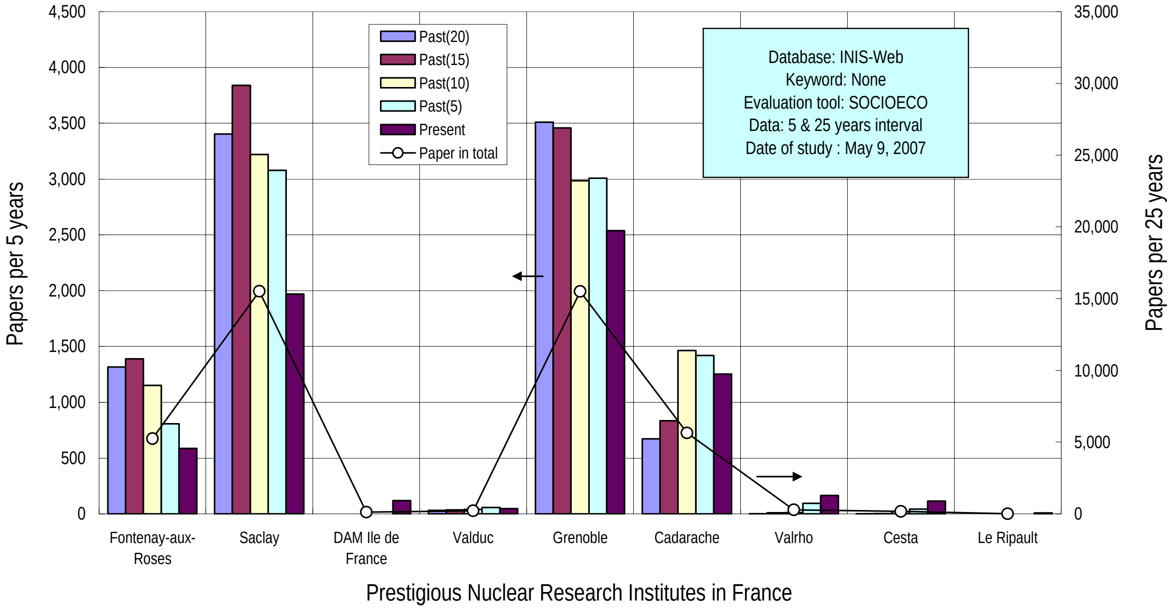

Fig. 1 All papers published at 9 French PNRIs during the period 1978-2002. Open circles show the total published papers during 25 years at each institute (scale is shown on the right-hand side) and the columns show the papers published during 5-year increments at each institute (scale is shown on the left-hand side). Database used was INIS.

3.2 Institutional comparison by INIS

The next step was to look at comparing these top French institutes to a selection of international institutes noted in section 2.1. **Figure 2** shows the total number of papers provided by JAERI and 9 other PNRIs over the 25 year period of the study (the third French institute, Cadarache, fell below the threshold used for the analysis).

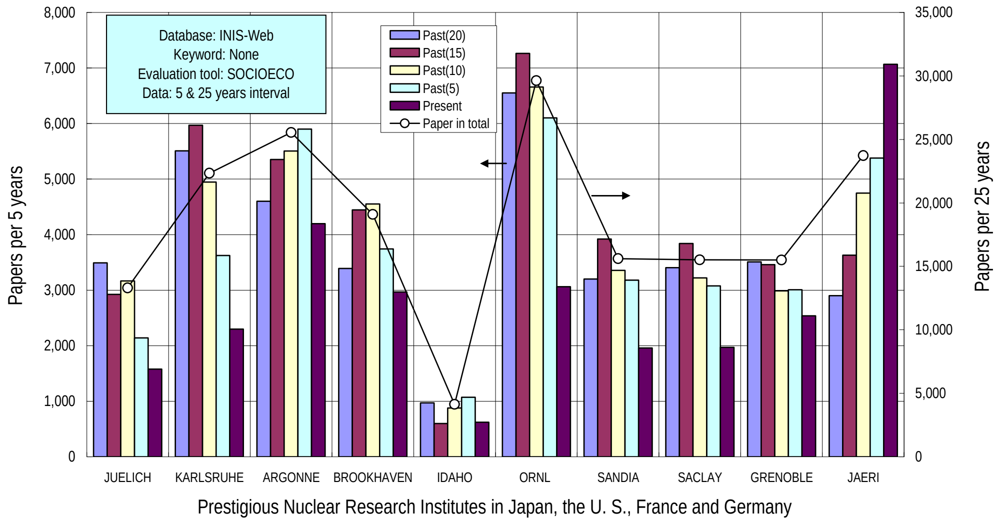

Fig. 2 All papers published in JAERI and 9 PNRIs during the period 1978-2002. Open circles show the total published papers during 25 years at each institute (scale is shown on the right-hand side) and the columns show the papers published during 5-year increments at each institute (scale is shown on the left-hand side). Database used was INIS.

After review of the data, the following conclusions can be reached:

(1) Over the 25 years of research activities, the papers are of the order

ORNL>ANL>JAERI>FZK>BNL>SNL>Saclay>Grenoble>FZJ>Idaho・・・・・・・・・/2/

JAERI is in the 3rd position, following ORNL and ANL. Through interviews with corresponding managers, it was understood that the change of nuclear policies (e.g., de-emphasis of reprocessing policies in the U. S.), the nuclear accidents (e.g., TMI (1979) and Chernobyl (1986)), and economical dynamics (e.g., the 2nd oil shock in Japan) and so on, are significant factors having much influence on research activities, including the number of research publications produced. Therefore, the capability of knowledge retention is affected by those external events.

(2) For each 5-year period of research activities, the number of papers in JAERI increased period to period. However, research papers in the other 9 PNRIs decreased from the past (20) to the present. A comparison between ORNL and JAERI at present (1998-2002) shows that ORNL is about 3,000 and JAERI is about 7,000. Just reviewing the numbers, it appears that readers would think that JAERI is alone in increasing its research activity in the world and the other 10 PNRIs are decreasing their research activities. This viewpoint is, on the surface, rather unlikely. To gain further insight as to its validity, the principal author carried out a similar bibliometric analysis using WOS.

3.3 Institutional comparison by WOS

WOS focuses mainly on the research papers submitted to journals in the field of natural sciences; WOS has the advantage of being able to show a citation index or an impact factor. Research papers presented at international conferences and published in the form of proceedings are usually omitted, however. Because WOS has a large volume of citations, though, WOS data may be a good representation of publishing patterns in advanced research fields.

A bibliometric study was done similar to that of the INIS database. Results obtained are shown in **Figure 3**. Note that in this case, the time span was extended an additional 5 years from 1978-2002 (present) to 1978-2007 (present-m) as denoted in the legend of the figure.

Conclusions reached from this analysis were interesting.

(1) It is evident that there is a significant difference between the totals for U.S. papers and those from the other international sources. It is surmised that WOS may draw its data primarily from U.S. data sources, especially for historical periods.

Among the U.S. papers, the ranking according to WOS is of the order

ORNL>ANL>BNL>SNL>Idaho ・・・・・・・・・・・・・・・・・・・・・・・・・・/3/

(2) As was clear from equation /2/, ORNL here is the champion, too. One regrets to say that Japan, France and Germany totals are negligible, based on the data available within WOS.

(3) It is worth to mention that in the 5-year data increment comparisons within WOS, all research institutes had a tendency to increase from the past (20) to date. This observation is apparently the reverse to that shown using the INIS database. The authors attribute this reversal to the likelihood that journal publishing is less dependent on the factors influencing research report and conference paper generation noted as contributing factors to the INIS database results. A shortcoming of WOS, though, is that there is insufficient bibliometric data for Japan, Germany and France (only Cadarache even appears at all). Thus at the moment, it is not realistic to carry out meaningful international comparisons using WOS, although it was valuable for U.S. sources and to verify research trends.

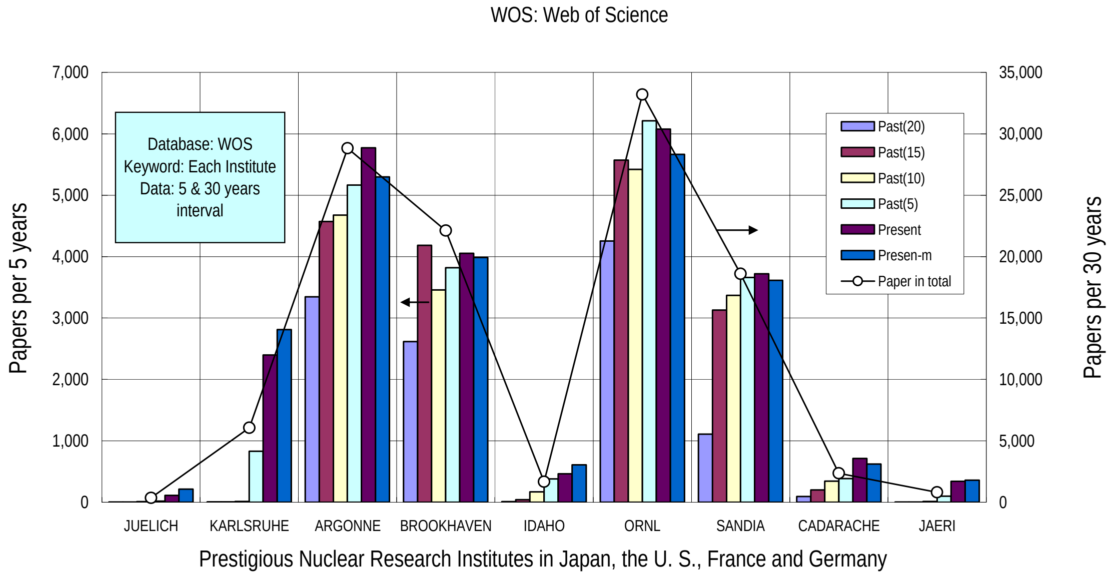

Fig. 3 All papers published in JAERI and 8 PNRIs during the period 1978-2007. Open circles show the published papers during 30 years at each institute (scale is shown on the right-hand side) and the column shows the papers published during every 5-year intervals at each institute (scale is shown on the left-hand side). Database used was WOS.

3.4 Institutional comparison by ECD

To gain a third perspective of the results available from these prestigious institutes, **Figure 4** illustrates the total number of papers using ECD as the basis.

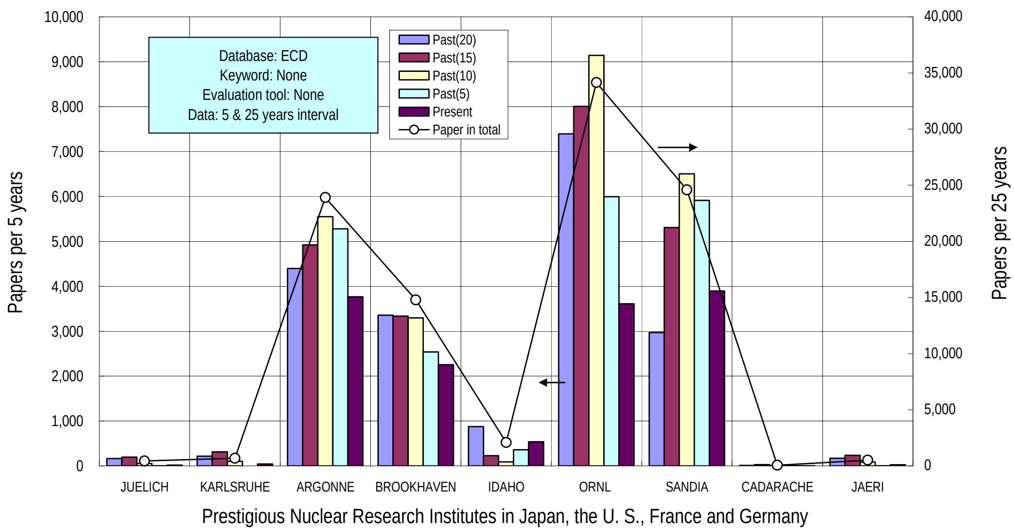

Fig. 4 All papers published in JAERI and 8 PNRIs during the period 1978-2002. Open circles show total published papers during 25 years at each institute (scale is shown on the right-hand side) and the columns show papers published during 5-year increments at each institute (scale is shown on the left-hand side). Database used was ECD.

The following observations can be made from these results.

(1) For the time span of 25 years (1978-2002), non-U.S institutes have a very poor number of papers reported (only 4 of the PNRIs selected for the study appear). This is a quite different point of view from the INIS analysis but quite similar to that of WOS. Likely, ECD and WOS are the distinguished databases targeted at reflecting U.S. research. For ECD, this has been verified to be

the situation for the period evaluated. Out of the U.S. papers evaluated in ECD, they are ranked in the order of

ORNL (34,149 papers)>SNL>ANL>BNL>Idaho ・・・・・・・・・・・・・・・・・・/4/

ORNL is here the champion, too. One regrets to say that JAERI is in the 7th position, almost negligible. However, this appears due to the strong U.S.-focus of the database, not necessarily reflective of JAERI's research efforts.

(2) For the time span of 50 years (1953-2002), the total number of papers are of the order of

ORNL (55,857 papers) >ANL (37,129 papers) >
SNL (24,628 papers) >BNL(24,289 papers)>Idaho (2,398 papers)・・・・・・・・・・・/5/

It should be noted that SNL may have additional papers that have a different subject scope, while SNL and Idaho did not publish papers before 1979 and 1975, respectively as the named institute.

(3) For the 5-year increments of research activities, papers vary from one to another time span. Around the past (10) timeframe (1988-1992), a significant reduction of papers occurred at most U.S. institutes. Possible factors contributing to this reduction learned during interviews could be changes to the nuclear mission by the U.S. government, reduction of human resources to create and process papers, and reduced reporting requirement policies being put into place.

3.5 Comparison of databases for Japan, the U.S. and European sites

The results from the three databases used in the present study were compared with each other, using ORNL, FZK, Cadarache and JAERI as representative international institutes for each figure. **Figures 5** through **8** illustrate these comparisons.

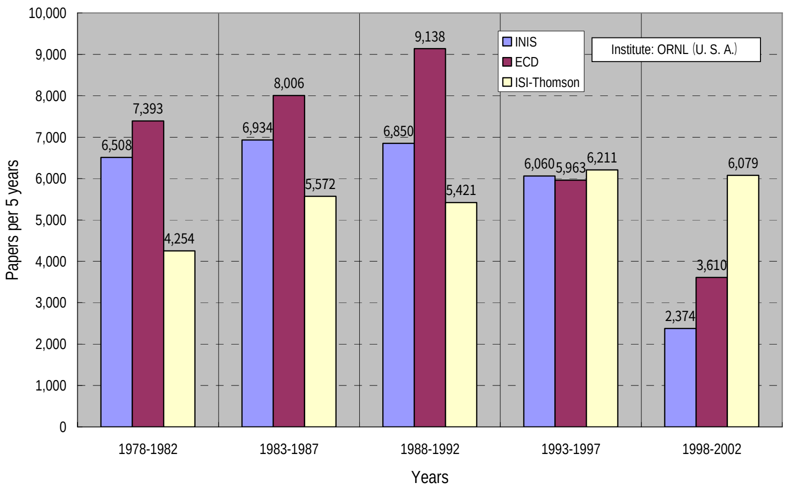

Fig. 5 Research papers registered in INIS, WOS and ECD as a function of 5-year time spans at the PNRI ORNL, U.S.

Trends from **Fig. 5** (ORNL) show that research papers registered by INIS gradually decrease from the past to the present. Those registered by ECD also show a decrease after the 1988-1992 timeframe, while those registered by WOS increased overall. With respect to ORNL, INIS, ECD and WOS worked well, as all databases show good coverage.

Trends from **Fig. 6** (FZK) show that research papers registered by INIS gradually decrease from the past to the present, but those registered by ECD have considerably less magnitude although also show a decrease. For those registered in WOS, there is an increase. This appears to imply that WOS is likely the preferred source to use to find papers from FZK, especially at the present stage.

Trends from **Fig. 7** (Cadarache) show that research papers registered by INIS as well as by WOS are gradually increasing from the past to the present, while those registered by ECD are much less and negligible. This appears to imply that both INIS and WOS are preferred sources when trying to find papers from Cadarache, France.

Trends from **Fig. 8** (JAERI) show that the number of research papers registered by INIS is significantly large in magnitude, while those registered by WOS and ECD are much less so and negligible. This implies that the INIS database is the predominant source for research in Japan.

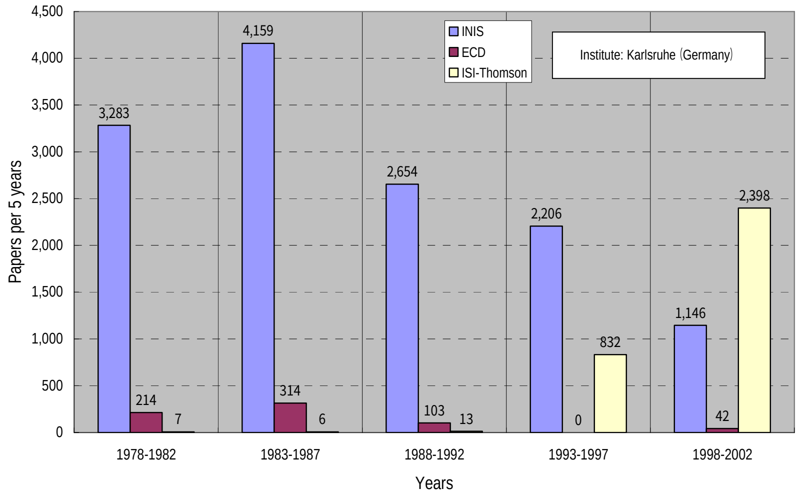

Fig. 6 Research papers registered in INIS, WOS and ECD as a function of 5-year time span at the PNRI FZK (Karlsruhe), Germany.

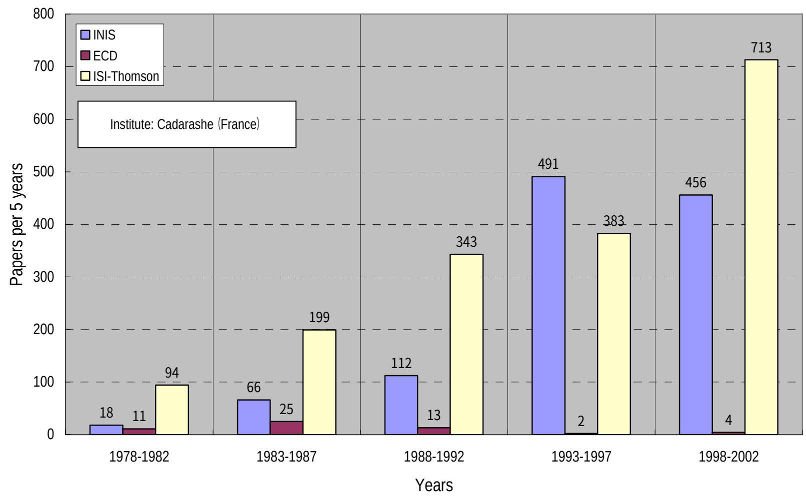

Fig. 7 Research papers registered in INIS, WOS and ECD as a function of 5-year time span at the PNRI Cadarache, France.

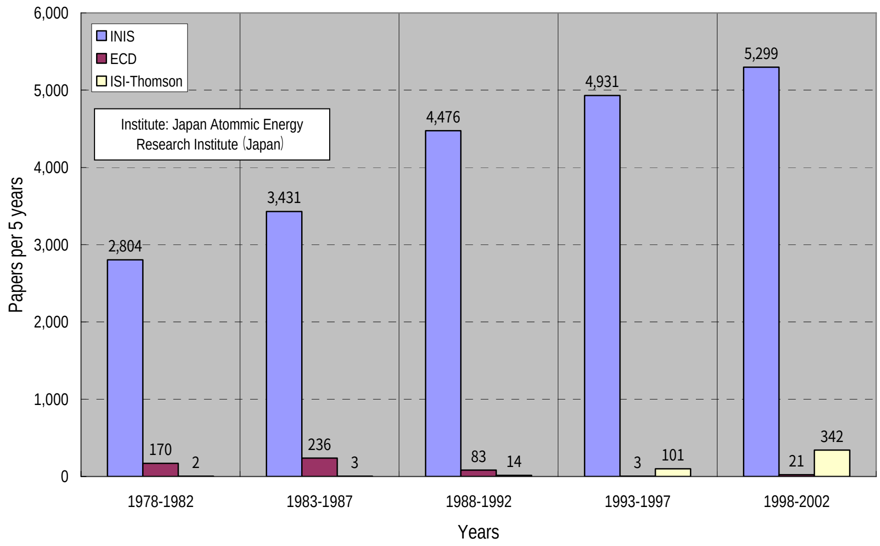

Fig. 8 Research papers registered in INIS, WOS and ECD as a function of 5-year time span at the PNRI JAERI, Japan.

4. CONCLUSIONS

(1) The present bibliometric study shows that research knowledge from JAERI and 10 PNRIs is retained successfully and is available in the INIS database, as well as the more U.S.-focused WOS and ECD systems. The retained knowledge (some over 50 years old) could and should be utilized for educational and training purposes.

(2) Well-retained and indexed knowledge can provide a sound basis for institutional comparison which is valid from the viewpoint of nuclear knowledge management. Within the present study's scope and period evaluated, the world champion among JAERI and the 10 other institutes is ORNL. This is supported by the volume of papers included in INIS, WOS and ECD, although international information in the latter two is limited.

(3) INIS is an advanced, key tool for performing international comparisons among PNRIs. Over the 25-year time span of research paper publication, JAERI is the 3rd ranked institute following ORNL and ANL.

(4) INIS database results revealed that Saclay is the French domestic champion regarding research paper publication.

(5) Different characteristics exhibited by individual databases can sometimes generate conflicting bibliometric results. This was true among INIS, WOS and ECD when looking at trends between 5-year periods. It implies that results from analytical tools used in bibliometric studies should be viewed with careful consideration to learn of any influencing factors.

(6) Based on interviews, use of WOS has tended to grow for U.S. and Europeans, while use of INIS has predominance in Japan, and ECD in the U.S. However, users looking for research results from JAERI and other non-U.S. institutes would be better served using INIS. ECD and WOS are both valuable for U.S. research results, with the latter system potentially growing in international content.

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NUCLEAR EDUCATION, TRAINING AND QUALIFICATION OF PERSONNEL WITHIN THE UNITED KINGDOM NAVAL NUCLEAR PROPULSION PROGRAMME

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ABSTRACT

This paper outlines the nuclear reactor technology education and training given by the Nuclear Department to uniformed personnel destined to become nuclear submarine naval reactor plant operators and to civilian support personnel within the wider Naval Nuclear Propulsion Programme. It describes the Nuclear Department's military and civilian student customer base and its teaching disciplines and facilities. The paper also details the marine engineering officer and technician training pipelines as well as some of the education and training provided to civilian support staff.

1. Introduction

This paper outlines some key aspects of the shore based nuclear reactor technology education and training given to uniformed and civilian personnel destined to take up posts within the Naval Nuclear Propulsion Programme (NNPP) by the Nuclear Department (ND), Defence College of Management and Technology (DCMT)[1] in conjunction the Systems Engineering Group (SEG)[2], HMS Sultan. A mix of shore based education and training followed by specialised functional and on-job training form the backbone of the NNPP military training pipelines, conducted in accordance with the Defence Systems Approach to Training since the beginning of the nuclear submarine programme. This Paper also covers the ND customer base, purposes, resources and range of teaching disciplines as well as outlining generic reactor plant operator training. It also details the nuclear submarine engineering technician and engineering officer education and training pipelines as well as some of the courses given to various grades of civilians, that contribute to personnel being suitable qualified and experienced to take up posts within the NNPP.

2. Military customer base

A very important part of the ND military customer base is naval officers who undertake the 25-week Nuclear Reactor Course (NRC), attracting a Post Graduate Diploma in Nuclear Reactor Technology. The newly promoted naval officers are designated as Assistant Marine Engineering Officers (AMEOs) destined to become nuclear submarine reactor plant supervisors following the NRC, a number of additional specialised courses and a lengthy period of on-job training at sea. Another important part of the military customer base is the further education of experienced

[1] ND, DCMT is part of the UK Defence Academy and is lodger unit at HMS Sultan
[2] SEG is part of the Defence College of Electro Mechanical Engineering (DCEME)

AMEOs returning from sea appointments, who undertake the Nuclear Advanced Course (NAC), a one-year Master of Science degree course in Nuclear Technology and Safety Management, alongside selected NNPP civilians, both of whom being designed for design and procurement type jobs following graduation. ND also provides a very significant amount of nuclear reactor technology education to the various systems engineering training courses run by SEG for nuclear submarine marine engineering ratings and non-commissioned officers; in turn, SEG provides systems engineering related training to the majority of the ND educational courses. Furthermore, ND provides a 12-week course in nuclear reactor technology to all nuclear submarine executive officers and weapon engineering officers, thus is unique in having a vital roll to play in the education and training of all naval officers and marine engineering ratings destined for nuclear submarine service.

3. Civilian customer base

The prime ND civilian customer base consists of MoD civilians who work within the NNPP at various levels of experience and competence. While ND has a varied course portfolio that matches civilian customer requirements, the basic course for civilian personnel destined to support the NNPP at 'Awareness' level is the 2-week nuclear introductory course; the 8-week Nuclear Warships Support Course is designed for the more experienced senior 'Practitioner' level personnel; and the various postgraduate level courses delivered by ND, including the NRC and NAC previously outlined, are tailored for the more technically advanced personnel operating at the so called 'Expert' level within the NNPP. An equally important part of the civilian customer base is non-MoD civilians who primarily work for the MoD's Defence Industrial Partners, employed on nuclear submarine development and design, build and test, dockyard maintenance, safety authorities and safety justification issues and decommissioning related activities. In addition, ND provides nuclear accident countermeasures courses to the UK emergency services that form part of the national and local nuclear accident response organisations.

4. ND purposes, staff and facilities

The prime purposes of ND are the provision of nuclear education and training in support of the NNPP, training in Radiation Protection for all three armed services, research, consultancy, advice and support to the NNPP and provision of nuclear training and consultancy services to civil nuclear sector. The total ND complement is 40 posts, of which 30 are involved in academic delivery and 10 in support and administration. While the majority of the academic deliverers are MoD personnel[3] there are 2 non-MoD civilian Senior Lecturers work within ND but are employed by a commercial company called 'Flagship', who also provide the majority of the support staff functions. In addition to the usual classroom and syndicate rooms ND has access to extensive nuclear, radiological and chemical laboratories, a bespoke nuclear library, scanning electron microscope, irradiation facilities (X-ray, gamma and neutron), maintainer training aids, basic principles simulator that consolidates education and a range of class specific nuclear submarine high fidelity simulators that consolidate training.

5. Nuclear training profile and teaching disciplines

ND and SEG have a portfolio of 45 different courses ranging from one day to one year and form introductory to MSc level. 30 courses are academic based and 15 are

[3] 1 Professor, 4 Principal Lecturers, 13 Senior Lecturers, 3 Higher Scientific Officers, 1 Scientific Officer and 6 Royal Navy personnel

systems engineering based, covering military students ranging from junior naval rating to admiral rank, with civilians ranging from semi-skilled to managing director level. While ND delivers most of its traditional NNPP related courses in-house an increasing percentage of bespoke courses are delivered peripatetically. ND has a significant range of teaching disciplines ranging from ‘enabling’ subjects, ‘core’ academic subjects and ‘specialist’ subjects, with most of the specialist areas supported by research activities. The academic enabling subjects are mathematics, statistics, computing, atomic and nuclear physics and general engineering. The core academic subjects are reactor physics, radiation protection, reactor engineering, reactor safety, thermal hydraulics, nuclear safety, nuclear materials and nuclear chemistry. Specialist subjects and academic staff research areas include computational reactor physics, criticality, radiation shielding, structural integrity, computational fluid dynamics, thermal hydraulics, risk assessment, nuclear safety management, environmental impact assessment, radiation emergency planning and response and nuclear decommissioning.

6. Operator training

Marine engineering officers and ratings destined to become naval reactor plant supervisors, panel operators and machinery space watch keepers, undergo a similar generic operator training regimes, but at differing educational levels commensurate with their level of responsibility on the reactor plant. The shore side elements of this training regime commences with academic courses, mostly delivered by ND, through systems engineering, operational and simulator training, delivered by SEG. This is followed by a period of on-job training at sea culminating in a plant based operational board before personnel are considered suitably qualified to operate the naval reactor plant, at the various levels of responsibility.

7. Marine engineering technicians

Following a marine based electro-mechanical apprenticeship, junior technicians within the NNPP undertake the 10-week Nuclear Propulsion Systems Course (NPSC). Following qualification in the more junior (Category C) watch keeping positions and a substantive period at sea these technicians will return for the Nuclear Propulsion Operators Course (NPOC). The 14-week NPOC is a prerequisite qualification course for further qualification as reactor panel operator, designated a Category B watch keeper. Following qualification and a further substantive period at sea in this more responsible watch keeping position, senior technicians return for the 18-week Nuclear Propulsion Supervisors Course (NPSC)[4], a prerequisite for the so called Category A plant supervisory watch keeping position. The overall training pipeline from Category C to Category A watch keeper, including necessary shore training courses, sea and shore maintenance workshop employment takes many years to complete[5].

8. Marine engineering officers

Marine engineering officers are either recruited directly from university or have been promoted from the Chief Petty Officer or Warrant Officer ranks. In both cases these officers undertake a Systems Engineering Management Course (SEMC), which is somewhat reduced in length for officers promoted from the ranks, who will already be

[4] The academic element of the NPSC is 18%, the NPOC is 35% and the NPSupC is 50%

[5] During this period, selected marine engineering ratings will normally progress up through the ranks through selection for promotion to Petty Officer, Chief Petty Officer and Warrant Officer.

very experienced in nuclear submarine systems engineering matters. In addition all graduate officers have to undertake a 7-week Officers Nuclear Operators Course (ONOC) Phase 1, followed by ~ 23 of initial sea training in a nuclear submarine, as part of their 2-year SEMC, which enables them to qualify in all subordinate watch keeping positions and obtain the required level of knowledge of nuclear submarine engineering systems. Regardless of background, all marine engineering officers are required to be educated to postgraduate level by ND on the Nuclear Reactor Course (NRC).

9. Nuclear Reactor Course

The NRC is part of the recently introduced phased and streamlined postgraduate level educational programme called the Nuclear Engineering Educational Programme (NEEP), specifically designed to meet the future nuclear engineering educational needs of NNPP marine engineering officers. The NRC provides students with a detailed understanding of the core principles of nuclear technology, including classroom delivery in reactor physics, reactor engineering, radiological protection, reactor safety, materials, chemistry, reactor dynamics, accident studies, nuclear safety management and regulation and related disciplines associated with the naval reactor plant and a study project in a technical area of particular professional interest. While the NRC is an educational prerequisite for naval reactor plant supervisors, its aims are to educate officers and their civilian (officer equivalent) counterparts from the Naval Reactor Test Establishment at Dounreay in nuclear reactor technology and nuclear propulsion engineering so that, with further training, they can take up senior operational posts and subsequent wider posts in support of the NNPP. Following the NRC, graduate officer students undertake an 11-week Officers Nuclear Operators Course (ONOC) Phase 2, before proceeding to sea for further on-job training to qualify as reactor plant supervising officer, entitled the Engineer Officer of the Watch.

10. Nuclear Advanced Course

Following two or three years at sea, selected marine engineering officers will return for the Nuclear Advanced Course (NAC), as previously outlined. While the NAC/MSc is normally conducted full time over one academic year, it is modularised and is delivered in 3 Phases, with Phase 1 attracting a postgraduate certificate, Phase 2 a postgraduate diploma and Phase 3 an MSc degree, with returning officers having the option of attending Phases 2 and 3 only. The NAC also caters for inexperienced but academically qualified NNPP civilians, through an enabling up front 2-week introductory course.

11. Civilian personnel

In addition to the postgraduate level qualifications that a number of civilians gain form attendance on the NRC and NAC, the vast majority of the MoD's NNPP civilians undertake a series of short courses specifically designed to meet the level of responsibility commensurate with the relevant support post or position, normally in nuclear submarine design, procurement, safety organisations and dockyards. There are three levels of responsibility for civilian posts within the NNPP all designated as 'Nuclear Suitably Qualified and Experienced Persons' (NSQEP). The three NSQEP levels are 'Awareness', 'Practitioner' and 'Expert'.

12. Awareness level NSQEP

The basic level of NSQEP is the Awareness level, where personnel are fully aware of the safety management procedures and safety culture that exist within their organisations and are thoroughly conversant with its Nuclear Accident Response Organisation (NARO). Typical qualification and experience requirements are the ND delivered 2-week Nuclear Introductory Course and the 1-week Nuclear Accident Procedures Course followed by at least 6 months experience in post. Once so qualified, the individual retains NSQEP awareness level qualification indefinitely.

13 Practitioner level NSQEP

The next level up is the Practitioner level NSQEP, who has the ability to draft and critically review safety management procedures, participate in the safety clearance process and NARO operations, sit on safety committees and authorisation groups and participate in licensing/authorisation and internal/external audits. The typical qualification and experience requirements are ND delivered shorts courses, such as the 6-week Nuclear Systems Designers Course (which qualifies for a postgraduate certificate if accompanied by a project) or the 8-week Nuclear Warship Support Course and the 1-week Nuclear Site Safety Justification Course, combined with at least 18 months experience in post at awareness level. Individuals will lose their Practitioner status after 4 years employment outside the NNPP and subsequently have to re-qualify by time/experience.

14 Expert level NSQEP

The highest level of NSQEP is the Expert level, which normally requires post graduate nuclear qualifications and chartered engineer status (or equivalent). While they need to be educated to Practitioner level at minimum, most would have undertaken the ND delivered NAC/MSc or NRC/PgD or the ND Nuclear Radiological Protection Course (PgD in Radiation Protection). Individuals must have least 5 years experience in Practitioner level posts and Expert level status is lost after 3 years outside the relevant experience field. They will also have national and international peer recognition in their respective fields

NUCLEAR EDUCATION IN ARGENTINA: PAST, PRESENT AND FUTURE

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ABSTRACT

The aim of this presentation is to describe nuclear education and training in Argentina, particularly in the National Atomic Energy Commission (CNEA). It started with the beginning of nuclear activities in the early fifties, and is based on formal education at three academic institutes, and "on the job" learning via a fellowship programme. The evolution of CNEA educational system is described, including its projection to other countries. Current expansion of the programme to face the relaunching of a national nuclear plan and the main problems affecting it are also analyzed.

1. Introduction

Nuclear energy's history in Argentina is marked by some important achievements, including early introduction of nuclear power generation, self-sufficiency in the fuel cycle, development of medical applications and exportation of nuclear technology. Fulfillment of these goals has always been based on a long-standing active policy of human resources development
For more than 50 years the Argentinean Atomic Energy Commission (CNEA) has been deeply involved in nuclear education and training, offering academic studies and "training on the job" opportunities to young technicians and graduate students [1].
The aim of this presentation is to describe the development, current situation and prospectives of this long lasting effort, and to share our experiences and lessons learned.

2. A quick review on the argentinean nuclear sector

The Argentinean Atomic Energy Commission (Comisión Nacional de Energía Atómica – CNEA) was created in 1950. Since the onset of these activities the country maintained a policy of technological autonomy search in the peaceful uses of nuclear energy.
From the very beginning the decision of introducing nuclear energy generation for the country was taken, and further steps were guided by the idea of using nuclear activities as a catalyst for general industrial development. All the technological decisions were merged into the idea of continuous and broad development of knowledge and human resources capacities.
Research reactors and nuclear power plants development and construction became driving forces. The first research reactor built in the country began operation in 1958, and 9 years later a production reactor of local design and construction started supplying most of the radioisotopes used in the country for medical, industrial and agricultural applications.
The first nuclear power plant feasibility studies were done locally in 1965. Priority was given to participation of local industry, and resulted in qualitative jump in general industrial procedures, introducing Quality Assurance concepts.
The first NPP was connected to the grid in 1974, and the second one ten years later.

After three decades of sustained growth, and in accordance with a trend that started in industrialized countries, in the mid 1980´s nuclear activities began to decline in Argentina, due, in this case, to a combination of financial and political reasons. Major projects were delayed due to lack of funding and political support, and in the case of the third NPP, finally stopped.
Recently, the whole world became conscious about the consequences of global warming on climate changes, as well as about the risks associated with the dependence of energy mainly on fossil fuels. Nuclear energy became a quite clear option worldwide, and Argentina was not an exception to that trend.
The argentinean government has recognized the importance of including the nuclear option in the energetic matrix for the country, and has given extra support to the nuclear sector. In 2006 announced a new policy in the nuclear field, including completion of the third NPP, life extension of the second one, and feasibility studies for a fourth NPP.

3. Reinforcing nuclear knowledge assets

In this context of high demand of qualified workforce, the main concerns regarding nuclear human resources are, as in many other countries, loss of critical knowledge peril, need to identify key experts and present-future knowledge gaps, capture of knowledge from leaving professionals, and share and transfer of relevant knowledge.
The need of a strategy to face the problem is an internationally well known issue that affects the nuclear community. It has been analyzed in many publications [2-5] and conferences (e.g. [6]).
A concentrated effort on human assets development is under way, including doubling the number of students and fellowships devoted to nuclear engineering, nuclear reactors and radiochemistry, and increasing the number of fellowships for a “training on the job” programme, assigning priorities to critical knowledge maintenance and transfer.
Taking into account problems such as lower enrollment in technical studies, hard competition with growing private industries job offers, and international demand of graduates in nuclear areas, it is not an easy task.

4. Historical evolution of Nuclear Education in Argentina

From the very beginning of the Argentinean nuclear development, the availability of competent human resources was considered a necessity and a top priority. In the fifties most distinguished chemists, physicists and technologists of the country were recruited for reactor physics, radiochemistry, metallurgy and radioisotope applications. Early courses were afterwards consolidated with the creation of academic institutes in association with national universities.
Even though disciplines such as Engineering (mainly civil) and Chemistry were rather strong in the country in the fifties, other areas relevant for nuclear activities either had little development in the universities, as Physics, or none at all, as Metallurgy.
The programme started in the early fifties with courses and schools on reactor physics, metallurgy, radioisotope applications and nuclear physics.
A major milestone was the creation in 1955 of the Physics Institute (nowadays Balseiro Institute, named after its creator and first Director), in a joint venture between CNEA and the National University of Cuyo. Located in Bariloche, in the South-West of the country, it exemplifies the interweavement between development and education in nuclear activities. It share laboratories with an important CNEA Atomic Center and its faculty consists of active technologists and researchers. Its full-time students are supported by CNEA fellowships.
Simultaneously, and in close contact with the Bariloche Physics Institute, a series of lectures by leading foreign experts at CNEA set in 1955 the foundations of the formation in Metallurgy. A formal framework for this activity was established in 1962, when the first of a

series of ten annual Panamerican Courses on Metallurgy, sponsored by the Organization of American States (OAS), took place at Buenos Aires. As it was planed, Pan-American Courses of metallurgy were moved afterwards to Mexico. Nevertheless, CNEA remained active in the field through annual courses, seminars and colloquia attended by hundreds of Argentinean and foreign professionals.
In the mid 1970´s, with one NPP already operating and a second one under construction, the need for Nuclear Engineers began to be felt. A study was made of nuclear engineering careers in Europe and the US, and a School of Nuclear Engineering was created in 1977, attached to the Balseiro Institute. Laboratories and a Research Reactor, RA-6, were built to support the experimental work.
In 1993, education in materials science attained full university status when the Sabato Institute was founded, as a joint venture between CNEA and the National University of San Martín. The formula of full-time students, fellowships, and technologists / researchers as teachers first implemented in the Physics Institute, was also applied. This Institute offers undergraduate and graduate studies in Materials Science and Technology, leading to Engineer, Master and PhD degrees.
Formation in Radiochemistry began in a similar way - with the establishment of some research groups and the first courses on the subject in 1952 -, and rapidly gained momentum.
Human resources development in this field continued by means of courses and alliances with different universities, until the recent creation, jointly with the National University of San Martín, of the Dan Beninson Institute of Nuclear Technology. As well as formation in radiochemistry and nuclear applications, it offers graduate studies in nuclear reactors.
Regarding health applications, CNEA has promoted the activities since the late fifties, with courses on dosimetry and in radioisotope applications that have been attended by hundreds of professionals, mainly physicians.
Close collaboration in the area of nuclear medicine was established between CNEA and several universities and health institutions. Two Nuclear Medicine Centers devoted to research, teaching and health services, were created.

5. Present capabilities in Nuclear Education

The conception of CNEA´s programme for human resources development, sustained continuously through the years, has been to form professionals with a strong scientific and technological background, and not just specialists for the nuclear techniques of the day.
Based in the understanding of the rapidly evolving field of nuclear technology, to form creative workers with problem-solving skills, backed by their solid formation, able to keep up with this high rate of changes, was and still is the target.

At present, CNEA human assets development is based on two main branches:

➢ **Education in its three Institutes**

Today they offer graduate and postgraduate studies in nuclear engineering, materials science and engineering, physics, radiochemistry, nuclear medicine and nuclear applications. Through the years, almost 1000 young have completed their graduate studies, and around 700 have obtained Master and PhD degrees. Besides, thousands from Argentina and other countries have taken short courses on different related topics. These CNEA's "nuclear education capacities" were recently recognized by IAEA, proposing Balseiro Institute to be a unique regional reference center for nuclear education in Latin-America.

➢ **Training on the job programme**

Learning by doing under the direction of senior staff members has proven to be a confident source of trained personnel and a convenient way of transferring both explicit and implicit knowledge to the new generations. Quoting a former CNEA president "experience is something that can not be bought or borrowed"

So, as an important instrument for human resources development, since the early sixties CNEA has also maintained a “training on the job” fellowships programme.
Fellowships are offered to technicians and undergraduate, doctoral and post-doctoral students in working areas selected taking into account the relevance of the subject to the main projects, and the availability of adequate direction and facilities. The need of knowledge transfer from experts retiring in the near future is also considered.
Fellows are being trained in CNEA laboratories, under supervision of staff members, mainly in: nuclear energy in its main areas, spent fuel management, radioactive wastes, environment; nuclear applications of radiations and radioisotopes, uranium prospecting, alternative energy sources, as well as some basic physics, chemistry and biology.
Some of the fellows continue afterwards their career in CNEA and its related companies of the nuclear sector, and others become engaged by the national industry or other research, development and innovation national or international institutions.
Around 200 young technicians and professionals are yearly participating in this programme, for periods between 2 to 5 years.

6. Brief description of CNEA academic institutes

Balseiro Institute, located at CNEA Bariloche Atomic Centre in the South West of the country, was created in 1955. It offers graduate and post-graduate studies in Nuclear Engineering, Mechanical Engineering, Physics, Technological Applications of Nuclear Energy and Medical Physics.
Almost 300 students have graduated in Nuclear Engineering and around 50 have got their PhD. Around 900 physicists have graduated, and more than 300 have got a PhD. Also close to 100 professionals have completed post-graduate studies in Medical Physics, and a similar number in Technological Applications of Nuclear Energy.
Its main infrastructure includes advanced laboratories for engineering and physics, library, research reactor for training, and particle accelerators.

Sabato Institute, located at CNEA´s Constituyentes Atomic Centre, close to Buenos Aires city, was created in 1993. It offers graduate and post-graduate studies in Materials Engineering, Materials Science and Technology, and Non Destructive Testing.
More than 60 Materials Engineers have graduated, while more than 130 have obtained Master and PhD degrees in Materials Science and Technology. Around 20 professionals have completed post-graduate studies in Non Destructive Testing.
Its main infrastructure includes advanced laboratories for materials science, physics and non destructive testing, library, research reactor, and tandem heavy ion accelerator.

Beninson Institute, located at CNEA Ezeiza Atomic Centre, close to Buenos Aires city, was created in 2006 to provide full academic status to a long lasting educational activity.
It offers graduate and post-graduate studies in Nuclear Medicine, Radiochemistry and Nuclear Applications, Nuclear Reactors and the Fuel Cycle. It also hosts post-graduate courses in Methodology and Application of Radio nuclides, Dosimetry for Radiotherapy and Physics for Radiotherapy.
From this Institute and previous Ezeiza´s educational activities, which lasted for more than three decades, more than 2000 professionals have completed specific topical courses.
Its main infrastructure includes advanced laboratories for radiochemistry, nuclear applications, nuclear materials, radiological protection, library, hot cells, radioisotope production reactor and its associated plant, and irradiation facilities.

7. International projection

Since its very beginning, CNEA´s efforts in education have been opened to nationals from other countries, mainly from the Latin American region.

About 60 foreign students have graduated from CNEA Institutes, while hundreds have assisted to topical courses, seminars and training on the job stays, using CNEA's financial support, or aided by bilateral agreements or by International Agencies as IAEA, the OAS or United Nations via UNDP. As an example, in the period 1999-2006 the country has received more than 280 foreign fellows and scientific visitors under IAEA Technical Cooperation programmes, almost 130 of them in CNEA working groups . Also training of foreign staff related to exports of nuclear technology as research reactors, radioisotopes production plants, fuel fabrication plants, etc., has been accomplished at CNEA laboratories.

