NESTet 2013

NUCLEAR **EDUCATION** AND **TRAINING**

Transactions

Madrid, Spain
17 -21 November 2013

EUROPEAN NUCLEAR SOCIETY

ENS CONFERENCE

organised in collaboration with:

AMERICAN NUCLEAR SOCIETY

IAEA

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ISBN 978-92-95064-19-5

These transactions contain all contributions submitted by 15 November 2013.

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What are the needs with regard to nuclear education and training?

FROM OPERATION TO DECOMMISSIONING, A TRAINING CHALLENGE IN JOSE CABRERA NPP

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ABSTRACT

The Decommissioning Phase (D&D) of nuclear facilities in Spain is currently a responsibility of ENRESA (a national waste management public company), to which ownership of the facility is transferred once it has ceased the operation in accordance with Spanish Nuclear Regulation Jose Cabrera NPP (owner Gas Natural Fenosa) was shut down end of April 2006. In February 2010 the installation has been transferred to ENRESA.

The D&D strategy chosen has been “immediate dismantling”. One of the main advantages of immediate dismantling is to include, in the decommissioning team, people who were involved in the operation of the facility with knowledge of the plant and its operational history. The immediate dismantling strategy has maintained significant number of jobs in the installations (about 70 workers from operation, mainly employees from Gas Natural Fenosa). This ensures a gradual transition and minimizes an uncontrolled loss of resources and knowledge.

Given the novel and diverse nature of D&D, a number of new activities are involved which require training, especially during the transition period, between plant operation and the implementation of a decommissioning, where a number of modifications; both technical and organizational; had needed to adapt the plant to meet new objectives and requirements.

Aspects of qualification of the responsible personnel and other personnel are subject to the regulatory authorization. As compared to operation the requirements have been adapted, according with the progress in dismantling and thus with continuous reduction of the radiological risks. The main objective is to ensure the protection of the workers, the public and the environment against radiation and other hazards.

This paper gives an overview of the experience of José Cabrera NPP in the training and the change of qualification of the workers from operation to decommissioning.

The training plan of each worker or group of them has been designed taking into account the background of the worker and the training needs of the job according to the new objectives and requirements.

1. Introduction

The José Cabrera NPP (hereinafter JCNPP or Zorita) has been a pioneer in the development of the nuclear industry in Spain from its beginnings to its complete D&D. The Spanish nuclear industry has considered Zorita as a training school where technicians have been trained and have been implemented new developments, requirements and even new regulations. The training in JCNPP has been adapted to the circumstances following the evolution of the life cycle of the plant.

The decommissioning option chosen is “immediate dismantling of the installation” leaving the site free for “industrial use”.

Human resources management, knowledge management and training play an important role to develop the decommissioning process. The main objective is to ensure the protection of the workers, the public and the environment against radiation and other hazards and, also to ensure that the tasks are completed with respect to safety, schedule, quality, and cost considerations

2. Human resources management & Knowledge management

Knowledge is a dominant feature in our society; knowledge is the basis for all that we do every day. But what is knowledge? Among other definitions we find that “Knowledge is a familiarity with someone or something, which can include facts, information, descriptions, or skills acquired through experience or education. It can refer to the theoretical or practical understanding of a subject.” (Wikipedia). We can define two types:

Implicit or Tacit Knowledge is the kind of knowledge that is difficult to transfer to another person by means of writing it down or verbalizing it.

Explicit knowledge is knowledge that has been articulated, codified, and stored in certain media. It can be readily transmitted to others. The information contained in encyclopedias are good examples of explicit knowledge.

For example, stating to someone that “dog is a mammal” is a piece of explicit knowledge that can be written down, transmitted, and understood by a recipient. However, the ability to speak a language, use algebra or design and use complex equipment requires all sorts of knowledge that is not always known explicitly, even by expert practitioners, and which is difficult or impossible to explicitly transfer to other users.

The conservation and management of explicit knowledge can be relatively easy as it is related to the maintenance of records in physical or digital, but the conservation and management of tacit knowledge is more difficult because it will be closely related to the Human Resources Management (HRM).

In order to ensure a gradual transition and to minimize an uncontrolled loss of resources and knowledge, the Human Resources Management in JCNPP has maintained significant number of workers from operation with specific skills. In JCNPP has been done reassignment of personnel to new job positions/posts, some of them not previously existing during the operating phase.