8. Final remarks

Argentinean CNEA´s fifty years of experience have confirmed the validity of its basic educational principles: to provide a solid basic formation, complemented with important problem-solving skills, developed in an actively working environment, sharing everyday experience with professionals involved in real nuclear projects.

More than forty years of "learning by doing" at CNEA laboratories have resulted not only a valuable method for training and selecting professionals and technicians for the Institution while transferring implicit knowledge to the new generations, but has also provided creative manpower with problem-solving skills to national universities, R&D institutions and industry.

At present, Argentina has significant means to provide the qualified personnel necessary for the growth of nuclear activities in the country, with capacities and equipment that can be offered to international projects on nuclear education. Based on its 50-year experience on international cooperation in this field, CNEA is willing to contribute to the worldwide effort in developing human resources for the nuclear future.

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INSTN: CEA'S INSTITUTION DEVOTED TO NUCLEAR EDUCATION AND TRAINING

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ABSTRACT

Originally designed to train mainly engineers and researchers already involved in their professions at EDF in the nuclear industry, the INSTN has now set up a broad range of further education in leading-hedge technological disciplines (nuclear engineering, health science, nanoscience, material science) relying on the skills available at the CEA and in other organizations and industries such as, for the nuclear power sector, EDF and AREVA. Overall, its main activities cover high level education programs in partnership with universities and engineering schools, professional training for CEA as well as nuclear operators and coordination of doctoral and post-doctoral educational programs. Currently, the INSTN ambition is to reach a European and international dimension by strengthening and developing already existing transnational cooperation with universities and enterprises from the European Union as well as third countries in the frame of the European Community programs.

Introduction

The Institut National des Sciences et Techniques Nucléaires (INSTN) is an advanced education institution devoted to post-graduate education and professional training in nuclear science and technology. Created within the French Atomic Energy Commission ("Commissariat à l'Energie Atomique", CEA) in 1956, it is placed under the joint supervision of the Ministry of National Education and the Ministry of Industry.

INSTN provides students with high scientific qualifications, professionals and engineers with specialised education in all disciplines related to nuclear energy applications. Academic courses and professional training sessions are designed to put students in direct contact with specialists of each discipline providing up-to-date knowledge and know-how. To this end, INSTN has an in-house academic and administrative staff of around 115, plus the backing of some 1,200 collaborators from French and foreign Universities, research organizations (CEA, CNRS, INSERM …), hospitals, industry (EDF, AREVA…).

The institute has its own experimental facilities: an experimental reactor, ISIS (700 kW), a 2 MV Van de Graaff accelerator, new generation PWR simulators (SIREP for normal operation and SIPACT for accidental situations), scanning and transmission electron microscopes fitted with an energy dispersive X-ray analyser, simulation work sites for radiation protection, and several laboratories (nuclear physics, metallurgy, radiochemistry, biology...) where students acquire experience every year. In addition, its location facilitates the access of students to the extensive facilities of CEA laboratories.

The main mission of the INSTN is to contribute to dissemination of the CEA's expertise through specialised courses and continuous education, not only on a national scale, but across Europe and worldwide.

This mission is focused on nuclear science and technology, and one of its main features is a Nuclear Engineering diploma. Bolstered by the CEA's efforts to build partnerships with universities and engineering schools, INSTN has developed links with other higher education institutions, leading to the organisation of more than twenty-five jointly-sponsored Masters graduate diplomas. There are also courses covering disciplines in the health sector: nuclear medicine, radiopharmacy, and training for hospital physicists.

Continuous education constitutes another important INSTN activity. Short-term training programs (lasting a few days to a few weeks), mainly in French language, are designed for professional engineers, researchers or qualified technicians.
In 2007, INSTN hosted about 7500 specialists for some 2900 days of training in various fields: nuclear power plants, materials, nuclear fuel cycle, environment, health physics, security, safety, radiobiology, molecular imaging, radiochemistry, etc.. The actual complete panel of training offered by INSTN covers more then 200 different topics.

INSTN coordinates various PhD programs within the CEA which hosts approximately 1100 young scientists preparing doctoral theses in its laboratories. Research topics include all CEA areas of expertise: fundamental research in physical sciences or life sciences, research and technology for industry, R&D for nuclear energy, protection and nuclear safety. A special attention is given to the theses quality improvement. In particular, a careful preparation of subjects and, as far as PhD candidates are concerned, a rigorous selection, annual activity reports enabling a better follow-up of their research, a series of specific training completing their background are implemented.

Concerning doctoral studies INSTN offers 9 advanced courses in nuclear engineering taught in English (one module per week) to be held in Saclay, France, in September and October 2008. These doctoral-level courses address both PhD students and post-docs in nuclear research. Further information can be obtained on INSTN's website.

The following chapters will focus on INSTN's education and trainings activities in the fields of nuclear engineering and radiation protection.

Education in the field of Nuclear Engineering at INSTN
The "Nuclear Engineering degree" in France is delivered by the INSTN, also called "Génie Atomique" course. It represents a "specialized" course (Master after the masters degree in nuclear engineering) designed for engineers who can thereby acquire a broad view of sciences and techniques implemented in the nuclear energy sector based on a specific high level fundamental courses in disciplines such as reactor physics, thermal hydraulics and nuclear materials.
The "Génie Atomique" course is organized by INSTN in Saclay and Cadarache research centres for the "civilian" students and in Cherbourg for the future officers and staff of nuclear submarines and aircrafts carrier at the EAMEA military school. The curriculum, which is defined by the INSTN's professors last one calendar year and takes place in two phases:
- a first phase, from September till end of March, is devoted to the study (course, exercise and laboratory sessions) of "purely" nuclear related topics such as: nuclear physics, neutronics, applied thermal hydraulics, nuclear materials, nuclear mechanical design criteria, nuclear instrumentation, radiation protection and safety, reactor operation and control (PWR), nuclear fuel cycle, decommissioning and nuclear reactor systems. This phase totalizing more than 550 hours includes practical projects using the "major" neutronics, thermal hydraulics, mechanical and radiation protection computer codes as well as laboratory sessions on training reactors, PWR simulators and nuclear instrumentation tools.
- A second phase, from April till early September, consisting of an internship period for the students hosted by industry, universities and research centres in France and abroad. Since specialization in nuclear engineering is a multidisciplinary training, projects conducted by the students during this period provide them the opportunity to apply the systemic view acquired during the first phase to a concrete industrial situation. A Master thesis report is established and a defence is organized and evaluated by a selected jury.

This educational scheme is unique in France in terms of the number and volume of the courses and the installation involved in the training. Since its inauguration in 1956, INSTN has graduated more than 4500 students (cf. Figure 1) active today in all the major organizations (mainly EDF, AREVA and CEA) of the French nuclear industry and research centres.

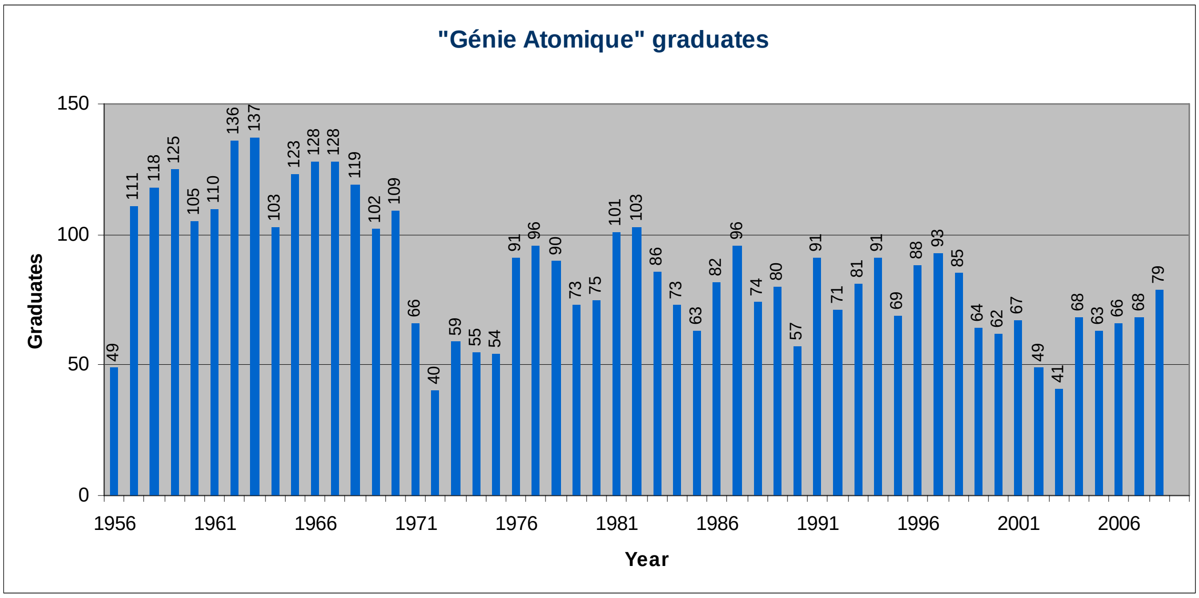

Fig.1 "Génie atomique" students registered from 1956 to 2008

Since 2003, the course is organized according to a modular structure to facilitate the mobility of French and European students taking advantage of established schemes of mutual recognition and harmonisation of best practices established under the different European Framework Programmes Coordination Actions (FP5 & 6), the ENEN and the NEPTUNO projects. The different modules are presented Figure 2 and exams are scheduled at the end of each module.

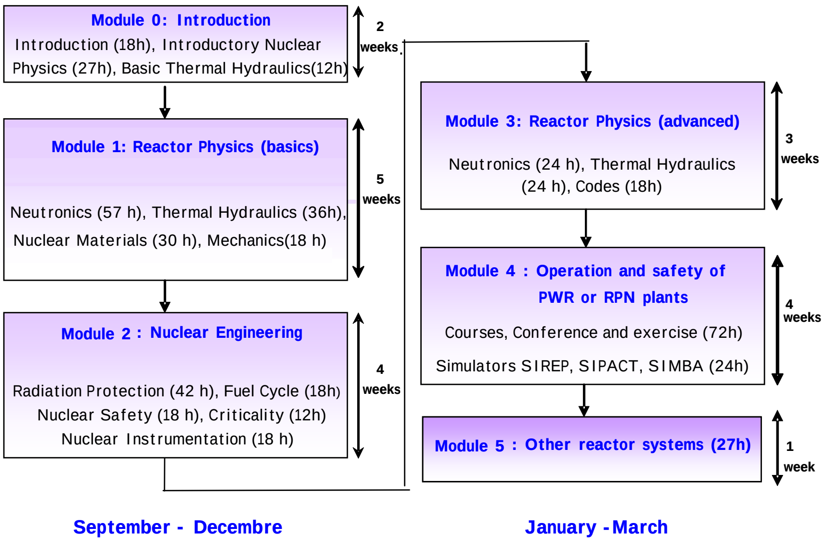

Fig.2 "Génie atomique" training modules

This modular structure of the curriculum offers young professionals the possibility of having an easier access to training on the subject of their choice. Furthermore, a comprehensive knowledge in nuclear engineering can be acquired by following the different modules over several years.
During the last period, industry representatives have clearly expressed their increasing need to engage high level engineers, educated in the field of nuclear engineering to face the new challenges of what is now called the "Nuclear Renaissance". INSTN together with University Paris Sud 11 developed a new masters degree in nuclear engineering opened to students from France and abroad. The objective of this speciality is to provide in-depth training in the field of nuclear reactor physics for the purpose of using existing tools, developing and

installing third-generation reactors, and designing and developing the future systems still known as 'integrated systems'. The following courses (Table 1) will be taught in English.

	Course	Number of Hours	ECTS
UE1	Introductory to Nuclear Engineering and to Nuclear Physics	55	5
UE2	Neutron Physics – Part I	50	5
UE3	Neutron Physics – Part II	40	4
UE4	Heat Transfer – Nuclear reactor thermal hydraulics	70	7
UE5	Nuclear Materials	50	5
UE6	Use of codes, mini-projects	30	4
UE7	Pressurised water reactors – Nuclear reactors systems	50	5
UE8	Nuclear fuel cycles, Safety & Criticality, Radiation Protection	50	5
	Total	~ 400	40
Internship		5 months	20

Table 1. Courses that will be taught in the frame of the Master in Nuclear Engineering

Radiation Protection education and training

At the national level, INSTN plays a pivotal role in all the level of radiation protection education from high school graduate to engineer level. The choice of different training levels results from the analysis of the needs expressed by professionals and industrial operators. Four categories of personnel need to be trained in Radiation Protection: i) the staff capable of performing routine actions in the field of radiation protection, ii) technicians for the performance of radiation protection measurements and a check of their effectiveness, iii) advanced technicians participating in the definition of radiation protection measures and capable of managing action teams, iv) engineers developing the design, risk prevention and control of installations and monitoring of the exposed personnel in normal or accidental situations. Accordingly, four types of courses has been developed by INSTN (cf. Figure 3), each corresponding to a category of personnel: i) first level of general training in radiation protection (PNR, eight weeks), ii) the Technician Diploma in Radiation Protection (BT, four months + one months of practical work), iii) the Advanced technician Diploma (BTS, six months + two month of practical work) and iv) the Master in Radiation Protection (six month + six months of practical work). Those highly specialized theoretical and practical courses, which are recognized by professionals and operators, are open to students but also to employees willing to improve their professional qualification in the Radiation Protection field. The Master degree is approved by the French Ministry of Education and will reach a European dimension by September 2008 (cf. European and international education at the INSTN).

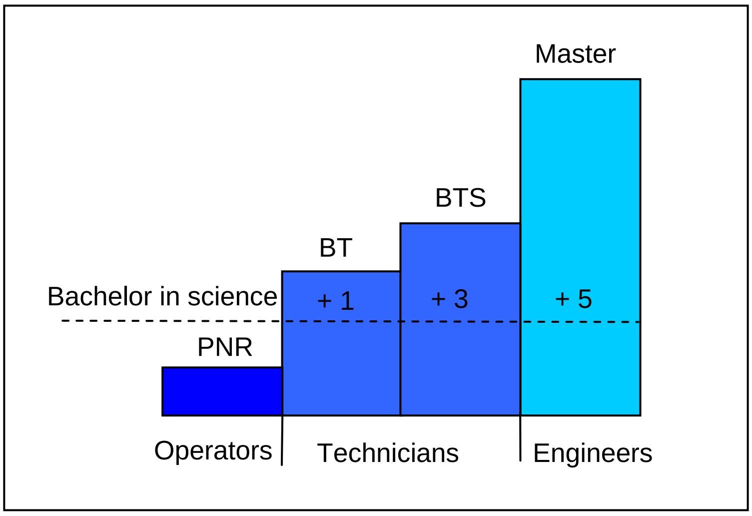

Fig.3 Initial training of professionals in radiation protection

In addition to those courses designed to prepare for a degree, INSTN offers also a wide variety of training sessions for users of radiation sources and exposed personnel. Some of those courses follow regulatory requirements (competent person, transport of radioactive material) or specific requirements of the operators, such as the CEFRI courses. CEFRI (stands for the French Committee for Certification of Companies for Training and follow-up of personnel working under Ionizing Radiation) is the only certification agency in France for outside companies that employ workers in ionizing environments. Its purpose is to check the proper application of French regulations governing radiation protection in a quality system. It grants a four years certification to the companies, temp agency and training institutions. Training is a major requirement of CEFRI, which sets the programs and duration of each course and stipulate the procedures for a school site as well as the teachers training requirements. Several INSTN trainers has the CEFRI certification which enables them to give lectures and manage CEFRI accredited courses. In 2007, 181 courses on “Risks prevention” accredited by CEFRI has been held for almost two thousand operators from EDF, CEA, AREVA and other companies.

European and International educational at the INSTN

The strategy of INSTN at the European and International level complies with the CEA directives. Cooperation at the European level is one of the priorities of the CEA that is involved in over 180 projects under the 6th European Framework Programme and coordinates 34 of them. INSTN has been involved in these actions by participating to the European Nuclear Engineering Network (ENEN) under FP5 and coordinating the Nuclear European Platform of Training and University Organisation Network (NEPTUNO) under FP6. INSTN plays also a key role in the management of up to 25 theoretical and practical trainings in the molecular imaging field in the frame of the Networks of Excellence European Molecular Imaging Laboratories (EMIL, www.emilnet.org) coordinated by the CEA and Diagnostic Molecular Imaging (DiMI, www.dimi.eu) coordinated by the MPI in Cologne. More recently INSTN has been involved in several ERASMUS curriculum development programs such as the European Masters in Radiation Protection (EMRP) and Molecular Imaging (EMMI, presented as P1.62) which is coordinated by INSTN. Jointly developed by the CEA/INSTN and the Universities of Paris-Sud 11, Antwerp (UA), Crete and Torino, EMMI will welcome in September 2008 its first students in France, Italy and Belgium. This high level program is promoted and financially supported by the European Commission. Its ambition is to ensure a high level teaching program in the emerging field of molecular imaging from which will graduate scientists destined to work in research as well as in the Industrial field.

The Institute has been awarded the extended European University Charter 2007-2013 and, as stated in its Erasmus Policy Statement (EPS), it intends to strengthen and extend the undertaken actions by:

- implementing European master and doctorate curricula as well as intensive programmes in the fields of nuclear engineering, nanoscience, health technologies, material sciences, mathematics and applications in which the CEA is a major player,
- increasing the number of multilateral cooperation with higher education institutions and enterprises,
- promoting the mobility of students and teaching staff to favour scientific exchanges, cooperation and dissemination of best practice.

Traditionally, INSTN also organises courses exclusively intended for specialists from foreign countries under the auspices of the International Atomic Energy Agency (IAEA).

Conclusion

INSTN is one of the major players in France in education and training on nuclear engineering and radiation protection fields. In addition, it implements high level educational programs in partnership with universities and engineering schools as well as professional training in the new fields explored by the CEA’s research team. With a wealth of experience in international collaboration for many years, INSTN is highly committed to the development of the European higher educational area in nuclear sciences and technologies.

CAPACITY BUILDING INITIATIVES FOR THE NUCLEAR SECTOR IN SOUTH AFRICA

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ABSTRACT

South Africa is facing a serious challenge of meeting current and future energy demand. In order to address this challenge head-on, the government has promulgated a number of nuclear-related policies and programmes that particularly look at capacity building, research and development The biggest challenge is to provide a critical mass of human capital to address a nuclear expansion programme that will see an addition of about 20 000 MW of nuclear power by 2025. One notable programme to address this challenge is the South African Nuclear Human Asset and Research Programme (SANHARP), whose aim is to facilitate a broad-based national programme that will deliver on capacity building and research and development initiatives for and in partnership with the nuclear sector. Although focusing on the upper part of the skills pyramid, SANHARP seeks to play a further role in initiating and facilitating the alignment and co-ordination of funding programmes.

1. Introduction

South Africa's electricity utility, Eskom, intends to build an additional 40 000 MW of energy by 2025. Of this, 20 000 MW will be from nuclear sources, composed of new conventional nuclear power plants and the pebble-bed modular reactor, when the technology has been successfully demonstrated. This nuclear expansion programme will be kick-started with *Nuclear 1* – the supply of about 3 800 MW from PWR technology to be operational by 2016. This will then be followed by a fleet quadruple that of Nuclear 1 by 2020 to 2025. The skills requirements for the expansion programme for Eskom alone are illustrated in Table 1.

	Nuclear 1	Fleet (X4)	Localisation
1. Power Stations	1000	3200	3200
1.1 Engineering	100	300	2500
1.2 Programmes	100	400	600
1.3 Other	100	200	400
2. Nuclear Programmes	300	900	3500
Total (Eskom)	1300	4100	6700

Source: TSAPRO, 2008

Table 1 Eskom's skills requirements by 2020

2, Discussion

There are currently a number of educational courses provided at institution and industry levels aimed at the nuclear sector in South Africa. These have been in place to support the already existing nuclear infrastructure.

2.1 Education and Training Programme

2.1.1 Nuclear Education (Institution level)

Courses that are currently on offer and being planned are shown in Table 2.

Institute	Course	Stage of Development
Nelson Mandela Metropolitan University (NMMU)	Bsc Reactor Physics and/or Radiation Protection	Under Discussion
	Diploma: Radiation Protection	Under Discussion
Northwest University - Faculty of Engineering (Postgraduate School of Nuclear Science & Engineering)	Masters & Doctorate: Nuclear Engineering	Currently Offered
	Postgraduate Diploma: Nuclear Engineering	Applied to provide
	Masters: Nuclear Project Management	Currently Offered
Northwest university - Center for Applied Radiation Science & Technology	Bachelors (Hons) & Masters: Applied Radiation Science & Technology	Currently Offered
Stellensbosch University	Bachelors (Hons): Radiation & Health Physics	Currently Offered
	Bachelors (Hons) Nuclear Physics	Currently Offered
University of Cape Town	Nuclear Power Engineering and Nuclear Power Sources: 4th year Electrical Engineering Module	Currently Offered
University of the Witwatersrand	Postgraduate Diploma: Radiation Protection	Currently Offered
	Postgraduate Diploma: Physics, engineering and Safety of Nuclear Power Reactors	Currently Offered

Table 2 Nuclear education courses provided at various South African Institutes

2.1.2 Industry Training

Table 3 shows education and training programmes provided by industry.

Arecsa Human Capital	Joint venture between South African Nuclear Industry (headed by Necsa) and Areva
IAEA fellowships	
AFRA workshops and training courses	
Bilateral arrangements between SA nuclear organisations and overseas institutions	Training and staff exchanges
In-house training	e.g. at Koeberg Nuclear Power Station and Necsa

Table 3 Training provided in industry

2.2 Funding Programme

In support of the South African government’s vision for expanding nuclear energy in the South African electricity mix, the Department of Science and Technology (DST) undertook to establish a coordinated programme to advance skills and innovation frontiers along the value chain of the Pebble Bed Modular Reactor (PBMR), ranging from basic and applied research in all applicable science and engineering disciplines, to manufacturing and distinctive aspects of waste management. The PBMR Human Capital Research and Innovation Frontier Programme (PHRIFP) was established out of a consensus of key stakeholders in nuclear energy. In February 2005, PBMR (Pty) Ltd was awarded a one-year contract to initiate the implementation of the Programme.

Since the initiation of the Programme, the South African government has reiterated its commitment to nuclear energy as a significant ingredient of the future electricity mix. It is envisaged that the expansion of nuclear power will in the short to medium term come from conventional nuclear power technologies such as Pressurized Water Reactors.

Skills to support the future nuclear energy industry would need to be broadened to support the entirety of the government's strategy for the industry, that is, the technologies that will be employed in the near to medium term and longer term technologies, such as the PBMR.

The PMBR, being only one of a number of nuclear technologies, and given a number of applications of nuclear technology (beyond energy), a decision was taken to expand the scope of PHRIFP to address the skills needs of the entire nuclear industry. To this end, PHRIFP was renamed the South African Nuclear Asset and Research Programme (SANHARP) and the secretariat moved from the PMBR (Pty) Ltd in Centurion to the South African Nuclear Energy Corporation (NECSA) in Pretoria West.

The vision of SANHARP is to facilitate a broad-based national programme that will deliver on capacity building and research and development initiatives for and in partnership with the nuclear sector in South Africa.

The mission of SANHARP is initiate, facilitate and support education, learning, knowledge transfer and research programmes that would provide solutions to the current and future human as well as intellectual capital requirements of the SA nuclear sector.

SANHARP has the following objectives:

1. To strategically position the development of human and intellectual capital for the SA nuclear sector on the local and international platform.
2. To promote teaching, research and innovation capacity in South African secondary and tertiary institutions in strategic areas of science, engineering and technology for the nuclear sector.
3. To facilitate nuclear skills development through skills transfer programs, collaboration and co-operation as part of technology acquisition from local and international institutions.
4. To develop a critical research and skills base to support the SA nuclear sector.
5. To promote and ensure comprehensive public awareness and understanding of nuclear related issues.

Aimed at achieving the above objectives, SANHARP is running the following projects:

1. The Bursaries Scheme which offers full sponsorships to students in selected areas of science and engineering from undergraduate level to postgraduate level. There are currently more than 160 bursary holders in the scheme and the number is expected to reach 500 in the next 5 year.
2. The Schools Outreach Project seeks to ensure a pipeline of learners with a strong foundation in mathematics and science to take up undergraduate bursaries which are offered by the Programme. The project currently offers bursaries (scholarships) to students from grade 10 to grade 12 in 32 so-called Dinaledi Schools (Science- and Mathematics-themed schools)
3. The Nuclear Hub Website dedicate to provide awareness of nuclear industry and serve as a hub for different stakeholder users

4. The Research Chairs (who's management is under the NRF's South African Research Chairs Initiative, SARCHi) seeks to create chairs in defined research themes pertinent to nuclear technology
5. Communities of Practice aimed at supporting stakeholder-groups and associations in the nuclear industry

Figure 1 shows funding of education programmes along the skills pyramid. Although there are funding programmes, these are rather sporadic and properly streamlined and co-ordinated. There are now attempts co-ordinate programmes through the education and training sub-committee of the newly-formed *Nuclear Industry Association of South Africa (NIASA)*, an association representing the nuclear industry.

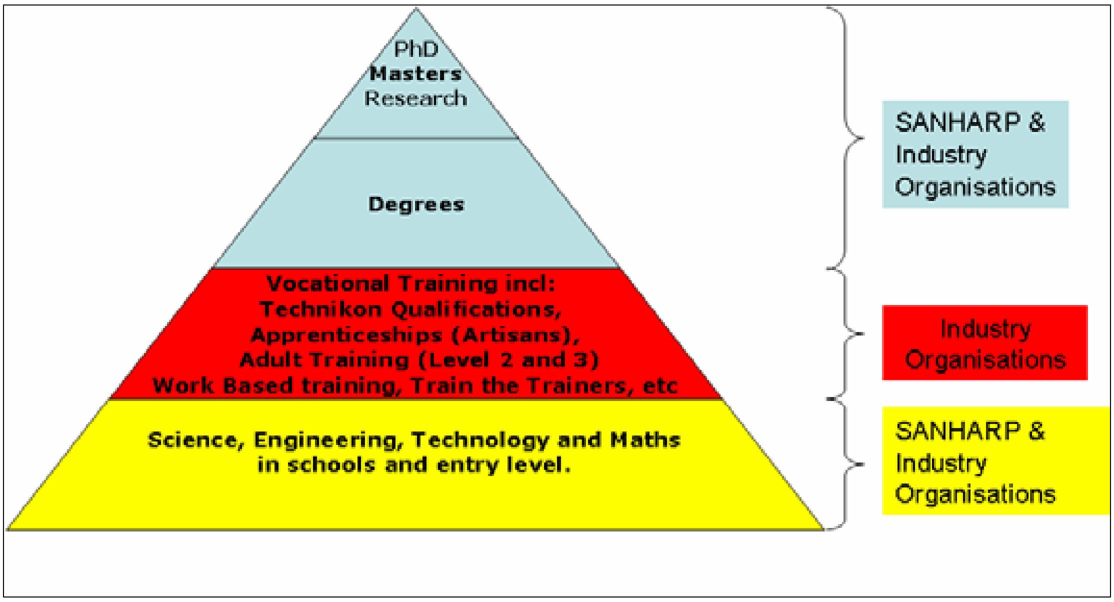

Figure 1 Funding programmes for nuclear education and training along the skills pyramid

Conclusion

South Africa has a challenge to develop a critical mass of skills required by the nuclear expansion programme that will see 20 000 MW of power from nuclear sources by 2025. Although government has responded to this challenge by establishing SANHARP which will address the high-end skills within the skills pyramid, there is a need to address all required skills in a co-ordinated fashion. To this end the NIASA education sub-committee will attempt to create a framework that will be holistic in addressing skills requirement for the South Africa nuclear expansion programme.

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THE USE OF MOBILE LEARNING TECHNOLOGY IN THE NUCLEAR SCIENCE AND ENGINEERING PROGRAMS AT THE UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY

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ABSTRACT

The Ontario Province of Canada is dependent on nuclear power for 50% of its electricity production. There is increasing demand for graduates of nuclear engineering and science programs to provide the expert human resources needed to operate, maintain and extend the life of the current units, and to deign, construct and operate new units. Reflecting the extensive use of computers in the nuclear industry, the specialist nuclear education programs should also make strong use of computers to enhance the learning process. The only nuclear engineering undergraduate degree program in Canada is offered at the University of Ontario Institute of Technology (UOIT), where every student is issued with a standard configuration laptop computer. Through a coordinated, comprehensive and ubiquitous use of digital technologies, UOIT has built a unique technology-enhanced learning environment, wherein the use of laptop computers, learning management systems, powerful course-specific software programs and comprehensive online interactions define the educational experience for all students.

1. Introduction

Nuclear generated electricity was first produced in Canada in 1962, from the Nuclear Power Demonstration (NPD) unit, the first CANDU (CANada Deuterium Uranium) power plant. From that small beginning grew an industry that conducts world-class research, development, design, construction, commissioning, operation and maintenance of nuclear power plants, as well as research reactors and several related technologies. The Province of Ontario, with a population of 13 million, has been the centre of Canada's nuclear industry, in particular approximately 50% of the electricity used in Ontario is generated from CANDU nuclear units. Two other provinces each operate 700 MW CANDU units.

The current fleet of Canada's nuclear plants ranges in age from 15 to 37 years, with a substantial amount of life-extension work having already been carried out on the older units, and similar projects being planned for the remaining ones. The continuing increase in demand for electricity as the population grows and its standard of living increases, and despite strong conservation efforts and the transfer of significant manufacturing capacity abroad, the Government of Ontario has requested proposals for new nuclear generation. In addition to meeting increased demand, the new units are required to enable the closing of the remaining coal fired generation, so as to meet environmental targets to reduce green-house gas as well as particulate emissions.

2. Human resources development for Canada's nuclear industry

Corresponding to the aging of the nuclear power plants is the demographics of the workforce. About half of the engineers and scientists in the nuclear industry are reaching retirement age in the next five years. A similar situation exists in several other high technology industries in Canada, and world-wide in the nuclear technology sector.

During the design and construction of the early units, particularly in the 1970s and early 1980s, a combination of university science and engineering programs and industry-specific training produced the required skilled personnel. As the design activities decreased in the late 1980s and the construction of new units in Ontario essentially stopped by mid 1990, universities no longer had the number of students required to keep offering nuclear-specific courses and degree programs. At the start of the new millennium the industry recognized the lack of specialized graduates being produced by universities, and decided to establish the University Network of Excellence in Nuclear Engineering (UNENE) to address this problem (1). The specific mandates of UNENE are to fund research chairs at the seven member universities located in Ontario, to fund additional nuclear-specific research at any Canadian university, and to offer a course-based Master of Nuclear Engineering program. Unique features of the latter are the offering of courses on weekends, and the option to take any course at any of the participating universities.

The appointment of professors with specialist knowledge in the nuclear field has enhanced the offering of undergraduate courses, and has provided new consulting services to industry. The increased profile of nuclear research at the universities, and the public's awareness of employment opportunities in the nuclear sector have also raised student interest in these courses. However, the majority of university graduates hired into the nuclear industry gain their nuclear-specific knowledge after becoming employed in the industry, typically via company or other specialized training courses.

Apart from universities, community colleges are graduating technicians and technologists, and are supporting apprentice programs that produce the trades people who are in even greater demand than scientists and engineers. With a few exceptions these graduates have received little if any nuclear-specific education, and will require the specialist training after joining a particular company.

Industry training remains a critically important part of ensuring that the required specialist knowledge and skills are given to the men and women working in the nuclear sector. Training that requires such specialized equipment as full-scope replica simulators, systems and components unique to a given unit, tasks to be performed within the plant, are best conducted by the particular company that is responsible for the operation and maintenance of the equipment.

3. UOIT's nuclear degree programs

A somewhat unique combination of events led to the establishment of nuclear degree programs at the University of Ontario Institute of Technology (2). These events included the aspects of plant aging and demographics described above, the location of 12 CANDU units within a 25 km radius of UOIT, the decision by the operator of these units (Ontario Power Generation) to move their nuclear head office staff from downtown Toronto to within the above mentioned 25 km radius of UOIT, and the recognition that the combination of demographics, plant life extension and new build projects will require an unprecedented number of nuclear science and engineering graduates.

The first intake of students into the undergraduate nuclear programs took place in September 2003, with 110 students selected from over 400 applicants. The first graduates of these programs joined the work force in 2007, and initial feedback indicates that the nuclear-specific education they received has resulted in enabling them to become more productive sooner than graduates of the more typical science and engineering programs.

The master of Nuclear Engineering program, both research and course based has recently received approval, and will have its first students in the 2008-09 academic year.

While classroom lectures remain an essential part of the education provided at UOIT, the use of computers to enhance learning has been a key aspect of the success of the programs and our graduates. The CANDU reactors, by their unique characteristics, required the use of computer monitoring as early as the 1960s, and the use of computers was extended to control and safety systems with each subsequent power plant. As well, Canada was an early developer of full-scope nuclear plant replica training simulators, with the first such training tool for the Pickering A units becoming operational in 1976. The unique synergy of the use of computers in the CANDU reactors and operator training programs made the extensive use of computers in UOIT's nuclear degree programs a logical outcome.

4. The use of mobile learning technology at UOIT

UOIT's goal from the outset was to be both a research-intensive and a student-centric institution. An important additional mission of the university was to investigate how strategies for college-university transition could be facilitated through co-location and the application of information and communication technologies (ICT) to facilitate movement of students from one level of education to the other. The university administrators envisioned the incorporation of ICT throughout all aspects of the institution. They believed that the use of computer technology to enhance learning would support high achieving students who would be fully prepared for the emerging high-tech world of work. Consequently, the university was designed as a fully "laptop" university, the second in Canada, and the first in Ontario. Planning included building both an online infrastructure and a purpose-built physical infrastructure, to facilitate learning both on and off campus, from any location and at any time in lecture halls, research laboratories, the library, and in public areas such as study halls, cafeterias and on-campus restaurants. The combination of ubiquitous Internet access and the provision of standards-based laptop hardware has allowed UOIT to establish a teaching and learning environment that addresses total student access to learning technologies, creating common access to a unique web-centric learning environment.

The "web-centric" learning environment at UOIT can be defined as the strategic integration of information and communication technologies into all aspects of the teaching and learning processes. Through coordinated, comprehensive and ubiquitous use of digital technologies, UOIT has built a unique technology-enhanced learning environment, wherein the use of laptop computers, learning management systems (LMS), powerful course-specific software programs and comprehensive online interaction defines the educational experience for all students.

A "web-centric" learning environment is best described as the coordinated implementation of institutional services and learning infrastructures to support network-based teaching and learning. The adoption of digital technologies within higher education institutions requires investment in both hardware and software, and in the necessary support systems to provide a learning environment where students experience both a "high-touch and a high-tech" educational experience, and where faculty are supported in their use of both new network technologies and new pedagogical approaches to instruction (3, 4).

Four support components and/or services systems form the core of the web-centric environment at UOIT: Learning Infrastructure, Online Educational Services, the Mobile Learning Program, and Research Support. Each component provides a foundational element for the strategic use of information and communication technology at UOIT. Rather than merely applying ICT to enable distance learning or distributed education, UOIT has developed a unique learning model, whereby digital technologies enhance face-to-face (F2F) education through the application of digital technologies to enhance student engagement, both online and in F2F classroom settings, in a coordinated strategy. To that end, all learning spaces are equipped with instructional technology that supports the blending of online and classroom-based interaction. All learning spaces are equipped with smart podiums to facilitate F2F instruction using laptop computers, data projectors, DVD players, and Internet access.

Laptop programs are most often valued for their provisioning of hardware and campus connectivity. However, the value of the laptop component of the web-centric learning environment is not only the distribution of 4500 IBM ThinkPad laptop computers, but also making available the necessary course-specific software for learning. All laptop computers are “imaged” with course and/or program specific software that students require for specific courses or programs. Software is preloaded each summer when all student laptop computers are returned to the university for refurbishing and re-imaging. Making software available centrally to students results in standardized software tools for students and financial benefits for procurement and institutional support. In addition, standard software packages assist faculty in designing courses and specific activities using pre-selected course software. For example, students in the Faculty of Energy Systems and Nuclear Science have access to nuclear plant simulation programs on their laptop computers.

The adoption of ICT and its effect upon pedagogy continues to challenge institutions with the question of how best to address paradigm shifts in both teaching and learning. Research indicates that students and faculty experience frustration with the introduction of new technology without also having the appropriate support structures in place (5). To successfully merge traditional F2F lectures with the development of an online learning community, UOIT recognized that it is imperative to develop strategic support systems that can provide a seamless environment whereby students and faculty could receive assistance when required. By empowering both faculty and students with “right-fit” technologies, the institutional focus was to enhance students’ education/experiences. The UOIT institutional support centers are depicted in Figure 1.

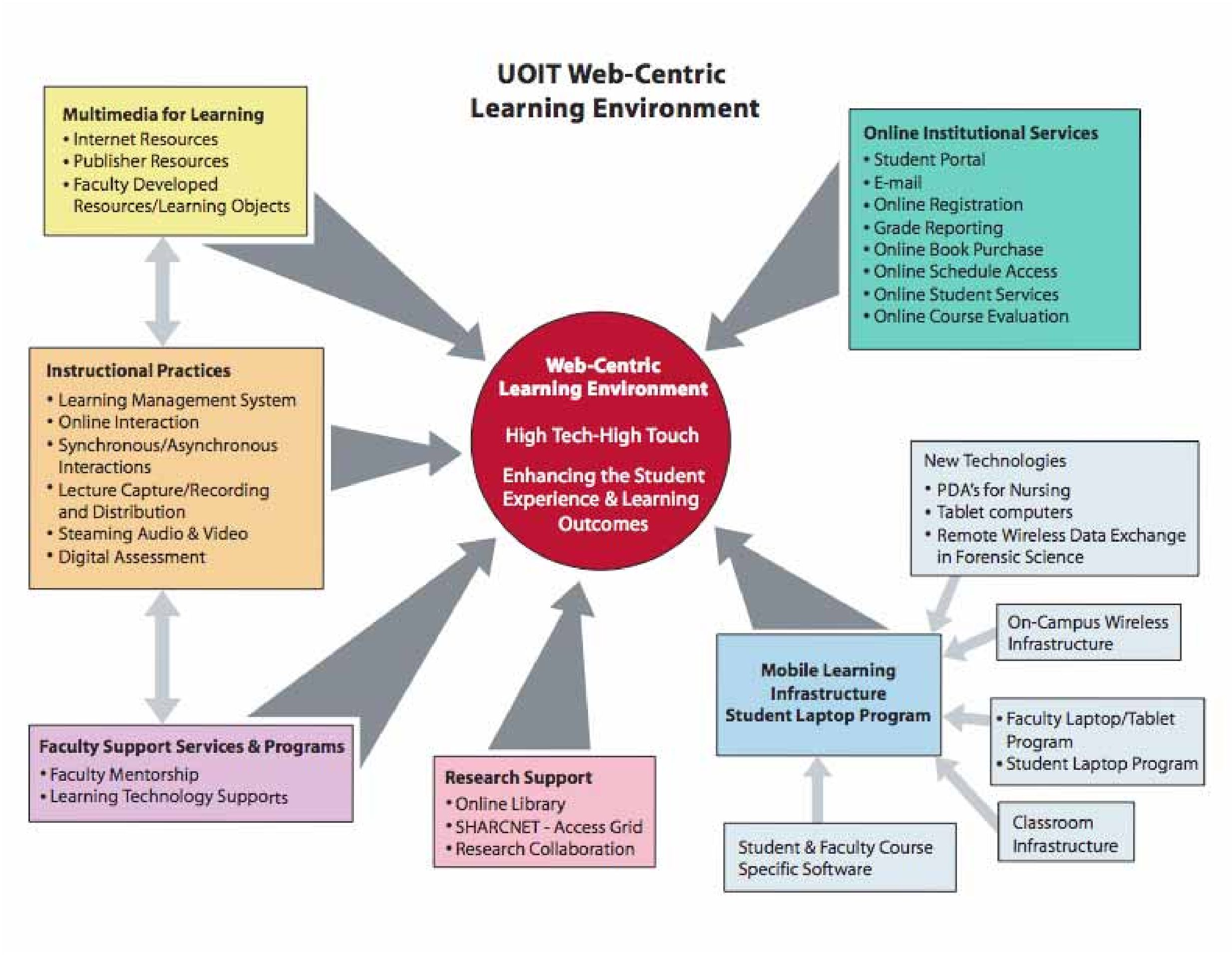

Fig 1: Web-centric learning environment

Finally, the potential impact on other postsecondary institutions emanating from UOIT's pioneering development of a web-centric learning environment may be substantial. While many institutions are expanding their use of information and communication technologies on campus and encouraging the adoption of mobile computing devices by students, the scale and scope of the current integrated technology-enhanced learning environment positions UOIT as a leader in the field of campus-based "web-centric" learning. The scope of the technology provision at UOIT and the scale of the implementation and use of "network" technologies are providing important theoretical and practical insights into best practices regarding technology adoption by universities.

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Radiation Protection

RESULTS OF THE EUROPEAN NETWORK ON EDUCATION AND TRAINING IN RADIATION PROTECTION (ENETRAP 6FP)

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ABSTRACT

Occupational, public and environmental radiation protection is a major challenge in the industrial applications of ionising radiation. As is the case with all nuclear expertise, there is a trend of a decreasing number of experts in radiation protection. Maintaining a high level of competencies in this field is crucial for (i) the future research and development of applications of ionising radiation and (ii) the assurance of the protection of workers, the public and the environment.
In answer to the need for a harmonised European approach of education and training (E&T) programmes in radiation protection and, based on that, the mutual recognition of Qualified Experts, the ENETRAP project (EC contract number FI6O-516529) made a study of the current European E&T issues.

1. Introduction

This project deals with the development of an E&T structure in radiation protection (RP), based on an analysis of needs, qualification requirements, etc of the different Member States. Studies [1] have shown that a wide variety of national approaches for E&T of the qualified expert, as required in the European Basic Safety Standards, exist in the EU Member States, the New Member States and the Candidate States. The development of a common European radiation protection and safety culture and, based on that, the mutual recognition for experts becomes a real need. The harmonisation of E&T is a good starting point. Moreover, finding a common basis for E&T will favour the mobility of workers and students throughout the European countries.

The main objectives of this project were:
- to better integrate existing E&T activities in the RP infrastructure of the European countries in order to combat the decline in both student numbers and teaching institutions;
- to develop more harmonised approaches for E&T in RP in Europe and their implementation;
- to better integrate the national resources and capacities for education and training;
- to provide the necessary competence and expertise for the continued safe use of radiation in industry, medicine and research.

These objectives were reached by the establishment of a European E&T network in radiation protection that addressed following tasks:
- assess training needs and capabilities;
- identify the potential users and their future involvement in order to insure the sustainability of the network;
- launch a consortium of universities with the aim of create an European Master in Radiation Protection (EMRP);
- review the scientific contents of E&T activities;
- explore the effectiveness of on-the-job training and identify options for additional programmes;

- propose recommendations for the recognition of courses and competencies of radiation protection experts (RPEs);
- make recommendations for revising the current European Radiation Protection Course (ERPC) to include a system for credit points and modern educational tools, such as distance learning.

An important tool developed and used during this project was the ENETRAP questionnaire, which allowed to study the education and training needs for radiation protection experts, officers and workers. More then 40 questions covered topics such as adequateness of RPE's, self-sustainability of national E&T programmes, regulation and recognition, implementation of on-the-job training, availability of distance and/or e-learning, etc.
This study enabled us to put forward recommendations for a harmonised approach of the education and training schemes and to promote the quality of the E&T programmes, the mutual recognition of skills and mobility of workers and students.
The outcome of the questionnaire also served as an input for the EUTERP Platform [2].

2. Project outcome

The results of the ENETRAP study concern the following main subjects:
- Assessment of training needs and capabilities, and recognition of competencies and diploma's within the EU Member, the New Member States and the Candidate States;
- Analysis of existing IAEA and EC requirements related to E&T in radiation protection
- On the job training and work experience;
- New concepts and tools : distance and e-learning;
- Developments with regards to training: suggestions for the creation of a European "reference" training scheme;
- Developments with regard to education: establishment of a consortium of universities and a European Master in radiation protection.

All deliverable report can be foud on the project website www.sckcen.be/enetrap.

2.1 Assessment of training needs and capabilities, and recognition of competencies and diploma's within the EU Member, the New Member States and the Candidate States

A questionnaire, structured around the above mentioned objectives, was prepared and distributed to 31 countries. Constructive responses were obtained from 28 countries.
A significant amount of data and information was provided. The results can be summarised in the following conclusions:

i) There are significant differences in interpretation of the roles of the RPE and the radiation protection officer (RPO) across Member States. These differences have a strong influence on specified legislative requirements with respect to RPE and RPO as well as on the approaches taken with respect to Education and Training. There are wide ranging approaches to the latter.

ii) On the basis of the information provided via the ENETRAP questionnaire and given the significant issues with the interpretation of key roles, it is difficult to conclude a workable “de-minimus” level of training for the RPE (or RPO). Further investigation of this issue is required.

iii) The majority of Member States have mechanisms in place for the recognition (and re-recognition) of the Radiation Protection Expert. However, the approaches taken vary significantly and are difficult to compare.

iv) Only a minority of countries have a formal system for mutual recognition or RPEs (RPOs and workers) and the study did not elicit a consensus view as to what could constitute minimal requirements for mutual recognition.

Issues ii), iii) and iv) above all warrant investigation beyond the scope of the current ENETRAP project. For pursuing these issues further, the results have been presented in the first EUTERP workshop. This resulted in 8 recommendations, mainly to the European

Commission, which have been discussed in the Expert Group according to Article 31 of the Euratom Treaty for their relevance in the revision of the Euratom BSS.

2.2 Analysis of existing IAEA and EC requirements related to E&T in RP

For European Union Member States, requirements related to RP training are laid down in the European Basic Safety Standards and appending documents. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, issued by the International Atomic Energy Agency (IAEA) were co-sponsored by a number of international organisations, among these organisation such as the World Health Organization (WHO), the International Labour Organization (ILO) and the Nuclear Energy Agency. However, only the IAEA is running an extensive training programme in radiation protection.
Within the framework of the ENETRAP project, the content of the current European Radiation Protection Course (ERPC) has been compared with the requirements published by the EC and by the IAEA. This in order to be able to develop a revision of the current ERPC which can serve as a "reference" European training scheme.
It was found that the scientific/technical content of the ERPC is totally in accordance with the Basic Syllabus of the Qualified Expert in Radiation Protection in Communication 98/C133/03. The Additional Material of this Communication is also covered in detail to a great extend. In the ERPC, 50% of the training is theoretical courses and 50% is practical, exercises, demonstrations and scientific visits. In addition to this distribution, 3-6 months of practical experience in a company is mandatory (postgraduate) or offered (professionals). This approach fits entirely the statement in Communication 98/C133/03 that training needs are to be supplemented by practical experience.
The aim of the IAEA Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (PGEC) is to meet the initial training needs of professionals at the graduate level or equivalent in order to acquire a sound basis in radiation protection and the safe use of radiation sources. It is tailored for a wide range of professionals but not specifically addressing the qualified expert as defined in the European Basic Safety Standards. In the PGEC syllabus, the legislative framework and regulatory system is covered in more detail than in the ERPC. However, in comparing the curricula they can be considered as very much equivalent.
ENETRAP takes into account the requirements of both EC and IAEA when developing a common basis for European radiation protection training schemes. It also recommends that IAEA and EC cooperate more closely with the objective of further developing common standards with regard to education and training in radiation protection and waste safety, and exchanging information and training materials, in order to make efficient use of resources.

2.3 On the job training and work experience

A suitable qualification for responsible personnel in RP (e.g. RPE, RPO, and Medical Physicists) must be in general a combination of theoretical knowledge, and the ability (competency) to practice RP.
While the theoretical knowledge is acquired by suitable education and by attending training courses, competency and skills can only be obtained by appropriate on-the-job training OJT followed by a period of work experience (WE).
In order to identify fields for OJT, provide feedback from existing OJT programmess and to compare the different practical approaches, some questions in the ENETRAP questionnaire dealt with OJT and WE. The evaluation with respect to OJT and/or WE has shown that:
- two-third of the EU-Member States have implemented some kind of OJT and/or WE in their national legislation, however clear definitions are rarely found;
- only few countries have levels or classifications for OJT and/or WE, with a duration of several weeks up to some months (OJT);
- OJT and WE is especially required in all medical sectors and nuclear installations like power plants.

Based on the feedback from trainees of existing OJT programmes, it can be concluded that OJT provides better chances for future job opportunities and increases international flexibility among EU partners. Training providers for all practices are only available in some countries; thus a list with facilities for foreign trainees would be helpful.
As result of its evaluation ENETRAP recommends covering OJT together with E&T in the EU Basic Safety Standards and their guidelines for implementation. OJT should be specified by its content (syllabus, learning objectives), availability of necessary facilities and infrastructures as precondition for OJT, assessment of the competence of the participant, format of certificate, recognition of OJT, and responsibilities of host organisation and trainees. OJT should be a key element in both the training and education programmes in RP.

2.4 New concepts and tools: distance and e-learning

A study was performed which included an analysis of e-learning methodologies and resources. The study was performed in two ways: 1) e-learning educational models or methodologies (the method to management didactical resources in time, pace and environment); and 2) e-learning platform to indicate which one is the most adequate for fitting the requirements for the implementation and validation of European E&T programmes. The study of the current existing e-learning platforms and pedagogical methodologies was an important part to choose the best e-learning tools and develop the future activities in E&T in RP.
Different platforms had been studied in order to guess which one could fit better to ENETRAP objectives. In order to obtain the most appropriate platform for ENETRAP needs was necessary the analysis of certain aspects and compare them among all the studied platforms. Some of these aspects were: functionality, architecture, course organisation, design possibilities, communication tools, files management, multilanguage possibilities, assessment tools, methodological resources, multimedia resources, compatibility with other platforms, use and access conditions, necessary requirement, cost and security.
The obtained results had been used to select the best way to host learning activities in the framework of the ENETRAP project.

2.5 Developments with regard to training: suggestions for the creation of a European "reference" training scheme

In this context, a syllabus has been developed. It has been named "ENETRAP Training Scheme" ETS The existing syllabi have been studied for the development of ENETRAP Training Scheme; the one of the post graduate course of IAEA, the one of the former ERPC and the one of the second year of the French Master of radiation protection called M2RP. It was point out a by the surveys carried out by the Commission indicate a wide diversity of current practice in Member States. The ETS has been developed with the aim of harmonizing the training dispensed through out Europe because of the report of a large diversity of approaches for E&T.
It is a modular approach that has been carried out for ENETRAP Training Scheme. The scheme is structured around three modules constituting the "Common basis" and five other specific modules (NPPs, Research reactors – Waste management, decommissioning – Non-nuclear research, oil & gas – Medical – NORM). The total duration is eight weeks and a half with an On the Job Training period for each specific module.
With this modular structure, participants will have more flexibility to compose their own training in respect of ENETRAP training Scheme in order to become "Qualified Expert". It is possible by this way to customise a professional curriculum.
Possibilities of usage of new modalities of education and training such as e-learning, web casting have been studied. The objectives and purposes were to introduce Information and Communication Technologies ICT in order to improve the E&T in RP by facilitating on the one hand the access to resources and services, and on the other hand, the exchanges and collaborative works between learners and teachers.

The use of Open and Distance Learning (ODL) is one of the means to ensure the future supply of appropriately educated and skilled personnel for those who use ionising radiations across Europe and secondly, to meet the increasing demand and decreasing number of radiation protection experts available in Europe. Open and Distance Learning contributes to promote mobility of workers and students throughout the European countries where students can be taught at "Anytime, Anyplace, Anywhere".

2.6 Developments with regard to education: establishment of a consortium of universities and a European Master in radiation protection

This European Master in Radiation Protection (EMRP) is used to harness and coordinate European expertise in this field in order to develop a high level education Master's programme as called for Bologna declaration. This will ensure the future supply of appropriately educated and skilled personnel for those who employ ionizing radiations across Europe.
The EMRP will thus respond to both the increasing demand and decreasing number of radiation protection experts available in Europe and help local skills shortages by facilitating the mobility of graduates through mutual recognition of their qualifications. Finally, an important part of the Masters programme will allow candidates to achieve the status of a Qualified Expert as defined in the 96/29 European directive.
Progress has been made to harmonise the training of radiation protection experts in the health, industrial or nuclear regulation fields. The present project will use an educational approach to provide harmonisation in this highly specialised field. By building on the expertise available in some universities who have experience in this field, this educational and training programme will be opened to all European Member States. The new qualification will ultimately allow a greater mobility to the future workers in this field across Europe.
This educational and training programme will last one year as a 2nd year of master degree.
The final diploma will be a joint diploma recognised by all the partner countries (France, Scotland and Czech Republic). It will be awarded after completion of written examinations on theoretical matters and a public defence of a personal work done during an on job 6 months training. To obtain the join diploma the students will have to fulfil requirements regarding European mobility of at least 6 months in one of the partner institutions during 2 years of their master studies. Students will come either from undergraduate scientific domains, mostly from physics background, but also from health, environmental and chemical sciences, or from professional positions as a part of livelong learning.
On line and e-learning modalities will be used by some partners to cope with the challenge of distance, multiple languages and on the job training requirements.
Accreditation or validations will be gained according to the academic and governmental rules of the respective participant countries.
The European Master in Radiation Protection will welcome its first students in September 2008. The four partners in this project are:

- The University Joseph Fourier Grenoble 1, Grenoble, France (EMRP project leader)
- The North Highland College, Thurso, Schotland - UK,
- The Czech Technical University, Prague, Czech Republic,
- The Institut National des Sciences et Techniques Nucléaires, Gif-sur-Yvette, France.

3. Conclusions

The development of a common European radiation protection and safety culture and, based on that, the mutual recognition of radiation protection courses and the acquired competencies of radiation protection experts is a real need. The harmonization of E&T is a requisite starting point and will furthermore help and promote the mobility of workers and students throughout the European countries.
ENETRAP was a study programme, with the aim to gather information on several key-issues with regard to E&T in RP. The results of the ENETRAP project were transferred to the umbrella organization EUTERP, which was launched in 2006. The main objectives of this Platform are to better integrate E&T into occupational radiation protection infrastructures in the Member, Candidate and Associated States of the European Union, to facilitate the

transnational access to vocational education and training infrastructures, to harmonise the criteria and qualifications for and mutual recognition of RPEs and to remove obstacles for the mobility of these experts within the European Union.

The collaboration from almost all European countries to the ENETRAP questionnaire and the positive response to the first EUTERP workshop confirm the European need and interest to a harmonised approach of E&T in RP in all domains where ionising radiation is used.

Future initiatives should deal with establishing reference training schemes that meet the requirements for the RPE and the RPO, methodologies for comparison of training courses to that reference scheme, evaluation of training material, events and providers and the implementation of a mutual recognition system for RPEs.

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[2] www.euterp.eu

Long-term program on education and training of the professionals involved in nuclear safety and radiological protection in Poland within the confines of EU project "Transition Facility"

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ABSTRACT

In December 2007, in a frame of EU action Transition Facility, the new long term program "Nuclear Safety and Radiological Protection" (CRIS No 2005/017-488.03.06) of extended education and training for the groups professionally involved in nuclear safety and radiological protection was established. The basic target of the project is to elaborate a system of teaching and training that best responds to the national needs and makes the best use of the national experimental facilities. The project is coordinated by Central Laboratory for Radiological Protection and will be evaluated and implemented together with Institute of Atomic Energy at Swierk (working with highly radioactive substances, running the only one in Poland nuclear reactor). Moreover, a numerous of high skilled experts from various research and technological institutes have been involved. This program meets requirements to establish framework for central orientated education system and urgent need of more harmonized approaches for education of specialists involved in development of nuclear energy in Poland as well as for education of high skilled physicians in rapidly developing nuclear medicine sector.

Introduction

It has became clear that professional education of qualified personnel employed in places where ionising radiation is used or made, needs support by the basic education that should result in much better preparation of beginner students to adopt a higher educational level. In Poland number of hours dedicated at primary and secondary schools to nuclear physics is too small to make the teaching of this subject truly effective. Moreover, high-school students encounter series of difficulties in perception of the nuclear science. These result from not only small number of lecture hours dedicated to nuclear physics, but also from the lack of appropriate school laboratories. This requires an urgent promotion of more harmonised approaches for education in the nuclear sciences and engineering. Currently, the national education and training framework is developed to link together institutes and universities and governmental atomic agency as well as regional institutions responsible for radiological safety.

National regulation on education in the fields of nuclear safety and radiological protection

The national regulation (Atomic Law - Act of Parliament of 29 November 2000 with subsequent amendments) [1] established legal basis for people professionally involved in nuclear safety and radiological protection. The National Atomic Energy Agency's President certificates educational centres, assigns of examines board and issues authorization relevant to the particular type of position. This new legal provision establishes framework for central orientated education system and prompts an urgent promotion of more harmonized approaches for education in the nuclear sciences and engineering.
In chapter 3 of the Act that is dedicated to the nuclear safety, radiological protection and employees health protection one implements position of an authorized radiological protection inspector. Although, responsibility for compliance with nuclear safety and radiological

protection requirements shall rest with the manager of the organizational unit, the inspector of radiation protection holds internal supervision for compliance with nuclear safety and radiological protection requirements in the unit conducting the activities/practices involving exposures according possessed by him authorization [3]. An employment of inspector is obligatory and is indispensable condition to possess a license for such kind of activity. In a frame of his duties the inspector performs particularly:

i. control of activities in respect of labour instruction relating to the nuclear safety and radiation protection and work conditions permissible for particular worker groups,
ii. registry of workers and different persons, staying in conditions at the risk exposure,
iii. control state of education and training standard,
iv. elaboration of dosimetric monitoring programme in work environment and implementation of individual doses records system for acceptance by manager of organizational unit,
v. co-operation with security institutional services and the labour hygiene, persons implementing the programme of assurance of quality, the fire - fight services and environment protection service in extension of protection against ionizing radiation,
vi. applying to manager of organizational unit with conclusion about inhibition of work, when the conditions violate permission (license) or regulations of nuclear safety and radiological protection,
vii. supervision of conduct action according the facility emergency preparedness plan in a case of radiation emergency.

The scope of radiation protection inspector's capabilities comprises (inter alia):

i. formulation of illation to manager of organizational unit about changes of working conditions, in peculiarity in situation, when the results of measurements of individual doses motivate such conclusion;
ii. monitoring the workers' qualification and protective measures in respect of nuclear safety and radiation protection and formulation conclusions to manager.

Furthermore, according to the Act obligation, The Council of Ministers, issued in the form of regulation, the <u>types of positions important for ensuring nuclear safety and radiological protection [2]</u>, detailed conditions and proper procedures for the Agency's President for issuing authorizations for radiological protection inspectors and people occupying positions mentioned above, together with required scope of training, requirements for the bodies conducting the training, taking into account the training curriculum and organizational forms, standard form of authorization certificate and overall scope of inspector's authority and duties. Types of positions having the essential importance for assurance of nuclear safety and radiation protection jointly with obligatory scope of education [3] are presented in Tab.1 and Tab. 2.

The currently crucial problem is tutoring and authorisation of medical physics experts which specialization has been recommended by Council Directive 93/47/EURATOM and implemented recently by polish regulation. The new educational system (3 years specialization) has been worked out and submitted for acceptance by Ministry of Health [4]. National Society of Radiation Protection Inspectors organizes every year workshops that offer great help to the groups professionally working with ionising radiation: medical technicians, State's borders' officers, officers of local governments etc. by disseminating the recent achievements in the field of nuclear physics and radiation protection.

Recently, the basic principles of the educational framework have been formulated in the long term programme of the Ministry of Economy "The Energy Policies in Poland until 2030". This framework will evolve in the course of the development of Nuclear Energy in Poland (first Nuclear Power Plant is foreseen in 2021) and will be shaped by present requirements in European countries.

This new legal provision establishes framework for central orientated education system of the groups professionally connected with the nuclear radiation. This is forcing the national educational centres to elaboration of such a system of teaching and training that responds best to the national needs and makes the best use of the national experimental facilities [5].

Tab 1: Types of positions having the essential importance for assurance of nuclear safety and radiation protection jointly with obligatory scope of education.

Position	Required education		Seniority (years) in hazard condition	scope of training and examination
	high level	secondary level		
research reactor operator	physicist, chemist, electrician, mechanic, computer scientist	nucleonic science engineer, power industry specialist engineer, electrician, electronic engineer	2 year in nuclear reactor unit	R-O
dosimetry specialist in research reactor, senior dosimetry specialist in research reactor	physicist, chemist, electrician, mechanic, computer scientist	electrician, electronic engineer	1 year in dosimetry department of nuclear reactor unit	R-D
manager of research reactor shift	physicist, chemist, electrician, mechanic, computer scientist	electrician, electronic engineer	1 year (high educ. level) 3 years (secondary educ. level) reactor operator post	R-OK
manager of research reactor	physicist, chemist, electrician, mechanic, computer scientist		1 year as manager of research reactor shift	R-OK
assistant director on the nuclear safety and radiation protection in unit exploring of research reactor	physicist, chemist, electrician, mechanic, computer scientist		1 year as manager of research reactor	R-OK + R-D
expert on the nuclear material inventory records	any	any	1year in the unit with storage of nuclear materials	S-E
operator of spent nuclear fuel storage facility	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	1 year in the unit exploring of spent nuclear fuel storage facility	S-O
manager of radioactive waste disposal facility	physicist, chemist, electrician, mechanic, computer scientist		1 year (high educ. level) 3 years (secondary educ. level) radioactive waste neutralization plant	S-O
manager of radioactive waste neutralization plant	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	3 years spent nuclear fuel storage facility or radioactive waste neutralization plant	S-O
operator of accelerator used in non medical purposes, excluding accelerators used for vehicles control on border gates	physicist, chemist, electrician, mechanic, computer scientist	electrician, chemist, mechanic, nucleonic science engineer	0 year (high educ. level) 1 years (secondary educ. level) in accelerator laboratory	A-A
operator of accelerator used in used for vehicles control on border gate	any	any	0	A-A
operator of accelerator used in medical purposes and radiotherapy devices	physicist, chemist, biologist, medical, technical	electrician, electronic specialist mechanic, nucleonic specialist	0 year (high educ. level) 1 years (secondary educ. level) level in accelerator laboratory	S-A
operator of devices used in brachytherapy	physicist, chemist, biologist, medical, technical	electrician, electronic specialist mechanic, nucleonic specialist	0 year (high educ. level) 1 years (secondary educ. level) in radiotherapy laboratory with radioactive sources	S-Z

Tab. 2. Detailed conditions of authorization the particular type radiation protection inspector, with regard on kind of activity connected with level of risk of radiation exposure, ad quem supervising inspector gets authorization.

Activities and practices involving exposures	seniority (years) in hazard condition		scope of training and examination
	higher education	secondary education	
Storage, transport, turnover or use of sealed radioactive sources, instalaling, use and maintenance of equipment containing radioactive sources with activity leas than 10 fold specified value, item needs to be declared or permitted.	1	0	IOR-0
i. Manufacturing, conversion, storage, disposal, transport or use of nuclear materials, radioactive sources, radioactive waste, and turnover them, excluding usage of radioactive sources for medical purposes, and also storage, transport, turnover or use of sealed radioactive sources, installing, use and maintenance of equipment containing radioactive sources with activity less than 10 fold specified value, that needs to be declared or permitted. ii. Construction, exploitation, closure and decommissioning of radioactive waste disposal facility. ii. Manufacturing, installation, use and maintenance of equipment containing radioactive sources and turnover such equipment; excluding radioactive sources devices used for medical purposes, and also, installation, use and maintenance of equipment containing radioactive sources with activity less than 10 fold specified value, item needs to be declared or permitted. v. Activation and application of the ionizing radiation generating devices used for not medical purposes and activation of laboratories and workrooms for application of RTG devices. v. Intended addition of radioactive substances in the processes of manufacturing consumer and medical products and trade in such products as well as importation to the Republic of Poland territory and export from this territory consumer and medical products, with the addition of radioactive substances.	3	1	IOR-1
i. Conversion, storage, disposal and transport of spent nuclear fuel. ii. Constructing, commissioning, operation and decommissioning of nuclear facilities as well as spent nuclear fuel disposal facility, and constructing, exploitation of spent nuclear fuel storage facility.	4	2	IOR-2
i. Use radioactive sources for medical purposes, manufacturing, installation use and maintenance of equipment containing radioactive sources for medical purposes as well as activation of laboratories and workrooms where these devices will be used, excluding RTG devices used for medical diagnostic purposes, surgical radiology, surface radiotherapy and non cancer radiotherapy as well as laboratories used these devices. ii. Intended administering of radioactive substances people and animals for medical and veterinary diagnostic, treatment or scientific investigation.	4	2	IOR-3

EU action “Transition Facility - Nuclear Safety and Radiological Protection”

In December 2007, in a frame of EU action Transition Facility, the new long term program “Nuclear Safety and Radiological Protection” (CRIS No 2005/017-488.03.06) of extended education and training for the groups professionally involved in nuclear safety and radiological protection was established. The project is coordinated by Central Laboratory for Radiological Protection and will be evaluated and implemented together with Institute of Atomic Energy at Swierk (working with highly radioactive substances, running the only one in Poland nuclear reactor). Moreover, a numerous of high skilled experts from various research and technological institutes have been involved, i.e.: The Institute of Nuclear Chemistry and Technology in Warsaw (inventors of many nuclear methods for technological processes,

irradiations, for environment protection), Warsaw University of Technology (Institute of Precision and Biomedical Engineering, which is leading unit on development and safety of radiological equipment and medical software), Warsaw University (Faculty of Physics, Nuclear Physics Division) and National Atomic Energy Agency (regulatory body). The basic target of the project is to elaborate a system of teaching and training that best responds to the national needs and makes the best use of the national experimental facilities. The special efforts has been made to prepare module structured of education materials that consist of lectures, experimental demonstrations, videos, laboratory practices, information on accessible e-learning systems and, excursions to the nearby nuclear centres. Apparently the courses organised must be attractive and responding precisely to the established needs.
This extended program of training will covers all positions having the essential importance for assurance of nuclear safety and radiation protection (Tab 1., Tab 2.) with special emphasis on nuclear facilities inspectors. The program consists of 360 hours of lectures, 40 hours of laboratory exercises, and 12 hours of computing skills and covered a wide range of topics, inter alia: basis of nuclear physics and ionising radiation, radiochemistry, natural and man-made sources, detection of ionising radiation, application of ionising radiation in medicine, technology, and science, biological effects of ionising radiation, basic quantities and units of radiation dosimetry, dosimetric instrument and measurement devices, principles of nuclear safety and legal provisions concerning radiological protection. The tree levels of training i.e: basic, extended, specialization has been elaborated. The 20 lecturers and trainers are involved. The program will evolve in the course of the system development and will be shaped by current European and International recommendation i.e.: SAT (Systematic Approach to Training) [7-9]. The program will stimulate and enhance the efficiency of the training actions in universities, research and technological institutes, and the teachers' educational centres [10].
The close collaboration with EC various education centres is necessary for understanding the technological progress made in various countries and for updating current knowledge and to provide the public with sufficient and competent information.

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[1] ACT OF PARLIAMENT of 29 November 2000, Atomic Law, Polish Journal of Laws, No.3 item 18 , 2001 (in polish)
[2] DECREE OF CABINET COUNCIL'S of 18 January 2005, Types of positions having the essential importance for assurance of nuclear safety and radiation protection, Polish Journal of Laws, No.145 item 1217, 2002 (in polish)
[3] Safety of Nuclear Installations IAEA Safety Series 110;
[4] DECREE MINISTER OF HEALTH of 24 December 2002, Conditions of safe application of ionizing radiation in medical purposes and procedures of internal audit, Polish Journal of Laws, No. 241 item 2098, 2002 (in polish)
[5] Recruitment, Qualification and Training of Personnel for Nuclear Power Plants IAEA NS G 2.8;
[6] Means of evaluating and improving the effectiveness of training of nuclear power plant personnel, IAEA TECDOC 1358;
[7] Safety Assessment for Spent Fuel Storage Facility, IAEA Safety Series 118;
[8] Operations of Spent Fuel Storage Facility, IAEA Safety Series 117.
[9] Nuclear Power Personnel Training and its Evaluation", Technical Reports Series 380, IAEA, Vienna, 1996.
[10] Training the staff of the regulatory body for nuclear facilities: a competency framework. IAEA TECDOC 1254.

IAEA Education and Training in Radiation Protection, Transport and Waste Safety- Status and New Developments for Sustainability.

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Abstract

IAEA's education and training activities in radiation, transport and waste safety follow the resolutions of its General Conferences and reflect the latest IAEA standards and guidance. Since 2001 IAEA has been implementing a "Strategic plan on Education and Training in Radiation Protection and Waste Safety", which is aimed at establishing sustainable education and training programmes in Member States by 2010. In implementing the strategy, IAEA organizes post-graduate educational courses in Arabic, English, French, Russian and Spanish at regional training centres around the world. Additional training events aimed at specific audiences, such as Regulators, are run at the national and regional level. In total, more than 30 standardized training packages have been developed and translated to facilitate global consistency and harmonization of training events. To promote sustainability and self-dependency, IAEA also organize Train the Trainers events to develop a pool of qualified trainers, with the appropriate skills, and who are familiar with IAEA developed training package. Additional initiatives aimed at building capacity in Member States include: establishing eLearning; developing a syllabus and teaching aids for training of Radiation Protection Officers; and developing information materials for radiation workers.

I. Introduction:

The statutory safety functions of the International Atomic Energy Agency cover the establishment of and provision for the application of safety standards for protection of health, life and property against ionizing radiation. Education and training is a major element of the IAEA's mechanism for the application of safety standards and for strengthening radiation safety infrastructures in its Member States. The education and training activities follow the resolutions of its General Conferences and reflect the latest IAEA standards and guidance. IAEA prepared a "Strategic Approach to Education and Training in Radiation and Waste Safety" (Strategy on Education and Training) aiming at establishing, by 2010, sustainable education and training programmes in Member States, which was endorsed by the GC(45)/RES/10C in 2001. In line with this resolution, the IAEA has developed a number of different training schemes. The Steering Committee for education and training in radiation protection and waste safety advices the Agency on the implementation of the long term strategic plan. Regional, national and collaborating training centres, international organizations like European Commission and International Radiation Protection Association (IRPA) are represented in the steering committee.

II. Training Schemes

Post-Graduate Educational Courses (PGECs).

This long duration post-graduate educational course in radiation protection and safety of radiation sources constitutes a comprehensive and multidisciplinary programme with theoretical and practical training aims. It is aimed to educate and train young professionals, to provide the necessary basic tools for those who will be recognized as qualified expert in radiation protection in the later years and be involved in education and training in radiation protection and safety of radiation sources. PGEC is hosted by the Regional Training Centres (RTCs) around the world with the Agency support and delivered in line with the IAEA Standard Syllabus (Ref:1) in five of its official languages. They include Argentina (Spanish), Syria (Arabic), Morocco (French),

Belarus (Russian), Malaysia, Greece and South Africa (English). Every year over100 participants benefit out of this educational course which is the initial training to acquire sound basis in radiation protection and safety of sources.
Presenter's material as PowerPoint slides are developed by the Agency in line with the Standard Syllabus in all the languages of the course delivered and provided to the RTCs. This ensures that the same message is conveyed at all the training centres.
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Specialized Training Courses (STCs)& Workshops.
The training courses are usually shorter in duration. They are run for one or two weeks and are aimed at participants who already have attended PGECs. Workshops are task or practice -specific and provide more opportunity to the participants for in depth training and exchange of information. Topics covered are wide ranging and include the regulatory framework, occupational exposure (external and internal), patient protection (diagnostic radiology, radiotherapy and nuclear medicine), radioactive waste management, transport of radioactive materials, safety of radioactive sources and safety in industrial applications. They are regularly organized as national or regional courses for different target audiences, such as regulators or radiographers. Each year about 25 such regional training events are organized in different Member States. Customized training materials are developed that are used in training programmes. The training materials are also translated to Agency official languages, (Annex-I)

Other Training Mechanisms:
The other training mechanisms are aimed at achieving the training objectives through field training (On the Job Training), Distance Learning or Training the Trainers.

On the Job Training (OJT)
This is expected to be supplementing the classroom training, with a prerequisite of attendance to either PGEC or STC. The objective of this technique is to provide individual practical training in a chosen practice for a longer duration, under the direct supervision. The duration is dictated by the training theme, varying from 1-3 months. The added value is the opportunity to work in well developed centers. The successful completion of PGEC, STC and OJT could make an individual eligible to be recognized as qualified expert.

Distance Learning (DL)

IAEA successfully concluded a `Distance Learning' project in Radiation Protection in the Asia and the Pacific region. The participating countries were Australia (coordinator), Korea, Indonesia, Mongolia, Thailand, The Philippines and New Zealand. This learning method was used both nationally and internationally. Distance learning complements the class room training and found useful where only small number of people need training or where target population is scattered or live far from national training centers. This is good tool for refresher training or as pre training to prepare an individual to attend a training course. The exemplary quality learning material developed for the distance learning is now being used for providing pre training for PGEC participants. The objective is to harmonize the level of knowledge in radiation protection of all the PGEC participants coming from different educational and cultural background. The selected participants receive the pre training CDROM in their home country and prepare themselves for the long duration PGEC. The material is translated to Arabic, Russian and Spanish.

Training the Trainers:

This training mode covers mainly lectures on pedagogical skills. This methodology is adopted to build competence at the national level a sufficient number of trainers in radiation protection with

competencies in radiation protection and teaching. Consequently the training syllabus includes teaching and communication skills to be a good lecturer, organization of training events including laboratory exercises and to introduce to the participants IAEA developed training CDs so that they are used effectively in future training courses. The training course is designed to be interactive with presentations by the participants. In addition to national trainers, it is also intended to develop a pool of international trainers through train the trainers workshops. The selection of participants to the workshops takes into account these requirements. IAEA has so far conducted more than 10 train the trainers workshops for radiation protection in medicine, radiation protection in industrial applications at national, regional and interregional level. The workshops have facilitated in developing expert trainers and create a Data Base of trained trainers.
In addition, IAEA through its PGEC has introduced this module to the participants, who in later years may become trainers

III Development of training material for other job categories

Radiation Protection Officers

Ssignificant effort and progress has been made with respect to the establishment and consolidation of the PGEC as the primary training route for new professionals in the field of radiation protection in Member States. That being the case it was felt that it was appropriate to increase emphasis on the promotion and development of training for Radiation Protection Officers (RPO), this being a significant element with regard to the successful implementation of the strategic plan. A standard syllabus was developed taking in to consideration that the primary role of the RPO is one of “supervision” which if effective, will assist the employer/registrant/licensee in ensuring the application of relevant standards. The syllabus is divided into core and supplementary modules. While the core module is a compulsory module, the supplementary module is practice specific. Training material for the core module is developed and the material pertinent to the nine supplementary modules is also complete.

Information materials

The recommendations of the Conference on `Occupational Radiation Protection’ in Geneva,2002, relate to information exchange between interested parties, wider dissemination of information and more active involvement of workers, employers, regulators and radiation protection specialists in information exchange leading to a better and broader understanding of radiation protection practices and promote the evolution of safety cultures in the workplace. This led to the development of information material like cautionary posters intended for display at workplaces, designed to reduce the number of near misses and the risk of serious accidents**.** The materials include topics like use of high-activity or high-dose rate sources such as irradiators and industrial radiography devices, in order to reinforce the need for safety procedures to be followed at all times.

IV. The Way Forward

Considerable work has been undertaken in pursuance of the strategic aims for education and training and in completing the key functions. In order to be able to achieve overall objective of self-sustaining training activities within Member States, there is a need to establish a national strategy for education and training. It is possible to establish a national strategy only if the training needs are systematically assessed and identified**.** The *Appraisal Methodology* adopted by the Agency provides solution to identification of training needs

The Agency has developed an Education and Training Appraisal (EduTA) protocol document which describes the objectives, the methodology for carrying out a detailed appraisal and the expected results of the appraisal. The objective of the EduTA mission is to carry out a detailed appraisal of the status of the provision for education and training in radiation protection including the identification of the national education & training needs and areas where provisions should be improved to meet the national E & T needs as well as international standards and best practices. Member States will benefit by identifying the training needs and in planning future E & T strategy.

An EduTA becomes most appropriate and beneficial to a country when the provisions for education and training in radiation safety have been established or are at an advanced stage of development and implementation. The Agency has already completed four such appraisal missions and two more are planned for this year.

Elearning :.. The objective of eLearning is to create from the existing distance learning course material an e-learning course to demonstrate the pertinence and efficiency of such an approach to training. IAEA has made the training material available in the web format, to be introduced as a training course. Elearning is challenging as it is self learning, and is expected to provide learners a perspective that is difficult to achieve through classroom or paper-based training programmes.

VI. Conclusions

The Agency continues to implement the Strategic Plan, however the ultimate effectiveness of the strategic approach to education and training and other IAEA initiatives rests upon the commitment of Member States to develop national strategy and sustainable training programmes in radiation safety. By working together more progress can be made towards the realization of a harmonized approach for education and training. These steps are essential ingredients for maintaining high standards of radiation safety worldwide.

Annex- 1

Training Packages developed by the Division of Radiation, Transport and Waste Safety

Regulatory Oversight

- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Nuclear Medicine (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Nuclear Gauges and Well Logging (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Industrial Radiography (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Radiotherapy (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Industrial Irradiators (E,S,A,F)*
- IAEA Training for Regulators on Authorization & Inspection of Radiation Sources in Diagnostic & Interventional Radiology (E,S,A,F)*
- IAEA Training for Regulators on Authorization and Inspection of Cyclotron Facilities (E)
- IAEA Training Course on Customs Radiation (E,F,S)*
- IAEA Training Course for Lawyers (E,F,A)*

Patient Protection

- IAEA Training Course on Radiation Protection in Diagnostic and Interventional Radiology (E,A)*
- IAEA Training Course on Radiation Protection in Nuclear Medicine
- IAEA Training Material on Radiation Protection in Radiotherapy
- IAEA Training Material on Radiation Protection in Cardiology
- IAEA Training Material on Prevention of Accidental Exposures in Radiotherapy.

Source Safety & Security

- IAEA Training Course on Radiation Protection and Safety in Industrial Radiography
- IAEA Training Course on Radiation Protection and Safety at Industrial Irradiation Facilities
- Concepts of Radiation Protection and the Safety of Sources

Occupational Radiation Protection

- IAEA Training Course on Assessment of Occupational Exposure due to Intakes of Radionuclides (E,S)*
- IAEA Training Course on Assessment of Occupational Exposure due to External Radiation Sources (E,R)*
- IAEA Training Course on Occupational Radiation Protection
- Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry
- IAEA Training Course on Neutron Dosimetry
- IAEA Training Course on Workplace Monitoring

Quality Management

- Quality Management Systems for Technical Services in Radiation Safety

Waste Management

- IAEA Training Material on Safety Assessment of Near Surface Low and Intermediate Level Radioactive Waste Disposal Facilities
- IAEA Training on Safety of Radioactive Waste Management
- IAEA Training on Management of Mining and Milling Waste
- IAEA Training on Management of NORM Residues
- IAEA Training Material on Remediation of Contaminated Sites
- IAEA Training Material on Decommissioning of Nuclear Facilities

Transport Safety

- IAEA Publication – Safe Transport of Radioactive Material – Third Edition - Training Course Series 1-2002 (some training courses in Spanish)*
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PGEC

Part I to XI (E, A, F, S, R)
Instructions to Practical lessons

Distance Learning

23 lessons in 4 Modules (E, A, S, R)*

Elearning

The distance learning modules in web format

*** All the training materials are available in English. Few are translated to other official languages as indicated in the paranthesis. E –English, A-Arabic, S-Spanish, F-French, R-Russian**

IAEA PUBLICATIONS IN THIS AREA

[1] *Safety Standards Series RS-G-1.4, Building Competence in Radiation Protection and the Safe Use of Radiation Sources, IAEA, Vienna, 2001.* This Safety Guide provides guidance for the regulatory bodies for the establishment of training and qualification requirements and a strategy for building competence. The Safety Guide is jointly sponsored by WHO, PAHO and ILO;

[2] *Safety Report Series No.20, Training Courses on Radiation Protection and Safe Use of Radiation Sources, Vienna 2001.* This report provides assistance to trainers and training providers on how to set up training courses, distance learning and on the job training as well as to establish training centres. It addresses the development and provision of training in protection and safety in a range of activities involving work with ionizing radiation. It supersedes the IAEA Technical Reports Series No. 280 on Training Courses on Radiation Protection that was published in 1988.

[3] Training Course Series 18, Standard Syllabus for the Postgraduate Educational Course in Radiation Protection and the Safe Use of Radiation Sources, IAEA, Vienna 2001 is intended to facilitate the implementation of such courses by Universities and training centres. The course is aimed at professionals in the early stage of their careers. The structure of the syllabus follows the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. This syllabus supersedes the one published in 1995.

SUBJECTS AND COURSES RELATED TO RADIATION PROTECTION IN HUNGARIAN UNIVERSITIES

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ABSTRACT

In the present Hungarian academic system 11 universities provide courses where nuclear science and/or applications of ionising radiations are read. To some extent all of them include radiation protection, but forms, synopses and subject titles show great variety. Main types of undergraduate and graduate university courses where radiation protection is taught: engineering (chemical, mechanical, environmental), medical, natural sciences (physical, chemical, geological etc.), military, agriculture and forestry. There is no direct “nuclear engineering” education in Hungary, only “nuclear techniques” can be chosen as major subject group.
Topics of some subjects read in the engineering physicist courses of BME are discussed in details, as well as some aspects concerning the transformation of a single-level academic system to a multi-level one and the contradictory effects of budget deficiencies. RPE and RPO training required by European guidance also have a close connection to university education.

1. Introduction

Radiation protection is a typical interdisciplinary science. It is basically related to nuclear physics, human biology, physical- and radiochemistry, but has some “contact points” with military, social and economical sciences as well. It is of course, however, that if a national higher education system contains a separate university faculty for either “nuclear science” or – more frequently – “nuclear engineering” several subjects covering the topics of health physics, or with a somewhat more practical nomination, radiation protection are offered as parts of the major course. This is not the case in Hungary. Generally speaking, radiation protection is taught at universities where ionising radiation is applied and thus its health effects should be explained and accounted for.

2. Pertinent university courses

In the past years the Hungarian higher education system experienced a major change as the country accepted the Bologna Process. Since the signing of the Bologna Declaration in 1999, Europe has gradually been moving toward a two-phase system of separate bachelor’s (BS) and master’s degrees (MS) see for example reference [1]. As an obligatory part of this process, Hungary phases out the traditional “long first degrees” one phase system. In addition to the introduction of the BS – MS structure and its temporary co-existence with the traditional one phase educational scheme, PhD programs and various types of graduate education are also present in the profiles of Hungarian universities. As a logical consequence of these modifications, new courses and "core subjects" are introduced, nevertheless the situation of radiation protection-related subjects do not show fundamental changes.

Generally a subject means a series of lectures and – possibly and in our case desirably – laboratory and/or calculus exercises. A subject normally takes a single academic semester. The value and degree of difficultness of a subject is expressed with a credit number. In keeping with the general practice of two-phase academic scheme subjects are categorised as compulsory and elective ones. The former type is compulsory for all students of a faculty course; the latter belongs to certain specialisations only ("branches" in the Hungarian academic terminology.)

It is high time to define as accurately as possible the topics of radiation protection oriented subjects. Considering at least 50 subjects of 11 different Hungarian universities, this "universal curriculum" is the following:

- I. Dose definitions
- II. Biological effects of ionising radiations
- III. Scientific bases of the regulatory system
- IV. Components and sources of dose exposure
- V. Measurement and calculation of doses
- VI. Protective actions against population, workplace and accident doses

Main types of undergraduate (BS and one phase) and graduate (MS, special post-gradual and PhD) university courses where radiation protection is taught are the following:

- Engineering (chemical, mechanical, environmental) – Type "E" (see Table 1 in Chapter 5 below)
- Medical – Type "Me"
- Science (physical, chemical, geological etc.) – Type "S"
- Military – Type "Mi"
- Others (agriculture, forestry etc.) – Type "O"

Future secondary school physics teachers attend courses of type "S". Detailed descriptions of all these courses are available from the web sites of the appropriate universities; see e.g. [2], [3] and [4].

3. Detailed syllabi of radiation protection subjects of the Faculty of Natural Sciences at the Budapest University of Technology and Economics (BME)

3 out of the 8 faculties of BME offer radiation protection oriented subjects for undergraduates. These faculties and courses are: Faculty of Natural Sciences/course of physics; Faculty of Mechanical Engineering/course of energetic engineering, Faculty of Chemical and Biotechnology/course of environmental engineering. At present BS and one-phase courses are running. The following detailed syllabi belong either to the new BS courses or to the one-phase courses; but the latter will be part of the MS courses the first of which will start in September 2009.

3.1. Radiation Protection I.

This subject is offered in the frame of Physics BS course as a compulsory subject. It includes fundamentals of each topic of the "universal curriculum" given in Chapter 2, including an important introductory part on nuclear physics, especially on the nature of radioactive decay and radiation types, as well as the types of interaction between ionising radiation and matter. It is a minor deficiency of the present curriculum that this new version does not include laboratory exercises; however, calculus is part of the lectures to some extent. Credit value: 2. (The former one-phase subject included laboratory exercises for a joint credit value of 4.)

3.2. Radiation Protection II.

This subject will be offered at the Physics MS course as an elective for students attending the branch of nuclear techniques, at present it is read at the one-phase course. Laboratory exercises accompany the lectures for a total credit value of 4. Topics I to III of the “universal curriculum” are revised; then focus is put on the measurement, calculation and mitigation of external and internal dose exposure (topics IV to VI). Nuclear analytical methods related to the analysis of samples for the calculation of internal exposure are emphasised, details of spectral evaluation are also added. Laboratory exercises: whole body counting, radon and radon EEC measurements, environmental monitoring with on-line aerosol sampling and measurement.

3.3. Radioactive Waste Management

This subject is offered as an elective one for the students of the one-phase courses of Physics. It is distributed into two subjects for the BS – MS scheme. The new versions will have credit values 2 and 3, respectively, the MS course will “inherit” the laboratory exercises (analysis projects for “delicate” waste streams of NPP origin) now belonging to the one-phase course. The BS version is offered to students of Mechanical Engineering as well. Details of topics IV and VI of the “universal curriculum” are presented. The first classes are devoted to classification of wastes; discussing exemption and clearance levels in details as well. Then the origin of waste streams are described and relevant components are introduced: operational and decommissioning wastes of NPP’s, wastes from research facilities, wastes from industrial and medical applications, weapons and – last but not least – TENORM (technologically enhanced naturally occurring radioactive material) wastes are the categories. Finally waste processing technologies are summarised, presenting methods of volume reduction, conditioning procedures and assessing temporary and final disposal. The option of reprocessing spent fuel is compared to disposal; new research areas as transmutation are also included.

3.4. Migration of radiocontamination in the environment

This subject is also offered as an elective one for the students of the one-phase courses of Physics and will be part of the MS scheme. The credit value is and will be 3, covering the lectures and calculus exercises. The migration of radioactive substances in environmental media connects emissions to immissions, dose constraints to dose limits. That is, this subject gives interesting details on topics III to V of the “universal curriculum”. Migration processes are described for homogeneous and heterogeneous media (atmosphere, surface waters, ground water, biological systems) by means of dynamic and static models. Differential and integral equations are presented and discussed in details.

3.5. Question marks

University courses should reflect comprehensive scientific facts based on recent research results. However there are numerous contradictory or still not unambiguous areas and problems in health physics which should be presented and explained in a holistic manner for interested young people introducing “pros” and “cons” and still unconfirmed assumptions as well. Some of these “question marks” are the following:

- Validity of LNT theory, facts confirming or refuting hormesis and supralinearity;
- Individual cell doses, extension of microdosimetry to tissues,
- Applicability of radiation weight factors and relative biological effectiveness for different exposure situations;
- Generation of dose constraints, validation of exposure scenarios;
- Clearance versus exemption;

- Potential dose exposure: how probabilities can be multiplied with doses.

4. RPE/RPO training at Hungarian universities

The standardisation of terminology concerning the special tasks of radiation protection professionals is a current item workshops and conferences. Terms like qualified experts, medical physics experts, radiation protection workers, radiation protection officers and radiation protection experts are regularly defined and re-defined. The training and in-service training of radiation protection workers, experts and officers (the two latter professions are not completely distinguished in Hungary) has a three-level national system: basic, advanced and comprehensive degrees are to be obtained depending on the positions and job type of the experts. The Hungarian RPW/RPE/RPO scheme was presented at the 2007 EUTERP Workshop in Vilnius, see ref. [5]. It is of course that advanced and comprehensive courses can be based on appropriate university subjects, however, practical, legal and regulatory aspects should be emphasised. About half of the universities having radiation protection in their curricula offer RPE/RPO graduate courses for professionals. In addition to them, students who attend a whole series of RP subjects (such as described in Chapter 3.1. – 3.4) are entitled to sit for an appropriate RPE examination as an integral part of their graduation. About 20 % of new RPE/RPO degrees are obtained this way. Data are summarised in Table 1 in the next Chapter.

5. Summary

The various types of pertinent university courses and subjects are summarised in Table 1 below. Figures in the table cells mean students per year for the appropriate courses and programmes. Separate columns indicate the frame figure of BS and traditional “one-phase” students attending RP subject courses, diploma theses in RP per year, PhD school applicants for RP programs and the presence or absence of separate RPE/RPO training at the appropriate university.