3. Decommissioning strategy

Training is one of the essential tools required to achieve a successful transition from the operating phase of a nuclear facility to he decommissioning phase and to implement the decommissioning strategy. The training requirements will, however, depend, among others, of the decommissioning strategy chosen.

The International Atomic Energy Agency IAEA has defined three options for decommissioning:

- **Immediate Dismantling** (Early Site Release/Decon in the US): This option allows for the facility to be removed from regulatory control relatively soon after shutdown or termination of regulated activities. The D&D activities begin within a few years, depending on the facility. Following removal from regulatory control, the site becomes available for re-use (New nuclear installation, Industrial installation or other use).
- **Safe Enclosure** (or Safestor SAFSTOR): This option postpones the final removal of controls for a longer period, usually on the order of 40 to 60 years. The facility is placed into a safe storage configuration until the eventual dismantling and decontamination activities occur.
- **Entombment:** This option entails placing the facility into a condition that will allow the remaining radioactive material to remain on-site indefinitely. This option usually involves reducing the size of the area where the radioactive material is located and then encasing the facility in a long-lived material such as concrete, theoretically preventing radition release.

UNESA, Unión Española de las Compañías Eléctricas (Spanish Utility Association) is a professional organization which represents the Spanish Utilities interests. Regarding D&D, UNESA has issued Appendix J to the standard contract UNESA-ENRESA to cover the radioactive waste management and D&D of NPP.

The Appendix J of the mentioned contract defines the activities generic program, the way to coordinate those activities and the responsible entity in the process, where the basic milestones are:

- The Cessation of Operation.
- The Ownership Transference to ENRESA.
- The D&D Start Date.
- The Decommissioning Statement.
- The Site Return.

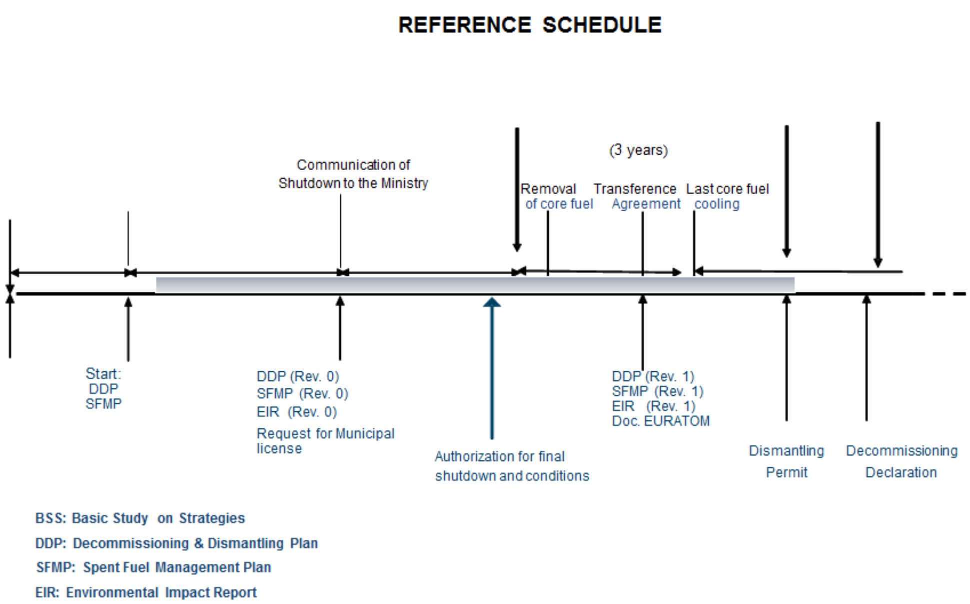

Fig 1 Spanish Strategy Schedule.

The decommissioning option chosen in José Cabrera NPP was **Immediate Dismantling** that option will be the option follows by other plants in Spain. Figure 1 shows the schedule of Spanish strategy.

Five years before the shutdown, starts the decommissioning on the planning stage. Two drafts of the licensing documentation have been considered. The decommissioning project started 4 years before the shutdown. The first documentation was the Basic Study on Strategies to indicate the best approach; strategies and methods for the D&D Project. Three drafts or proposal of regulatory documentation have been required before obtain the "Dismantling permit", 46 months after the definitive shutdown.

One of the main advantages of the chosen decommissioning option is that you can keep the knowledge of people who have worked in the previous phase and you can preserve as much as possible the tacit knowledge.