University	Type	Students of RP subjects	RPE/RPO courses	Diploma thesis in RP	RP PhD programs
BME Budapest	E	50-80	Yes	1-3	1-2
DE Debrecen	S	10-20	No	2-5	1-2
ELTE Budapest	S	10-15	Yes	2-4	-
SE Budapest	Me	70-80	Yes	2-5	1-2
SZTE Szeged	S, Me	5-10	Yes	1-2	-
PE Veszprém	E	15-20	Yes	5-7	1-2
ZMNE Budapest	Mi	15-20	Yes	4-6	1-2
SZIE Gödöllő	O	25-30	No	1-2	-
PTE Pécs	S, Me	15-20	No	1-2	-
KE Kaposvár	Me	10-15	No	1-2	-
NYME Sopron	O	15-20	No	2-4	-

References

[1] World Education News and Reviews (WENR) volume 17 (2004) Issue 1. http://www.wes.org/ewenr/04jan/Feature.htm

[2] ELTE Budapest: http://www.elte.hu/egyetemrol

[3] SE Budapest: http://dataweb-systems.hu/usnen/index.php

[4] DE Debrecen: http://www.cic.klte.hu/ttk50/fiztcs.htm

[5] Pellet, S. et al. “Radiation Protection Training in Hungary since 1988” at “First EUTERP Platform Workshop Definitions, Qualifications and Requirements for Radiation Protection Experts, Radiation Protection Officers and Radiation Workers Vilnius, 2007.

Transdisciplinary aspects of education and training in radiological risk governance.

- Integrating ethics for a new expert culture -

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Summary

This text argues for a transdisciplinary and inclusive approach to education and training in radiological risk governance. The focus on the 'governance' approach implies that the area of application is taken broader than occupational radiological protection. Therefore the text addresses as well radiological protection officers and experts as nuclear engineers and policy makers.

Starting from four cases to 'set the scene', we first reflect briefly on what it would mean for a nuclear engineer, a radiological protection expert or any other person with a certain responsibility in radiological risk governance to 'do the right thing' in cases where ethics come into play. A substantial volume of contemporary literature has been written on ethics and risk, not only from out of academic moral philosophy programmes, but also in research and policy related to radiological protection. Until today however, none of these reflections and recommendations have led to considerations among nuclear policy makers from research and industry on the need to adapt nuclear training and education programmes accordingly.

Our aim is to seek connection between theory and practice of making moral judgements in face of uncertainty and complexity on the one hand and expert culture and the supporting ways of – interactively - generating insight into these uncertainties and complexities through research and education and training on the other hand. Instead of putting 'what is right and wrong' when it comes to making decisions in complex ethical cases, we make an argument for the need to foster 'reflexivity' as a central attitude in 'expert culture' for anyone with a specific responsibility or interest in the case. In the last paragraphs, we argue that the methodological characteristics of reflexivity can be extrapolated as methodological characteristics of expert culture, research and related education and training, and that they emerge as two central principles for 'good risk governance': transdisciplinarity and inclusiveness of 'stakeholders'. The text then concludes with some examples of courses in ethics and radiological risk governance, as organised by the Belgian Nuclear Research Centre SCK•CEN.

Structure

1. What could be happening in the world while you are reading this.
2 'Doing the right thing': on justification in face of uncertainty and complexity.
3 Ethics and expert culture: moral judgement through interaction.
4 Ethics and radiological risk governance: the importance of joint justification.
5 Reflexivity as a central attitude in expert culture.
6 'E&T^{plus}': transdisciplinarity and inclusiveness as 'tools' to foster reflexivity.
7 SCK•CEN's courses on ethical aspects of radiological risk governance.

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1. What could be happening in the world while you are reading this.

(1) A worker needs to execute a special task in the controlled area of a nuclear power plant. The group that is ‘on shift’ consists of two workers, of which one of them is female. The female worker says to her colleague: ‘You go into the area to do that work. I want to minimise my risk, as I plan to become pregnant in the near future’.

(2) The medical sector makes use of volunteers to test medicines and pays them as a compensation for potential side effects and risks. Although candidates have to undergo health tests and psychological tests, it is observed that mainly poorer people present themselves as candidates.

(3) A national radioactive waste agency looks for a candidate municipality to host a RW disposal site. It insists that the siting decision has to be taken democratic, and with the involvement of all stakeholders. Together with the local citizens of two volunteering municipalities, the agency designs a package of socio-economic compensation and a system for the future involvement process and the long-term management of the compensation fund. As the process develops, one can observe that it gets more and more the character of a competition to get the disposal site.

(4) A nuclear expert is inquired about the aspects of radioactive waste production of the 4th Generation nuclear power plant technology during a hearing in a parliamentary commission. The expert claims that this future technology will be more 'sustainable', as the waste volumes will be reduced due to optimised use of uranium resources and especially because the decay time can be brought back to a few hundred years with the use of transmutation.

Apparently, apart from the observation that the four cases all deal with 'risky situations' in one or another way, at first sight, they seem to have nothing extra in common. There are three nuclear cases and one non-nuclear. The first case is connected to occupational radiological protection while the others relate to a broader notion of 'risk governance'. Moreover, the involved people 'act' from out of different interests and responsibilities, in different roles and situations, while the time frames at stake vary from 'now' to 'the far future'.

What the cases do have in common on a more conceptual level is the fact that all involved people deal with situations that are characterised by uncertainties and complexities that complicate the assessment of the 'risk' involved. These uncertainties and complexities emerge with the question (1) on what basis the involved people would be able to 'justify' their 'act' and its consequences as a kind of accountability towards others, and with the question (2) to what extent a reflection on this first question would help them in judging whether they are 'doing the right thing'.

2 'Doing the right thing': on justification in face of uncertainty and complexity.

The above presented cases are just four realistic examples (that is: existing in reality) of situations where ‘responsible acting’ is needed

- for which there exists no factual logic or procedures ‘in the books’;
- that you cannot train in class or in the laboratory;
- for which you cannot always rely on similar (comparable) cases from the past.

In other words, the cases show situations in which responsible acting is needed 'in face of uncertainty and complexity' in the presence of a certain risk. What becomes clear anyway is that, in these cases, 'responsible acting' is apparently more than 'correctly executing procedures and tasks connected to the job' with the aim of 'managing' the risk, and that one can essentially not rely on acquired natural sciences and technology insights and expertise for this. This 'more' could be described as making use of a 'moral stance', or the ability to make a 'moral judgement', and the four cases hopefully illustrate that this moral stance even goes beyond the eventually existing ethical code connected to the job (the 'mandate') to trigger personal morality.

In this, one should also take into account the possibility that not all involved people are aware of the envisaged risk, or of the own or others' responsibility. Not only in less complex situations of our daily life, but also in the above sketched cases, people tend to 'justify' their acts based on widely held common-sense beliefs and thus on conscious or unconscious judgements that do not take full account of all relevant knowledge, norms, values and different views and value judgements. One could immediately state that it is not always (or even never?) possible to do this 'holistic' justification exercise 'before acting'. In real life, we all tend to do something that can be called 'narrow framing of justification'. This narrow framing can be based on several factors, such as fear, urge, interest or belief, but also on 'accountability' with regard to the own mandate. The woman in the first case apparently misinterprets the occupational radiological protection specifications related to pregnant women from out of a urge for protection of her future child. The poorer medicine test volunteer may oppress the fear for detrimental side effects due to an urgent need for money, while the new medicine project manager, in need for test persons, tries to take this situation of 'injustice' ('poor people to test medicines for the rich') into account as much as possible by eventually protecting volunteers 'against themselves'. The waste agency mandatory may act through a top-down 'means-ends' approach from out of his/her government mandate 'to find a solution for the waste', while local municipalities, eager to receive the compensation, may end up in a competition to get the site. The nuclear expert founds his thesis on scientific insights into phenomena of radioactive decay and transmutation and translates his reasoning into a 'vision' that is (al but not consciously) also supported by his belief in science and technology, while the politician may trust or distrust the expert and thus accept or reject the argument according to how it would fit into his/her political programme.

3 Ethics and expert culture: moral judgement through interaction.

A more elaborated analysis of the four presented cases is beyond the scope of this text. Rather, based on this 'problem setting' and in the context of this text, we want to reflect briefly on what it would mean for a nuclear engineer or policy maker, a radiological protection officer or any other person with a certain responsibility in radiological risk governance to 'do the right thing'. Both the nuclear scientist and the moral philosopher would agree that rationalist and logic reasoning based on either 'pure' natural sciences or one 'pure philosophy' would not deliver a satisfying answer to this question, at least not an answer that would univocally generate consensus among all involved people. Both could agree however that the best way would be to explore 'cross-over' thinking, based on elements brought in from various sides; that is: not only experts' nuclear or moral-philosophical knowledge, but also practical, normative, cultural and historical knowledge. The biggest challenge here would not be to extract a solution (a 'product') out of this spectrum of knowledges, but the act of jointly identifying what knowledge (explanatory, normative, …) is relevant and how it can be used in the judgement.

A substantial volume of contemporary literature has been written on ethics and risk, not only from out of academic moral philosophy programmes, but also in research and policy related to radiological protection. Until today however, none of these reflections and recommendations have led to general considerations among nuclear policy makers from research and industry on the need to adapt nuclear education and training programmes accordingly.

If it would appear to be impossible to inscribe guidance for every realistic 'complex' situation where responsible acting in face of the radiological risk is needed into transparent and unambiguous procedures (and the above sketched cases could be seen as proof for this), then it would turn out that 'expert judgement' necessarily will need to incorporate the use of additional 'moral judgement' that could deal with this uncertainty and complexity[3].

What this specific expert moral judgement is about, what the (practical) implications are for traditional science & technology research and related policy and communication is the subject of ethics and expert culture research. Ethics and expert culture research relies on interactive reflection between human scientists and nuclear and radiological protection experts and practitioners. Research on expert culture focuses specifically on the decision support context of expert functioning, including the expert's work methods, constraints, used underlying hypotheses, limitations of current knowledge (or of knowledge as such) and dynamics of interactions with other experts, policy makers and civil society.

What this kind of research proves in the first place is that 'classical expertise' is relative, not in the way that provided expertise would be true or false depending on the context, but rather in terms of its limitations to generate insight and advice if not taking into account all scientific, social and normative aspects. In addition, Paragraph 6 on transdisciplinarity will state that this generation of insight is more than adding up 'complementary expertise'.

For now, we would like to state that, given the focus on the interactive character of the research, the distinction between 'research' on the one hand and education and training on the other hand becomes vague and irrelevant in the context of ethics and expert culture. Rather than the traditional uni-directional teaching or 'advisory' approach, the interaction 'beyond disciplines' and beyond areas and levels of expertise becomes the essential learning experience and way of generating knowledge and insight. In this approach, the notions of reflexivity, transdisciplinarity and inclusiveness become essential (see paragraphs 5 and 6). The central idea of expert culture in connection to the introduced 'additional moral judgement' for now is that this judgement should not be understood as the experts sole and definite recommendation, advice or view on the case, but that it is essentially generated *through interaction*.

4 Ethics and radiological risk governance: the importance of joint justification.

Referring back to the previous paragraph, the question remains then how 'moral judgements' could help in these cases, and how they could be 'instrumentalised' in expertise in risk governance. Classical moral philosophy deals with the inquiry of the potentialities and impotentialities connected to these kinds of justification exercises, and tells us that, in order to make good decisions, it is not enough to simply know what 'rules' (or procedures) we should follow. We have to know how to adapt those rules to our circumstances, and to do that effectively we must know why specific moral norms are justified, and what the boundary conditions are to using them in combination with factual (scientific) knowledge. This is a philosophical question, but with practical (and sometimes far-reaching) consequences. Anyway, in the frame of this text and referring back to the presented cases, one could ask whether there exists a 'special morality' (behaviour, value set, normative framework, code of conduct, justification method) typical for radiological risk governance that would (need to)

[3] A short introduction of what this uncertainty and complexity can mean in the context of radiological risk governance was given in the related article 'A transdisciplinary approach to education and training in radiological protection and nuclear engineering', Michèle Coeck, Gaston Meskens, Gilbert Eggermont , SCK•CEN, European ALARA Network Workshop 2006 Prague, Czech Republic, September 2006

come on top of our personal morality and the common-sense moral ideas that make up a good society (such as equity, freedom of speech and helping those in need)? Or maybe there exists a specific radiological risk governance morality that would even affect our personal morality and those common-sense moral ideas?

Everyone familiar with radiological risk assessment knows about the special character of the radiological risk at low doses. Insight into the stochastic character of the cause-effect relation at low doses led to the nowadays broadly accepted regulation based on the linear non-threshold hypothesis and the basic principles of radiological protection (justification – limitation – optimisation). This regulation obviously does not exclude a possible effect, but it enables the organisation of a 'reasonable' occupational safety culture for both industrial and medical workers. The bigger problem comes of course when risk assessment has to take into account complex 'unpredictable' pathways of radioactivity in space and time on the one hand, and unforeseen events 'from outside' that would increase the risk and/or make it less controllable. Running ahead of the further elaboration, we state that here morality comes in. It will appear that there is no 'special' morality specifically connected to the radiological risk, but that rather one of those common-sense moral ideas that 'make up a good society' will come into the picture.

In the context of occupational risk management, the issues of unpredictable pathways and unforeseen events 'on the work floor' are principally inscribed into the regulation. That is: of course safety regulations and safety culture should ensure everything reasonably possible (1) to minimise the radiological risk 'in daily routine practice' and (2) to avoid events (incidents and accidents) that would enhance the risk. However, in occupational context, the radiological risk 'as such' is *justified*. Every technician or manager working in or around controlled nuclear areas is (or should be) aware of the risk, and accepts it as such, together with (or thanks to) a guarantee of an organised safety culture of 'protection' that aims at optimising doses and takes into account fixed and rigid dose limits. This is why the basic principles of occupational radiological protection start with the principle of justification: first, the risk is *jointly* justified, and then the management to minimise and optimise can start.

If we would apply these basic principles of radiological protection to the context of risk management of the ecosystem and the so-called 'general public', the picture becomes different. There the full complexity of risk assessment and subsequent governance emerges by way of those complex 'unpredictable' pathways of radioactivity in space and time, and those unforeseen events 'from outside' that would increase the risk and/or make it less controllable. The disintegration of a waste disposal site in the future, and the consequent migration of radioisotopes and possible uptake in the food chain is a typical example of the first problem, while human error causing a nuclear accident or unintended human intrusion in a waste disposal site are typical examples of the second problem.

There is no highbrow historical analysis needed to understand that joint justification processes with civil society supporting the existence of (peaceful) nuclear activity have never happened in the past, and that the evidence of involving civil society in the siting of radioactive waste repositories has only been acknowledged recently by industry and authorities. One can of course immediately add that this is not a typical nuclear problem, as it also appears in the context of other risk-inherent technological applications such as genetic manipulation, nanotechnology or fossil fuels. Indeed, it is generally said that these phenomena are typical symptoms of the 'technocratic approach' originating from late-modern industrial and technological optimism, and that any 'reform' of these approaches for the better of society would need to touch upon the deep roots of how our modern democratic societies work. However complex the question might be, this can – speaking in moral terms - of course not be used to evade it.

As a kind of conclusion to this reasoning, we could state that good risk governance starts with joint justification involving all possibly affected people. In the case of occupational risk governance, this condition is principally taken up in the basic safety regulations. In the case of risk governance towards society and the ecosystem, it is not.

This text relates to education and training, and is not aiming to make suggestions to reform existing regulations and political decision making systems to include joint justification as an essential part of 'good risk governance' (although this kind of suggestions indeed deserve attention more than ever). Our aim is to seek connection between theory and practice of making moral judgements in face of uncertainty and complexity on the one hand and expert culture and the supporting ways of generating insight into these uncertainties and complexities through research, education and training on the other hand. In this respect, morality in connection to risk governance has thus to do with the willingness to create conditions for joint risk justification, and the willingness to critically inquire all factual-scientific and normative aspects that come into play in this justification exercise. Acceptance of this argument would immediately lead to an understanding of its implications in terms of responsibility of each actor or 'moral agent' (being it the nuclear expert, the politician or the civil society representative) related to the way we look at issues and to the way we are able to deal with - or even transcend – our so-called 'narrow framing'.

5 Reflexivity as a central attitude in expert culture.

Paragraph 3 and 4 give us now the necessary elements to describe the 'moral stance' we talked about in paragraph 2. While this stance was still explicated there as synonym to 'the ability to make a moral judgement', recalling paragraph 3, we would rather describe it now as 'the ability to *contribute to* making a moral judgement'. The combination of the willingness to recognise 'other expertise' (experts or laypersons knowledge) in the interest of making moral judgements through interaction (paragraph 3) and the willingness to create conditions for joint risk justification or justification of a 'risky practice' (paragraph 4) automatically implies a critical stance towards the own knowledge or expertise. The moral stance appears thus to be one of 'attitude of openness or intention' in combination with a critical attitude towards 'the own expertise'. This stance can also be described as 'reflexivity', or as the attitude of being sensitive to the conditions in which (own and others) knowledge is produced and can be used.

We don't want to fall into our own trap here by making an attempt to 'define' what 'reflexivity' is. The concept of reflexivity originates from social theory and the very short meaning in that context could be boiled down to the attitude of 'agreement' that theories in a discipline should apply equally forcefully to the discipline itself. Obviously, the concept has direct relevance for theories of knowledge, including the way knowledge is produced and can be used in 'real cases', and the implications for the way knowledge producers and disseminators (experts, scientists, stakeholders) can act in these real cases.

Instead of going deeper into these philosophical reflections, we prefer to present some 'characteristics' of reflexivity that could serve as basis for reflection and discussion.

inside (starting with the ‘self’)
→ awareness of own knowledge
→ recognise incompleteness and relativity of own knowledge
→ recognise own ‘sense for justice’
→ awareness of - and insight in - own values
→ value own reputation with regard to ‘credibility’

outside	(looking towards the situation, the others / in context / in perspective)
	(curiosity / ‘the beginner’s mind’)
→	awareness of (other’s) knowledge
→	recognise incompleteness and relativity of knowledge as such
→	awareness of - and insight in - values / context / perspective
→	recognise others ‘sense for justice’
→	value others reputation with regard to ‘credibility’

We propose that these methodological characteristics of reflexivity could then as well be extrapolated as methodological characteristics of expert culture, research and related education and training. They emerge as two central principles for 'good risk governance' and the related research and education and training: transdisciplinarity and inclusiveness of 'stakeholders'. To conclude this article, we will sketch how these principles could be inscribed in an 'E&T^{plus}' for the case of radiological risk governance (paragraph 6) and give an example on how this could be put in practice in education and training programmes (paragraph 7).

6 'E&T^{plus}': transdisciplinarity and inclusiveness as 'tools' to foster reflexivity.

It is true that a young engineer, in order to become an expert in stress corrosion cracking of NPP vessel steel, does not need to be able to make value judgements on the national energy policy of his/her country, or on how to involve civil society in RW disposal siting. But regardless of the specific content of the nuclear job, the question of whether he/she has a responsibility to reflect upon aspects of risk and societal justification of 'his/her' technology is more difficult to answer. Instead of going into deeper discussion on societal accountability of (nuclear) scientists and engineers, we would like to focus on the importance of the balance between 'specialist' and 'generalist' – or rather 'transversalist' – education in this respect.

We state that, in this context, to learn to develop and use skills 'to think out of the box' is not the young engineers duty, but his/her *right*. Given the fact that nuclear technological applications are in the centre of the recent societal debates related to technology, sustainable energy policy, globalisation and environmental challenges (such as the climate change debate), any existing portfolio of courses on nuclear technology would be incomplete without an additional introduction on ethics and risk governance, philosophy of technology and on aspects of sustainable development in relation to economy and ecology. A student or young professional in nuclear engineering or radiological protection should have the chance to enrich his/her education and training with insights into political, economical and social dynamics around nuclear technology applications and the chance to learn to develop and test own critical opinion on all dynamics in front yet behind the scenes.

Just as for the four cases of the introduction, there are no procedures or norms to learn, develop and acquire 'proper' ethical or moral skills. Making reference to the previous paragraphs, we could state that education and training programmes on ethics and risk governance, similar to the above sketched cross-over research, have a character of transdisciplinarity and inclusiveness.

It is only since the last decade that nuclear technology assessment studies and related critical reflection on societal aspects have been taken up also 'within' the nuclear community instead of only in the academies philosophy departments. Thanks to the recognition of the intrinsic social dimensions of the complexity of ‘impacts of technology on society’, well-known disciplines such as ‘technology assessment’ and ‘risk assessment’ gradually start to move away from a pure ‘rationalist’ exact sciences - approach to a more transdisciplinary approach by way of including other disciplines such as philosophy and sociology. Transdisciplinarity can be seen as a principle 'for a unity of knowledge beyond disciplines'. In this respect, it could be understood as a principle of integrative forms of research, comprising a family of methods for relating scientific knowledge and extra-scientific experience and practice in problem-solving. In this understanding, transdisciplinary research addresses issues of the real world, not issues of origin and relevance only in scientific debate. This connection to the real world is of course crucial in the envisaged E&T programmes.

Through transdisciplinary learning, young professionals should f.i. become able to

- use factual knowledge from natural sciences and technology in critical analysis;
- interpret and learn from historical lessons;
- recognise, state and accept uncertainties instead of trying to exclude them;
- better understand social mechanisms, also in the working environment;
- broaden the risk scope to ‘multifactorial concerns’ in complex (hazardous) situations;
- recognise the relativity of expert knowledge.

In this sense, transdisciplinarity can be seen as an attitude of 'standing in the middle of reality' (professional, social) while seeing this reality as the learning environment. It requires an interactive practice of problem solving oriented thinking and acting across disciplines, taking into account that own (disciplinary) knowledge is always relative. In extension, transdisciplinarity also incorporates so-called ‘indigenous knowledge’ (knowledge brought into the group by ‘non experts’ or (local) stakeholders). Discussing ethical cases should thus be done with everybody involved, or thus 'inclusive', in these cases, whether in occupational circumstances (workers, nuclear policy makers, radiological protection officers, patients, …) or in the broader social context (engagement of civil society).

7 SCK•CEN's courses on ethical aspects of radiological risk governance.

The Belgian nuclear research centre has build up a thorough experience with education and training in radiological protection for the industry, the medical sector and for interest groups of civil society. Since five years, the research centre is also offering courses on ethical aspects of radiological risk governance for the broad audience of industry, the medical sector, the academic sector and policy makers. The course is a joint initiative of the International School for Radiological Protection (isRP) and the PISA group (Programme of Integration of Social Aspects into nuclear research).

The course is lectured in three different formats depending on the target audience (see below), but the basic structure and lecturing approach is essentially the same. During the first part, course participants are taken on an introductory journey through basic risk governance and philosophy of ethics (see table, part 1). During this theoretical part, the group is already invited to comment on presented philosophical ideas (deontologism, utilitarianism, anthropocentric world views, …) and ethical considerations in relation to practical cases (such as smoking, use of radioactivity in consumer products, climate change, biodiversity…)

Course on ethical aspects of radiological risk governance

Part 1 – theoretical introduction to ethics and risk governance

1 On risk, transparency and free choice
2 Justification in face of complexity
3 Basic philosophy of ethics
3 Basic philosophy of ethics
4 Dealing with uncertainty and ambiguity in the ‘real world’
5 Ethics and technology
6 Reflections with regard to the application of the principles of radiological protection
7 Some ethical considerations

In the second part, course participants gather in groups. Each group chooses one of a series of presented cases (similar to those of the introduction to this text) and discuss the case on the basis of a set of investigating questions (table, part 2)

Course on ethical aspects of radiological risk governance

Part 2 – group work on case studies - investigating questions

- what are the relevant norms involved ?
- what are the relevant values ?
- what are the aspects of justification ?
- where is the uncertainty ? what are the aspects of complexity ?
  (scientific ? normative ? both ?)
- who is responsible for what ?
- what could be a recommendation (‘solution’) in this case ?

Based on the above described structure, the course programme is currently lectured in three formats:

Format 1 – 1,5 hours – lecture with plenary group discussion
Introduction to ethics and radiological protection for technical staff and radiological protection officers.

Since a few years; the standard course on radiological protection for technical staff of the industry contains an introduction to ethics and radiological risk governance. The theoretical introduction is kept concise and to the point, and the cases are oriented to realistic situations on the work floor.

Format 2 – 4 hours – lectures with discussions in groups
Extended course on ethical aspects of radiological risk governance

This course is part of the curriculum of the postgraduate programme Radiological Protection Expert organised by the XIOS Technical University (Diepenbeek, Belgium) and the international school for Radiological Protection (isRP) of the Belgian Nuclear Research Centre SCK•CEN. Course participants come from the wide spectrum of professions (industrial and medical). Therefore, cases cover as well societal policy issues as medical and nuclear-industrial cases.

Format 3 – 3 hours – lecture with discussions in groups
Round table discussion on ethical aspects of radiological and nuclear safety for engineers, as part of the SPERANSA course (an initiative of the CHERNE Network)

The course starts with an introduction to the philosophy of ethics and to the actual discourse on ethics and technology. In a second part, reflections on the applications of the radiological protection principles are made. In a third part, based on a number of key ‘investigating questions’ derived from part one and two, course participants work in small groups to analyse a selection of 'complex problems’ (or ‘ethical cases’ such as those presented in the introduction of this text) that are taken from the real world of applications of radioactivity. In a fourth concluding part, the whole group discusses the reflections made by the different working groups and will make an attempt to draw some ‘guidelines’ that could assist practical complex problem solving with regard to radiation safety.

Suggestions for further reading

A transdisciplinary approach to education and training in radiological protection and nuclear engineering. Michèle Coeck , Gaston Meskens , Gilbert Eggermont , SCK•CEN
European ALARA Network Workshop 2006 Prague, Czech Republic, September 2006

Ethics and Radiological Protection, Gilbert Eggermont and Bernard Feltz (eds)
Bruylant Academia, 2008, ISBN 978-2-87209-894-1

SCK•CEN – PISA projects on Risk Governance
http://www.sckcen.be/pisa

Network for transdisciplinarity in sciences and humanities
http://www.transdisciplinarity.ch/

Poster Session

PERSONNEL MANAGEMENT POLICY OF EDO «GIDROPRESS» TO RETAIN AND TRANSFER NUCLEAR KNOWLEDGE

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ABSTRACT

Experimental and design organization EDO «GIDROPRESS» was set up in 1946 to participate in developing nuclear engineering. The work team gained its position among the leading organizations in the world in creating new technologies of nuclear energy. In the early 90-ies as a result of socio-economic problems in the Russian Federation a lot of efficient specialists left their work in nuclear industry for other activities that were far from NPP designing. It was the most urgent task of EDO «GIDROPRESS» save the nuclear knowledge and to recruit a new generation of engineers. Thanks to the consistent policy in personnel management the situation changed for the better and the staff vacancies were filled up with skilled specialists. Today EDO «GIDROPRESS» has a structured system of nuclear knowledge retention and its transfer to university graduates. The given paper covers the work with promising young people, which is one of the most important elements of the system.

1. Introduction

EDO «GIDROPRESS» was set up on January 28, 1946 and has been developing the designs for equipment and systems for nuclear industry since then. Today EDO «GIDROPRESS» performs a lot of design, computational, engineering, industrial, research and development work in creating reactors and is a leading enterprise in the nuclear power industry of the Russian Federation. Thanks to successful operation of the designed equipment the organization enjoys recognition and respect both in Russia and abroad.

In working on the problem of qualified personnel recruitment, nuclear knowledge retention and transfer, the personnel management service of EDO «GIDROPRESS» is guided by the principle: Correct policy of personnel management is a key to successful operation of the enterprise. The challenges of the policy of personnel management at EDO «GIDROPRESS» are:

- personnel recruitment;
- creation of favorable conditions for an early adaptation of graduates at the enterprise;
- support of highly qualified specialists;
- nuclear knowledge transfer to the new generation of specialists in the industry;
- advanced training of the specialists.

The experience in personnel management at EDO «GIDROPRESS» made it possible to develop and improve the system of personnel recruitment, improvement of employees' qualification, retention and transfer of the nuclear knowledge the enterprise had gained for many years. The basic elements of the system are as follows:

- communication with technical schools and universities;
- annual internship of graduates;
- annual conference for specialists below 33 years of age;

- visits of graduates to NPPs;
- improvement of qualification for all employees by continuous training course in the organization and at specialized Russian and international training centers;
- creation of favorable conditions for scientific activities;
- generalization of experience gained at EDO «GIDROPRESS», related to the process and history of VVER reactor development by issuing special leaflets, books and guides.

The present paper briefly covers the activities in one of the key elements of the above system, namely, a choice of promising students for their subsequent employment at EDO «GIDROPRESS» and transfer of nuclear knowledge to young engineers.

2. Work with high schools

EDO «GIDROPRESS» is situated in the town of Podolsk, Moscow region. Podolsk is one of the largest industrial centers of the region. The population of Podolsk is 179,5 thousand people. Most employees who work for the enterprise are local residents and therefore one of the main tasks of the service is to make an assessment of amount of qualified personnel to be recruited in the future and orientation of high school students to get a higher education in appropriate engineering sciences in the best national engineering universities. For this purpose once every year the enterprise opens its doors to welcome the best students of the town. A questionnaire is circulated while the students are at the enterprise to learn how they do at school, what their hobbies are and what universities they plan to enter after they leave school.

The students visit the design departments and familiarize themselves with experimental and research facilities of the enterprise. The top management and the leading specialists of EDO «GIDROPRESS» inform them of the challenges and prospects of the enterprise and the nuclear engineering industry, as a whole and of the role of a young engineer in the up-to-date society. Usually after the action the students decide to devote their life to nuclear power industry and work for EDO «GIDROPRESS». The data from the questionnaires are processed and saved in the personnel management service database for subsequent work.

Thanks to constructive dialogue and continuous keeping in touch with the teachers the personnel management service of EDO «GIDROPRESS» every year gets information on the school leavers Podolsk who enter universities. The information is the source for creating the database on the students who study at universities that train engineers for nuclear power industry. The database is periodically updated. 23 students entered universities to get a profession needed at the enterprise in 2007. Today the database has entries on more than 200 students of different grades who are local residents.

3. Work with universities

Most employees of EDO «GIDROPRESS» have graduated from Moscow Institute of Physical Engineers, Moscow Power Engineering Institute and Bauman Moscow State Technical University. A number of departments at these universities have been traditionally training specialists for nuclear power industry.

Today the enterprise is in need of young specialists with up-to-date knowledge. Along with the work with the students who are in the database of the enterprise the top managers of the personnel management service of EDO «GIDROPRESS» and the top management of design and calculational departments work at the Vacancy Fairs in the universities. We give the students information on the domestic and international projects EDO «GIDROPRESS» participates in, inform them on the conditions of work, salary and carrier prospects for young specialists, social guarantees and invite them for cooperation.

It is worth mentioning that in their first years at the university diligent students can work at the enterprise during their summer holidays. Senior-year students have part-time work at the enterprise. They have a supervisor as they write their graduation papers at the enterprise. The graduation paper generally corresponds to the specialization of the division the students work in. The students get a salary and enjoy the medical care at the polyclinics of the enterprise free of charge. They are granted medical insurance certificate and they enjoy the company social activities and make tours of the Russian Federation arranged by the trade union of EDO «GIDROPRESS». Thus, good working conditions as wellas salary and professional and carrier prospects attract the graduates of the universities and confirm them in their wish to work for EDO «GIDROPRESS» after they get a higher education.

4. Internship of graduates

Every year university graduates come to work for EDO «GIDROPRESS». The administration of the enterprise do their best to let the young specialists become efficient in their scientific and technical activities, master their knowledge and gain new knowledge of patents and specific technical information and within a short period of time become a highly skilled engineer. For this purpose a system for internship of the graduates was established many years ago and «Positions on the work with young specialists at EDO «GIDROPRESS» were updated in 2003. The positions establish the procedure of internship for young specialists who have just graduated from universities and define the work of the department manager with the graduate during work for the first year at the enterprise.

The purpose of the internship of the young specialists is their training to expand the range of interests and learn the processes of design work. During the internship the efficiency and skills of the young engineers are determined to use their knowledge the best possible way at the enterprise. They acquire the needed practical and organizational skills to perform their duties and learn their job responsibilities, specific features of their work and gain specific knowledge.

During the first year of his work internship program is compiled for a young engineer and he has a coach who is a highly qualified specialist of the division. The main task of the coach for the graduate is to transfer the knowledge and experience gained by the former during his work for EDO «GIDROPRESS». The young specialist is supposed to get acquainted with the organizational structure of the enterprise, regulatory documents that are in force at the enterprise and are used there, get ready for the exams in national and international NPP safety standards.

The young engineers go to an operating nuclear power plant. V.P.Denisov, chief specialist in NPPs and the oldest employee of the enterprise has written a leaflet «The activities at EDO «GIDROPRESS» in the field of using the nuclear power for 60 years». It gives a detailed description of the principles of NPP operation, the physical fundamentals of the chain reaction, the design of VVER reactor and the history of nuclear power industry and of the enterprise.

As soon as the internship is over, the young specialist and his coach make a report for a board of specialists to sum up the results of the internship. The managers and leading specialists are the members of the board. By the results of the interview the board draws the Protocol with an assessment of the results of the internship and gives the recommendations for the further work of the young specialist. As a rule, following the successful internship the young specialist is given a promotion by certification commission.

5. Advancing the professional level of young engineers

Annual training course is realized in EDO «GIDROPRESS» divisions, its purpose being elevation of professionalism and qualification of the employees. The curriculum of the course and the subjects are approved by the heads of divisions and the most qualified and experienced specialists of the enterprise present the lectures.. Besides, Rosatom has centers for advanced training of specialists in nuclear industry. The specialists of the enterprise take part in seminars and training courses that are performed within the framework of IAEA Department for technical cooperation. Publishing of 12 volumes entitled «Creation of VVER reactors for NPPs» was an important event in the history of the enterprise, that summed up the work of a few generations of specialists at EDO «GIDROPRESS». The books were written both by the specialists who had worked for more than 50 years and young engineers who had started working not long before.

The top management and administration of EDO «GIDROPRESS» encourage the wish of talented engineers, including young engineers to take up post-graduate courses to get a doctor’s degree. On December 11, 2006 EDO «GIDROPRESS» got a license that gives it the right to work in the field of post-graduate education. The council of Doctors of Science was set up to award a degree of a Candidate of Science in engineering that comprises. The post-graduate education envisages training in the following aspects of nuclear engineering:

- «Reactor construction, machines, units and processes for materials in nuclear engineering»;
- «Nuclear power plants, their designing, operation and decommissioning».

Every year 10 people take up the post-graduate course in EDO «GIDROPRESS».

6. Popularization of engineering art

Young engineers from EDO «GIDROPRESS» actively participate in conferences, seminars and meetings at regional, all-Russia and international level. It enhances the engineering art and the attractiveness of the work of a skilled engineer and creates interest in the carrier of an engineer among youngsters.

A Conference of young specialists has been arranged at EDO «GIDROPRESS» since 1999 where young engineers, students and post-graduate students coming from the enterprise and the leading universities of Russia make their presentations. The conference gives them an opportunity to show the creativity and a capability to solve complex and off-standard problems. Winners of the conference are determined by the results of the presentations. Top management and administration of the enterprise gives them prizes and later promotes them. In 2007 three additional promotional prizes were set up to encourage the young engineers. S.L.Lyakishev, a design engineer who was the winner of the Conference was sent to international conference of young engineers in power industry (IYCE 2007), that took place in Budapest in 2007.
It is a tradition to host the «International seminar on horizontal steam generators» and «The Scientific and Technical Conference on Safety Assurance of NPPs with VVER » at EDO «GIDROPRESS». A specific feature of these actions is the integration of generations because they are joint efforts of work teams of experienced specialists and the new generation of engineers.

Since 2003 the specialists of EDO «GIDROPRESS» have actively participated in all-Russian competition «Engineer of the year» that is sponsored by the Russian Union of scientific and engineering organizations. The Competition had a few nominations including the nomination «Nuclear power engineering» and in two versions:

- «Engineering art of the young» - for engineers aged below 30.
- «Honoured engineers» for specialists aged above 30 who have worked as engineers for more than 5 years.

For the period of participation in the competition 2 specialists of EDO «GIDROPRESS» became the laureates in the nomination «Engineering art of the young», 1 engineer was awarded in the nomination «Engineer of the year» among qualified engineers and

4 specialists from EDO «GIDROPRESS» got the diplomas of Honoured engineer in the nomination «Nuclear power engineering».

7. The results of quality management policy of EDO «GIDROPRESS»

It was stated above that the peculiarity of the early 90-ies was a decay in many branches of the Russian national economics. Nuclear power industry was unfortunately incapable to avoid it, too. A lot of educated, efficient and skilled specialists, most of them young and efficient people, left their work in nuclear industry enterprises, including EDO «GIDROPRESS» for other activities that were far from NPP designing and as a result of it ageing of the personnel at the enterprise can be observed. In order not to lose the experience gained by a few generations of nuclear power engineers a reserve was formed from the key experts who possess critical knowledge. The reserve is expanded by young engineers of new generations. Thus, no trends in the activities of EDO «GIDROPRESS» were lost.

As the socio-economic situation in the Russian Federation changed for the better, young engineers began joining the work team of EDO «GIDROPRESS». It became possible thanks to a consistent personnel management policy of the enterprise in personnel selection, adaptation and training to improve the qualification of young specialists and opening up the prospect for their carrier. In 1996 the average age of the employees was 50 years and beginning with 2001 it has been 46 years.

Today EDO «GIDROPRESS» is staffed with qualified personnel and has designs to work on for the future, which permits to offer Russian and international partners projects of advanced reactors and equipment. The designs have accumulated the 60 year experience of design activities, analytical, theoretical and experimental substantiation of design solutions and engineering judgment in developing the equipment for different types of reactors for NPPs. The designs were developed on the basis of up-to-date regulatory documentation of the RF with account for its development and with account for the international requirements and recommendations of the International Atomic Energy Agency (IAEA), European Utility Requirements (EUR) and publications of International Nuclear Safety Advisory Group (INSAG). The latest generation of improved reactors ensures a high and qualitatively new safety level.

8. Conclusions

Nuclear technologies go through the period of active development today. Nuclear power engineering has experienced stagnation not only in Russia but also in a number of the countries in the world. Unfortunately, the knowledge in the field of nuclear power engineering was not much in demand at that time and the problem of nuclear knowledge management is quite acute for further existence and successful development of nuclear engineering. Under the circumstances EDO «GIDROPRESS» works in mastering the up-to-date approaches and methodologies in the field of nuclear knowledge management and retention and to offer the world community their experience in retaining the qualified personnel of the enterprise.
To improve the efficiency of operation EDO «GIDROPRESS» plans to use international experience as well as the guides issued under the auspices of IAEA in issues covering the nuclear knowledge management and participate in educational programmes of IAEA devoted to NKM.

EDO «GIDROPRESS» plans to participate in the work of international conferences, meetings and forums on issues of nuclear knowledge management and retention. The representatives of our organization are ready to take part in technical meetings on the exchange in experience of nuclear knowledge retention, improvement of the skill of the personnel in scientific and design organizations and preparation of appropriate regulatory guides.

THE CURRENT CONDITIONS FOR TRAINING OF NUCLEAR POWER PLANT PERSONNEL IN HUNGARY

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ABSTRACT

The state owned Paks NPP Ltd. as a unit of the Hungarian Power Utilities (MVM) Group since 2005 has recently had to meet challenges such as the strengthening on the liberalized energy markets, the drastic increase of competitiveness and the difficulties of manpower supply appearing due to the 25 years of plant history.

To correct the current situation the MVM Holding and of course Paks NPP Ltd. therewithin intend to make multi-level measures to not only reverse the negative tendencies but to give a boost for necessary development actions.

Despite the general problems with skilled personnel training so typical to the energy industry, the in-site training system together with the required infrastructure operate with uniquely good conditions and at high quality.

1. Introduction

The only commercial nuclear power plant of Hungary has been in service since 1982. The four WWER-440 design units with their nearly 40% representation play a decisive role in the domestic electric energy supply. As a result of every effort of the country, the Russian-design reactors have always operated with high safety and availability indicators.

Among the most spectacular results of the on-going refurbishment programs, the most important ones are the reactor power uprating (2 out of 4 reactors run with 510 MWe, while the other 2 at 470 MWe output) currently underway and the extension of the unit service times with additional 20 years is just right in the last phase of the licensing process. Additionally, the 74% public acceptance of nuclear in the country is a promising condition to give space for two new units at the Paks site estimated to accrue around 2020.

2. Description of the training organization and infrastructure at Paks NPP

The Paks NPP as the sole nuclear utility in the country maintains its own training organization and infrastructure primarily mandated to provide all required special qualifications for both the plant staff and the employees of its contractors performing work within the site.

The plant’s training system along with its supporting infrastructure – considering the special Hungarian environment – have developed more or less in consonance with the global nuclear expectations. While at the end of the 70s and the beginning of 80s, the first generation of operators received their initial training abroad, only those were allowed to participate in the commissioning and start-up of unit 1 in 1982 who had attended the internal courses and passed the corporate exams.

Further important milestones of the development are represented by the inauguration of the first training centre building suitable primarily for the training of operators in 1986, the full-scope replica simulator in 1988 and for the last, the Maintenance Performance Improvement Centre in 1997, respectively. The latter have been completed in frame of an IAEA sponsored project which – while before that the Paks development programs had attempted to cope with the always more and more stringent international expectations – appeared to have set a good example and represent vision from many aspects for all the other nuclear training centres. As the results accomplished by the project, not only a unique maintenance training centre facility has been constructed but also the existing training system has been completely recomposed according to the principles of Systematic Approach to Training.

The plant and the training organisation has always turned much attention to continuously improve the means of training. Among the modifications implemented in the full-scope simulator, the reactor protection system refurbishment was the most significant (making the Paks units the first to have digital reactor protection system applied), where the simulator – after meeting all conditions – has not only been used for testing but also had served before as a developers' environment for the project.
The currently running reactor uprating project requires replacement of further basic hardware and software equipment and the balance of plant upgrading necessitated by the service time extension of the Paks units envisages the construction of a completely new full-scope simulator.

The exclusive feature of the Maintenance Performance Improvement Centre (MPIC) created to respond to maintenance training needs is primarily the training oriented placement and use of real primary circuit main components (reactor, steam generator, reactor coolant pump, etc.). The initial and once for a lifetime fortune that these equipment were imported from Zarnowiecz of Poland and Greifswald of Germany established only a framework for using the MPIC. The real value of the installation – all in all – are the SAT-based training programs tailored to maintenance job-positions, the extremely well prepared instructor staff and the new culture of initial- and continuing training, making the best of the opportunities with an intensity never experienced in the maintenance area before.

The training, training organization and development roles are played by a department with somewhat 50 persons with a representation of nearly 20 full-time instructors. Besides, approximately 40 additional staff members play – with more or less frequency – part time training roles. Unlike in the general practice, full time instructors are required to have nuclear professional history providing them with proper skills and prestige in addition to a so called 'Qualified Nuclear Power Plant Instructor' certificate to be held by both full- as well as part time instructors. This is a program of about six months of initial and annual continuing training that involves a university (Technical University of Budapest – Faculty of Ergonomics and Psychology) focusing on pedagogy, methodology as well as transfer of knowledge and skills in training of adults and presentation, available for 8 years.

3. Human resource management aspects

The state-owned Paks Nuclear Power Plant until the end of the 1990s has taken human resource management with ease and comfort. As the only but securely marketable product of the plant has always been and is electric energy, its managers and professionals have never been expected to function day-by-day in an innovative, competitive environment as the other players of the market. Besides, in the "rural environment" – as required in the early years – striving for self-supply, the plant has maintained staff for many fields of services (IT, engineering support, vocational secondary and high-school, security, transports, industrial medical services, water sports centre, etc.). The relatively low production cost of the electric energy generated in Paks as well as the lack of competition environment has not necessitated any downsizing for long. At the beginning of the millennia though, the plant's HR policy was strongly affected by the earnest of the energy market liberalization as well as by labour-, taxation and retirement laws. The increase of efficiency and cutting production costs there within stepped into the front light with much emphasis. After 2005 – as an affiliate of the MVM-holding - for the foundation of the long-term objectives and as a response to market challenges, the program of efficiency increase became even more definitive.

Considering the high mean age of the plant personnel, the headcount rationalization currently underway can practically be managed by retirements. This - painless as it is – solution generates difficulties in workforce provision and knowledge management. Since the beginning of the 1990s, the headcount of Paks NPP has continuously been decreasing and this phenomenon in response to actions of the past years have considerably accelerated. Besides the conscious downsizing, the very low rate of fluctuating manpower results, that the amount of professionals to be replaced is minimal.

4. The needs of Paks NPP for professionals

The direct need of an operating nuclear power plant for supply of professional is generally low which is especially true as there is a program of many years targeted to increase organizational efficiency. The first unit of Paks NPP has been operating for more than 25 years therefore the mean age of the personnel is fairly high. Out of the annual retired staff only 2/3 is replaced with new hires. The tasks of the not-replaced retired staff members are handled with internal reorganization or if necessary with cross-training. Thus, typical to the posts that remain to be filled in with fresh supply, that diverse academic education/qualifications are required. The need for new headcount in the specific areas or professions is 1-2 per year typically in more fortunate situations a maximum of 5-10. These figures themselves are not a problem with the plant as the resources of this low headcount are most certainly available in the labour market.