The duration of the transition period, i.e. between the shutdown and the start of the D&D, can be crucial to preserve the knowledge of the people. Excessive time leads to the loss of personnel due to retirement, transfer or abandonment of the company. In the case of José Cabrera this time was relatively short, less than four years, taking into account that at least this stage should be 3 years.

In the world there are several strategies to decommissioning and dismantling a NPP such as:

- The plant operator is responsible for decommissioning of the facility and carries out the decommissioning using his own personnel.
- The responsibility for decommissioning is the plant operator, but the decommissioning is performed with the support of specialist contractors.

Each strategy has its advantages and disadvantages. In Spain the operator transfers the ownership to ENRESA in order to undertake the D&D project. In this case ENRESA is the plant operator contracting part of the staff who is familiarized with the facility systems, configuration, and operating history of the facility. The decommissioning is performed with the support of specialist contractors, being necessary to ensure that the contractor personnel are adequately trained in decommissioning. Also it is needed to provide sufficient information and/or training in relation to the facility systems, configuration and operating history.

4. Adaptation of the personnel from the operating phase to the decommissioning phase.

One of the most relevant challenges of the transition period (from the operating phase to the decommissioning) has been the transference of ownership from Gas Natural Fenosa to ENRESA. This transference has been produce on 11 February 2010 and involves a change in the organization of the project.

This change in the organization aims to adapt it to the new activities and objectives. The following two organization charts (Figures 2 and 3) show the organization in force at a plant during the operating (ownership Gas Natural Fenosa) and decommissioning (ownership ENRESA) phases.

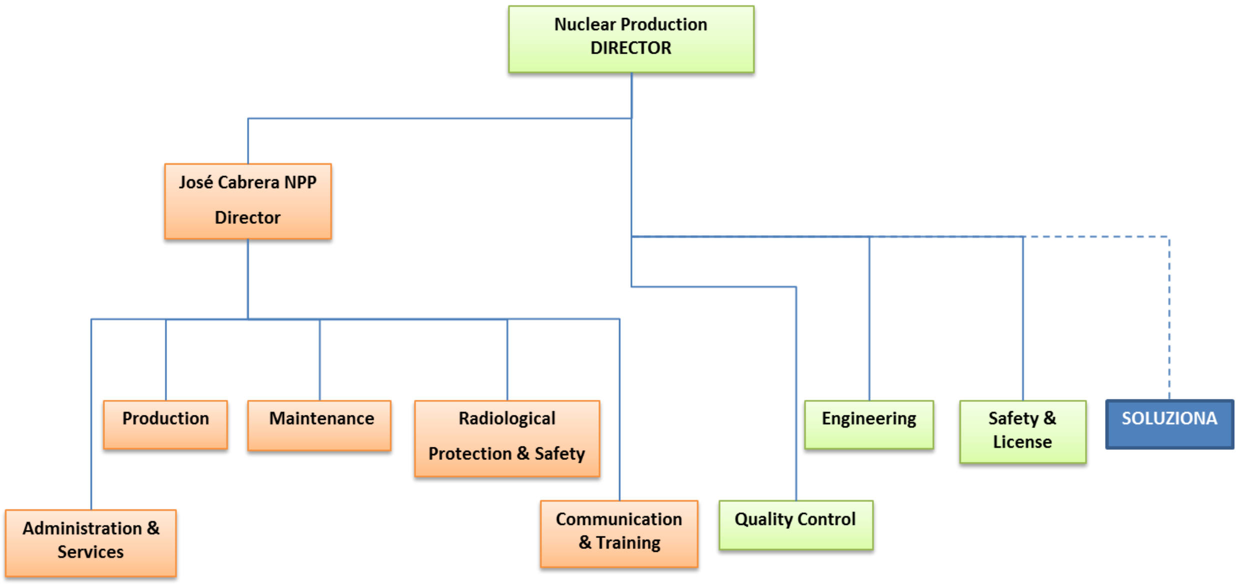

Figure 2. José Cabrera NPP Operating Organizational Chart (Gas Natural Fenosa).

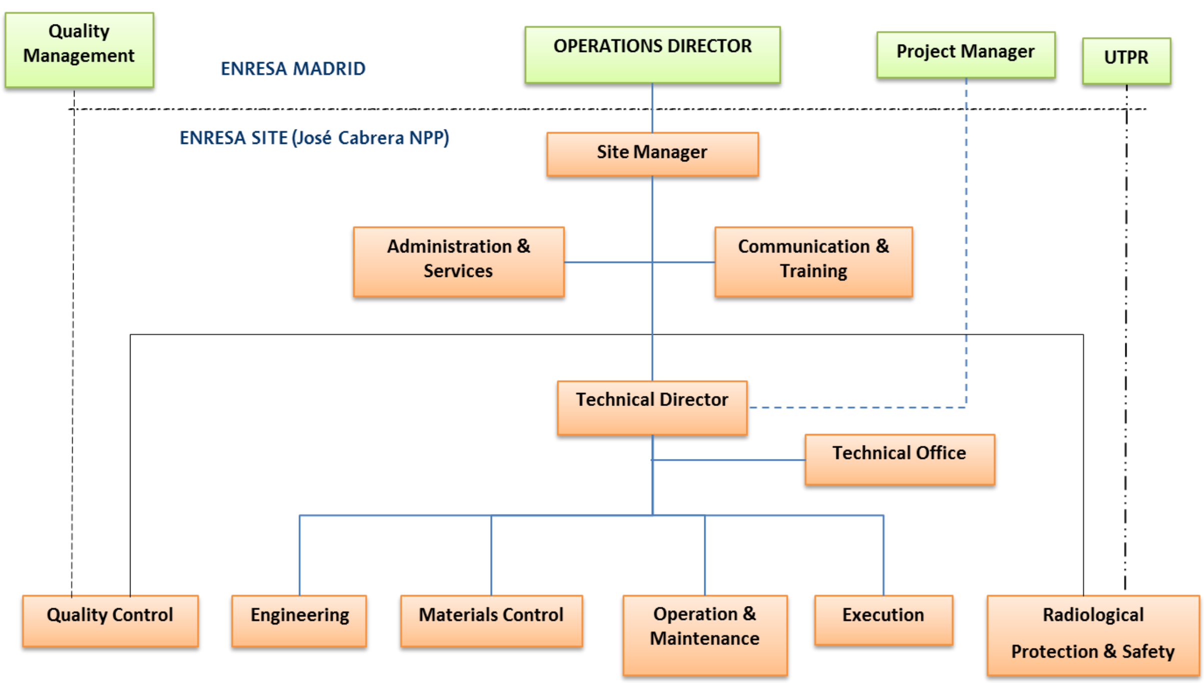

Figure 3. José Cabrera NPP D&D Organizational Chart (ENRESA).

The adaptation of the personnel to the organizational changes has required specific training, especially with regard to how to adapt to the new company procedures and culture and new corporate systems (Document Management System, Integrated Improvement System, Regulatory Requirements [IS-19, IS-24, etc.]).

5. Adaptation of the personnel to the new configuration of the plant

After definitive shutdown of the plant and prior to decommissioning, there are several works that can be carried out as preparatory activities. These new activities require specific training, especially during the transition period, where a relevant number of modifications had needed to adapt the plant to meet new objectives and requirements. Some examples about this kind of works are the next:

- Transfer fuel to dry storage system,
- Dry fuel storage,
- Decontamination of the primary system and auxiliary systems
- Radiological characterization of the facility,
- Systems removed from services
- Other activities aimed at facilitating the subsequent D&D process.

Although there has been an important change from operation phase to the decommissioning phase (Table 1), the ultimate objective has always been the same "The workers acquire and maintain the skills necessary to perform their job efficiently and safely".

OPERATION	DECOMMISSIONING
Reliance on permanent structures for the operating life of the plant	Introduction of temporary structures to assist dismantling
Safety management systems based on an operating nuclear facility	Safety management systems based on decommissioning tasks
Established and developed operating regulations	Change of regulatory focus
Predominant nuclear and radiological risk	Reduction of nuclear risk, changed nature of radiological risk, significantly increased industrial risk
Focus on functioning of systems	Focus on management of material and radioactivity inventory
Access to high radiation/contamination areas unlikely or for short periods	Access to high radiation/contamination areas for extended periods. Importance of Radioprotection measures
Low radiation/contamination levels relatively unimportant	Low radiation/contamination levels important for material clearance
Relatively stable isotopic composition	Isotopic composition changing with time
Routine amounts of material shipped off-site	Larger amounts of materials shipped off-site
Well-known working environment	Possibility of unknown working environment
Routine training and refresher training	Retraining of staff for new activities and skills or use of specialized contractors.
Repetitive activities	One-off activities

Table 1. Operation and decommissioning training requirements.