The problem is with the schools and institutes developing young professionals or graduates, whether or not they can or dare maintain classes or faculties specializing in nuclear with these low volume needs. Should this phenomenon reside for many years the situation may evolve to the obvious conclusion that the vocational schools and universities shall lose their knowledge base and skills to teach on disciplines in the non-sustainable areas.
If the universities' scientific labs fade away, that would very fast affect to the performance of the complete scientific- and industrial support in service for the power plant. The situation above was analyzed from the plant's point of view however, similar conditions can be identified from the aspects of other players of the Hungarian nuclear area, let it be a research institute or regulatory organization.

5. Options that can help manage the problems of supply of professional sin the Hungarian nuclear area

The proper response to the above challenges must be found in a short period. The MVM-group and the Paks NPP Ltd. therewithin intends to bring in a multi-level series of actions to initiate the mitigation of these negative tendencies and to give a kick to the necessary development for the secondary and higher level education as well as in the area of adult training.

The basic principles of this package of actions are the following:

- The problems of the nuclear area must be addressed and resolved as part of the energy sector.
- The planned actions must be based on a declared and approved medium-term Hungarian energy- and the associated development strategy.
- The academic education and training capacities must be calculated on the basis of the medium-term needs of the absorbing market (energy- and nuclear installations, schools, research institutes, authorities and background design, fabrication, installation, etc. industry)
- In the reformed national vocational and higher education system, the opportunity of cross-region enforcement of interests of the sector must be found.
- Actions must cover the complete education spectrum, from hiring into vocational schools to mastering.
- At last, spheres of interests must be identified along which willingness to finance medium-term accomplishment of goals for the provision of professional to the energy sector - both on a state- and private investors' level – is showing.

6. Actions underway

The Paks NPP Ltd. is determined to further strengthen its corporate, internal training system and while retaining its values, to improve its functioning and increase its efficiency to meet the expectations of the changing environment.

Within that a significantly higher emphasis is placed on the training of the contractors' employees. In the new training system under construction the most important goal is to rigorously retain the high requirements but the modular structure and the partial qualifications concentrating on particular task groups shall allow a higher flexibility and cost-efficiency for both the training organization and the partners.

In Paks, there has been a secondary vocational school specializing in energetic fields since 1985. The school, run basically on plant support but operated by a foundation indeed used to be the primary resource of professional to meet the needs of the plant. The stagnating and later, the decreasing recruitment needs has had its kickback on this excellent education institute also which has more and more changed its profile to include curricula without direct relevance to the energy industry. To cure this problem, with agreement of the management of the MVM and the Paks NPP, the operating organization was renewed in 2007, which immediately developed a brand new medium-term concept. Its essence is that the school must be developed to become a national centre for secondary vocational education in energetic studies. For this goal, the Pask plant shall continue to provide basic financing support but the school must build a live and vivid relationship with the affiliates of MVM and the Suppliers, extending the scope of opportunities for skills training and building closer ties between the student and the potential employers. An important item of the concept is the description of employment and career opportunities provided by and the increase of popularity of the energy sector.

The plant maintains a traditionally good relationship with institutes of the higher academic education moreover the Technical University of Budapest has operated a branch faculty in Paks for 15 years specializing in energy sector studies. Co-operation agreements are in place to be the framework for bringing the needs of both the universities representing the basic resources of engineer supply on the most critical areas and of the plant closer, as well as to build relationships.

Among the contents of these agreements it should be highlighted that 15 out of the students of the Technical University of Budapest, are awarded by the plant with scholarship. It should be noted that these bilateral relationships and the fiscal support made available by the plant themselves are insufficient to maintain great and expensive laboratories, workshops or the study reactor operated at the Technical University of Budapest therefore, the financing of such features must be placed on a different basis according to the above principles.

Taming the Chernobyl Avalanche

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ABSTRACT

The neutron kinetics equations are one of the cornerstones of the theory of nuclear reactors. The awareness of the nuclear engineering students of its importance is a precondition that the new generation will handle the presently operating and future nuclear power plants safely. They have to learn how to design control systems for reactors with an inclination to an avalanche like power increase.

The classical neutron kinetic equations with six delayed groups are not solved analytically. Here they are solved both numerically and with a corresponding block diagram and applied for a Chernobyl type reactor. The results are displayed graphically.

The Chernobyl type reactors have positive void coefficients. When water is replaced with steam the power is increasing. A sudden increase of the steam content causes a rapid power increase.

The importance of choosing the magnitude of the void coefficient and the parameters for the automatic control system is demonstrated.

1. Introduction

Now, 22 years after the Chernobyl accident it is important for today's and tomorrow's generations of nuclear engineers to learn to design control systems for reactor with runaway characteristics.

The Chernobyl type of reactor (RBKM) core is a huge graphite cylinder (7 m high, 12 m diameter) and within some 1600 channels with water and steam cooled fuel rods inside. The fission neutrons are slowed down (thermalised) mainly in the graphite and a portion of them is absorbed in the water. When a part of the water is replaced by steam (void) the absorption becomes less, causing a positive reactivity contribution. This is the positive void coefficient. After the accident the enrichment of the fuel was increased the neutron spectrum became harder resulting in a lower positive void coefficient

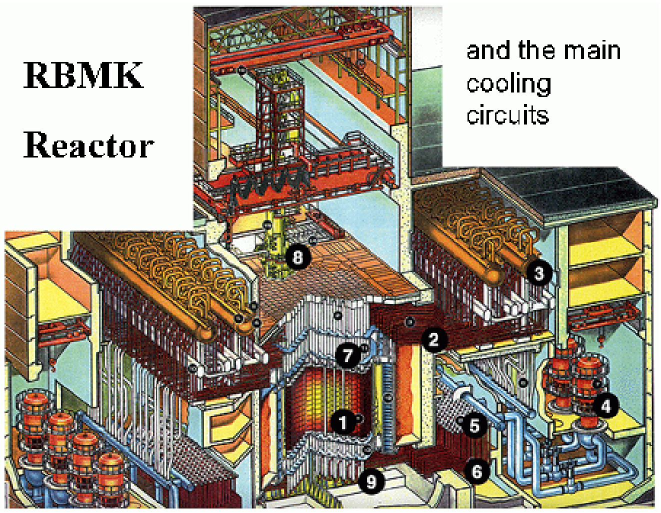

Figure 1, the Chernobyl Reactor

2. The experiment

At the Chernobyl experiment due to the abrupt decrease of the speed of the main circulation pumps and the sudden drop of the reactor pressure at low reactor power and heavy Xenon poisoning the steam (void) content in the coolant channels increased suddenly from a few percent to about 50%. Thus the positive void coefficient - about 30 pcm/% - caused a large reactivity insertion.

The neutron flux and thereby the reactor power increased very fast. Due to the thermal inertia of the fuel and the small value of the fuel temperature coefficient the Doppler effect could not break the power excursion. Therefore, to characterize the process at the initial phase, to use only the reactor kinetics equations is sufficient.

3. The simplified neutron kinetics equations

$$\frac{dN}{dt} = \frac{\delta k - \beta}{l} N + \sum_{i=1}^{6} \lambda_i c_i \quad \text{and} \quad \frac{dc_i}{dt} = \frac{\beta_i}{l} N - \lambda_i c_i$$

Here

t time (sec)

N neutronflux(proportional to the reactorpower)

δk change of the effective neutronmultiplication factor (k_{eff})

ß sum of the delayed neutronfractions (here0.006502)

$ß_i$ the i:th delayed neutronfraction

l neutronmean lifetime (here0.001 sec)

λ_i i:th decay constant (sec^{-1})

c_i concentration of the i:th fraction of the delayed neutrons' precursors,

At steady state, when time is zero t=0 all time derivatives are equal to zero, all d/dt=0 and the initial value of the relative power equals unity N(0)=1, and also no reactivity perturbation is present δk=0

N(0)=1 $\quad \frac{dN}{dt} = 0 \quad \delta k = 0 \quad \sum_{i=1}^{6} \lambda_i c_i = \frac{\beta}{l} \quad \frac{dc_i}{dt} = 0 \quad c_i(0) = \frac{\beta_i}{l\,\lambda_i}$

Delayed neutron data for thermal fission in U^{235} is used

Group	1	2	3	4	5	6
Fraction ßi	0.000215	0.001424	0.001274	0.002568	0.000748	0.000273
Decay constant λ_i	0.0124	0.0305	0.111	0.301	1.14	3.01

The initial values of the delayed neutrons' precursors are;

i	1	2	3	4	5	6
$c_i(0)$	17.3387	46.6885	11.4775	8.5316	0.6561	0.0907

4. Using the MATLAB notations

x(1)=N x(2)=c_1 ………… x(7)=c_6 the code is

```
%Save as xprim7A.m
function xprim =xprim7A(t,x,i)
```

```
DeltaK=i*0.010*0.50; %voidcoef=i*0.010pcm/percent void change, void increase 50percent
xprim=[(DeltaK/0.001-
6.502)*x(1)+0.0124*x(2)+0.0305*x(3)+0.111*x(4)+0.301*x(5)+1.14*x(6)+3.01*x(7);
0.2150*x(1)-0.0124*x(2);
1.4240*x(1)-0.0305*x(3);
1.2740*x(1)-0.1110*x(4);
2.5680*x(1)-0.3010*x(5);
0.7480*x(1)-1.1400*x(6);
0.2730*x(1)-3.0100*x(7)];
```

To study the importance of the magnitude of the void coefficient, it is enough to plot the first colon of the xmatrix. The rows of the x matrix are the time steps.

```
%Save as ReaktorKinA.m
figure
hold on
for i=0:1:3
[t,x]=ode45(@xprim7A,[0 0.2],[1; 17.3387; 46.6885; 11.4775; 8.5316; 0.6561; 0.0907],[] ,i);
plot(t,x(:,1))
end
hold off
```

5. The result

Is given in the following plot;

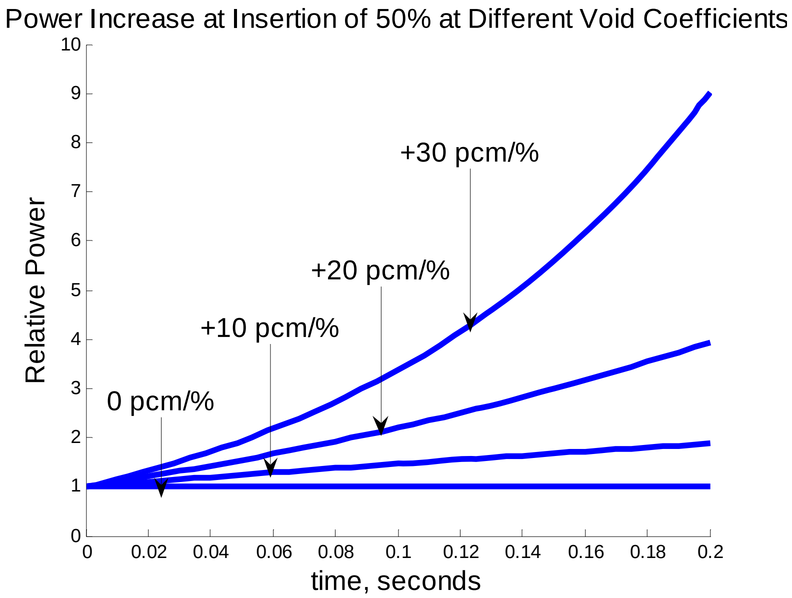

Figure2. Power Increase at the Insertion of 50% Void at Different Void Coefficients

6. Block diagram

Using the same parameters a block diagram is created here with SIMULINK

Delayed group 1
Gain1A = 0.2150 Gain1B = 0.0124 Gain1C = 0 0.0124 Integrator1 = 17.3387 (is the initial value of the first delayed group)

Delayed group 2
Gain 2A = …………………….

GainN = -1.502 [= 6.502 – 5 (= the void reactivity perturbation)]
IntegratorN = 1 (is the initial value of N)

The controller is represented with a zero pole block; (s – 1)/s(s – 1)
Here are the; zeros: [1], poles: [0 1], gain: [1]
Here the absorber rods are represented with an amplifier, the gain is 50

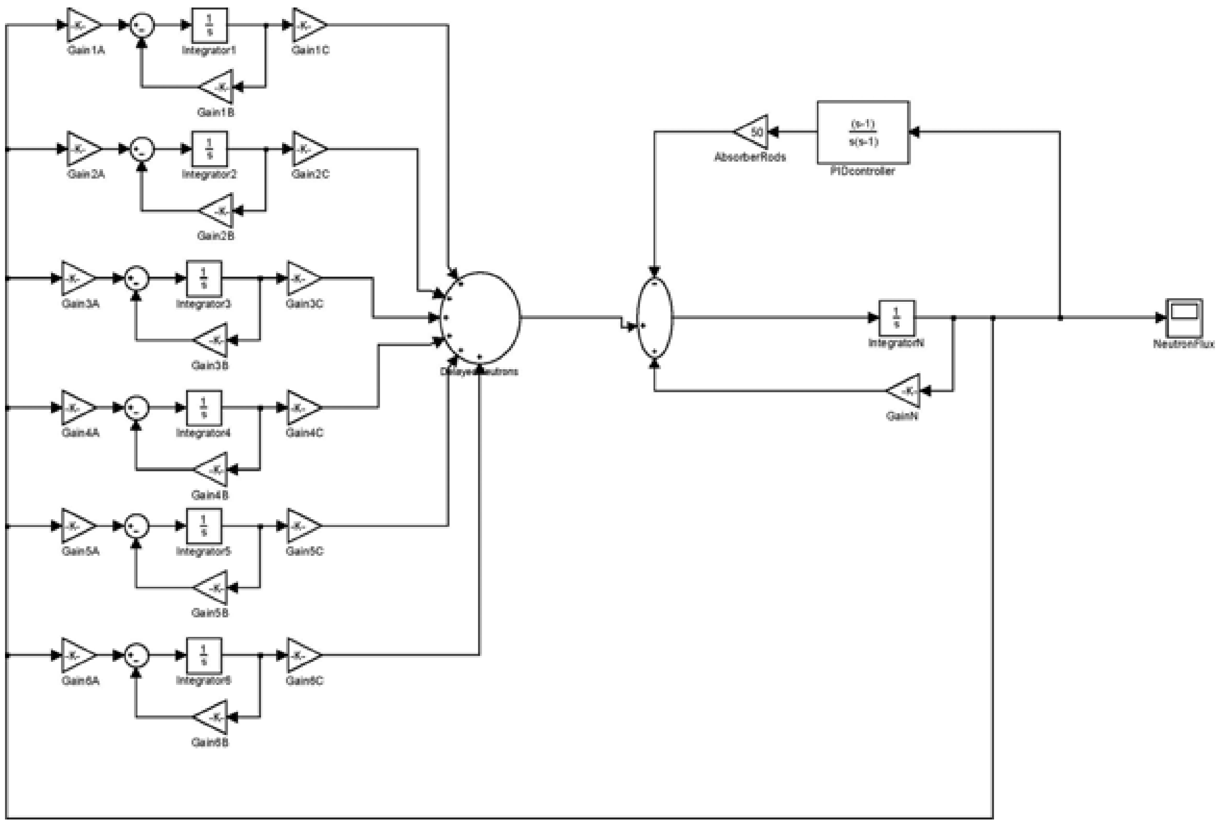

Figure 3. Block diagram of the neutron kinetics (with six delayed groups) and the automatic control system with a PID (Proportional and Integrating “1/s” and Differentiating “s”) controller

In this case study, a 10 % pcm/% void coefficient is used and the perturbation is as earlier 50% void increase. The system response without an automatic control system is like an avalanche

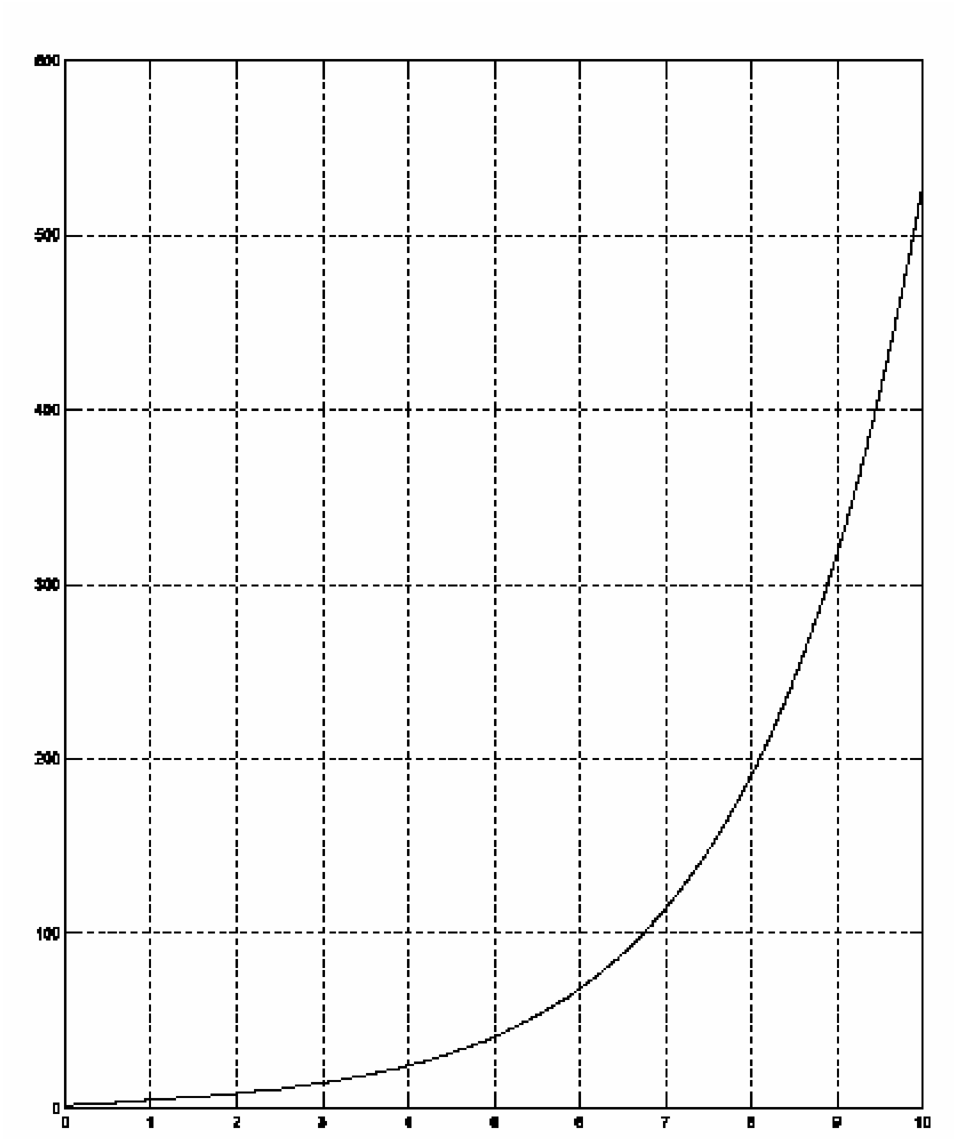

Figure 4. System response **without** an effective automatic control system.
Relative neutron flux (Power) vs. time (sec)

There is of course no construction which can take a 500 times power increase in 10 seconds. At the Chernobyl accident the result was a disaster with and elapsed time much shorter than 10 sec.

7. Automatic control

In theory one can specify a control system and a connected absorber rod actuator to team this transient. To achieve this, the control action must be extremely fast and must start effectively within a fraction of a second. However to realize a mechanical absorber rod operating device with the required speed is very difficult. For this example a PID controller is chosen and the absorber rods are represented with an amplifier which follows the output of the controller. The result is quit reasonable.

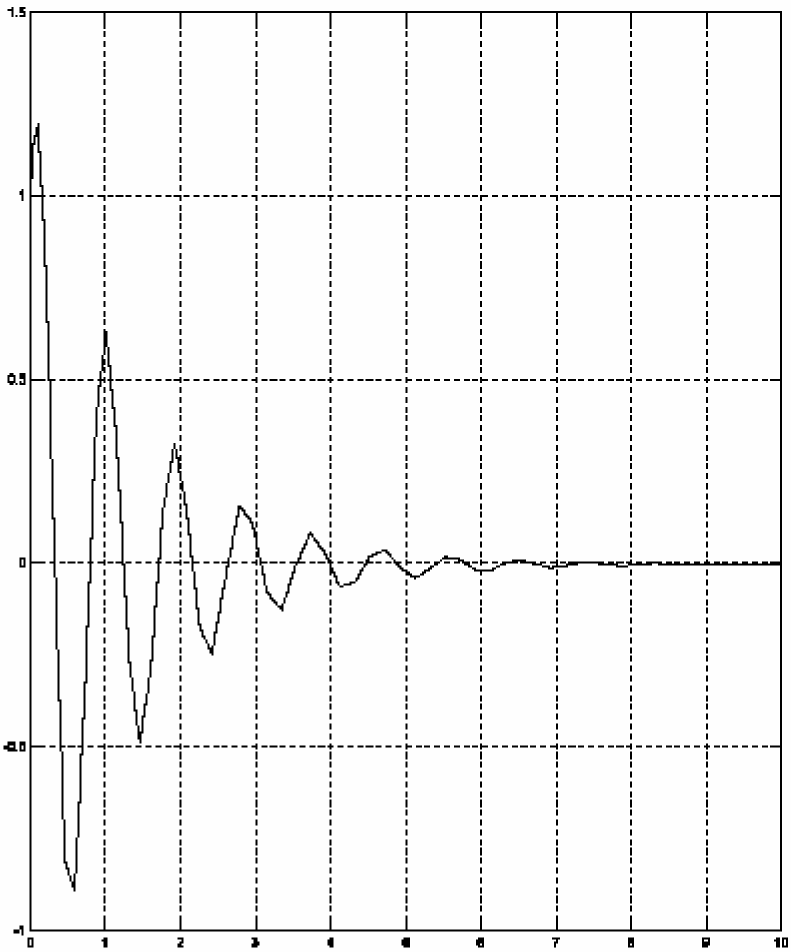

Figure 5. System response **with** an automatic control system (PID).
Relative neutron flux (Power) vs. time (sec)

The Chernobyl disaster demands many analyses to really understand what happened there and how to avoid anything similar in the future. This article is such a one.

8. References

University textbooks on nuclear engineering contain the applied equations. Textbooks on information technology and numerical analyses contain the applied methods.

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Computing the Chernobyl Avalanche
Calculation of the neutron flux, fuel and moderator temperature transients for Research Reactors
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NUCLEONICA SCRIPTING

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ABSTRACT

An overview of the Nucleonica scripting language and module is presented. A detailed case study on targeted alpha therapy is described which demonstrates powerful features of Nucleonica for modelling experiments through the use of batch scripts.

1. Introduction

Nucleonica applications are designed to be very user friendly, intuitive, and require a minimum of learning time [1,2]. For users, who prefer a more "hands on" approach, Nucleonica provides this with its scripting module. Scripting refers to a programming task, in which pre-existing components or applications are connected to accomplish a new task. In accordance with this definition, the Nucleonica scripting gives the user a powerful programming interface through which he/she can access basic nuclear data and run all the Nucleonica applications.

2. The Scripting Language in Nucleonica

The Nucleonica scripting is an easy-to-use physically intuitive object oriented programming language. The basics of the language, such as variable types (*int*, *double*, *string* or arrays), logical (&&, ||) and mathematical (+, -, *, /, %) operators, control structures (*for* and *while* loops, *if* statements) and built-in functions (*sin*, *log*, *print*, *abs*, *exp*, *sqrt, pow* etc.), are described in detail in the respective section of the Nucleonica wiki [3]. This wiki also serves as an on-line reference on the features of the implemented classes, their properties and methods. With ready-to-use examples and pre-defined scripts, which are largely enriched with comments and explanations, users can easily learn the language and save the time when developing their own scripts. The basic components of the language (classes) are summarised in Table 1.

Class	Main methods	Related applications	Related classes
nuclide, vnuclide	*Decay()*	*Decay Engine*	*decayResult*
	Dosimetry()	*Dosimetry and Shielding*	*doseResult*
	DecayInfo()	*Nucleonica database*	*decayInfo*
	Radiations()	*Nucleonica database*	*radiations*
range	*CalculateMono()*	*Range and Stopping Power*	*rangeResult*
	CalculateCompound()	*Range and Stopping Power*	*rangeResult*
transport	*Calculate()*	*Transport and Packaging*	*transportResult*
korigen	*callKorigen*	*webKORIGEN*	*korigenResult*

Tab 1: Basic components of the Nucleonica scripting language

In the script, the classes are instantiated through the objects which provide access to specific properties (*object.property*) and methods (*object.method(parameterlist)*). The *nuclide* class is of the central importance in the Nucleonica scripting, as it gives access to all basic properties of nuclides and implements the most important Nucleonica applications, such as “Decay Engine” and “Dosimetry and Shielding”. The *nuclide* class is instantiated in two steps. First, the *nuclide* object is declared and, then, its properties are initialized using the *Create()* method:

```
nuclide Th232;                 // Declare the nuclide object with name Th232
Th232.Create("Th", 232, 0);    // Get properties of Th-232 from the Nucleonica database
```

Three parameters of the *Create()* method define a nuclide of interest, i.e. specific element, isotope and isomeric state (0 refers to the nuclide's ground state). Once the *nuclide* object is created, one can use its properties and methods to access and manipulate the related nuclear data. For example, the *Th232.Halflife* property returns the half-life of ^{232}Th, and the *Th232.Activity(amount, fromQuantity, toQuantity)* method converts given amount of ^{232}Th between different quantities (activity, mass, number of atoms) and measurement units (e.g. Bequerels, Curies).

Using the *print()* function, which accepts a string as an input parameter, one can readily display the nuclide properties in the script output window. As shown in the following examples, the string to be displayed can be composed by the concatenation of ordinary strings and implicitly or explicitly (using *format()* function) converted numerical values (“+” serves as the concatenation operator):

```
// the integer atomic number Z is converted implicitly to a character string
print("Atomic number of Th-232 = " + Th232.Z);
// the explicitly formatted atomic mass (AWR_C12) shows 3 digits after the decimal point
print("Atomic mass of Th-232 = " + format(Th232.AWR_C12, "0.000") + " a.m.u.");
// the decay constant (natural log(2) divided by the half-life) is shown in scientific notation
print("Decay constant of Th-232 = "+format(log(2)/Th232.Halflife,"0.00E+00")+" per sec");
```

More specific nuclear data can be retrieved from the Nucleonica database using the *nuclide.DecayInfo(daughterIndex)* and *nuclide.Radiations(RadiationType)* methods. The *DecayInfo()* method retrieves decay data for a specified daughter nuclide in the nuclide’s decay chain, which are returned as properties (such as *BranchingRatio*, *Energy, DecayMode*) of the *decayInfo* object. The *Radiations()* method returns the list of energies and per-decay emission probabilities for the decay radiations of the requested type (α, β, γ, n, p, spontaneous fission fragments, discrete energy electrons, X-rays or annihilation photons) emitted in the decay of the given nuclide.

Among other *nuclide* object methods, the *nuclide.Decay()* method allows the user to perform radioactive decay calculations. Through its extensive lists of input and output parameters, the method provides the full functionality and flexibility of the respective Nucleonica Decay Engine application. The input parameters include the amount of the nuclide, the length of the time interval, the number of time steps, the accuracy of the calculation, and 15 additional options specifying the list of the target quantities (such as, gamma emission rate, ingestion and inhalation radiotoxicities, α, $\alpha+\beta$, and $\alpha+\beta+\gamma$ isotopic powers etc.), which are required in the calculation output. The results of the decay calculations are returned in the *decayResult* object, containing an array of the cumulative (e.g. the total activity and radiotoxicity of the parent nuclide and all its decay products) and nuclide specific (for the parent and each daughter nuclide) data, evaluated for the specified points of time.

Whereas the *nuclide* represents a real physical object, the *range* object corresponds to setting up an experiment. Through the *range.CalculateMono()* method, one can calculate the range and stopping power for the specified projectile type and single element target. To define the "experimental setup", the method uses 7 parameters, namely: 1) the type of the projectile (e.g., 2 – protons, 7 – other ions); 2) the projectile material index, if projectile type is 7; 3) the projectile energy; 4) the energy units (e.g., 0 means MeV); 5) the atomic number of the target element; 6) the density of the target material; and 7) the physical state of the target (e.g., 0 - for solids and liquids). The results of the calculation are returned in the *rangeResult* object, which, first, has to be created, as shown in the following example:

range ProtonsInTh; // Declare the *range* object for protons in thorium
rangeResult Range_Results; // Declare the *rangeResult* object
// Calculate the range and stopping power for 33.5 MeV protons in the thorium target
Range_Results = *ProtonsInTh.CalculateMono*(2,0,33.5,0,*Th232.Z*,*Th232.Density*,0);

In addition to the built-in functions, user-defined functions, e.g. for numerical integration, can be included in the script. The scripts can be directly entered and run in the Nucleonica source editor page. Scripts can be also developed locally on the user's computer and then uploaded, stored and run in the server. The stored scripts can be further modified, downloaded or distributed to other users.

3. Case Study: A Nucleonica script for ^{230}U production optimization

The isotope pair ^{230}U/^{226}Th has been recently identified [4] as being suitable for targeted alpha therapy. In the current case study, a Nucleonica script is described, which models the production of ^{230}U through the proton irradiation of natural thorium, as shown in Fig.1.

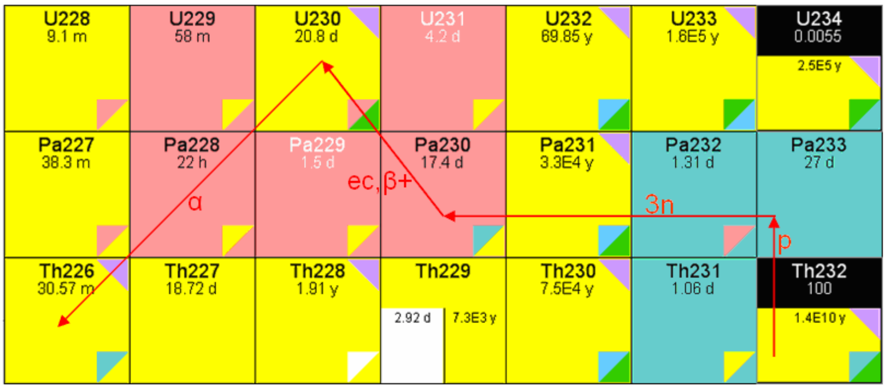

Fig.1. ^{230}U/^{226}Th production scheme: ^{230}U is accumulated in ε/β^+-decay of ^{230}Pa, produced in (p,3n)-reaction on ^{232}Th (graphic from the Nucleonica Nuclide Explorer).

In the following sections the production steps are described in detail and illustrated by the most significant lines of the script. The full script is available on the Nucleonica wiki [3].

3.1 Modelling the production of ^{230}Pa

At this stage of the experiment, the thickness of a thorium foil is the most important parameter. It determines the amount of ^{230}Pa produced at the end of the irradiation and influences the efficiency of the subsequent radiochemical separation. From the threshold behaviour of the ^{232}Th(p,3n)-reaction (see Fig.2), one can infer the lower limit of the useful energy range of protons to be $E_{min} \approx$ 15 MeV. Assuming E_{max} = 33.5 MeV for the energy of the incident protons, the estimate for the foil thickness is then $X_{foil} = R_p(E_{max}) - R_p(E_{min}) \approx$ 2.23 mm – 0.58 mm = 1.65 mm, where $R_p(E)$ is the range of protons with energy E in thorium. The respective Nucleonica script looks as follows:

Range_Results = *ProtonsInTh.CalculateMono*(2,0,33.5,0,*Th232.Z*,*Th232.Density*,0);
double Emax_Range; *Emax_Range* = *Range_Results.ProjRange*;
Range_Results = *ProtonsInTh.CalculateMono*(2,0,15.0,0,*Th232.Z*,*Th232.Density*,0);
double Emin_Range; *Emin_Range* = *Range_Results.ProjRange*;
double FoilThickness; FoilThickness = Emax_Range - Emin_Range;

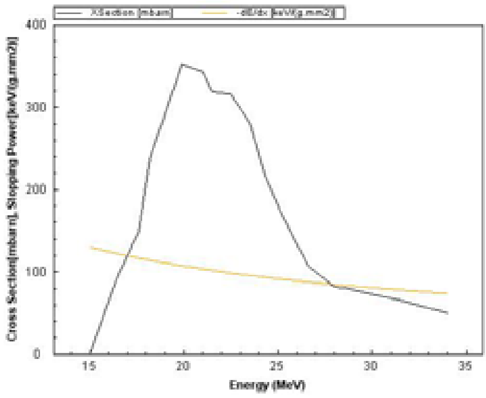

Fig.2. The experimental cross-section $\sigma(E)$ for the reaction ^{232}Th(p,3n)^{230}Pa [4] and the calculated stopping power $S(E)$ for protons in thorium as functions of the proton energy.

To calculate the amount of ^{230}Pa produced by the end of the irradiation, one needs first to evaluate the average cross-section $\langle\sigma\rangle$ for the (p,3n)-reaction. Assuming constant proton flux inside the target, one can obtain the following formula:

$$\langle\sigma\rangle = \frac{1}{X_{foil}} \int_0^{X_{foil}} \sigma(x)dx = \frac{1}{\rho X_{foil}} \int_{E_{\max}}^{E_{\min}} \sigma(E) \frac{d(\rho x)}{dE} dE = \frac{1}{\rho X_{foil}} \int_{E_{\min}}^{E_{\max}} \frac{\sigma(E)}{S(E)} dE = 163\ mb$$

where ρ - the target density, $\sigma(E)$ - the reaction cross-section and $S(E) = -dE/d(\rho x)$ - the proton stopping power as functions of proton energy E (see Fig.2). Below is a part of the user-defined function *AverageXSection*(), which implements this formula using a trapezoidal integration:

```
double AXS = 0;                                   // Average cross-section
for (i = 1; i < 16; i += 1)                       // Loop on the proton energies
{  Range_Results = ProtonsInTh.CalculateMono(2,0,pE[i-1],0,Th232.Z,Th232.Density,0);
   double F_Emin; F_Emin = XSection[i-1] / Range_Results.STotal;
   Range_Results = ProtonsInTh.CalculateMono(2,0,pE[i],0,Th232.Z,Th232.Density,0);
   double F_Emax; F_Emax = XSection[i] / Range_Results.STotal;
   AXS += (F_Emin + F_Emax) * (E[i] - E[i-1]) / 2;  }
AXS = AXS / (FoilThickness*Th232.Density);        // Final normalization
```

Here, *E*[] and *XSection*[] are the proton energy and reaction cross-section arrays respectively, *STotal* is the property of the *rangeResult* object giving the value of the total stopping power. Having evaluated the average cross-section, one can easily calculate the production rate of ^{230}Pa as $R_{Pa\text{-}230} = N_{Th} \langle\sigma\rangle X_{foil} I = 1.0 \cdot 10^{12}$ s^{-1}, assuming the atomic density $N_{Th} = 3.04 \cdot 10^{22}$ cm^{-3} and the proton current I = 200 µA.
Once the production rate of ^{230}Pa is known, the amounts of ^{230}Pa and ^{230}U, obtained by the end of the irradiation period, can be evaluated. Using Bateman's analytical solution for the system of differential equations, governing the nuclide decay and buildup, one can obtain:

$$A_{Pa}(t) = R_{Pa-230}(1 - e^{-k_{Pa}t}), \qquad A_U(t) = R_{Pa-230} \frac{k_U \cdot k_{Pa} \cdot BR_{Pa,U}}{k_U - k_{Pa}} \left(\frac{1-e^{-k_{Pa}t}}{k_{Pa}} - \frac{1-e^{-k_U t}}{k_U} \right),$$

where $A_{Pa}(t)$ and $A_U(t)$ - the activities of ^{230}Pa and ^{230}U at time t, k_{Pa} and k_U - the decay constants of ^{230}Pa and ^{230}U, and $BR_{Pa,U}$ - the branching ratio for the decay of ^{230}Pa to ^{230}U. In the script, these quantities are calculated by the user function *Production*():

```
for (t = 0; t <= time; t += time/10)         // loop over 10 time steps from 0 h to 50 h
{  APa = R_Pa230 * (1 - exp(-kPa * t));
   AU = R_Pa230*kU*kPa*BR_PaU * ((1-exp(-kPa*t))/kPa-(1-exp(-kU*t))/kU) / (kU – kPa);
   print("" + (t/3600) + ", " + (APa) + ", " + (AU));  }
```

In addition, the function outputs the results in a form suitable for the Nucleonica graph module (see Fig.3). The calculations show that, by the end of the 50 h irradiation, 80.5 GBq of ^{230}Pa together with 0.23 GBq of ^{230}U are produced.

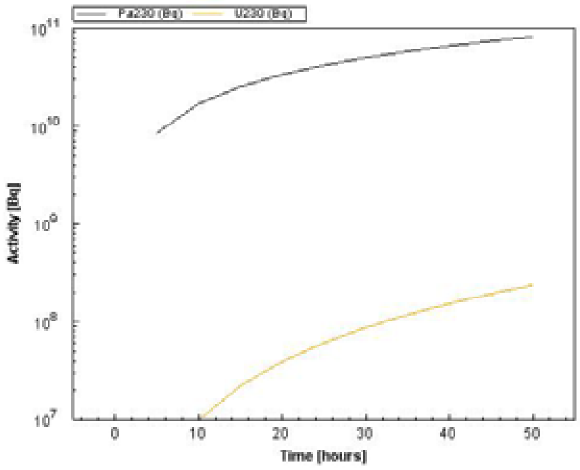

Fig 3. The production dynamics of ^{230}Pa and ^{230}U during 50 h proton activation of the Th foil

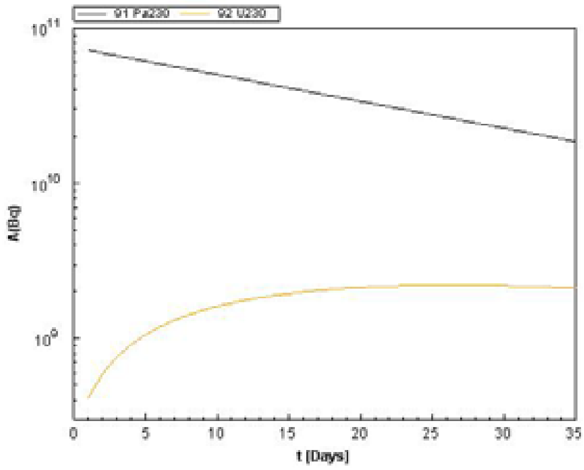

Fig 4. The 35-day-dynamics of ^{230}U accumulation in the decay of ^{230}Pa

3.2 Modelling the accumulation of ^{230}U

To model the accumulation of ^{230}U following the irradiation period, an object of the nuclide mixture class *vnuclide*, consisting of 80.5 GBq of ^{230}Pa and 0.23 GBq of ^{230}U, was created and the *vnuclide.Decay*() method was employed. Fig.4 demonstrates the obtained dynamics of the ^{230}U activity within the 35-day-long post-irradiation interval. One can see from the graph that the ^{230}U activity reaches its maximum in 24-30 days after the irradiation. The more accurate value t_{max} = 26.9 days for the optimum accumulation time interval has been obtained in the script by implementing the formula:

$$t_{\max} = \frac{1}{k_U - k_{Pa}} \ln\left(\frac{k_U}{k_{Pa}} + \frac{A_U(0)}{A_{Pa}(0)}\right) .$$

From Fig.4, however, it follows that the actual separation of ^{230}U can be performed up to 2 weeks earlier without a significant loss in the resulting activity of the target nuclide (compare A_U(12 day) = 1.88 GBq and $A_U(t_{max})$ = 2.34 GBq). This process of in-growth and separation can be repeated as long as significant activity of ^{230}U can be produced.

4. Conclusions

The Nucleonica scripting is an object oriented language which is based on the physically intuitive classes, methods and properties. Through the script interface the user has access to the main Nucleonica applications and nuclear data. By combining results from multiple Nucleonica applications and nuclear data, users can go beyond the conventional single-application approach for solving their specific experimental tasks and problems.

5. References

[1] J. Magill et al., Nucleonica: A Nuclear Science Portal, ENS News, Issue No.17 Summer (July 2007), see www.euronuclear.org/e-news/e-news-17/nucleonica.htm
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USING SPREADSHEETS FOR PROMOTING STUDENT UNDERSTANDING OF LIGHT WATER REACTOR OPERATION

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ABSTRACT

There is a universal need for engineers to understand dynamic physical systems and being able to determine the outcome of such systems. The training of nuclear reactor control room staff involves the use of full-scale simulators with very accurate models of the nuclear reactor process. However, it is not feasible to use such simulators to study the underlying fundamental processes in order to help students of reactor physics to obtain an understanding of the basic principles. For this purpose simple spreadsheet simulations that illustrate different aspects of the nuclear reactor process are very useful. Using examples from courses in basic reactor physics, it is shown how Microsoft Excel can be used as a tool for the study of dynamic problems, e.g., natural circulation cool down and xenon poisoning, as well as steady state calculations of steam quality and void.

1. Introduction

Simulations and simulators are commonly used for the training of personnel required to operate complicated dynamic systems such as aircraft, ships and nuclear power plants. It is recognized that simulations allows the student of such a system to acquire an accurate mental model of the system and to become proficient in its operation. Simulators also provide a safe environment where accidents can be simulated and emergency procedures practiced. For students of physics and engineering there is a universal need to understand the basic principles governing dynamic, i.e., time-dependent physical systems and being able to determine the outcome of such systems. For this purpose, simulations on a much smaller scale can provide a useful means of promoting the understanding of basic physical principles. It is important to emphasize that in most cases, these simulations cannot stand on their own. The simulations need to be accompanied by introductory presentations of the concepts.

Given the constraints sometimes imposed by the mathematical skills of students, different softwares that facilitate the modelling and simulation of dynamical systems have been developed. One often-overlooked alternative to these softwares is to use commonly available spreadsheet programs, e.g., Microsoft Excel. The first spreadsheet program, VisiCalc by Dan Bricklin and Bob Frankston, was released to the public in 1979. The concept of a computerized accountant's grid where one could modify the content of any cell, and the entire spreadsheet would be automatically recalculated, quickly caught on and spreadsheet programs became the most commonly used tools for accounting and financial calculations. Today Microsoft Excel, which remains true to the original concept of the accountant's grid, has evolved into a powerful mathematical software that is of use in almost all fields of science and technology [1]. Although spreadsheet programs are probably not the ideal solution for any given problem, they have advantages that in many cases far outweighs the limitations:

- Spreadsheet programs do not have the steep learning curve of other more complex, and possibly more capable, software.
- Modern spreadsheet programs combine powerful calculation capabilities with very useful graphing features, which is extremely important for the visualization of results

of calculations. Custom controls, e.g., spin buttons, allow a high level of interactivity where changes in parameter values are immediately reflected in the data output.

- A spreadsheet program is almost always included in software bundles installed on personal computers giving students easy access to the software.

From a science education point of view spreadsheet programs can be used for many different purposes such as calculations, visualizations and also simulations of dynamic systems [2].

2. Steady state calculations

The calculation of quantities such as steam quality and void in a BWR operating at constant power involves steady state calculations, which for training purposes can be performed using spreadsheets. Spreadsheet programs are suited for the visualization of different concepts and allow a high level of interactivity allowing students to try out different “what if” scenarios.

2.1 Steady state calculation of steam quality and void in a BWR

In a BWR a complicated relationship exists between the steam quality and the resulting void fraction. Depending on whether or not the two-phase flow is considered to be in thermal equilibrium and whether or not the two phases are moving with the same velocities, several different models for calculation of the void fraction exists. From a student point-of-view it is of interest to perform calculations of steam quality and void fractions using different models in and parameter values in order to obtain an understanding of the process. The task is easily performed using spreadsheets, e.g., Excel as shown in Fig 1 where the spreadsheet itself mainly serves the purpose of visualizing the results of the calculation. Most of the calculations are performed using Visual Basics for Applications (VBA), Microsoft’s common application scripting language that is fully integrated with Excel [3].

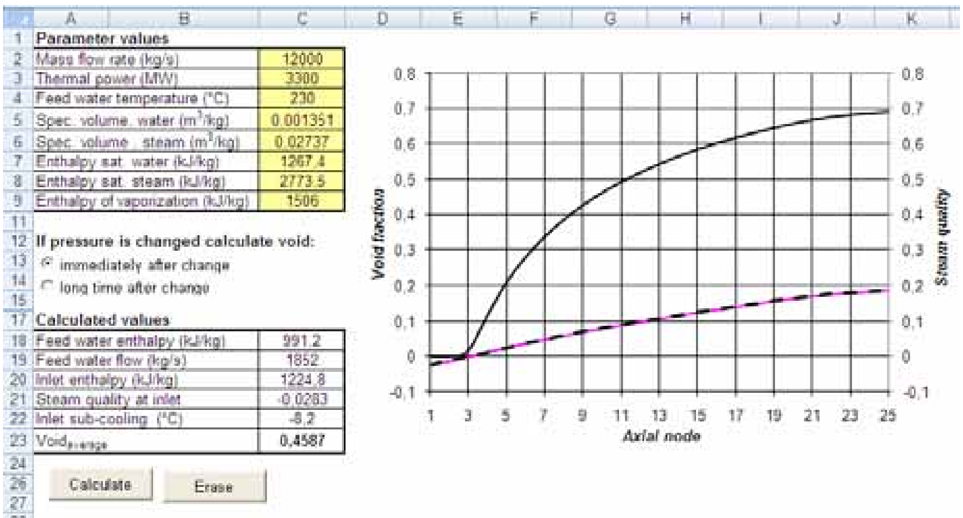

Fig 1. An example of a spreadsheet for the calculation of the axial distribution of steam quality and void fraction in a BWR for a given axial power distribution. The model used does not include sub-cooled void.