Many activities and tasks during decommissioning are specifics and only performed one time; for example in José Cabrera NPP the task “Segmentation of internals of reactor vessel”. In such situations it is necessary a specific training program course and training in mockup before the implementation on site.

A new workforce culture (working in a new risk context) focuses on job task has been implemented, as a way to identify hazards before they occur. In D&D Radiological Protection are more relevant than the nuclear safety and conventional risks increase during decommissioning: fire, explosion, electrocution, failure of partially dismantled structures, etc. The Safety culture focuses on the relationship between the worker, the task, the tools, and the work environment. It is necessary to maintain the safety focus of the Staff.

One of the highest radiological risks in D&D is the risk of internal contamination with radioactive material. It has been necessary a extensive monitoring program of workplace and individual contamination.

6. Decommissioning Training courses

One of the pillars of training for decommissioning is the programming of new and recycling courses, which have periodically involved workers of all levels of responsibility.

The decommissioning of a nuclear power plant implies the performance of complex tasks. For this reason ENRESA is implementing a complete training plan, with a view to provide all the workers with the knowledge necessary to guarantee their safety and ensure strict compliance with the requirements imposed by the standards. The Training Plan for the Decommissioning of José Cabrera NPP has applied the directives of the Regulations on Nuclear and Radioactive Facilities, the Regulations on Protection against Ionizing Radiations and the Framework Plan for the Prevention of Occupational Risk.

There is an advantage in using the operators who were engaged during the production phase of the facility, and who are fully familiar with the facility and the operational procedures. These operators and supervisors have a specific license from regulatory body (Consejo de Seguridad Nuclear).

The typical tasks undertaken by the operators include de-fuelling, safety surveillance, waste handling, waste processing, decontamination, and process facility operations. To ensure that all decommissioning work is completed in a safe and efficient manner, the presence of supervisors to oversee the operators is essential.

The training program designed in JCNPP considered two types of workers: personnel with license and personnel without license. During the three first years of decommissioning JCNPP has organized 1,019 courses, attended by some 7,730 people; these courses have included almost 4,000 classroom hours, implying some 19,971 man·hours. (see Tab. 2). Part of those courses has been received by personnel with license (See Tab. 3).

Year	Nº Courses	h TOTALES	Nº persons	hxH
2010	307	794	2364	5803
2011	340	1181	2741	7636
2012	372	1141	2608	6532

Table 2. Training courses of Non-Licensed Staff (Personnel)

Year	Training environment	Nº Courses	h Hours	h TOTAL	Nº persons	Manxh
2010	Face to face teaching sessions	57	54	156	288	640
	Tutored Studies	10	56	56	120	672
	TOTAL	**67**	**110**	**212**	**408**	**1312**
2011	Face to face teaching sessions	43	75	142	479	840
	Tutored Studies	1	2	2	11	22
	TOTAL	**44**	**77**	**144**	**490**	**862**
2012	Face to face teaching sessions	34	77	215	345	733
	Tutored Studies	4	8	8	36	78
	TOTAL	**38**	**85**	**223**	**381**	**811**

Table 3. Training courses of Licensed Staff (Personnel)

Table 4 is an outline of the contents of decommissioning training courses that would be applicable to both managers and professional staff. In this table we can see the training similarities with operation phase and specific training courses applied to decommissioning.

TRAINING: SIMILARITIES WITH OPERATION PHASE
BASIC INITIAL TRAINING
➢ Access Course.
○ General Information (Enresa and Decommissioning Project)
○ Emergengy Plan
○ Safety Culture
• *Radiological Protection and Industrial Safety*
• *Quality Assurance*
• *Actions in case of a fire / accident*
SPECIFIC INITIAL TRAINING (depending on job position)
➢ Radiological Protection
➢ Emergency Plan
- Practical exercices (classification of events, communications, radiological impact assesment,etc.)
➢ Fire Fighting
➢ Specific Tasks (job position)
CONTINUOUS TRAINING
➢ **Annual Training** (Emergency, radiological protection, etc.)
– *Documentation review, lessons learnt, etc.*
➢ **Regulator Control**
– *Annual Programme is sent to Nuclear Safety Council*
– *Training Annual Report*
➢ **Specific Programme for Personnel with License**
– *Supervisors*
– *Operators*
➢ **Common Topics (Operation-Decommissioning)**
– *Reglamentary Documentation*
– *Working Procedures*
– *International Experience, etc.*
TRAINING CHARACTERISTICS DURING DECOMMISSIONING PROJECT
ENRESA «WAY OF WORKING»
– *Information Systems*
– *Quality Assurance System*
– *Contracting Process*
– *Documentation Management and Records Keeping.*
ADAPTION TO DECOMMISSIONING SCHEDULE
– ***Preparatory Activities (2010-2012)***
• *Modificartion of Support Systems (ventilation, electrical, fire fighting,etc.) (2010-2011)*
• *Modification of Auxiliary facilities (Rad. Waste Stores,etc.)*
• *Configuration and Operation of New Installations (2012)*
• Decommissioning Auxiliary Building
• New Control Room
• Official Test Plan with Regulator
– ***Dismantling Activities***
• *Reactor Internals Segmentation (2011-2012)*
• *Radiological Components (2012-2013)*
• *Reactor Vessel Segmentation*
• *Loading and transfer of Special Waste to Dry Storage Area*
TRAINING ACCORDING TO ORGANIZATIVE CHANGES
• *Key job position incorporation*
• *Change of job position (dynamic organization)*
DECOMMISSIONING KEY PROCESSES
– ***Material Management***
• *Segregation and in situ Characterization process*
• *New equipment (compactor, crane, etc.)*
• *Material Release Methodology*
• *Surface Release Methodology*
– ***Safety Culture***
• *Adaption of Radiological Protection to Decommissioning.*
• *Industrial Safety (protective equipment, scaffolding, etc.)*

Table 4. operational versus decommissioning training courses

6. Conclusions

The José Cabrera NPP has been a pioneer in the development of the nuclear industry in Spain and also in the immediate D&D activities.

In order to achieve a successful transition from the operational phase of a nuclear facility to the decommissioning phase and to implement the decommissioning strategy the Human resources management, knowledge management and training play an essential role.

The specific nature of the Spanish case implies the transfer of the ownership from the previous operating to Enresa at the moment of granting of the dismantling permit. The transition period requires time of overlapping between the two organizations.

The adaptation of the personnel from the operational phase to the decommissioning phase requires specific training, especially regarding new organization and company culture, new responsibilities and requirements.

HIGHER LEVEL ACADEMIC NUCLEAR ENGINEERING EDUCATION IN FINLAND – NEED OF POST GRADUATES?

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ABSTRACT

Numerous new experts are needed in Finland to replace retirees and to recruit new ones for the various R&D tasks arising in the nuclear sector. The Finnish nuclear competence review in 2012 showed that of the 3300 professionals over 10% had a postgraduate degree – mostly obtained in the 70´es and 80´es. Even a mature field still needs many high level academics? Postgraduate researchers can be trained in a wide variety of technical and socio-economic R&D tasks of nuclear energy. Strict scientific approach partly assures the quality and enables to create a broader perspective. Besides innovativeness, problem solving skills, and specific personal competence, an expert has to understand nuclear safety and safety culture. In a small country, special and general knowledge may have to be compromised. Postgraduate E&T requires resources to pursue relevant R&D. In Finland long-term funding has been based on national research programs like SAFIR2014 (nuclear safety) and KYT2014 (nuclear waste management). Fusion energy research is fully coordinated by the Euratom-Tekes Association. For Generation IV activities an informal GEN4FIN network has been established. Academy of Finland has financed a research consortium called NETNUC 2008-2011 and the Ministry of Education and Culture is sponsoring the doctoral school on nuclear engineering and radiochemistry, YTERA 2012-2015. The future strategy of R&D and its role in postgraduate education is briefly discussed. We have utilized many European E&T schemes under EFTS (e.g. ENEN, PETRUS, CINCH) and the EU projects containing educational components. The role of European research facilities (JRC, JET, etc.) has been instrumental in researcher training. ENEN and its activities are connected to Finnish postgraduate activities. Fusion researchers have participated in two goal oriented training programs (GOT). The time span in achieving expertise is long: the steps M.Sc. → D.Sc./Ph.D. → “tenured position” takes a minimum of 5+5+5 years. Besides competent researchers, teachers and instructors are needed, too. Finnish universities have supported nuclear engineering education by creating new tenure track positions. Post graduate studies can follow three routes: 1) full-time (fast) researcher training at academic doctoral schools, 2) part-time graduate studies with university supervision, external instructors/mentors, and participation in R&D programs, or 3) completion of the degree by continuous education during the job.