In the example the steam quality, x, and void fraction, α, are calculated assuming a thermal equilibrium model with an algebraic relationship between the velocities of water and steam, i.e., slip ratio S [4].

$$x_i = x_{i-1} + \frac{\dot{Q}_i}{\dot{m}r}, \quad a_i = \frac{1}{1+\frac{1-x_i}{x_i}\frac{\rho_v}{\rho_l}S}, \quad \mathrm{S} = 0.93\left(\frac{\rho_\mathrm{l}}{\rho_\mathrm{v}}\right)^{0.11} + 0.07\left(\frac{\rho_\mathrm{l}}{\rho_\mathrm{v}}\right)^{0.56} \tag{1}$$

where $\dot{Q}_i$ is the nodal thermal power, $\dot{m}$ the mass flow rate and r is the enthalpy of vaporization.

3. Dynamic simulations

The simulation of a dynamic system involves the solution of differential equations. Spreadsheet programs are well suited for the purpose of solving various problems involving ordinary differential equations by means of the Euler method

$$y_{n+1} \approx y_n + h \cdot f(x_n, y_n), \tag{2}$$

which advances the stepwise solution of an ordinary differential equation from x_n to $x_{n+1} = x_n + h$ [5]. At the expense of simplicity it is of course possible to use other solutions methods such as Runge-Kutta.

3.1 Natural circulation cooldown in a PWR-type reactor

In pressurized water nuclear reactors (PWR) the coolant water is circulated in a primary-coolant circuit consisting of the reactor core (hot leg) and steam generators (cold leg) by means of recirculation pumps. In the steam generator heat is transferred from the primary coolant to a secondary system involving a steam cycle, usually a steam turbine and a condenser.

In the event of a recirculation pump failure, an emergency stop (scram) is initiated to stop the fission process. Even after the scram, decaying fission products in the nuclear fuel will release significant amounts of decay heat to the coolant. If a temperature difference is maintained between the hot and cold legs of the primary coolant circuit, the resulting difference in density between the two areas will give rise to a thermal driving pressure causing a natural circulation flow to be established. The thermal driving pressure is balanced against the total pressure drops associated with the fluid flow in the primary coolants system.

	A	B	C	D	E
1	**Inputs**				
2	C_p (kJ/kg/°C)	5,96			
3	Height difference hot leg, cold leg (m)	6			
4	Circulation flow at full power (kg/s)	12800			
5	System pressure drop at full power (Pa)	650000			
6	Power (MW)	2800			
7	Water density in cold leg (kg/m^3)	745,7			
8	Cold leg temperature (°C)	300			
9					
10					
11	**Calculated values**				
12	Decay heat after 5 minutes (MW)	72,5			
13					
14	Circulation flow (kg/s)	$t_{\text{hot leg}}$ (°C)	Water density in hot leg (kg/m^3)	Thermal driving pressure (Pa)	System pressure drop (Pa)
15	800	315	691,1	3213	5078
16	790	315	690,6	3241	4968
17	780	316	690,2	3270	4858
18	770	316	689,6	3300	4750

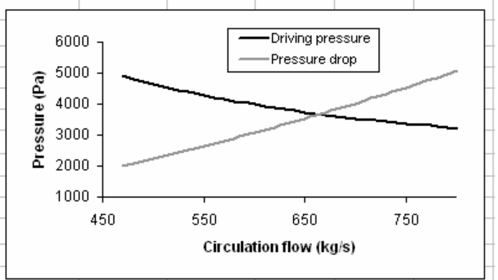

Fig 2. Worksheet for the simulation of natural circulation flow in a PWR nuclear reactor following a pump failure. In this case, using typical PWR data, the natural circulation flow 5 minutes after a scram will be $\dot{m} = 660\,\text{kg/s}$.

To determine the resulting natural circulation flow rate with the thermal driving pressure balancing the total pressure drop of the primary coolant system an iterative approach is used, Fig 2:

1. Calculate the decay heat.
2. Choose an initial value for the mass flow rate $\dot{m}$.
3. Calculate the temperature of the water exiting the reactor core using

$$T_{\text{hot leg}} = T_{\text{cold leg}} + \frac{\dot{Q}}{\dot{m} \cdot c_p}. \tag{3}$$

4. Calculate the density of the water exiting the reactor core, $\rho = f(p, T)$ [6].
5. Calculate the thermal driving pressure,

$$\Delta p_{\text{driving}} = (\rho_{\text{hot leg}} - \rho_{\text{cold leg}})gh . \tag{4}$$

6. Using the Darcy-Weisbach equation for fluid flow it can be shown that the total pressure drop due to friction is proportional to $\dot{m}^{1.75}$,

$$\Delta p_{\text{total}}(\dot{m}) \approx \Delta p_{\text{total}}(\dot{m}_0) \cdot \left(\frac{\dot{m}}{\dot{m}_0}\right)^{1.75} . \tag{5}$$

7. If $\Delta p_{\text{driving}} > \Delta p_{\text{total}}$ increment the mass flow rate $\dot{m}$ and repeat from step 3, otherwise stop.

3.2 Xenon poisoning in a nuclear reactor

When the first reactor with higher power, the "Pile B" in Hanford, WA, was started on September 26, 1944, the researchers came across the phenomenon of xenon poisoning. A few hours after the first start-up, the reactor stopped unexpectedly. The following day it started without any external intervention but after a few hours it stopped again. It turned out that the isotope Xe-135, which has the highest neutron absorbing ability of all the known nuclides, was created when running the reactor. When the concentration of Xe-135 became high enough, the resulting reduction in neutron flux caused the reactor to become subcritical.

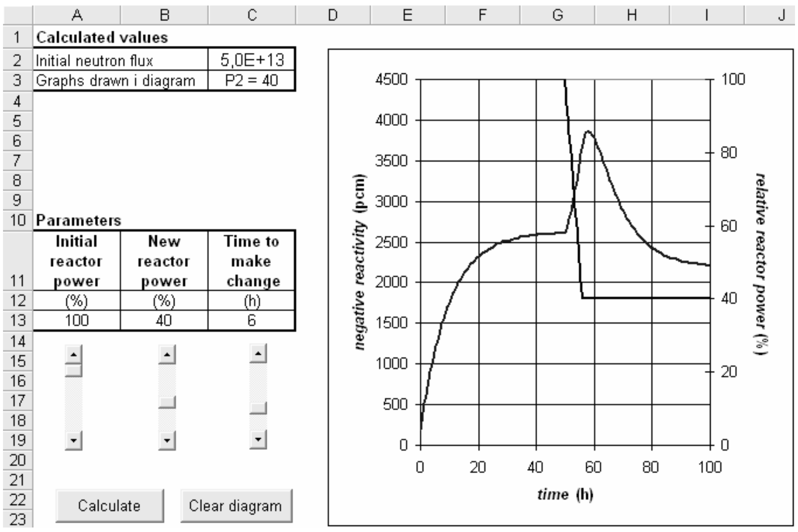

Fig 3. Simulation of Xe-135 concentration, expressed in terms of negative reactivity, in a typical reactor core. Approximately 2 days after the start of the reactor the Xe-135 concentration has reached an equilibrium level. A decrease in reactor power from 100% to 40% over a period of 6 hours creates a peak in the Xe-135 concentration that occurs approximately 8 h after the change was initiated. Approximately 2 days after the change a new, lower equilibrium level is reached.

In modern reactors xenon poisoning is a well-known effect that plays an important role from an operational point of view. All changes in reactor power and neutron flux will have an influence on the concentration and rate-of-change of Xe-135. The negative contribution to the total reactivity of the reactor from Xe-135 must be constantly predicted and corrected for when making reactivity changes to the reactor. For example, after a power increase, the Xe-135 concentration will initially decrease. If this is not taken into account, the power increase will become larger than anticipated. The concentration will reach a minimum some hours after the power increase and then increase to a new, higher equilibrium value.
In the operation of a nuclear reactor an equilibrium concentration of both Xe-135 and I-135 is reached as a result of competing processes. Xe-135 is produced directly as a fission product and indirectly following the β-decay of another fission product, I-135, that has a half-life of 6.7 h. The production rate of xenon is proportional to the neutron flux and also the amount of I-

135 present in the fuel. Xe-135 is removed from the reactor core by two processes, radioactive decay and neutron capture. The radioactive decay rate is proportional to the amount of Xe-135 present. Neutron capture converts Xe-135 to Xe-136, which has a low absorption cross-section. In this way Xe-135 can be "burned away" at a rate proportional to the neutron flux in the reactor. The rate of change of xenon concentration is expressed by the following equations,

$$\begin{cases} \dfrac{dN_{Xe}}{dt} = \lambda_I \cdot N_I + \gamma_{Xe} \cdot \Sigma_f \cdot \phi - \lambda_{Xe} \cdot N_{Xe} - N_{Xe} \cdot \sigma_{a,Xe} \cdot \phi \\ \dfrac{dN_I}{dt} = \gamma_I \cdot \Sigma_f \cdot \phi - \lambda_I \cdot N_I , \end{cases} \tag{6}$$

where λ is the decay constant, γ the fission yield, Σ_f the macroscopic fission cross-section for U-235 and ϕ the neutron flux in the reactor core. The equations can be solved using Euler's method in a spreadsheet, Fig 3.
Although the calculations can be done directly in the spreadsheet grid, in this case the calculations are performed in VBA, Fig 4. The advantage of using VBA for this purpose is that the resulting spreadsheet can be kept clean, only the data of interest for the students are shown. Compared to in-line formulas in worksheet cells, the VBA-code can be made much more complex while maintaining readability.

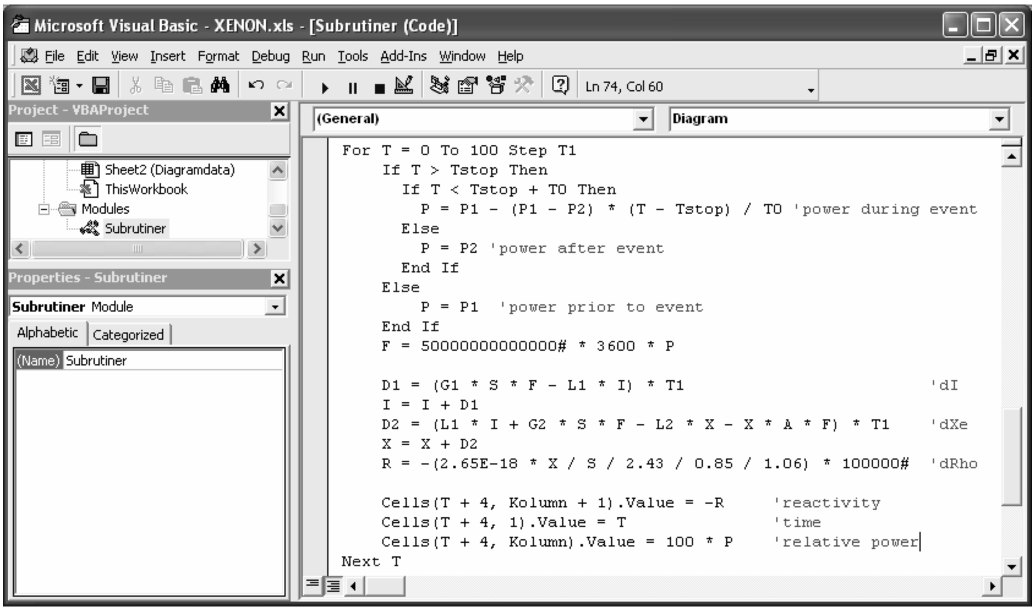

Fig 4. Part of the VBA-code used for the simulation of xenon poisoning in a nuclear reactor. The results of the calculation are transferred to a worksheet using the Excel function Cells(Row #, Column #).Value.

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THE INSTITUTE FOR NUCLEAR RESEARCH PITESTI- AN IMPORTANT FACTOR FOR EDUCATION AND TRAINING IN ROMANIAN NUCLEAR FIELD

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ABSTRACT

Institute for Nuclear Research Pitesti, Romania, is a complex R&D centre with over 30 years of activity in the nuclear energy field, deeply involved in the management and execution of the R&D National Nuclear Power Program. The main activities cover a large spectrum of nuclear energy. Based on the accumulated experience in developing codes, performing analyses, designing and conducting experiments an important knowledge was obtained. Taking into account the historical relation with different organizations, INR acted as a promoter of nuclear methods and techniques, transferring experience and knowledge. Based on the experimental and computing infrastructure and on the experienced personnel the Institute may become an important factor in nuclear education and training. This paper is intended to highlight the Institute competences and facilities and also the REFIN network, a Romanian Educational Network in Nuclear Physics and Engineering, like a good example for the Institute involvement in the national education and training in nuclear field.

1. Introduction

In the whole nuclear domain, the recent trends are based on a sustainable development, both for the nuclear power and the nuclear applications. Starting from this reality, it is neccessary to admit that the success of all these applications of nuclear knowledge depends upon being sufficient competent and well-qualified personnel for their implementation and that depends in turn on knowledge management, /1/. The knowledge management has been most visibly implemented in the nuclear research and industry as a response to the aging nuclear domain workforce.

In Romania, the state of the art of the nuclear knowledge is similar with other European countries, but some specificities should be mentioned here. Romania is one of the few countries with a dynamic development of nuclear power in the last two decades. First CANDU unit became commercial in 1996, and the second unit in 2007. A political decision in order to sustain the building of two new CANDU units until 2015 exists. Moreover, at high decisional level there are discussions about the necessity and opportunity to built another NPP with 2-4 reactor units with a different location than actual CANDU NPP. In this context, important requirements for new personnel are expected for the next 5-10 years. But, on the other hand, as in other countries, the personnel ageing effect, both in nuclear industry, research, and other organizations is visible. Also, it was occurred an important loss of high qualified personnel by emigration and cancellation by employee (motivated by the temptation of a transfer in other economy sectors). In parallel with the loss of qualified personnel, a decreasing of the interest of the young generation for nuclear field is felt. The number of students in nuclear field has decreased, also the number of courses and universities with nuclear subjects, /2/.

From this prospective point of view and accordingly with the requirements of the Romanian Nuclear Programme regarding the education and training of the skilled personnel for the nuclear facilities, we consider that the Institute for Nuclear Research from Pitesti can be and must be an important factor for education and training in Romanian nuclear field and not

necessary. The affirmation is based on the reality that the Institute has both the experimental and computational infrastructure but also the experienced personnel.
In the followings, we try to argue this affirmation by a short presentation of the Institute and also one of the most important INR realization in the educational and training area, i.e. the REFIN network, /3/ and /4/.

2. The INR and Competences- short presentation

The **I**nstitute for **N**uclear **R**esearch (INR) Pitesti was founded in 1971 and with the mission to foster the peaceful utilization of nuclear power. The Institute developed technologies, methods, computer codes, its own experimental infrastructure, directed towards an end-product or service with applications in a nuclear power plant (NPP). The Institute continues to act as a technical support institute for the safe and economical operation of the NPP, in accordance with National Nuclear Programme and international agreements on the safety of nuclear installations.

In Figure 1 the INR's assets are presented:

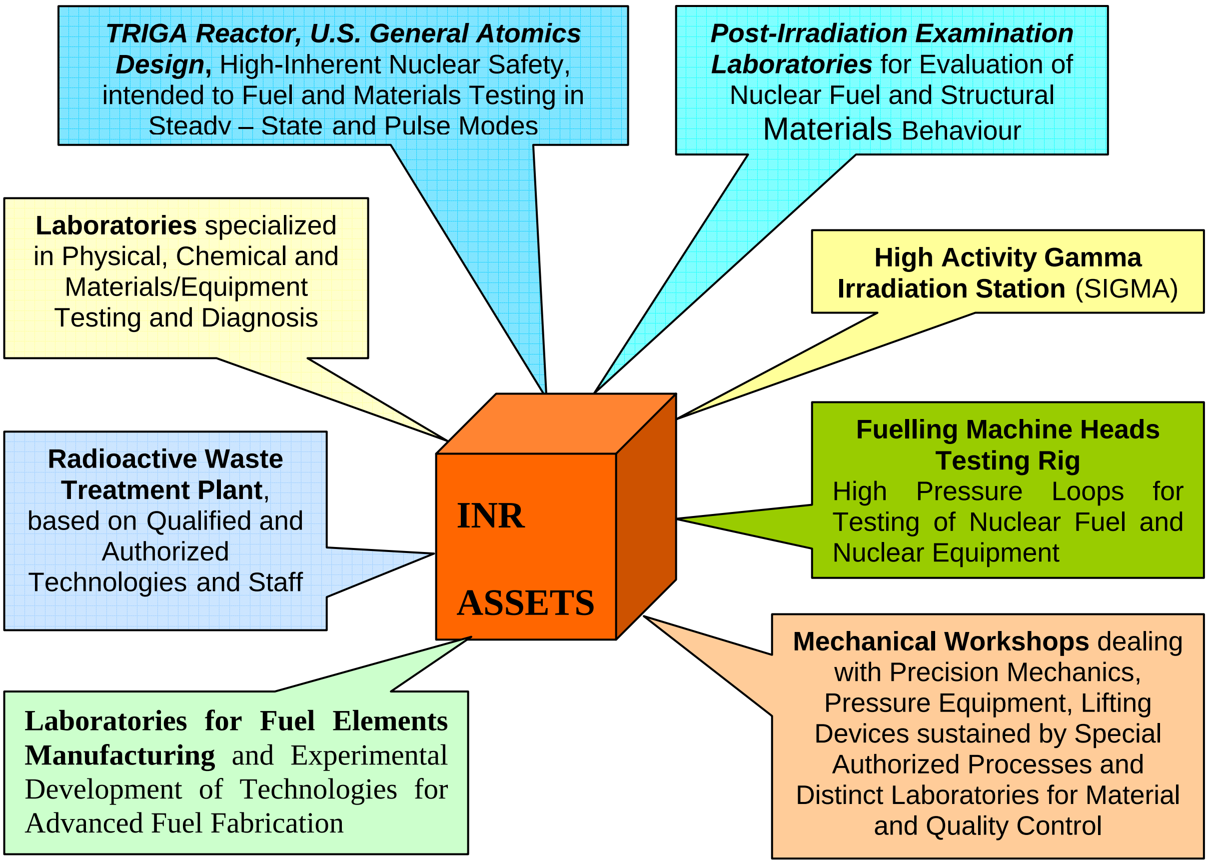

Fig. 1. The Institute for Nuclear Research assets

During the last 15 years, the research activity of the INR was mainly oriented towards applied and engineering research, within programmes with objectives connected to the CANDU NPP. To achieve these objectives, the Institute activities are oriented in the following main research areas:

- Reactor Physics and Nuclear Safety;
- Irradiation and Post-Irradiation Tests;

- Nuclear Fuel Cycles;
- Material Analysis and Evaluation;
- Out-of-Pile Testing;
- Radioactive Waste Management;
- Electronics, Instrumentation and Control;
- Radiation Protection, Environmental Protection and Civil Defence;
- Equipment Design, Development and Testing;
- Reliability and Testing;
- Quality Management.

The structure of the Institute research programmes is fully compliant with the research programmes engaged by the CANDU owners community. This also improves the ground of international scientific cooperation and exchanges throughout Europe and the whole nuclear world, which acknowledges the INR as a valuable partner.

The most known product of INR is the Romanian nuclear fuel technology. Most of the know-how was obtained in '80s. The pilot unit was designed, built and operated in INR. In 1992 the know-how, buildings, installations and people are transferred in the new company Nuclear Fuel Factory. That is a good example of knowledge transfer in our history.

3. REFIN- The Romanian Educational Network in Nuclear Physics and Engineering

In the last years, in INR were developed or are in progress some very important activities, related with the finding and implementation of the appropriate methods and tools for transfer and preservation of the relevant accumulated knowledge. On this way, in the following we present the Romanian Educational Network for Nuclear Physics and Engineering.

According to the requirements of the Romanian Nuclear Programme regarding the education and training of the skilled personnel for the nuclear facilities, a knowledge transfer network named REFIN (in Romanian: **R**etea **E**ducationala in **F**izica si **I**ngineria **N**ucleara) was developed since 2005. The knowledge target field is nuclear physics and engineering.

The Polytechnic University of Bucharest is the coordinator of this programme and other involved partners are University of Bucharest, University of Pitesti, University Babes Bolyai of Cluj-Napoca, University of Constanta, Institute for Nuclear Research Pitesti, Institute for Physics and Nuclear Engineering from Bucharest and the Training Center for Nuclear Units of Cernavoda NPP.

In Figure 2., the home page of the REFIN web-site in Romanian language is presented. The english version very soon will be in use.

Figure 2. The home page of the REFIN

The main objective of this network is to develop an effective, flexible and modern educational system in the nuclear physics and engineering area, that could meet the requirements of all the known types of nuclear facility and therewith be redundant with the perspectives of the European Research Area (FP7, EURATOM).
The construction of a such network is an important step in the improving both knowledge transfer process and collaboration between the responsible factors in the education and training of future specialists. In this way the knowledge transfer is made at all the level: explicit, implicit and tacit, due both the methods (mentoring, tutoring, e-learning, etc.) and a higher usage of the material base (documentation, experimental devices, models, etc.).

The education and training strategy of this network is divided into several topics: university engineering, master, post-graduate, Ph.D. degree, post-doctor's degree, training for industry, improvement. Thus, at the Institute for Nuclear Research (INR) Pitesti the students prepare the engineering diploma, Ph.D. students preparing the thesis, mixed (simulations and experiments) training stages for students, joined participations at nuclear meetings and conferences involving students, professors and INR specialists.
One of the most important activity performed in the REFIN frame in 2007 was the elaboration of the manual „Numerical and Experimental methods in Reactors Physics" by some INR experts in experimental methods and in numerical methods used in the reactor physics, /5/. The novelty of this manual is the double ways approach of the reactor physics: both the experimental and theoretical maner.
Related with this manual, between 12 and 16 November 2007 in INR was organized the pilot module course on „Numerical and Experimental methods in Reactors Physics", /6/. This course was attended by 42 master students in nuclear area, from the Polytechnic University of Bucharest, University of Bucharest, and the University of Pitesti. The students were divided in 3 groups for a good involvement of everyone in the course deployment. The course was performed by the INR experts
The main goal of the course was to offer at the participants not only a theoretical course about the reactor physics, but also the opportunity to make some experiments and some neutronic calculations with transport codes. So, if in the first day was devoted to a theoretical introduction into the basic knowledge of reactor physics theory and a summary description of the experimental methods, in the next 4 days each students group performed experiments or neutronic calculations by codes based on transport methods. The experiments were dedicated to the neutronic measurements (mainly the work with the detectors) and electronic measurement chain. So, were presented the most used measurement and data acquisition methods. The transport calculations, based on deterministic transport codes, referred to macroscopic cross sections obtaining and neutronic parameters local and global calculations. At the end of the course, the students were tested and the results were evaluated.
The course was modularly structured in order to allow a rapid implementation in the next stage of the REFIN project i.e. the e-learning system. The general aim of the e-learning system is to offer a modern tool for education including long-distance education, especially continuous education for nuclear industry personnel and other nuclear organizations such as research, regulatory, agencies, etc.
The e-learning system is intended to introduce both theoretical aspects and application aspects, mainly based on computer code simulations. Of course, short stages in INR for using the experimental infrastructure and to enter in contact with the specific community of practice is needed.
The project, involving a great contribution of INR, should be extended with the participation of other research organizations and end-users in order to cover the diversity and the dynamics of nuclear power and nuclear applications in our country.
Also, the main results of developing the excellence network might attract all interested organizations in the Romanian nuclear field (both during and after the project) and thereby will permit its expansion to other areas related with the nuclear field.

4. Conclusions

(C1) The project REFIN have contributed to a real link of INR with Romanian universities and end-users interested in nuclear education. Starting with a general exploration of the present situation in Romania and in the Europe, the project has identified the needs for a modern nuclear education and the optimal allocation of resources by partnership and by knowledge transfer. An important activity consisted of the initiation of the modular course „Numerical and Experimental methods in Reactors Physics". Based on this, the INR and Polytechnic University of Bucharest have started to introduce the e-learning system for nuclear education.
(C2) INR has an important infrastructure and important human capabilities in order to help educational organization to improve the quality of their work. INR offers some experimental works, calculation methodologies, computer tools and more important a real community of practice in order to prepare the future personnell for nuclear organizations.
(C3) INR capabilities are able to harmonize the classical methosd and the 21st century educational methods for a better education in the nuclear field.

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UTILIZATION OF ICT-BASED TRAINING / LEARNING FOR CAPACITY BUILDING IN RESEARCH REACTOR UTILIZATION

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ABSTRACT

Research reactors are devices designed to initiate, control and sustain nuclear chain reactions at a steady rate. They serve primarily as a neutron source and are basically utilized for research and training, materials testing, production of isotopes in medicine and industry. They allow training to be given to students, physicists and engineer trainees in relevant fields.

ICT has made possible the development of e-learning and several Virtual Learning Environments (VLEs) which can support a wide range of capacity building requirements, ranging from under-graduate and post-graduate programmes, Continuing Professional Development (CPD) courses, right through to short subject-specific and research courses, thereby eliminating the problems of conventional forms of training / learning, some of which are: limited access, cost effectiveness and language / cultural barriers.

This paper focuses on the utilization of these ICT-based training / learning for capacity building in research reactor utilization and concludes with suggestions on implementation strategies.

1. Introduction

It is inevitable in this day and age to discuss capacity building in nuclear science and technology without making mention of research reactor utilization, with reference especially to the utilization of ICT-based training / learning for capacity building and manpower development.
This is because ICT has drastically changed the face of capacity building through training / learning, and has opened up quite a lot of opportunities and 'high-ways' for the delivery of knowledge and information at the speed of light.
It is therefore imperative to properly harness and exploit the potentials in ICT-based teaching / learning for capacity building in research reactor utilization.

2. Research Reactors

Nuclear reactors are devices designed to initiate, control and sustain nuclear chain reactions at a steady rate. They are designed to maintain a steady flow of neutrons generated by the fission of heavy nuclei.
Nuclear reactors are however, differentiated either by their purpose or by their design features. In terms of purpose, they are either research reactors or power reactors.
Research reactors are operated at universities and research centres in many countries, including some countries where no nuclear power reactors are operated.
For almost 60 years, research reactors have been centres of innovation and productivity for nuclear science and technology. To date, some 672 research reactors have been built, and of these, 274 reactors in 56 countries continue to operate. However, nearly two-thirds of the world's

operating research reactors are now over 30 years old. Many of them have been refurbished to meet today's technological standards and safety requirements. [1]

3. Research Reactor Utilization

Research reactors have a wide range of utilization including analysis and testing of materials, and production of radioisotopes. Their capabilities are applied in many fields, within the nuclear industry as well as in fusion research, environmental science, advanced materials development, drug design and nuclear medicine.
Practically speaking, a low-power research reactor allows training to be given to students and physicist, engineer trainees and operators in various areas and fields of nuclear science and technology, amongst which some of them are the following areas: nuclear radiation measurement and application such as activity, dose, half-life, and so on; reactor theory, neutron transport by using spectrometry, neutron chopping and so on; short-lived radioisotope production; studies of reactor characteristics; extracted beam (neutrons) utilization; instrumental neutron activity analysis (INAA); reactor kinetics and dynamics; reactor operation and control by using an associated computer to simulate the reactor operation and control; criticality and power increase; relative and absolute flux measurements; control rod calibration; poisoning effect measurement; void coefficient determination; temperature coefficient measurement; radioisotope determination; reactivity measurement; radiation protection and shields measurement.
Like power reactors, research reactors are covered by IAEA safety inspections and safeguards, because of their potential for making nuclear weapons. India's 1974 explosion was the result of plutonium production in a large, but internationally unsupervised, research reactor. [2]

4. ICT-Based Training / Learning

Information and communications technology (ICT) has transformed the means by which we inform ourselves, remain up to date with world events and areas of personal interest, and further our learning. For many, books and journals are no longer the first or primary source of information or learning. We now regularly rely on images, video, animations and sound to acquire information and to learn.

ICTs have fundamentally changed the way we learn and communicate. They have transformed the nature of capacity building – where and how training / learning takes place and the roles of students and tutors in the training / learning process.

4.1 Learning Platforms

A Learning Platform is software or a combination of software that sits on or is accessible from a network, and which supports training, teaching and learning for practitioners and learners.
Learning platforms offer one or more of:

- a place to store, find, access and use prepared materials;
- a platform on which to build and deliver learning activity;
- a common and consistent interface and way of working;
- secure and controlled (login) access for trainers and trainees to materials;
- a set of communications possibilities, ranging from transmission of static information (timetables, policies etc) and narrative (notes, videos), through to discussions, collaboration and exchange.

- tracking and monitoring of learners' activity, performance and progress and, if linked to other business and information systems within the organisation, the potential to become the heart of a full managed learning environment.
- some learning platforms offer an offline facility, whereby content can be downloaded onto a laptop for use in sites without access to the network, then automatically updated when reconnected to the system.

Above all, it is an important point to realise that learning platforms are **not** about the technology, and do not provide quick technological fixes. They are about using technology, **where appropriate** (research reactor utilization in this case), to enhance training and learning.

4.1.1 Virtual Learning Environments (VLEs)

A virtual learning environment (VLE) is a set of teaching and learning tools designed to enhance a trainee's / student's learning experience by including computers and the Internet in the learning process. It is a set of integrated Web-based tools that enable trainers / tutors to create and administer courses and allow trainees / learners to gain access to those courses A VLE will typically include most or all of the following features:

Content creation or upload tools:
There will be some mechanism to get materials into the VLE. Most will provide an upload facility so one can add files to the course that one has created elsewhere. In some cases the VLE will also provide an authoring tool allowing contents to be created; this authoring tool is likely to be more restrictive than a dedicated Web page authoring tool.

Course structure:
Having got the materials into the VLE, one can give them some structure within that module or course; the VLE will then provide a navigation toolbar to the learners so that they can view the learning materials in the intended order.

Navigation Structure:
Structured delivery of knowledge / information supported by a standard navigation toolbar. Most VLE software assumes that trainees / learners work their way through linear sequences of instructional material. Hence, in most cases, they allow only a linear navigation structure, but others can be much more flexible allowing for more complex structures. They can accommodate alternative knowledge / information structures, e.g. multi-path sequence navigation structures.

Communication tools:
These are tools such as email, discussion boards and chat rooms and can be used for exchanges between trainer / tutor and trainee / learner and between trainees / learner and trainees / learner. These communication tools can really add to the richness of the trainees' / learners' learning experience if used properly i.e. making sure that there is a clear purpose for which one is using them for. For example, if a discussion group is been made us of, the trainees / learners should have a specific topic to discuss.

Assessment tools:
VLEs can provide tools for assessment, both formative (self testing) and summative (assessed). Built in tools can be useful for keeping track of the trainees' / learners' progress and the VLE will record scores from these assessment activities.

Management tools:

These tools make it possible to set up user accounts and access levels. In most cases, the trainees' / learners' progress can be tracked through courses. Course marks can also be recorded here (even if the assessment did not occur online).

Delivery of learning resources and materials:
For example, through the provision of lecture notes and supporting materials, images and video clips, links to other resources, and so on.

Consistent and customizable look and feel:
In most cases, a standard user interface that is easy and friendly for trainees / students to understand and use. Courses can be individualized with colours, graphics and logs, but the essential mode of use remains constant.

Other tools:
There is a range of other tools your VLE may include. For example, a few VLEs include a tool that allows trainees / learners to add their own notes within the learning package. Some VLEs have a special area where learners can submit work where learners can view it and add comments about it.

4.1.2 Why use VLEs for capacity building (training/learning) in research reactor utilization?

VLEs can offer trainees / students and trainers / lecturers some support with flexible and widening access to materials and resources. This has particular advantages for trainees / students who are studying (under-graduate, post-graduate, continuing professional development courses, and short-specific subject courses) on a part-time basis. Engaging and motivating trainees / learners in research reactor utilization can also be a challenge. VLEs can help pull together up-to-date, interesting and interactive electronic resources as well as additional supporting materials. VLEs can open up opportunities for new ways of training / learning and communicating, and can support collaborative learning and independent learning. A VLE can help establish a community more quickly and 'integrate' trainees / students into the institution. However, the advantages of using VLEs need to be weighed against the disadvantages and these are summarized in Table 1.

ADVANTAGES	DISADVANTAGES
Easy online delivery of materials. VLEs provide a 'shell' for a course or programme, allowing one to: publish existing documents and presentations easily; link to online sources of data, news services, records and publications; link to online resources such as simulations and tutorials.	VLEs can become a 'dumping ground' for materials not designed to be delivered online. If materials are not integrated or linked in any way to face-to-face teaching, they may not be used properly, or at all. Issues of copyright and Intellectual Property Rights (IPR) of materials need to be considered.
They are easy to use for trainees / students and trainers / lecturers.	VLEs may be relatively easy to use, but generally the software is still in its infancy, with one having to bear in mind that standards are still emerging.
They widen trainee / student access on and off campus to learning materials and resources. Trainees / students should be able to access	On- and off-campus access to hardware, networks and printing facilities can be problematic for both students and lecturers,

these resources at any time, in any place.	and raises issues of equality. Disability legislation and accessibility to online materials also need to be considered.
They offer the potential of supporting large groups of trainees / students. Economies of scale can be gained, for example, by producing one set of online materials that can be used and updated each year, and assessing trainees / students online.	Populating a VLE with material and assessment questions is a front-loaded activity and requires considerable effort and time in the short run.
They offer new ways of training / learning and teaching, such as collaborative projects involving trainees / students at a distance. They can also support active and independent learning, where trainees / students are actively involved with studying ideas, solving problems and applying their training and what they've learnt.	Such independent learning still needs to be guided and supported. Appropriate training and ongoing support is still needed for both students and lecturers.
They offer flexible support for trainers / lecturers, who do not need to be in a fixed time or place to support and communicate with trainees / students.	Lecturers need to plan online support carefully to avoid overload.

Table 1: Advantages and disadvantages of using VLEs for capacity building (training / learning) in research reactor utilization

5. Conclusion / Suggestions:

In conclusion, it is worthwhile to know that ICT-based training / learning can support a wide range of capacity building requirements for research reactor utilization, ranging from under-graduate and post-graduate programmes, Continuing Professional Development (CPD) courses, right through to short subject-specific and research courses, thereby eliminating the problems of conventional forms of training / learning, some of which are: limited access, cost effectiveness and language / cultural barriers.

However, putting into consideration the peculiarity of the developing nations, where there is limited access to the internet and wide/convenient bandwidth, traditional storage media, which are also known as CD or DVD ROMs can be made use of in transferring the knowledge, training and expertise required for capacity building in research reactor utilization in form of software (for example, a research reactor utilization software), which will encapsulate the fundamentals and a wide range of capacity building requirements for research reactor utilization.

6. References / further resources

[1] http://www-naweb.iaea.org/napc/physics/ACTIVITIES/Foreword.htm

[2] http://www.uic.com.au/nip66.htm

Calculation of the neutron flux, fuel and moderator temperature transients for Research Reactors

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ABSTRACT

When withdrawing or inserting control rods in the core of a research reactor generally only the end values of the resulting neutron flux is calculated. This code offers a possibility to - in advance - depicture the whole course of the changes of the neutron flux, the fuel temperature and the moderator temperature. Used are the reactor kinetics equations with six delayed neutron groups, the fuel and moderator thermal dynamics equations, first in the form of Laplace transform with simple time delays and than as first degree differential equations. This set of nine differential equations coupled together is solved numerically.

1. Introduction

The classical reactor kinetic equations with six groups of delayed neutrons (point kinetics) are not solved analytically. In the presented program the fuel and the moderator thermal dynamic equations are coupled to the reactor kinetic equations. The equation system is solved numerically. This short program is suitable to be used by nuclear engineering students when practicing at research reactors. The parameters to be used are of course depending on the reactor design.

2. The simplified neutron kinetics equations

are

$$\frac{dN}{dt} = \frac{\delta k - \beta}{l} N + \sum_{i=1}^{6} \lambda_i c_i \qquad \frac{dc_i}{dt} = \frac{\beta_i}{l} N - \lambda_i c_i$$

Here

t	time (sec)
N	neutron flux (proportional to the reactor power)
δk	change of the effective neutron multiplication factor (k_{eff})
β	sum of the delayed neutron fractions (here 0.006502)
β_i	the i:th delayed neutron fraction
l	neutron mean lifetime (here 0.001 sec)
λ_i	i:th decay constant (sec^{-1})
c_i	concentration of the i:th fraction of the delayed neutrons' precursors,

At steady state, when time is zero t=0 all time derivatives are equal to zero, all d/dt=0 and the initial value of the relative power equals unity N(0)=1, and also no reactivity perturbation is present δk =0

$$N(0)=1 \quad \frac{dN}{dt} = 0 \quad \delta k = 0 \quad \sum_{i=1}^{6} \lambda_i c_i = \frac{\beta}{l} \quad \frac{dc_i}{dt} = 0 \quad c_i(0) = \frac{\beta_i}{l\,\lambda_i}$$

Table 1: Delayed neutron data for thermal fission in U^{235} is used

Group	1	2	3	4	5	6
Fraction β_i	0.000215	0.001424	0.001274	0.002568	0.000748	0.000273
Decay constant λ_i	0.0124	0.0305	0.111	0.301	1.14	3.01

Table 2: The initial values of the delayed neutrons' precursors are;

i	1	2	3	4	5	6
$c_i(0)$	17.3387	46.6885	11.4775	8.5316	0.6561	0.0907

Using the MATLAB notations; x(1)=N x(2)=c_1 ………… x(7)=c_6

3. Fuel

The fuel temperature change (T_{Fuel}) follows after the power with a time delay (τ_{Fuel})

$$T_{Fuel} = \frac{c_{NF} N}{1 + p\tau_{\mathrm{Fuel}}}$$

T_{Fuel} Fuel temperature change

N Relative neutron flux proportional to the relative power

c_{FN} fuel temperature proportionality constant to relative power

p Laplace operator d/dt, 1/sec

τ_{Fuel} thermal time constant of the fuel, here 5 sec

t time, sec

The differential equation form is

$$T_{Fuel} + \tau_{Fuel} \frac{dT_{Fuel}}{dt} = c_{NF} N \quad ; \quad \frac{dT_{Fuel}}{dt} = \frac{c_{NF}}{\tau_{Fuel}} N - \frac{1}{\tau_{Fuel}} T_{Fuel}$$

At steady state (equilibrium) d/dt=0 N(0)=1

Suppose that at zero power the fuel temperature changes by 0.001 ^{0}C when N=1 and thereby c_{NF}=0.001

Suppose τ_{Fuel} =5 sec $\quad \dfrac{1}{\tau_{Fuel}}$ =0.2 $\quad \dfrac{c_{NF}}{\tau_{Fuel}}$ =0.0002^{0}C/sec

With the MATLAB notation x(8) = T_{Fuel}

and the neutron kinetics equations can be expanded to include the fuel dynamics

0.0002*x(1)-0.2*x(8)

3.1 The Doppler reactivity of the fuel is

$$\delta k_{Fuel} = k_{Fuel}(T_{Fuel} - T_{Fuel}(0))$$

Here

δk_{Fuel} the reactivity contribution of the fuel temperature change, at the initial phase (t=0), at steady state (equilibrium) is zero $\delta k(0)_{Fuel} = 0$

k_{Fuel} Fuel temperature coefficient (Doppler coefficient) here is -3.1pcm/^{0}C

The reactivity of the Fuel's Doppler effect is

$\delta k_{Fuel} = k_{Fuel} \cdot (T_{Fuel} - T(0)_{Fuel}) = -3.1 \cdot 10^{-5} \cdot (T_{Fuel} - 0.001)$

with MATLAB notation; DeltaKfuel = – 3.1·10^{-5}*x(8) + 0.0031·10^{-5}

4. Moderator

The differential equation for the moderator is similar to that of the fuel, when the moderator thermal time constant is much bigger then the fuel thermal time constant $\tau_{Moderator} >> \tau$

$$T_{Moderator} + \tau_{Moderator} \frac{dT_{Moderator}}{dt} = c_{NM} N$$

$$\frac{dT_{Moderator}}{dt} = \frac{c_{NM}}{\tau_{Moderator}} N - \frac{1}{\tau_{Moderator}} T_{Moderator}$$

$T_{Moderator}$ Moderator temperature change

$\tau_{Moderator}$ Moderator thermal time constant, here 100 sec

c_{NM} Moderator temperature proportionality constant to the relative power, suppose that at zero power operation the moderator temperature change is only 0.0005 ^{0}C when the relative power N=1. Then c_{NM}=0.0005

Suppose $\tau_{Moderator}$ =100sec $\frac{1}{\tau_{Moderator}}$ =0.01/sec $\frac{c_{NM}}{\tau_{Moderator}}$ = 0.0005·0.01 ^{0}C/sec = 0.000005

With the MATLAB notation x(9) = $T_{Moderatorl}$; and the neutron kinetics equations can be expanded to include the moderator dynamics too; 0.000005*x(1)-0.01*x(9)

4.1 Moderator reactivity contribution from temperature change

$$\delta k_{Moderator} = k_{Moderator} (T_{Moderator} - T(0)_{Moderator})$$

Here

$\delta k_{Moderator}$ the reactivity contribution of the moderator temperature change at the initial phase (t=0), at steady state (equilibrium) is zero $\delta k(0)_{Moderator} = 0$

$k_{Moderator}$ Moderator temperature coefficient here is - 0.6pcm/^{0}C

The reactivity contribution from the changing moderator temperature is

$$\delta k_{Moderator} = k_{Moderator} \cdot (T_{Moderator} - T(0)_{Moderator}) = -0.6 \cdot 10^{-5} \cdot (T_{Moderator} - 0.0005)$$

with MATLAB notation; DeltaKmoderator=-0.6·10^{-5}*x(9)+0.0003·10^{-5}

5. Control Rods

δk_{CR} the reactivity contribution of the control rods' movement are here with two different maximum values; 50 pcm respectively 60 pcm
The movements of the rods and the corresponding reactivity changes are given in Figure 1

5.1 The reactivity balance with the control rods, the fuel's Doppler effect and the moderator's temperature effect

$$\delta k = \delta k_{CR} + \delta k_{Fuel} + \delta k_{Moderator}$$

The reactivity balance with MATLAB notation;
DeltaK = DeltaKcr + DeltaKfuel + DeltaKmoderator

6. Results of the Computation

In Figure 1 there is the schematic of the control rod reactivity used in the calculations
In Figure 2 the calculated relative neutron flux is displayed
In Figure 3 there are the characteristics of the fuel and moderator temperature increase. The values are very small as here the calculations are performed for zero power operation when practically no power is generated in the fuel and transferred into the moderator. However the curves clearly demonstrate that the fuel's thermal time constant is much smaller than that of the moderator's

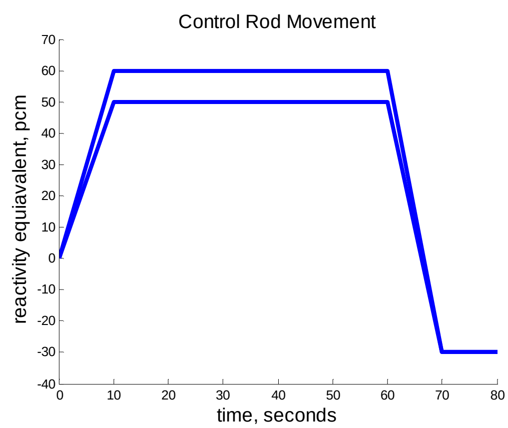

Figure 1, Schematic of the control rod reactivity

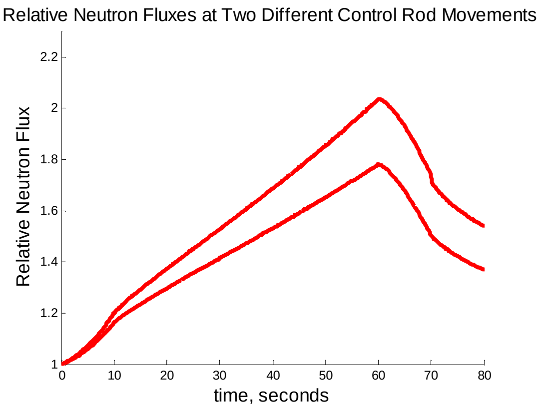

Figure 2, Relative neutron flux

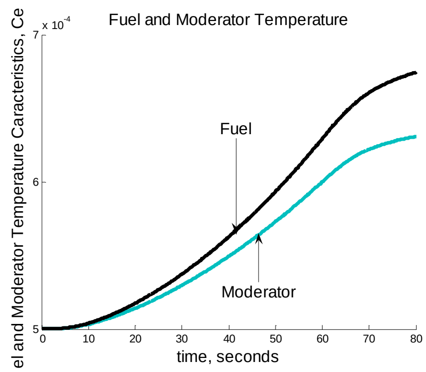

Figure 3, Characteristics of the fuel and moderator temperature increase

7. The Code

contains two parts

Part one

```
%Save as  xprim9FM.m

function xprim = xprim9FM(t,x,i)

DeltaKcr=i*10^-5;
DeltaKfuel=-3.1*10^-5*x(8)+0.0031*10^-5;
if t>=0 & t<10
    DeltaKcr=((i*10^-5)/10)*t;
end
if t>60 & t<70
DeltaKcr=(10^-5)*(i-8*(t-60));
end
if t>70
    DeltaKcr=-30*(10^-5);
end
DeltaKmoderator=-0.6*10^-5*x(9)+0.0003*10^-5;
DeltaK=DeltaKcr+DeltaKfuel+DeltaKmoderator;
xprim=[(DeltaK/0.001-
6.502)*x(1)+0.0124*x(2)+0.0305*x(3)+0.111*x(4)+0.301*x(5)+1.14*x(6)+3.01*x(
7);
0.21500*x(1)-0.0124*x(2);
1.424000*x(1)-0.0305*x(3);
1.274000*x(1)-0.1110*x(4);
2.568000*x(1)-0.3010*x(5);
```

```
0.748000*x(1)-1.1400*x(6);
0.273000*x(1)-3.0100*x(7);
0.000200*x(1)-0.2000*x(8);
0.000005*x(1)-0.0100*x(9)];
```

Part two

```
%Save as ReaktorKinFM.m

a=50;
b=10;
c=60;

figure
hold on
for i=a:b:c %i is the max Control Rod reactivity i pcm
[t,x]=ode45(@xprim9FM,[0 80],[1; 17.3387; 46.6885; 11.4775; 8.5316; 0.6561;
0.0907;0.001; 0.0005],[] ,i);
 plot(t,x(:,8))
 end
hold off

figure
hold on
for i=a:b:c %i is the max Control Rod reactivity i pcm
[t,x]=ode45(@xprim9FM,[0 80],[1; 17.3387; 46.6885; 11.4775; 8.5316; 0.6561;
0.0907;0.001; 0.0005],[] ,i);
 plot(t,x(:,9))
 end
hold off

figure
hold on
for i=a:b:c %i is the max Control Rod reactivity i pcm
[t,x]=ode45(@xprim9FM,[0 80],[1; 17.3387; 46.6885; 11.4775; 8.5316; 0.6561;
0.0907;0.001; 0.0005],[] ,i);
 plot(t,x(:,1))
 end
hold off

figure
hold on
for i=a:b:c
x=[0,10,60,70,80];
y=[0,i,i,-30,-30];
plot(x,y)
end
hold off
```

8. References

University textbooks on nuclear engineering, thermal dynamics and control engineering contain the applied equations. Textbooks on information technology and numerical analyses contain the applied method used to solve the differential equations..