1. Introduction

The electricity consumption in Finland was 85.2 TWh in 2012 and 25.9% of that was supplied by nuclear power. Imported electricity from Scandinavia and Russia amounted to 20.5%. We have four running units, Loviisa 1&2 and Olkiluoto 1&2, licensed to operate until 2027-2030 and 2018, respectively. The Olkiluoto 3 unit is under construction and for two more units, Olkiluoto 4 and Hanhikivi 1, decisions-in-principle have been ratified. Spent nuclear fuel is to be buried in a deep-rock repository. The underground rock characterization facility ONKALO for geological disposal in Olkiluoto has been excavated and POSIVA is waiting the construction license for the encapsulation plan and for the geological disposal facility. Spent fuel disposal operations are expected to take place in early 2020. The main building blocks to ensure nuclear safety and spent fuel management have been politically solved and the work continues with technical assessments together with R&D support. A critical condition to use nuclear energy is that enough competence exists to insure that all operations are safe. License holders are responsible to have the relevant know-how, but in addition independent expertise of regulators and researchers must be sufficiently available.

The nuclear competence level in Finland has been regularly assessed against the prevailing nuclear scenarios. A most hectic period started when the presently operating reactors were constructed around the 70´es. Then also the main nuclear research infrastructure was created. Later on, TMI-2, Chernobyl, and Fukushima and less severe incidents have made large impacts to nuclear research. Plant modernization projects managed to counteract the nuclear stagnation of the 90´es, but still in 2000 the worst nuclear competence scenario assumed “no new build and only replacement of retirees”. Even that scenario predicted a considerable E&T need for the new generation of professionals. The actual situation changed dramatically in 2002 when Olkiluoto 3 was decided. A large number of professionals have been replaced inside the nuclear sector and new ones recruited and trained. Academic research has not fully managed this situation: research positions are economically non-competitive, hard to create and fill. Part time postgraduate studies have been dispersed by the unavoidable project work.

This paper addresses the question whether we need research minded postgraduates with higher academic degrees or are experienced engineers sufficient to run safely our nuclear program. Clearly both are essential. Teachers, supervisors and instructors are indispensable in all nuclear E&T. Nuclear fission technology may be regarded a mature field in view of current science frontiers, but still numerous R&D problems have to be solved. Lately September 11 and Fukushima challenged the safety of present nuclear power plants. Demonstration of safety is multidisciplinary and involves cross-boundary issues which provide excellent ground for new innovations and insights. Widening the research to more exotic regions, like Gen IV, P&T of nuclear waste, thorium fuel and fusion, provides a huge number of postgraduate topics and enables to find new views and to further validate contemporary procedures.

Today, many factors, however, hamper nuclear energy research: degradation of present research infrastructure, political reluctance, large resource requirements, and cumbersome licensing of new facilities. No wonder, only a few countries can afford large scale nuclear research beyond industrial R&D. Academic studies in Finland have to be based on a few spearheads and full exploitation of domestic and international collaboration in wider areas. Nuclear engineering R&D tasks range from basic studies to continuous improvement projects, and to operation of all facilities in safe, economic and sustainable manner throughout all the phases from new build till decommissioning and waste management.

The entire nuclear sector needs postgraduates with fundamental researcher skills and proper attitudes. Besides innovativeness and an ability to tackle new problem areas, they are assumed to have basics of nuclear safety and safety culture. In a small country like Finland, one has to compromise between special and general knowledge. A large fraction of Finnish R&D in the public domain is being done by graduate and post graduate students – of course, senior experts are essential to supervise this work. Formally, the academic theses as research deliverables provide quality assurance of the projects; academic degrees can be included into an individual´s learning portfolio with ready accreditation. This paper deals with post graduate studies in Finland. In Section 2 the Finnish nuclear competence survey and the main universities involved are discussed. Section 3 describes the Finnish nuclear R&D networks and their role in postgraduate education. The doctoral school on nuclear engineering and radiochemistry is presented in Sec. 4. Section 5 concludes the paper.

2. Academic E&T activities of nuclear engineering in Finland

2.1 Nuclear competence in Finland - a survey

The intense nuclear activity in Finland has created a large need for new professionals understanding the special features of nuclear energy. The know-how situation has regularly been followed and recently an extensive human resource survey was published in 2012 by the so-called Competence Committee [1]. The statistics of this report notes that in 2010 the total number of nuclear energy personnel was 3285, and from them 1298 had a higher polytechnic degree or a university M.Sc. degree, and 387 a licentiate or doctor degree. Many of the 232 doctoral degrees were obtained in the 70´es and 80´es at the time when the present nuclear power plants and the related infrastructure were established. A large number of academically educated senior experts have in recent years retired or are close to do that.