INNOVATIVE APPROACH TO SIMULATE A RADIOACTIVE PLUME FOR TRAINING

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ABSTRACT

A new approach to simulate a radioactive plume was developed. The simulator is designed for Vehicle Monitoring System (VMS) training. It consists of a base station and several monitoring vehicles connected via limited band-pass cellular communication network. The simulator meets requirements such as running in real time with limited computer resources and generating well estimated radiation field. The simulator enables to generate time-depending plumes and simulate contamination fields generated on different weather stability and wind properties.

A function based on the Pasquill[1] Gaussian dispersion model has been adopted and expanded in order to simulate a plume generated by a wind characterized by altering direction and speed.

A simple, non-iterative mathematical algorithm to generate the simulator contamination field is presented in this work. The algorithm generates the plume according to parameters such as: sampling and eruption location, wind velocity, weather stability, time and eruption rate.

1. Introduction

A VMS has been lately developed by the NRCN Electronics Laboratories. The system, designed for radioactive radiation fields mapping, consists of a base station and a dozen monitoring vehicles, connected via cellular communication network. In order to enable operators' training, the VMS was designed with a special training mode. In this mode, the radiation field data received from the simulation software instead of the VMS radiation monitors. The parameters for this simulation software are received from the base station. This work presents an innovative simulation approach that enables to meet the requirements for the mentioned kind of system.

2. Discussion

A simulator for radioactive contamination field, used as a part of training system for the VMS operating teams, has to meet special requirements. Dispersion of radioactive material can occur in different locations, different types of weather stability and different static or dynamic wind parameters such as speed and direction. The new VMS adds additional limitations. All vehicles together with the base unit should operate at the same time. The trainer should be able to control all the above parameters in real time and transmit the data to all the stations via limited band pass cellular communication channel which is used to connect the stations. The computer resources designated for the simulator are limited; this means that a simple algorithm is needed to generate the field value at any vehicle location. Air pollution models are expected to simulate radioactive contamination dispersion and provide a realistic plume shape.

2.1. Air pollution dispersion models

A "box model" assumes that the contamination dispersion is in a box shape volume and that the contamination inside the box is homogeneously distributed. This model cannot be applied because the generated plume does not have a realistic shape which is needed to provide the trainee the necessary realistic contamination field feeling.

The "Particles Following" (PF) models are more efficient for estimating the plume shape. These models mathematically follow the trajectories of particles which are continually generated in large numbers by the simulation software. Particles course is simulated according to weather parameters, wind speed and wind direction. Lagrangian and Eulerian are examples for PF models. An example of particles distribution is demonstrated in figure 1.

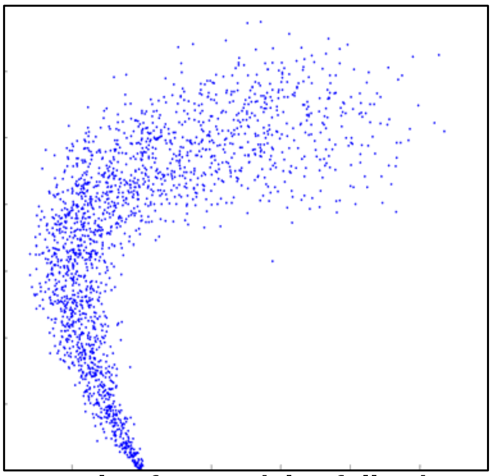

Figure 1: Example of a "particles following" models

Although the PF models generate a nice plume shape, they cannot be applied for the VMS simulation because of the limited computer resources available to implement the iterative function used to generate the plume.

The oldest and perhaps the most commonly used model type is the "Gaussian Model" (GM). This model states that the contamination perpendicular to the plume centerline has a normal probability distribution. Pasquill[1] model is an example to the GM. The basic function states that the contamination density C on [x,y,z] equals to:

(1) $$C(x,y,z)=\frac{Q}{2\pi\sigma_{y(x)}\sigma_{z(x)}u}Exp\left[-\frac{y^2}{2\sigma_{y(x)}{}^2}\right]\cdot\left\{Exp\left[-\frac{(z-H)^2}{2\sigma_{z(x)}{}^2}\right]+Exp\left[-\frac{(z+H)^2}{2\sigma_{z(x)}{}^2}\right]\right\}$$

Where:

Q – Contamination rate

U – Wind speed

$\sigma_{y(x)}$ – Y axis standard deviation (a function of the weather stability and location on X axis)

$\sigma_{z(x)}$ – Z axis standard deviation (a function of the weather stability and X location)

For $\sigma_{z(x)} << H$ the ground effect is negligible leaving a 2D Gaussian function.

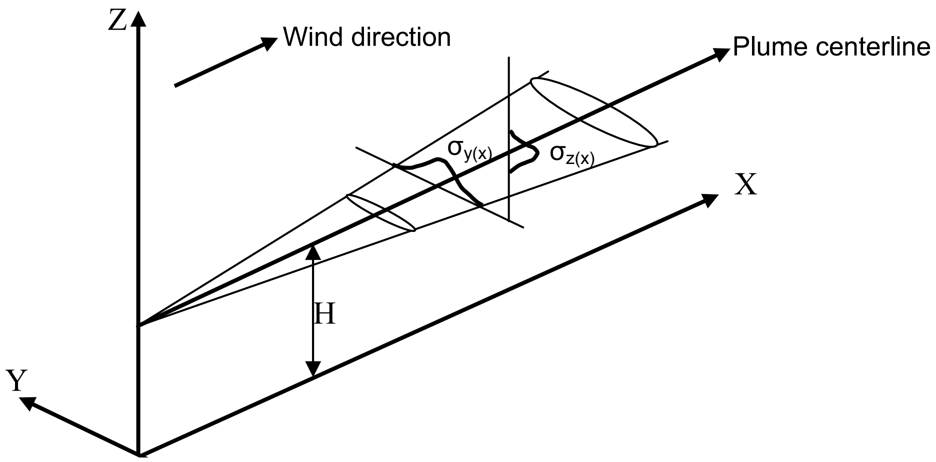

Figure 2: Plume simulation based on Gaussian dispersion model

The Gaussian Model meets most of the VMS simulator requirements. The model is based on a simple non iterative mathematical function that can be calculated using minimum computer resources; the trainer can control the function parameters in real time and transmit them via cellular channel. The model can simulate different types of weather stability and can give the trainee a realistic feeling of contamination field. The main disadvantage of the Gaussian

Model is that it cannot simulate a plume generated by a variable wind which changes its direction and speed in time.

3. Expanding the Gaussian Model

An expansion to the Gaussian model is suggested, to meet the VMS simulator requirements. The new model can simulate a plume generated by a wind with changing parameters, and keep the principle according to which the Gaussian distribution is perpendicular to the plume centerline.

A transformation to the XY plane is applied, so that instead of changing the plume state function, the plane is distorted. The assumption is that the wind direction changes linearly in time. The centerlines of contamination plumes are shown on figure 3. The figure demonstrates a 100 sec. eruption time at 1 m/s constant wind speed. These parameters generate a straight 100 meter plume centerline towards the wind course (figure 3a). In figure 3b wind direction is changed from the west at t=0 sec, to the south at t=100 sec, generating an arc shaped plume centerline. The constrains are the arc length and the angles. The free parameters are radius and circle center location.

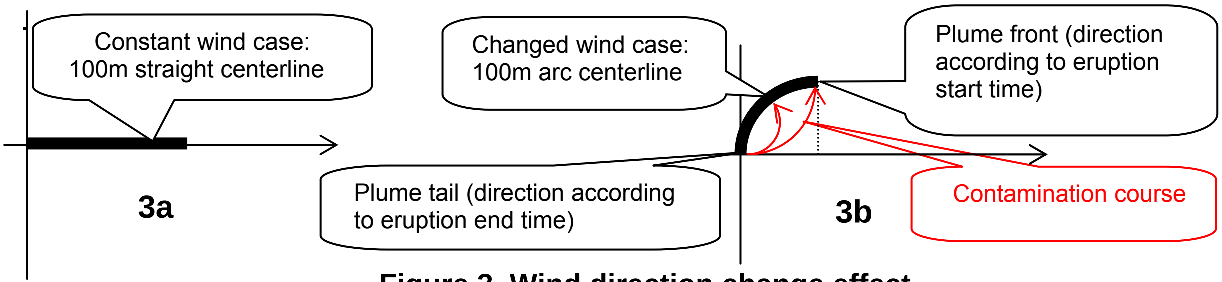

Figure 3. Wind direction change effect

Figure 4 shows a 120-degree (1/3 π) change in wind direction.

Where:

- z – Angle change [rad]
- $\alpha = \pi - z$
- L – Plume length [m]
- $R = L/z$
- $X = R \cdot \sin(\alpha)$
- $Y = R \cdot \cos(\alpha)$

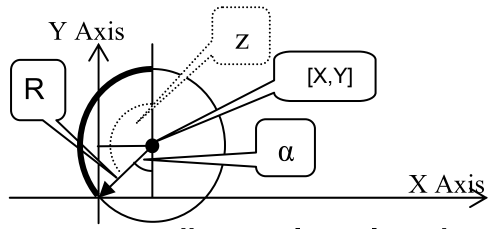

Figure 4: Arc parameters according to plume length and wind direction

For constant wind speed and effective plume width smaller than R ($R >> \sigma_y(x)$), it can be assumed that contamination intensity behaves as the Gaussian model. The intensity value is changed as a function of the distance from the plume axis. Hence, the distance between [x,y] point and X axis (plume axis without wind direction change) is transformed to the same distance between [x',y'] and the arc (wind direction change). The Gaussian distribution contamination that was perpendicular to the X axis is transformed to be perpendicular to the arc, at any point.

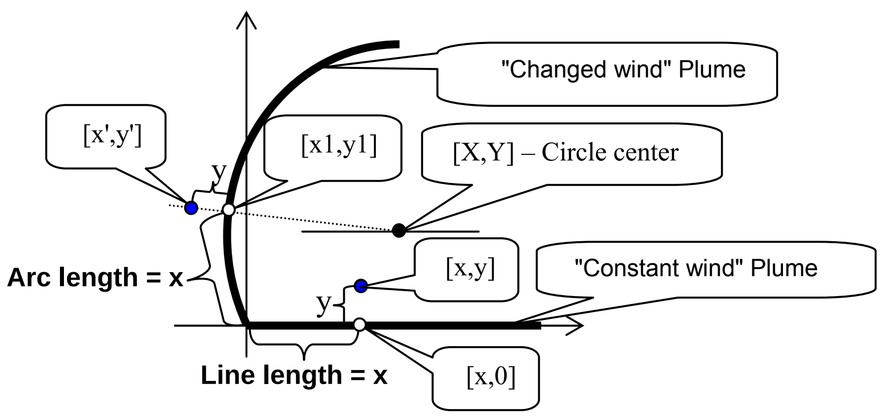

Figure 5. Gaussian distribution perpendicular to the plume center line

Figure 5 shows transformation of a point [x,0] on the X axis to [x1,y1] on the arc:

(2) $x1 = L/z(1 - Cos(x/L \cdot z - z + \pi/2)) - L/z \cdot (1 - Cos(z - \pi/2))$

(3) $y1 = L/z \cdot Sin(x/L \cdot z - z + \pi/2) + L/z \cdot Sin(z - \pi/2)$

The arbitrary [x,y] point transforms to [x',y']:

(4) $[x', y'] = [x1 - y \cdot Cos(\pi/2 - z \cdot (1 - x/L)), y1 + y \cdot Sin(\pi/2 + z \cdot (1 - x/L))]$

The result of the above is an algorithm to transfer any point [x,y] from a constant wind case to a new [x',y'] location on a changed wind case determined by the wind parameters.

(5)

$$[x, y] \Rightarrow \begin{matrix} [L/z(1 - Cos(x/L \cdot z - z + \pi/2)) - L/2(1 - Cos(z - \pi/2)) - y \cdot Cos(\pi/2 - z \cdot 1 - x/L)) \\ ,\ L/z \cdot Sin(x/L \cdot z - z + \pi/2) + L/z \cdot Sin(z - \pi/2) + y \cdot Sin(\pi/2 + z \cdot (1 - x/L))] \end{matrix}$$

4. Reverse Transform

In order to apply the above transformation to the VMS simulator, an inverse algorithm is required to obtain a contamination field value at any location [x',y'] on the transformed plane. The field value at [x',y'] (see figure 5) is calculated by finding the corresponding [x, y] point and placing it in the original contamination density function (at the pre-transformed plane). The algorithm includes five steps:

- Calculate the circle parameters, R,X and Y, based on the plume parameters L and z
- Find y - the distance between the circle and the field point [x',y']
- Find x – the arc length from origin to [x1,y1]
- Insert [x,y] value into the 2D distribution function to obtain the contamination field value
- Calculate the radiation field value based on the contamination density

<u>**Step 1 -** Calculate the circle parameters</u>

(6) $R = L/z$

(7) $Cos(\pi - z) = Y/R \Rightarrow Y = R \cdot Cos(\pi - z)$

(8) $Sin(\pi - z) = X/R \Rightarrow X = R \cdot Sin(\pi - z)$

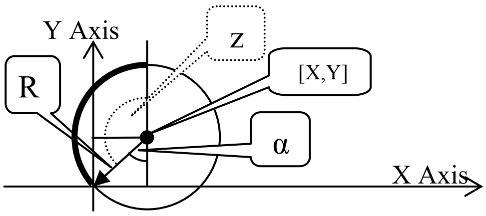

Figure 6. Circle parameters

<u>**Step 2 –** Calculate y - the distance between the circle and point [x',y']</u>

(9) $Cos(\alpha) = \dfrac{X - x'}{\sqrt{(X - x')^2 + (Y - y')^2}}$

(10) $x1 = R \cdot Cos(\alpha) + X$

(11) $a = \dfrac{y' - Y}{x' - X}, \qquad b = Y - a \cdot X$

(12) $y1 = a \cdot x1 + b$

(13) $y = \sqrt{(x' - x1)^2 + (y' - y1)^2}$

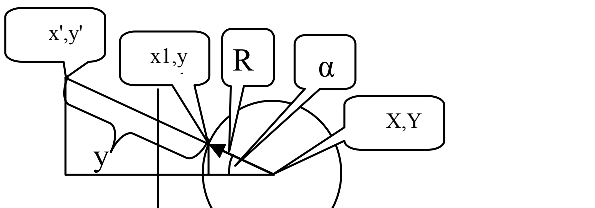

Figure 7. Calculate the value of y

<u>**Step 3 -** Calculate x - the arc length</u>

The ratio between the arc length and the circle perimeter (2πR) is identical to the ratio between the angle corresponding to the arc and 2π. It is easier to find the dotted arc length-**d** (figure 8) that complements the arc length to L.

(14) $$Cos\,(\beta) = \frac{y1 - Y}{\sqrt{(x1 - X)^2 + (y1 - Y)^2}}$$

(15) $$\beta = Cos^{-1}(Cos(\beta))$$

(16) $$d = \beta \cdot R$$

(17) $$x = L - d$$

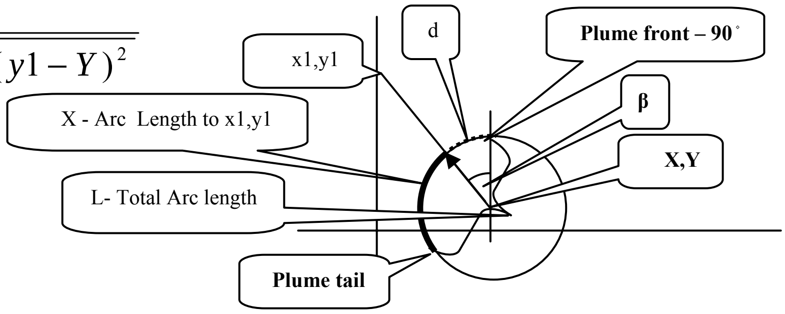

Figure 8. Calculating the x value

__**Step 4 -** Calculate the contamination field__

Placing $\sigma_y(x)$ and y on the 2D field function gives the required contamination value:

(18) $$F = C \cdot \frac{1}{\sigma_{y(x)} \cdot \sqrt{2\pi}} e^{-\left(\frac{y^2}{2\sigma_{y(x)}{}^2}\right)}$$

__**Step 5 -** Calculate the radiation field__

At any arbitrary point, the whole plume contributes to the radiation field. In a first order approximation, radiation field is proportional to a point source as $1/R^2$. Summing the radiation contribution from the proximity surrounding area to any point is satisfying for the training requirements.

5. Add speed change to the wind

When the wind continually changes its velocity and direction, the plume centerline shape changes to an arc with a radius that changes its length and origin (figure 9a,b and c). A reverse transform to this shape of plume is more complicated. For the VMS simulator, intermittent arc intervals with different radiuses are satisfying (Figure 9d).

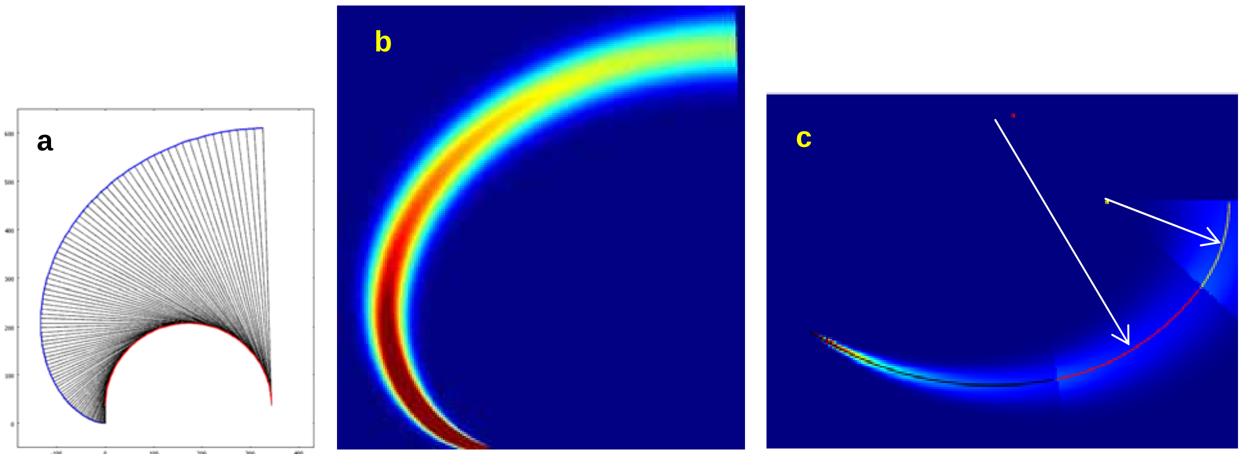

Figure 9 – Plume centerline generated from a wind that changes velocity and direction

6. Conclusion

A simple algorithm simulating a radioactive plume for training is presented. The algorithm uses small amount of computer resources that can be easily implemented on a standard mobile PC or microcontroller, to run in real time. The algorithm requires few parameters that can be easily spread through a limited band pass communication network. The plume dynamics is based on the Pasquill Gaussian atmospheric diffusion and is suitable to any weather stability class. The Pasquill model was expanded to be implemented in case of wind direction change.

7. Reference

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NUCLEAR TRAINING OPPORTUNITIES AT THE NEUTRON DATA MEASUREMENT FACILITIES OF THE JOINT RESEARCH CENTRE

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ABSTRACT

The Institute for Reference Materials and Measurements (IRMM) of the European Joint Research Centre (JRC) is equipped with a unique scientific infrastructure for highly accurate neutron cross-section measurements. It is a combination of a 150 MeV linear electron accelerator with neutron time-of-flight facility and a 7 MV light-ion Van de Graaff accelerator. The complementary research capabilities offered at the two accelerators create excellent opportunities for training. The institute hosts a number of PhD and post-doctoral fellows, visiting scientists and trainees every year. To respond to demands from the educational world the institute organises several hands-on training courses at university level. These regular training courses have the objective to initiate graduate or post-graduate students into the nuclear data field via exciting experiments at the appropriate level. This paper describes the neutron data facilities and nuclear training activities more in detail.

1. Introduction

The Institute for Reference Materials and Measurements (IRMM) in Geel, Belgium, operates two particle accelerator facilities: a 150 MeV linear electron accelerator (GELINA) with a high-resolution neutron time-of-flight (TOF) facility and a 7 MV light-ion Van de Graaff (VdG) facility used for the production of quasi-monoenergetic neutron fields. This research equipment is specially designed for the measurement of highly accurate neutron cross-section data. Measurements at these facilities provide data which form the basis for a wide range of evaluated neutron cross section data.

The development and improvement of a comprehensive neutron cross section database is essential for many areas of nuclear research and technology. For nuclear power production, neutron-induced reactions are definitely the most important interactions. Many reaction channels may occur in numerous isotopes. A precise knowledge of neutron cross sections, over a broad energy range, is of a great importance for a proper account of reaction rates and detailed neutron flux distributions in many nuclear applications [1]. Neutron cross sections are vital when evaluating the safety and risks related to the operation of nuclear power plants and to nuclear waste management. There is an increasing demand on the accuracy of the data for assessing criticality safety aspects and designing fuels for very high burn-up. Also the development of novel systems like accelerator-driven transmutation systems or new concepts for nuclear power production, as defined by the Generation IV International Forum (GIF), rely on accurate neutron cross section data [2].

The areas mentioned above demand for accurate high-resolution neutron data in the energy interval from thermal neutron energy up to the MeV-range. The neutron cross sections show resonance-type energy dependence in part of this energy domain. The resonance structure, which differs from isotope to isotope, cannot be calculated by theoretical models. Therefore, experiments with high energy resolution are required to resolve the resonance structure.

The energy domain of interest can be subdivided into two regions:

- resolved resonance region: to reveal the complicated cross-section resonance structure the extremely good energy resolution of a dedicated time-of-flight (TOF) facility as GELINA is required.
- unresolved resonance region and above: here the measured widths of the resonances are larger than the resonance spacing so that the resonances appear to be overlapping. In the energy domain of overlapping resonances and above, mono-energetic neutron beams, as produced with a Van de Graaff facility, are used.

Thanks to the combination of the GELINA white neutron TOF facility and the quasi mono-energetic neutron source at the VdG, the IRMM facilities cover the whole energy range from a few meV to about 24 MeV. As a result of this combination IRMM is one of the few laboratories in the world which is capable of producing the required accuracy of neutron data in the energy domains defined above. The extending of neutron cross section data and reducing the uncertainties will result in enhanced safety and efficiency of the present and future nuclear power systems. The neutron data measurement activities of IRMM fulfil one of the mandates of the EURATOM treaty, and follow the demands of nuclear industry and research laboratories for complete and evaluated data files on neutron induced nuclear reactions. Measurements carried out at GELINA and the Van de Graaff play a major role in establishing and improving the evaluated nuclear data file maintained at the OECD-NEA databank.

Attracting young people and passing on the best practices and experience is essential in this area. The complementary research capabilities offered at the two accelerators create excellent opportunities for training. The institute hosts a number of PhD and post-doctoral fellows, visiting scientists and trainees every year. To respond to several demands from the educational world the institute organises also hands-on training courses at university level. This paper describes the neutron data facilities and nuclear training activities more in detail.

2. Neutron Data measurement facilities

2.1 GELINA

The Geel Electron Linear Accelerator GELINA [3] is a white neutron source, where the TOF method is used to determine the energy of the interacting neutrons in the energy range covering 11 decades (1 meV – 20 MeV). Among the pulsed white spectrum neutron sources available in the world, GELINA is the one with the best time resolution. The resulting excellent neutron energy resolution is made possible by a combination of four specially designed and distinct units: a high-power pulsed linear electron accelerator, a post-accelerating beam compression magnet system, a mercury-cooled uranium target, and very long flight paths.

The GELINA neutron source is based on a linear electron accelerator producing electron beams with a typical beam operation mode characterised by 100 MeV average energy, 10 ns pulse length, 800 Hz repetition rate, 12 A peak and 100 μA average current. Using a unique post-acceleration pulse compression system, the electron pulse width can be reduced to approximately 1 ns (FWHM) while preserving the current, resulting in a peak current of 120 A. The accelerated electrons produce Bremsstrahlung in an uranium target which in turn, by photonuclear reactions, produces neutrons. Within a 1 ns pulse a peak neutron production of 4.3×10^{10} neutrons is achieved (average flux of 3.4×10^{13} neutrons/s).

The neutron energy distribution ranges from subthermal to about 20 MeV, with a peak at 1-2 MeV. In order to have a significant number of neutrons in the energy range below 100 keV, a hydrogen-rich moderator is added. The energy distribution of the partially moderated neutrons has approximate 1/E energy dependence plus a Maxwellian peak at thermal energy. By using collimators and shadow bars moderated or unmoderated neutron beams are selected. Further tailoring of the spectral shape is obtained with filters.

Fig.1. Aerial view of the GELINA time-of-flight facility

An aerial view of the GELINA facility is shown in figure 1. GELINA is a multi-user facility serving twelve completely independent flight paths and accordingly up to twelve different experiments can be carried out simultaneously. The up to 400 m long flight paths, which point radially to the uranium target, lead to experimental stations at distances of 10, 30, 50, 60, 100, 200, 300 and 400m. These experimental stations are equipped with a wide variety of sophisticated detectors, and data acquisition and analysis systems, especially designed for neutron-induced cross-section measurements with an exceptional precision and energy resolving power. Modern detection techniques such as advanced HPGe Compton-suppressed detectors and data acquisition systems based on fast signal digitisers are in use. The facility is operated in shift work on a 24-hours/day basis, for about 100 hours per week.

2.2 Van de Graaff facility

At the Van de Graaff (VdG) facility of IRMM quasi mono-energetic beams of neutrons are produced in the energy range up to 24 MeV [4]. Especially in the MeV neutron energy domain where the resonance structure of the cross-sections is averaged out, the high-resolution measurements at GELINA can be complemented by measurements at the VdG, where the experimental conditions are more favourable for weak cross sections and low sample quantities.

The Van de Graaff facility, shown in figure 2, is a 7 MV electrostatic accelerator for the production of continuous and pulsed proton-, deuteron- and helium ion beams. Ion beams can be produced with a current of up to 60 μA on target in DC mode and up to 5 μA in pulsed mode. The pulse repetition rates are 2.5, 1.25 or 0.625 MHz and the ion pulselengths are 2.50-1.25 ns FWHM depending on the ion energy. The energy of the mono-energetic neutrons is defined by using lithium, deuterium or tritium targets and choosing appropriate emission angles. Depending on the neutron energy up to 10^8 neutrons/s can be obtained.

At the VdG six beam lines with dedicated experimental set-ups for activation, fission and scattering experiments are attached to the accelerator. In contrast to GELINA, here, only one set-up can be used at a time. The facility is operated continuously for weeks without degraded performance.

Fig. 2. Van de Graaff accelerator

3. Nuclear training at the neutron data facilities

Within the seventh European Framework Programme (2007-2013), it is the objective of JRC to reinforce in the nuclear field its collaboration with the universities. Because JRC is a research centre, it is not its objective to play the role of a university. It will merely provide a contribution wherever its unique research facilities and in-field expertise can be an asset for university students. The working programme at the IRMM accelerator facilities is focussing on nuclear data for (1) nuclear waste transmutation, (2) innovative reactor systems, (3) basic research in nuclear physics and (4) nuclear standards. This forms an ideal background for the organisation of training activities at graduate and post-graduate level. It is the goal to attract young people, initiate them to the nuclear data domain and its technological context, to give them first working experience in a nuclear research environment and to transmit knowledge and best practices. The educational activities around the IRMM accelerator facilities can be subdivided in three major categories: (1) academic courses, (2) education of students as trainees and (3) training of PhD students and post-doctoral fellows.

To respond to several demands from the educational world the institute organises hands-on experimental training courses at university level. One course is organised within the framework of the Master of Science in Nuclear Engineering program of BNEN (Belgian Nuclear Education Network) [5]. This course is also recognised as an elective course in the ENEN programme [6] (2 ECTS points in the European Credit Transfer System) [7]. There are typically 10 students per course. Another course is part of the SPERANSA programme (Stimulation of Practical Expertise in Radiological and Nuclear Safety) of the CHERNE (European Collaboration for Higher Education and Research in Nuclear Engineering and Radiological Protection) network [8]. SPERANSA is a bi-annual ERASMUS intensive programme (IP) project for students of 6 European nuclear engineering institutions. For the SPERANSA courses there are typically 35 participating students. The following topics are covered during these two-days training courses: physics aspects of neutron cross-section measurements; neutron data for nuclear waste transmutation and design of advanced reactor systems and fuel cycles; data analysis techniques; physics of accelerators; safety aspects; radiation dosimetry. The experimental training part concentrates on time-of-flight neutron cross-section measurements and on neutron fluence spectrometry. A one week Summer School on Neutron Resonance Analysis, at a post-graduate level, will be organised in June 2008 [9]. This course is supported by the OECD/NEA and the Nuclear Data Section of the IAEA. Other courses are under discussion.

The JRC traineeship scheme opens a second channel of educational activities for graduate and post-graduate students. Traineeships in cross-section measurements and nuclear data research are offered at the accelerator facilities for graduate students preparing their thesis or for post-graduate students aiming at their first working experience in the nuclear field. There are two calls for traineeships per year. All trainees receive a standard living allowance. Details can be found in [10]. The duration of a traineeship at IRMM ranges typically from two to six months.

The neutron data facilities host also a number of PhD and post-doctoral fellows. PhD students and post-doctoral fellows work at IRMM during several years either with internal JRC grants [11] or with externally funded grants. It should be noted that JRC is hosting the PhD student but the PhD title can only be awarded by a university. Therefore usually a collaboration agreement with a university is established, so that the educational institution will survey that at the end of the research a PhD title can be awarded. In addition to these long-term PhDs and post-doc fellowships the neutron data facilities are hosting PhD students and post-docs for shorter periods of several weeks in the framework of the EURATOM Transnational Access projects NUDAME and EUFRAT [12].

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TRAINING COURSES ON ISIS REACTOR
AT SACLAY RESEARCH CENTER

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ABSTRACT

ISIS is an open core pool type reactor with a thermal power of 700 kW. In 2003 the decision was taken to transfer educational and training activities carried out on ULYSSE reactor (Argonaut, 100 kW) on ISIS reactor. Thus, from 2004 till 2006, ISIS reactor went through a major refurbishment of the control system and control room to adapt it to these activities. The refurbishment was defined taking into account the pedagogic needs : ability to carry out specific operations, development of a software with specific supervision screens used to visualize the evolution of reactor parameters and definition of ergonomic adapted to the educational and training activities. We present here the definition of the reactor refurbishment made to adapt the reactor to training courses, as well as some insight into the experiments that are carried out on the reactor using the developed supervision screens.

1. Introduction

As a part of the French Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution that provide engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications, including nuclear reactor theory and operation. Since 1956, the adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on experimental facilities. For this purpose, an Argonaut type reactor especially designed for training courses was constructed at the INSTN headquarter situated on the CEA Saclay centre. This reactor, so called ULYSSE with a nominal power of 100 kW, was operated from 1961 until 2007.

In 2003, when the decision was taken to shut down ULYSSE reactor after more than 40 years of operation, the leading strategy of completing theoretical courses with training courses was continued and it was decided to transfer the educational and training activities to another experimental reactor, so called ISIS and also located on the CEA Saclay centre. For this purpose, ISIS reactor had to go through a major refurbishment of the control system and control room to adapt it to these activities.

After an overview of the ISIS reactor characteristics, we present here the major steps of the reactor control system and control room modifications that were made to adapt the reactor to the educational and training activities. We then illustrate the use of the renewed control system, which include specifically developed supervision screens, with some experiments carried out in the frame of the courses organised by the INSTN.

2. ISIS reactor characteristics

ISIS is an open core pool type reactor with a thermal power of 700 kW. It is the neutron model of OSIRIS research reactor situated in the same building and which exhibits a thermal power of 70 MW. The reactor, that reached criticality in 1967, has mainly been used until 2004 for the test of new OSIRIS core configurations, for power cartography and gamma heating measurements, as well as to supply neutron and gamma fluxes for experiments in the core or its periphery.

ISIS core, shown in figure 1, contains 38 fuel elements (in red), 6 control rods (in dark green), 5 experimental cases (in light green, with 4 red disposals) and a wall of 7 Beryllium elements (in yellow) placed in a compact vessel. The core exhibits a section of 60 cm x 60 cm and a high of 90 cm. The fuel, in Silicide (U_3Si_2) form, is enriched at 19.75%. The fuel elements are made of 22 plates separated by a distance of about 2.5 mm where the water flows. The beryllium elements are used both as neutron reflector, to reduce neutron leakage on one side of the core, and as the starting neutron source though (γ, n) reactions. The experimental cases can be used to place experimental set ups (instrumentation, materials absorber material, test fuel, …).

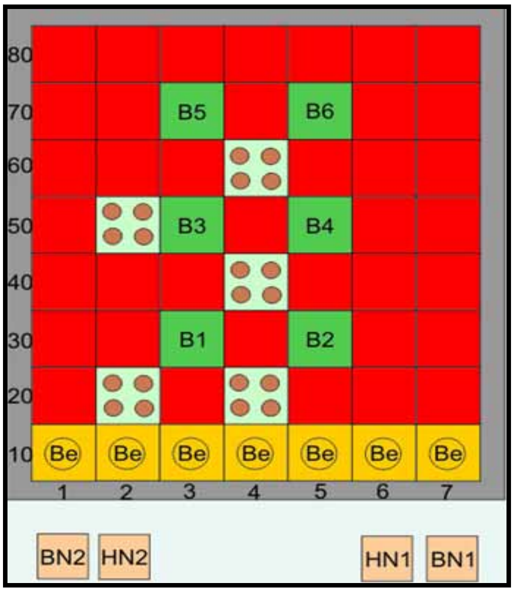

Figure 1: Core configuration.

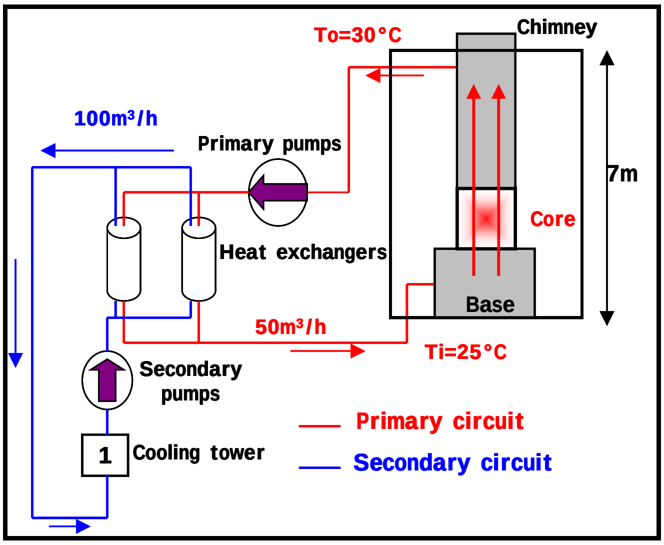

Figure 2 : Schematic of the cooling circuit.

The water circuit is shown in figure 2. The core is placed in a 7 meters deep pool, filled with light water that is used for moderation, cooling and biological protection. Once the water circuit is on, water flows from the bottom to the top of the vessel, between the plates of each element, and goes trough the chimney to reach the extraction pipe. The primary pump is used for the circulation of the water in the primary circuit ($50m^3/h$). Water flowing from the pump reaches the 2 heat exchangers in which the secondary circuit water is used to cool down the primary circuit. After being cooled down, the water is injected under the core, through a big metallic piece called “the base”, which support the structure of the core and the chimney deep inside the pool.

To measure the neutron density and to determinate the reactor power, ISIS is equipped with 4 detection systems, BN1 and BN2 (shown in figure 1) used in the counting mode at low power level (< 40 W) and HN1 and HN2 (shown in figure 1), typically used in the current mode above 10 W. These systems give a signal proportional to the neutron density.

3. Reactor refurbishment

From 1961, ULYSSE reactor located at the INSTN was operated for education and training courses. The reactor had been especially designed in 1960 for this application and latter on, in 1974, the reactor went through a major refurbishment of the control system to improve its control system. ULYSSE reactor was used for 46 years and an important background on the use of an experimental reactor for education and training activities had been gained. When transferring the activity on ISIS reactor this background was used to define the refurbishment programme of the reactor control system and control room. A committee that joined together the project managers, ISIS operators as well as the teachers and operators from ULYSSE reactor was formed.

The first step in the activity transfer was to evaluate the ability to reproduce or to adapt the experiments carried out on ULYSSE, as well as to found new experiments that can be carried out on ISIS taking advantage of its characteristics. The output of this work was used to define the specific modifications of the control system for the education and training activities, which came in addition to the "standard" refurbishment of ISIS control system that was operated since 1967. The modifications concerned control system equipments, the logic of the safety system, control system hardware, the ergonomic of the control board and control room, as well as of the development of a supervision software.

For example, the following modifications have been introduced. Thermocouples were added in the core to study the temperature effects. The logic of the safety system was modified to be able to individually drop each rod during standard reactor operation. Three operation modes were defined depending on the reactor configuration (natural convection or forced water circulation) and utilisation (education, experiments), the education mode being limited to a maximum power of 50 kW. The measured signals during reactor operation were extracted to be used in the supervision software that displays different screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor. Figure 3 and 4 show, respectively the control board and the major screen used to follow the operating (rod state and position, …) and measured parameters (signal of the detection system, doubling time, power, …).

All the modifications had to be approved by the French safety authority and needed an update of the operating licence obtained in 2006. The refurbishment programme was accomplished between 2003 and 2006, for a total cost of 2,2 M€. ULYSSE reactor was then definitively shut down in February 2007 and the training activities were transferred on ISIS reactor in March 2007. We present in the following paragraph three examples of experiments carried out on ISIS in the frame of INSTN educational and training courses.

Figure 3 : ISIS control board.

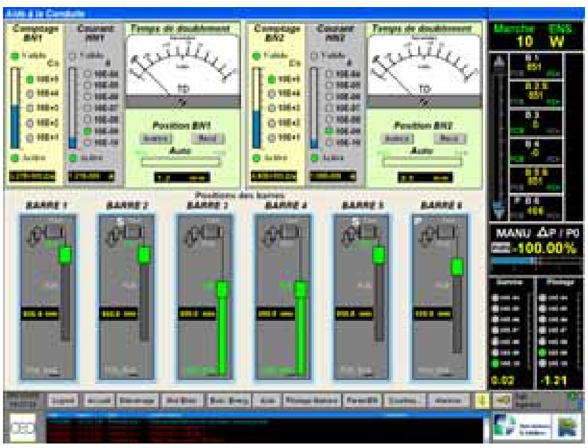

Figure 4 : Screen used for reactor operation.

4. Approach to criticality

Before reactor start up, it is necessary to safely determine a critical configuration of the control rods of the reactor. This is done by an approach to criticality through the removal of one of the control rods (rod B6) for a given configuration of the other rods. Figure 5 shows the supervision screen displayed to follow the evolution of BN1 and BN2 counting rates as well as B6 rod position as a function of the time during the approach. For each stabilisation of the counting rate for a given rod position, the measured counting rate N is extracted and used to draw the 1/N versus rod position curve, shown in figure 6. The position of B6 associated to criticality is established by extrapolation and can then be used to start up the reactor using the Nordheim curve and the calibration curve of the rod B6.

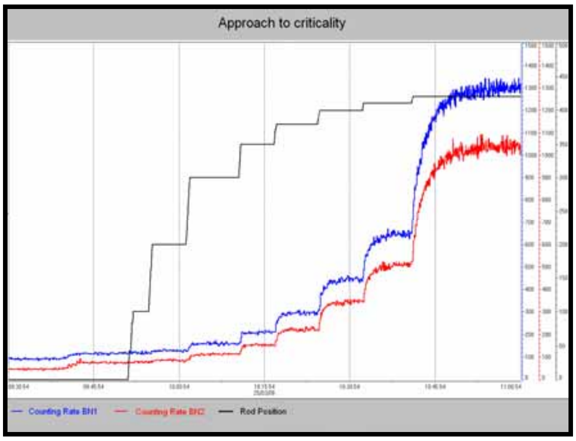

Figure 5 : Screen during approach to criticality.

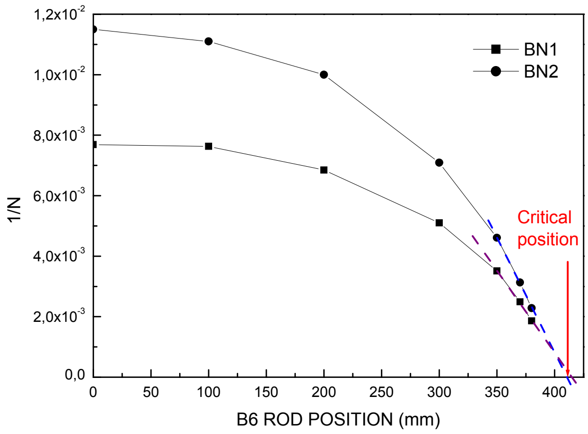

Figure 6 : Search for critical position

5. Temperature effects

When a reactor is operated at appreciable power, the energy produced by the fission reaction induces the increase in temperature of the fuel, the moderator and other material present in the core of the reactor. This, in turn, leads to a modification of the core reactivity ρ. In order to study the temperature effects, the following experiment is carried out. The reactor being stabilised at 500 W, the critical position of B6 and the water temperature are recorded. The reactor power is then increased and stabilised at 50 kW. The reactor is then switched to automatic control to maintain the power constant, i.e. the rod B6 is automatically moved to maintain the reactor critical. After a certain time at 50 kW, the new critical position of B6 and core temperature are recorded. Then the reactor is switched to manual control without any modification of the rod position, i.e. the evolution of the core temperature and thus core reactivity is no more compensated by the automatic move of B6. Figure 7 shows the evolution of rod position, reactor power and core temperature as a function of time during the experiment.

The figure shows that when reaching 50 kW, while there is not yet water temperature increase, the critical position of rod B6 has changed from 405 to 423 mm. This corresponds to a variation in core reactivity of about 120 pcm that can be attributed to the Doppler effect. The power being kept constant at 50 kW with the automatic control, the figure shows that the critical position increases with the water temperature. This corresponds to a decrease in core reactivity attributed to dilatation effect. Thus, the overall temperature coefficient is negative, i.e. the reactor is sub-moderated. After switching to manual control (at t = 16:02:30), we observe the self-stabilisation of the reactor whose power decrease by itself due to temperature effects. Finally, from the recorder critical position of rod B6 at 500 W and at 50 kW, the overall temperature coefficient is calculated : -17 pcm/°C.

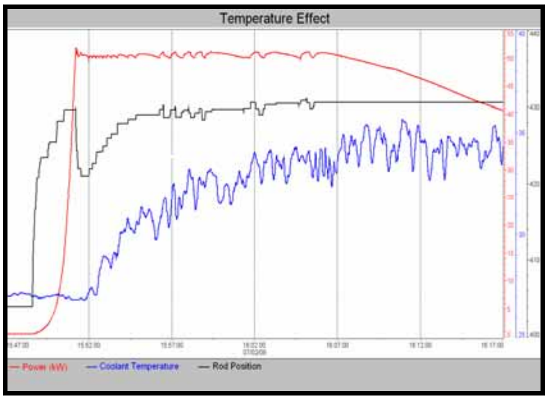

Figure 7: Screen during the study of temperature effects

5. Reactivity effect of experimental samples and set ups

ISIS reactor is equipped with 5 experimental cases that can be used to place experimental set ups. Each case is normally occupied by an aluminium box that contains four holes filled by aluminium cylinders (see position 64 in figure 1). In order to study the potential effect of experimental samples or set-ups on the core reactivity, the reactor being stable at 500 W, three of the four aluminium cylinders are successively removed from the box in position 64. Before and after each cylinder removal, the critical positions of rod B6 are recorded and reported in Table 1. Using the calibration curve of the rod, the variation in core reactivity associated with the removal of the cylinders is calculated and also reported in table 1.

Cylinder removed	Rod position (mm)	Reactivity effect on the core (pcm)
none	406	0
1	405	+ 8 pcm
1,2	394	+ 96 pcm
1, 2, 3	383	+ 184 pcm

Table 1 : Reactivity effect induced by aluminium cylinder removal.

It is shown that the removal of the aluminium cylinders increases the reactivity of the core through the replacement of aluminium by water, which increases the moderation factor. The different values in reactivity variation associated with the cylinder number are directly related to their relative position to B2 (completely extracted), B4 (completely inserted) and B6 (in intermediate position).

5. Conclusion

As a part of CEA, the INSTN provide engineers and researchers with a high level of scientific and technological qualification in nuclear reactor theory and operation. Since 1956, the adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on experimental facilities. For this purpose, ISIS reactor went through a major refurbishment to transfer the educational and training activities previously carried out on ULYSSE reactor. This transfer took advantages of the 46 years background on the use of an experimental reactor for education and training activities. This leaded to the use of a supervision software that displays specific screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor.

TRAINING POSSIBILITIES AT THE BELGIAN NUCLEAR RESEARCH CENTRE SCK•CEN

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ABSTRACT

Thanks to its thorough experience in the field of peaceful applications of nuclear science and technology, the Belgian Nuclear Research Centre SCK•CEN has garnered a reputation as an outstanding centre of not only research, but also education and training (E&T). The E&T activities at SCK•CEN cover among others nuclear engineering, reactor physics and operation, radiation protection, decommissioning and waste management. This paper gives an overview of the education and training possibilities at SCK•CEN.

1. Introduction

The Belgian Nuclear Research Centre SCK•CEN was created in 1952 in order to give the Belgian academic and industrial world access to the worldwide development of nuclear energy. It is a Foundation of Public Utility, with a legal status according to private law, under the tutorial of the Belgian Federal Minister in charge of energy. Since 1991, the statutory mission gives priority to research on issues of societal concern such as safety of nuclear installations, radiation protection, safe treatment and disposal of radioactive waste, fight against uncontrolled proliferation of fissile materials and fight against terrorism. The Centre also develops, gathers and disseminates the necessary knowledge through education and communication, and provides all services asked for in the nuclear domain (by the medical sector, the nuclear industry and the government). Today, about 600 employees advance the peaceful industrial and medical applications of nuclear energy, and realise a turn-over of about 80 M EURO.

SCK•CEN is also an important partner for training projects in Belgium (to the nuclear sector, the medical and non-nuclear sector), as well as at the international level (IAEA, EC, …). The Centre's know-how and infrastructure are also available for training purposes.

Our courses are directed to the nuclear industry, the medical and the non-nuclear industry, national and international policy organizations, the academic world and the general public. E&T programmes are also organised in cooperation with universities, technical universities, nuclear power plants and public and private health services. In addition, SCK•CEN is involved in international E&T research networks and programmes such as ENETRAP, EUTERP, EUNDETRAF, CETRAD, BNEN and ENEN.

2. Training topics

SCK•CEN provides courses on a wide range of nuclear topics. Following paragraphs highlight the principal areas of training.

2.1. Master of nuclear engineering (BNEN)

In collaboration with the major Belgian universities, SCK•CEN organises a one-year programme (60 ECTS) on nuclear engineering. The objective of this master is to offer present and future professionals and researchers a solid background in the different disciplines of nuclear engineering. The programme is taught in English. Its high modularity allows for optimal time management for teachers and students, it facilitates individual participation in selected courses e.g. advanced courses in the context of continuous professional development and it also facilitates foreign students participation in blocs of courses.

2.2 Nuclear reactor physics and reactor operation training

To guarantee the safe operation of present and future nuclear reactors the initial and continuous training of reactor operators has proven to be indispensable. In most countries, such training also results from the direct request from the safety authorities to assure the high level of competence of the staff in nuclear reactors. SCK•CEN organises such courses for, amongst others, reactor operators of the BR2-reactor at the SCK•CEN site, for the reactor operators and operation team heads of the PWR's situated at the DOEL-site (Belgium), and recently also for the new recruits of Suez in Belgium. The course covers nuclear reactor statics and kinetics. In addition to the theoretical courses, practical sessions on the BR1 research reactor are organised. Training courses on reactor operation are also organised on service basis for nuclear engineering students of various Belgian and foreign universities and technical universities.

Fig 1. Training of reactor pilots at SCK•CEN

2.3 Radiation protection

SCK•CEN's isRP (international school for Radiological Protection) coordinates and organises courses which deal with all aspects of radiation protection. The series "background and basic knowledge" consists of seven modules (nuclear physics, interaction of radiation with matter, radiation and dose measurements, biological effects, gamma spectrometry, legislation and ALARA and safety culture) and provides the theoretical and practical knowledge required for implementing radiation protection aspects in an industrial, medical or research working environment, both in daily practice and in long-term management. A course programme can be extended with one or more modules from the "nuclear and radiological expertise" series (covering topics such as: radon and natural occurring radioactivity, nuclear transport, on-site accident management, organization of emergency planning, radiochemistry, ethical aspects of the radiological risk, …), depending on the specific working environment of the students. On-site practical training exercises are organised and visits to different SCK•CEN installations and laboratories can be included. More information can be found on www.sckcen.be/isrp.

2.4 VISIPLAN 3D ALARA planning tool

The application of ALARA and the dose assessment for work in complex environments is a complicated task. Dose values are influenced by the geometry of the installation, the source distribution, the shielding configuration and the work organization. VISIPLAN 3D ALARA planning tool is a PC-based programme developed for the ALARA analyst or the person responsible for the assessment of the dose uptake of the workers. It allows to assess the radiation doses in a 3D environment and to compare different work scenarios. Typically, a three day course explains the VISIPLAN features.

2.5 Nuclear emergency management

Off-site nuclear emergency management concepts have been reviewed in-depth after the Chernobyl accident. SCK•CEN transmits its know-how in this field by a one-week European training course on "Preparedness and response for nuclear or radiological emergencies". The course aims at giving a comprehensive overview of off-site nuclear emergency management, its principles and their application to those involved in emergency planning and response, e.g. health physicists, technical and radiological advisors, civil and environmental protection officers. It covers the following major topics: principles of intervention, radiological evaluations, decision-aiding techniques and the decision-making process leading to optimised management options. The European and international dimension of the subject is treated (e.g. Community legislation, ECURIE and EURDEP). Other topics such as health effects, economic consequences and psycho/social aspects are also included.

Fig 2. Nuclear emergency management course

2.6 Decommissioning of nuclear installations

With the decommissioning of the BR3 reactor, a European pilot project, SCK•CEN succeeded at developing the best approaches for the optimization of dismantling, decontamination and decommissioning techniques and processes (including the restoration of nuclear sites to so-called 'green fields') Experience also includes the realistic assessment of costs, and the development of techniques for minimization of secondary waste and minimization of radiation doses to the personnel. The course on dismantling and decommissioning is based on this know-how and is primarily intended for dismantling project managers, safety engineers, health physicists, decontamination and dismantling operators. The course is also of interest to governmental and regulatory bodies dealing with decommissioning.

2.7 Radioactive waste disposal

Customised training courses are offered in the field of long-term radioactive waste management. The courses focus on final disposal as the preferred option to long-term radwaste management. Waste disposal requires selection and thorough characterization of a site, characterization of waste packages, and finally demonstration of long-term safety by means of performance and safety assessment. Courses are generally organised in three areas that are very closely linked, i.e.

- Characterization of radioactive waste packages in relation with its disposal;
- Site selection and site characterization;
- Integrated safety assessment modelling.

Training courses typically last for one up to two weeks and generally include hands-on computer sessions, technical workshops or field visits. The courses are directed to individuals having a controlling or supervising role within radwaste agencies or nuclear control bodies, or for technical experts who carry out the characterization of an existing or new site, characterise waste packages, or perform post-close assessments.

3. Approach

Except for the Master in nuclear engineering, all course programmes are tailored to the needs of the students and are available to fit into a larger modular programme.
The courses can be taught at the premises of the customer or at SCK•CEN's Conference Centre, offering fully equipped lecture rooms or at the venue of the customer. The Conference Centre is located next to the technical domain of SCK•CEN, allowing easy access for the practical training sessions. Several laboratories and installations are available and open to national and foreign students.

Fig 3. SCK•CEN's Conference Centre

The team of lecturers includes engineers, physicists, technicians, biologists, occupational physicians and social scientists who all bring insights and ideas from their specific background into the course programmes. As SCK•CEN staff members they have a solid knowledge and experience in their field, and can thus directly transfer their theoretical knowledge and practical experience to the various courses.

4. Graduate thesis, PhD and post-doc research

Next to courses SCK•CEN also offers students the possibility to perform their research work at its laboratories, at several levels.
On a regular basis, final-year bachelor or master students visit SCK•CEN and are guided by our researchers in their dissertation work.
In a conscious desire to increase its pool of highly specialised young researchers and to tighten its cooperation with the universities, SCK•CEN embarked in 1992 on a bold programme to hire about 10 PhD candidates and post-doctoral researchers every year. These early-stage researchers are recruited in the research domains that reflect the priority programmes and R&D topics of our institute.

COMPETENCE BASED APPROACH FOR EDUCATION AND TRAINING OF NUCLEAR ENGINEERS

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ABSTRACT

The Russian higher education standard prescribes that a university graduate should be capable to make the decisions, to take the responsibilities, to find the effective way for solving a non-standard task and the non-standard way for solving a typical task – the features related to so-called competences. Competences represent a combination of attributes – with respect to knowledge and its application, attitudes, skills and responsibilities – that are especially important for nuclear industry where a human error may lead to serious national or even international socio-economic consequences. This paper presents the competence based approach to education being developed in Moscow Engineering and Physics Institute, which is one of the most important suppliers of scientists and engineers for Russian nuclear industry.

1. Introduction

In the time of heightened international interest to the development of atomic engineering the process of preservation and management of nuclear knowledge acquires strategic value. Nowadays the enterprises of this field introduce various training aids, including simulators, systems of remote training, computer training systems and other technical means on the basis of information systems. However in order to maintain the efficiency of this process we need a clear methodological concept allowing to objectively estimate the level of the experts working at atomic power stations.

From the theoretical point of view such a concept can and should be based on modern pedagogical achievements, and from the technical point of view it has to be supported by rapidly developing information technologies. And it is necessary to consider the rates of progress in this area and a fast change of platforms of software products development that, certainly, creates difficulties in the realization of scale projects and causes their reorganization even in the process of their realization. On the other hand, a problem of the staff for new power units, the necessity to reduce the training duration of the staff, the requirement to maintain the flexibility and adaptation of the educational content to the current needs of the field demand fast response to the changes, both in a subject domain, and in a technical part of the realization of the training program for the experts in nuclear sphere.

2. Current trends in Russian higher education

Now in Russia it is possible to refer to the following tendencies in terms of data support of work with the staff and professional trainings, typical of specialized educational institutions and the educational centers at the enterprises of the field:

- increase of the application of IT solutions in the staff training;
- inclusion of "heavy" means of training (such as an analyzer for the research of emergency situations) into the university educational process in order to improve the

quality of the preparation of students;
- application of remote training technologies;
- expanded application of the Internet technologies both for the preparation of students, and for the tasks of the management of the staff qualification.

There are some problems of application and development of the information technologies (IT) in terms of staff training, like university budget constrains, insufficient coordination between universities and enterprises in IT area, unclear mechanism of collection, analysis and dissemination of software products, etc.

So we can speak about the necessity to formalize the process of knowledge management in the nuclear field. The international practice supported by the IAEA (International Atomic Energy Agency) indicates that this problem is considered in all the countries, especially in those where the nuclear power plant construction was postponed or in those where the accelerated implementation of nuclear power is planned. Not to lag behind, first of all, it is necessary to equip the Russian key higher educational institutions with computer training systems, simulators, including simulators of emergencies. It will allow improving the quality of senior students training.

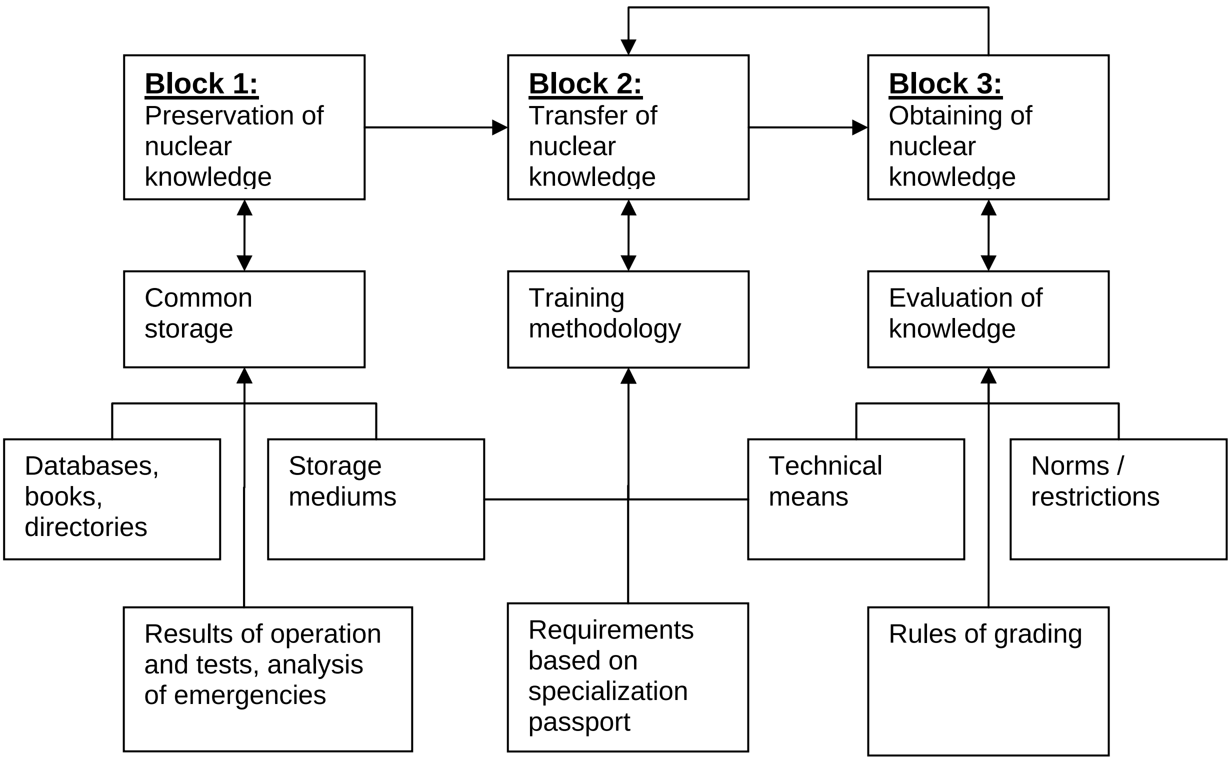

Fig. 1 Model of staff education for nuclear industry

The methodological concept of staff training includes three blocks (Fig. 1):

1. Formation of the well structured common information storerage and organization of its constant updating (preservation of nuclear knowledge).
2. Development of the training techniques based on pedagogical standards and modern training aids considering the possible restrictions such as training terms, economic and organizational factors (transfer of nuclear knowledge).
3. Development of full-function techniques of adequate and comprehensive evaluation of the training process and its results with the obligatory feedback, allowing to adjust the education process (obtaining of nuclear knowledge).

Today the active development of education and nuclear knowledge control methodologies (blocks 2 and 3 above) is being carried out in Moscow Engineering and Physics Institute.

3. Model of competences

The modern view at the methodology of the evaluation of the training results is specially focused on such priorities as free development of the person, formation of the creative initiative, independence, competitiveness and mobility of the future expert. One of the ways of fixing such skills and acquired abilities is the competence-based approach to the estimation of the training results. The competence based approach in education is the implementation of such educational programs that are directed on the formation of the ability to apply the received knowledge and skills independently in a certain context. And the approach covers all the spectrum of personal features, not just those that are purposefully formed through the training of certain disciplines (Fig. 2). Such important factor as the type of the person making critical decisions plays a huge role in the course of functioning of complicated technical systems, in the sphere of high technologies and innovative economy.

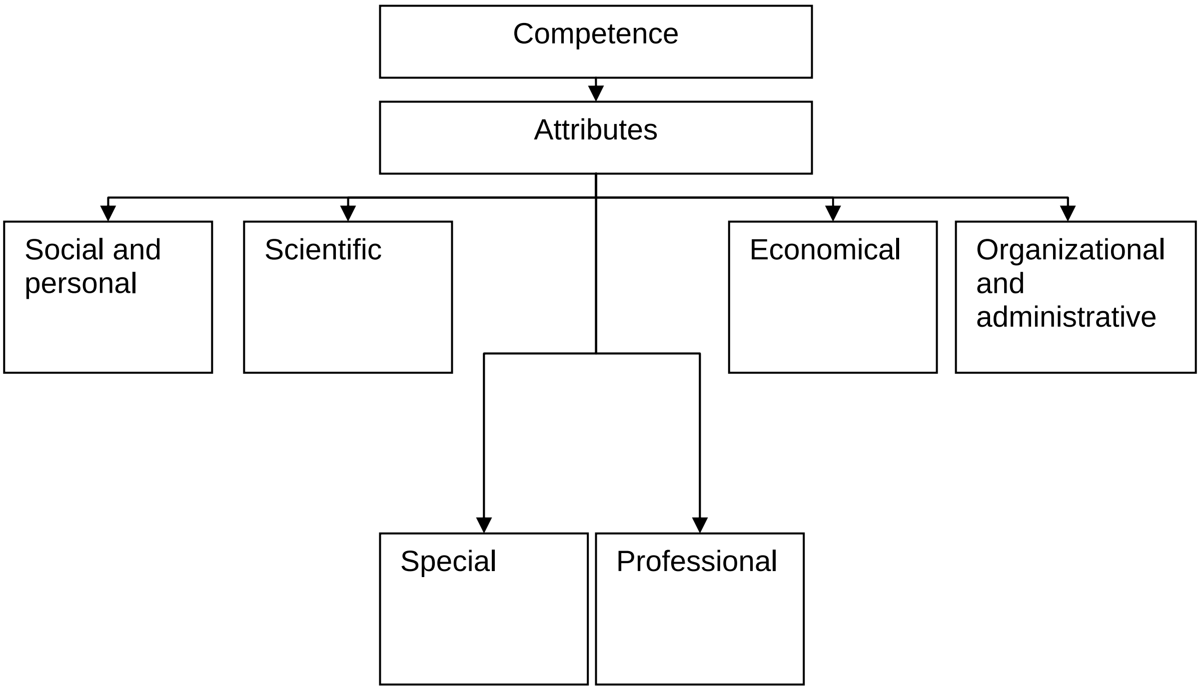

Fig. 2 Classification of competences in Russian education standard

It is necessary to note that the most actual are the techniques developed to deal with the disciplines that are highly critical in respect of cumulative cost of the error committed by the expert. Such disciplines are nuclear physics, nuclear engineering, medicine, transportation, governance and many other spheres of human activity.

Implementation of modern information technologies allows to solve a number of problems providing the students not only with a full-scale access to the necessary knowledge in hypertext, graphic, audio and video formats, but also to the modern systems of information search, and the possibility to model the future activity by means of special software. All that fully corresponds to the ideology of the formation of the expert who not only knows (what) but as well can (how), and the ability to expand the sphere of knowledge and to develop the set of skills independently is being built throughout the whole cycle of the training thus forming general, professional and educational competences (Fig. 3).

Thus using the competence based approach, the quality of the training can be evaluated by means of the model of competences by performing the following three steps:

- Step 1. To develop the global model of competences of a student including general and educational competences and to define the importance of these competences.
- Step 2. To evaluate a level of responsibility for the decisions made in the course of studying of the specialized disciplines.
- Step 3. To develop the specialized model of specific competences and to integrate it into the global model.

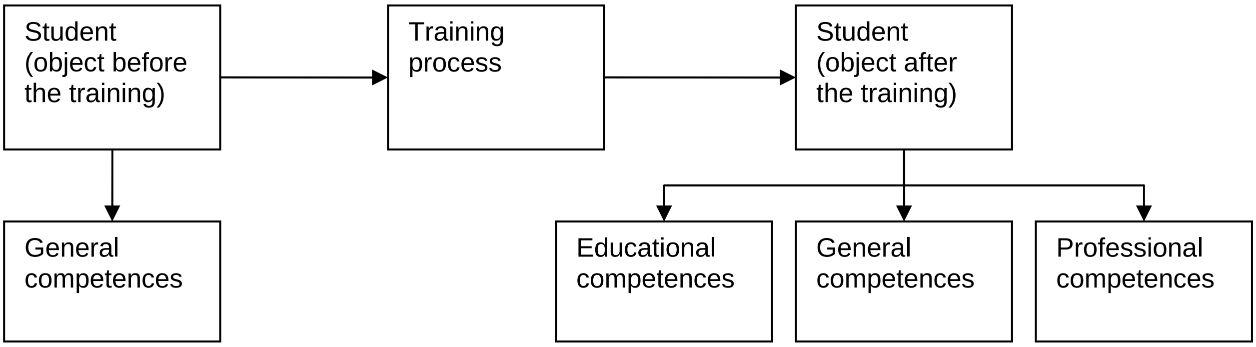

Fig. 3 Model of competences prior and after the training

Steps 2 and 3 are to be performed in accordance with the specific discipline being studied with the strong orientation on its purpose, tasks, detailed content and timetable, as well as on the set of economical and administrative constrains. Under this approach, Step 1 includes the processing of large volume of information and remains independent upon the specific discipline.

4. Results of education

The staff training in nuclear and adjacent matters requires a special attention and systematic approach. The evaluation of the training results depends on a set of various qualities of the individual (psychological, intellectual and personal character). The necessity to evaluate a graduate not just as a professional but also as a person is extremely important in the nuclear field for an error here might cost also human lives and serious environmental problems.

From the pedagogic point of view it is more difficult to develop the skills than to transfer the knowledge because it demands more time and resources. Formation of competences requires special attention according to the state educational standard of the third generation accepted in Russia and bearing in mind the specific of nuclear engineering. It is supposed that the new competence based methodology of the third generation will correspond to the concepts being developed in the frame of the Bologna process which Russia joined in September 2003 at the Berlin meeting of European Ministers of Education.

According to such concepts, the competences are interpreted as the common (coordinated) language to describe the academic and professional profiles and levels of higher education. In the frame of the competence model, a student has to be evaluated in 3 various directions:

- *Knowledge* and *understanding* (theoretical knowledge in the academic area, ability to learn and understand);
- *Knowledge how to do* (practical and operative application of knowledge to concrete situations);
- *Knowledge how to be* (values as an integral part of a way of perception and life with others in a social context).

The main objective of knowledge evaluation is to get the feedback. It is possible because the training is initially conducted on the basis of the constructed interrelations between educational modules and the competences to be formed in the training process. Therefore if the evaluation of a certain competence is out of the allowed range, it would be possible to define educational modules connected with this competence and to change them properly.

5. Conceptual model of knowledge management

According to the competence-based approach it is possible to allocate the basic stages of planning of the training in highly critical spheres. The methodical part (priorities and restrictions):

- Allocation of the target competences that should be developed or improved directly in the course of reception of the corresponding knowledge;
- Developing the hierarchy of competences;
- Attraction of the experts in a subject domain in order to define the priorities of each competence within the frame of the hierarchy;
- Control of judgments of the experts in terms of coordination and if necessary – their adjustment;
- Definition of a vector of the target competences scales to each group and to the hierarchy in general;
- Development of adequate scales and corresponding recommendations about the estimation of competences;
- Setting the restrictions for the minimum level of competence of the expert in general and on the certain competences in particular.

The subject part (cross communications between the information and competences):

- Decomposition of the training course into a set of sections, topics, blocks;
- Setting of a binary vector for the blocks formed as a result of decomposition and creating the list of competences for each of them;
- Resultant definition of the capacity of each block, characterizing the number of included competences and the level of importance of a given block in the creation of the curriculum considering the general estimation of the training results;
- Construction of a corresponding binary vector for each competence helping to define which block influences the given competence;
- Resultant definition of capacity of each competence, characterizing the number of blocks that influence the formation of the given competence and accordingly the number of the resources of various character that should be involved in the creation of the curriculum considering the general estimation of the training results;

The functional part (testing and receiving the feedback):

- Definition of the student's initial level (entrance testing) and socio-psychological portrait of an individual;
- Definition of the student's level in the course of training in several control points (intermediate testing), formation of a vector of changes of socio-psychological portrait of individual and accumulation of statistics on mastering thematic material, and formation of skills and abilities.
- Definition of the final level upon the graduating of the training course (final testing), with monitoring of a trajectory of the changes of the results in terms both of knowledge and socio-psychological portrait of the individual;
- Analysis of the results and formation of methodical instructions on modifications of techniques, format, subjects, and duration of the training course in order to achieve required level of separate competences and competence as a whole.

6. Conclusion

The methodology described above is being developed with a focus, first of all, on the creation of the curricula for the universities specializing in the nuclear field. But the basic elements of this methodology can be also used to manage the nuclear knowledge in scientific research institutions, regulatory bodies, and design and utility organizations of the nuclear power complex.

RAPHAEL EUROCOURSE: AN E-LEARNING APPROACH FOR TIMELY DISTRIBUTED COURSES

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ABSTRACT

Following the philosophy of the sixth framework program (FP-6) to produce structured knowledge a new approach of knowledge dissemination has been developed which fits the needs of the EUROCOURSE organised in the scope of the RAPHAEL project on Very High Temperature Reactors. The main challenges which have to be tackled are the timely distribution of the several EUROCOURSE seminars as well as the different scientific background of the participants. This new approach combines classical class based teaching with e-learning components. It is derived from the concept of blended learning and modified to fulfil the needs and boundary conditions introduced by the RAPHAEL project. The experiences from the first seminars show that this approach is usable and well accepted by the participants.

1 Introduction

Since 2004, the RAPHAEL Integrated Project [1] addresses the viability and performance issues of an innovative system for the next generation of nuclear power plants, the Very High Temperature Reactor (V/HTR), which can supply both electricity and heat for industrial applications, including hydrogen production.

In the frame of the Education & Training activities of RAPHAEL, an EUROCOURSE will be organised to disseminate basic knowledge as well as the latest developments to students and young researchers and engineers. The goals of the education and training activities in RAPHAEL are, on the one hand, to attract students to study High Temperature Reactor (HTR) technology and, on the other hand, to bring together experts and students. To establish long term connections between students and experts, and to allow the participants to follow the progress of the project, the EUROCOURSE consists of three seminars distributed over the lifetime of the RAPHAEL project.

In the frame of the RAPHAEL EUROCOURSE concepts have been introduced to fulfil the diverse challenges caused by the different types of participants and their distribution all over Europe. To meet these challenges, EUROCOURSE uses a mixture of classical teaching and e-learning components based on the concept of “Blended learning”.

This paper describes how e-learning concepts can be adapted to timely distributed courses and focuses on a new approach for preserving and extending knowledge in the domain of nuclear science.

2 RAPHAEL EUROCOURSE

The main challenge is that the course is intended for students and young engineers. It has to be taken into account that these groups have a different scientific background. The first group, the students, come from universities all over Europe. They have general but not specific knowledge of nuclear engineering. The latter group, the young engineers, have an extended and more specific and detailed knowledge of V/HTR technology, depending on the task they have to perform at their companies. Another challenge is the timely distribution of the EURCOURSE over the lifetime of the RAPHAEL project, where the time between the course seminars is approximately nine months. Additionally, it has to be taken into account that not all students and young engineers will be able to attend all EUROCOURSE seminars.

The main goal of the RAPHAEL EUROCOURSE is to introduce HTR technology, the historical background of this technology and the reasons why this technology can play an important role in the energy supply in Europe. The course is divided into three seminars, each 3-4 days long and taking place at different locations in Europe. There is an introduction and allows enough time for direct contact between students and experts.

The first seminar aimed to provide a basic overview of HTR technology, discuss different designs, as well as the role of HTR and V/HTR in the scope of Generation IV Reactors and other FP6 projects. Additionally, the inherent safety features of HTR technology, the main phenomena of core physics, and thermal hydraulics in the core were topics of discussion.

The second seminar covered two major topics: The first one was dedicated to fuel elements, their characteristics, and fabrication. The second topic was waste management, especially regarding results of the Plutonium and Minor Actinides (PUMA) [2] project.
This seminar was also supported by IAEA by providing lecturers from outside of EUROPE as well as fund for students from none EURATOM countries.

The third, and last seminar, will address the remaining aspects of an entire HTR plant, such as materials, system, and components, possible applications and processes as well as safety and the results of the subproject system integration.

The topics of all EUROCOURSE seminars consist of

- Core physics
- Thermal hydraulics
- Fuel
- Waste
- Material and components
- Safety
- System integration.

They cover all main aspects of the V/HTR technology and represent the research performed in the RAPHAEL project.

The first seminar was attended by 64 participants from 18 different countries and 32 universities, research centres, and companies. The second one by 54 participants from 14 countries and 26 universities, research centres and companies.

3 Preservation and Extension of Knowledge

To tackle the challenges mentioned above requires a concept how the single seminar can be structured to achieve at the end an integrated knowledge on V/HTR technology. The distribution in time and place requires modern approaches like e-learning concepts, web based technologies, and the combination of the two.

The most convincing e-learning concept for timely distributed courses is the concept called blended learning [3]. Blended learning is an approach quite common in the engineering sciences (e.g. we blend course work, exercises, practical training in various stages, excursions, seminars, and conferences, etc. to improve our own knowledge and that of our students).

3.1 How to select e-learning components for a special course

Blended learning is well organised and continuously monitored. The different learning forms are combined in a way that helps best to reach the goals. It is well known from pedagogical theory that best learning results can be achieved through a mix of methods and media which takes into account both the group of learners and the content of the course to be given. Therefore, to select components for a specific course requires a didactic concept which treats these questions in view of the actual knowledge situation of the learners. This can be reached hardly in conventional teaching but also seems to be impossible to achieve by e-learning methods solely. A mixture is necessary where the teacher takes over all the tasks which require human interaction and the computer gives support in those areas where pure information transfer has to be provided.

3.2 Blended learning course

The following describes a new approach for blended learning courses. They have a typical structure where presence and e-learning phases follow each other (Fig. 1). This course structure can be refined iterative.

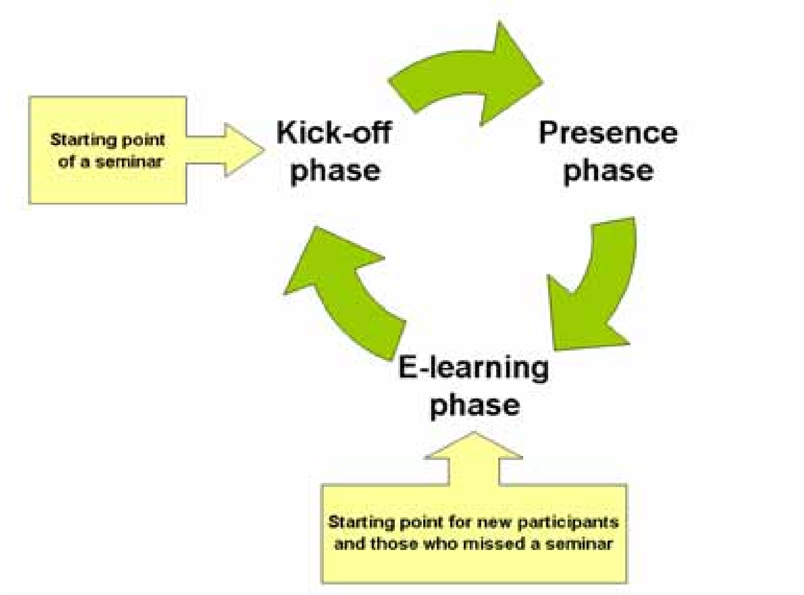

Fig. 1: Blended Learning Cycle

1. **Kick-off phase**
   The Kick-off phase is characterized by providing information about the seminar content and by an introductory session at the beginning of a seminar.

2. **Presence phase**
   The presence phase always starts with the introductory session (Kick-off phase) followed by lectures given by experts of the specific field.

   a. **Training phase**
      Depending on the seminar topics simulation based training will deepen the understanding of the lectures. Technical visits are another option for the training phase to combine theory and practice.

   b. **Evaluation phase**
      Each presentation phase is completed by an evaluation which gives feedback to the organisers how to improve further seminars and courses.

3. **E-learning phase**
   During the e-learning phase the learners can exchange documents and share files among each other. The teacher can provide PowerPoint presentations including audio, video, and animations. They can define exercises which students are able to use to deepen their understanding.

4 Best Practice – Adapting E-Learning Concepts

The blended learning concept fits well to meet the challenges of timely distributed courses. Changes of the concept have been necessary mainly in the production of the e-learning material, because the production of e-learning modules is very time consuming. The lecturers for this EUROCOURSE are selected from the partners of the RAPHAEL project. They do not have this time due to their normal research work. To provide the participants with more than just the presentations all lectures are electronically recorded, so both the presentations themselves and the explanations of the lecturers are available for the e-learning phase.

To bring all participants to nearly the same level of knowledge each seminar starts with the kick off phase by providing the participants with the abstracts and the preliminary presentations as well as useful links to web pages for further information on the seminar topics. To provide this information to all participants a dedicated web server is set up which acts as content provider for all content collected during the seminars.

A dedicated introductory session at the first seminar covering the basics of HTR technology also contributes to bring the participants to nearly the same level of knowledge.

The seminar itself is identical to class based teaching of blended learning, extended by either exercises, for example by simulating the behaviour of an HTR or by technical visits. The information provided serves as basis for the final phase of the seminar, the e-learning phase which allows the participants to work up the content of the seminar. This information also serves as material for the kick off phase of the next seminar together with new abstract and preliminary presentations. This information can also be used by those who could not attend a seminar.

After having completed the EUROCOURSE a set of documents will be available covering nearly all aspects of V/HTR technology which can be reused for further educational and training purposes.

4.1 Tools

Mainly three tools were used during the EUROCOUSE, a web server, a recording tool, and the Sinter Simulation Environment for simulation based training:

The Apache Web Server
A Web server, developed by the Apache Software Foundation, is freely available under the licenses conditions of the Apache Software Foundation [4].

Camtasia Studio
Camtasia Studio [5] is a commercial tool to record presentations. It integrates itself into Microsoft PowerPoint to make recording facile, and is also able to record all actions on a computer screen. It includes an editor, to edit recorded presentation, as well as a tool to convert the recorded presentation in different web based formats like flash.

Sinter Simulation Environment - Simulation based training
One example of simulation based training was included in the first seminar of the EUROCOURSE in Stuttgart.

Fig. 3: Sinter Simulation Laboratory

It was an exercise on the transient behaviour of an HTR core. The Sinter Simulation Environment [6], developed at IKE, offered the participants the opportunity to improve the memorization by training. This web-based tool (Fig. 3) was provided to simulate the withdrawal of the control rods at different velocities. In optimized views, forms for the input data of the most important core parameters were offered and the results were displayed (e.g. neutron flux, and temperature distribution in the core).

5 Conclusions

Until now, two of the three courses have been carried out, with approximately 90 participants and lecturers from Europe and, due to the collaboration with IAEA, from all over the world. The feedback from the participants, after these seminars, was very positive and the high number of participants shows the demand for more courses of this type. Getting a complete overview on HTR technology, as well as having all presentations available online, meets the needs of the participants, and those interested in this technology.

The new approach of blended learning fulfils the demands described above very well. Therefore, it could serve as an example for other timely distributed courses. The tools used to implement the concept are easy to use and do not require a complex and expensive technical infrastructure.

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NUCLEAR EDUCATION FOR A RESTART

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ABSTRACT

The last two decades have been a tremendous waste of opportunities in the nuclear field in our country squandering a relatively advanced position with the first operating nuclear power plant in Latin America. The present scenario imposed by the nuclear renaissance presses strongly on the human resource basis. The principal challenge is to cope simultaneously with the urgent need of prepared personnel and the quality of training required. In this aspect the University is playing an increasingly important role covering knowledge areas which were formerly limited to CNEA. An important campaign is necessary in order to deliver the correct message related to nuclear. It is of paramount importance to improve the public understanding on this technology and the role it can play in solving the increasing energy demand in a world of decreasing energetic resources.

1. Introduction

The last two decades have been a tremendous waste of opportunities in the nuclear field in our country squandering a relatively advanced position with the first operating nuclear power plant in Latin America. Atucha II Nuclear Project is a clear example: halted during almost the same period at 80% completion it has been a sink of funds dedicated almost exclusively to the maintenance of relevant parts waiting for better times to come...

Recently the government has announced and started completion of the plant and the amount of necessary human resources is not there. The scenario is further complicated for two reasons: nuclear is not an attractive choice for students nowadays and the staff of experts with sound experience in previous projects is retired or about to.

The first reason is partly due to the Chernobyl accident and the distorted and unfortunate picture that it draw about nuclear for the general public. Also important has been the inability of the nuclear sector (public and private) in transmitting a clear and credible message about the benefits of nuclear technology in different fields of human life. The second is associated to the lack of funding for nuclear projects for a long period of time and the corresponding gap in training activities.

In the previous context the "Instituto de Tecnología Nuclear Dan Beninson" (IDB) was created associating the Atomic Energy Commission (CNEA) with a Public University, Universidad de San Martín (UNSAM), in order to bring to the academic area training and research activities formerly reserved almost exclusively to the scientific institution. The main subjects involved are:

Nuclear Reactors and their Fuel Cycle
Radiochemistry and Nuclear Applications
Dosimetry and Physics of Radiotherapy
Methodology and Applications of Radioisotopes

These topics in the form of postgrade careers and courses are the core of our academic offer and we point to graduates in engineering, physics, chemistry and related areas. Simultaneously we train personnel for the nuclear sector companies “at demand” and we established a correspondence between both activities in order to optimize the agenda of the Institute personnel (mainly professors) due to the scarcity of senior experts, specially in selected areas.

2. Academic Offer

The Institute was created in december 2006 with a frame agreement between the involved institutions (1) and the academic offer was organized around activities of strong tradition in CNEA and not specifically covered by the other two academic Institutes of CNEA: Instituto Balseiro and Instituto Sábato. These are:

Careers

Specialization in Radiochemistry and Nuclear Applications (2):
It is a one year postgrade career (700 classroom hours). The objective is to provide students with high level knowledge in basic radiochemistry and expertise in the use of installations and equipment necessary for nuclear applications. This career has two orientations: general and radiofarmacy

Specialization in Nuclear Reactors and their Fuel Cycle (3):
It is a one year postgrade career (630 classroom hours). The objective is to provide the students with a general knowledge about the technology of nuclear reactors, the nuclear fuel cycle and the main disciplines involved. This allows an insertion in the professional area in basic or applied work.

Courses

Methodology and Applications of Radionuclides:
This 200 hours course provides the necessary knowledge -theoretical and practical-, for the use of radioactive substances taking into account the due precautions for the radiological protection of the involved personnel, technicians and public. It fulfils one of the basic requirements to get from the regulatory authority, the individual authorization for the manipulation of radionuclides.

Dosimetry in Radiotherapy:
This 200 hours course provides the necessary knowledge for the dose control in patients at a radiotherapy institution, fulfiling one of the basic requirements to get the licence as a Technician in Radiotherapy from the regulatory authority.

Physics in Radiotherapy:
This 360 hours course provides the necessary knowledge for the performance of a physicist in a radiotherapy institution. It is one of the requirements for a physicist to apply for a licence as a Specialist in Radiotherapy to the regulatory authority.

3. Brief historical background

In 1951 Dr . Walter Seelmann Eggebert created the first ***radiochemistry*** group in CNEA. After the installation of the first Phillips cyclotron in 1954 twenty new isotopes were discovered and characterized in few years, after fast radiochemical separations.
From that time radiochemistry applications has diversified enormously from basic science to uncountable industrial applications. Worth mentioning its role in nuclear medicine, and nuclear fuel cycle specially radioactive waste.
The formal training in the area intended to restore an integral vision in the professional career and it began in 1999 with the Master in Radiochemistry (in agreement CNEA-National Technological University) which was discontinued in 2005.
At present the academic activity is concentrated under the frame of CNEA-UNSAM agreement.

With respect to ***nuclear reactors*** the first course was organizad in 1952 briefly after "Nuclear Reactor Theory" from Glasstone Edlund was first published.
Many annual courses followed, always in CNEA, and they were the principal source of professional staff for the nuclear reactor projects, excelling Atucha I and Embalse Nuclear Power Plants. This activity had the academic endorsement of Buenos Aires University-Engineering faculty from 1981 to 1994.
As in the case of radiochemistry the Master in Nuclear Reactors followed (in agreement CNEA-National Technological University) from 1999 to 2005 and at present the preparation of human resources is focused in the career previously described under the frame of CNEA-UNSAM agreement.

As for the ***use of radionuclides*** (4), the first course was delivered in 1958 and since then other 95 followed. Some of them were hosted by different provinces. Up to now more than 1900 professionals graduated among physicians, chemists, physicists, engineers, etc. Recently and due to the high demand we admit technicians who can demonstrate at least five years experience in a nuclear medicine center.

Related to the use of ionizing radiation in human health, ***radiotherapy*** (5) is the application that uses the highest doses and thus requires great precision.
The Dosimetry and Physics of Radiotherapy courses handle these topics and have been doing so since long time.
Once again CNEA has been pioneer in the area preparing human resources with specific courses on radioprotection and nuclear medicine (1958) and radiotherapy (1964). 22 dosimetry courses have been recorded since 1964 with increasing participation of physicists and technicians. Physics of Radiotherapy records 21 courses. In both courses there is a limitation in the number of admissions, beyond the necessary background knowledge, imposed by the hospital practice.

4. Other Activities

A series of activities complementary of the main academic ones are performed at the Institute:

Our activities in the nuclear medicine field are being expanded incorporating short training courses for physicians, physicists and technicians. These courses aim to the use of Proton Emission Tomography combined with Computed Tomography (PET/CT) and the production of the necessary radiofarmacy compounds for diagnosis. This activity is performed with the "Fundación Centro Diagnóstico Nuclear" at Buenos Aires which is provided with the adequate equipment.

Special courses "at request". As example we can mention the four months full time courses on *"Basic training for operators of nuclear reactors-professional level"* and *"Basic training for operators of nuclear reactors-technician level"*

We are studying the implementation of a career related to energy, all forms of energy, covering technological, economic and political issues. Of course nuclear energy is included but we consider relevant to place it in the adequate context.

Other topics related to nuclear technology are the object of a regular programme of open seminars.

5. Final Remarks

The scenario imposed by the nuclear renaissance in Argentina presses strongly on the human resource basis. The principal challenge is to cope simultaneously with the urgent need of prepared personnel and the quality of training required. In this aspect the University is playing an increasingly important role covering knowledge areas which were formerly limited to CNEA.

The medical and industrial applications of nuclear technology have a predictable demand and there is a regular quantity of professionals willing to orient their careers in these directions.

A very different situation appears related to nuclear power. Here the demand of engineers founds difficulties related with public perception against nuclear and also a competing demand of engineers from other areas were big projects are underway with higher salaries and less public aversion.

An important campaign is necessary in order to deliver the correct message related to nuclear. It is of paramount importance to improve the public understanding on this technology and the role it can play in solving the increasing energy demand in a world of decreasing energetic resources. Also further precisions about the future national priorities in the area will create the conditions and enthusiast the students to enter into the fascinating and challenging world of nuclear technology.

References

(1) Frame Agreement between CNEA and UNSAM for the creation of the "Instituto de Tecnología Nuclear Dan Beninson", December 2006.

(2) Superior Council Resolution nº 178/2006. UNSAM

(3) Superior Council Resolution nº 179/2006. UNSAM

(4) Neuringer P., personal communication

(5) Feld, D., personal communication

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