The Nuclear competence in Finland report displays extensive statistics of personnel according to their specialist duties, competences, degrees, age distribution and work experiences, working sectors, and many other factors. As a conclusion, in the Finnish nuclear energy sector about 1200 new persons has to be educated and trained within twelve years to satisfy the estimated personnel of 4500 in 2025. Persons with higher university or polytechnic degree will increase about 35% from the level of 2010. The number of postgraduates is somewhat hard to predict due to the uncertain evolution of academic positions and the appeal in researcher tracks. The present situation is, however, not expected to change drastically except that licentiate degrees will most probably be gradually abolished.

The premises of Finnish universities to provide postgraduate education in nuclear sector are discussed in the next section. Some experts have in the past obtained their doctoral education in universities other than those specializing on nuclear sector education. Their nuclear qualifications come from on-the-job learning and supplementary education and training. Probably this route of "nuclearization" will continue and should be even enhanced.

As a continuation of the Nuclear competence in Finland survey, a new working group has recently been established to make a strategic roadmap up to 2030 involving R&D focus areas, its resource needs, and ways to enhance international collaboration. This project has an acronym YES, coming from "Nuclear Energy Strategy" in Finnish. YES-discussions deal also fusion research, EC Fusion Roadmap 2050, and its goal-oriented training tasks. An important work package in YES is to explore the need of researcher education. Postgraduate studies are fundamentally related to R&D and plans of its E&T can exploit experiences from our national research programs SAFIR2014 (nuclear safety) [2] and KYT2014 (nuclear waste management) [3], and their predecessors. All these programs have emphasized the importance of researcher training, and have used the number of M.Sc. and D.Sc./Ph.D. theses as performance indicators. Postgraduate studies require relevant research infrastructure which due to its expenses must more and more be based on international collaboration. A decision to decommission the Triga research reactor of VTT has been made and replacement of its activities should be found. Alternatives exist but how to make the selections. The strategy planning project YES attempts to respond these questions.

2.2 Universities involved in the nuclear energy sector education

Aalto University (Aalto) and Lappeenranta University of Technology (LUT) are the main academic institutions where nuclear engineering (NE) education has been widely covered. The Laboratory of Radiochemistry of University of Helsinki is unique in its own field in Finland. Several other universities are active in the nuclear sector within limited areas. University of Jyväskylä has expertise in nuclear physics, nuclear waste management, and in socio-economic topics. The Physics Department in University of Helsinki is e.g. studying nuclear materials. These are just examples of universities involved; a fuller description can be found in the competence report [1]. A characteristic feature in Finland is that the academic community is rather well networked and collaborative in many disciplinary areas. A wish of improvement is to further the dialogue and understanding between physicists, chemists, social scientists, etc. National research programs can have a great impact in satisfying this goal.

Aalto University started in 2010 when three former academic institutions, Helsinki University of Technology, Helsinki School of Economics, and the University of Art and Design of Helsinki merged. Nowadays Aalto consists of six schools where nuclear engineering is present in the Schools of Science, Engineering, Chemistry and Electronics. Aalto University is very multidisciplinary providing comprehensive coverage of the nuclear field from human behavior to dedicated technologies: fission and fusion reactor physics, thermal hydraulics, nuclear materials, structural safety, power systems, PSA, systems studies, organization management, automation and control, ICT and safety critical IT, and nuclear waste. These activities are scattered into many smaller units which necessitates efficient intra-university networking.

Aalto University has great expectations on multidisciplinarity and the catalytic effects research boundaries can create. On the top level strategy of Aalto sustainable energy has large priority and consortia like Multidisciplinary Institute of Digitalization and Energy (MIDE) have received considerable funding. In the School of Science the Aalto Energy Science Initiative (ESCI) encourages also nuclear projects. AaltoSafe is a platform planned for education and networking within nuclear safety. A master´s degree of Nuclear Engineering is not at the moment anticipated in Aalto. No doubt, such a degree would have an imago value, but to satisfy a comprehensive curriculum of nuclear engineering and, on the other hand, be flexible enough for academic ambitions may be incommensurable. The Otaniemi campus in Espoo is a huge technology concentration in Finland. In particular the vicinity of VTT technical research centre is crucial. Just to mention a few other examples of other R&D institutes: Geological survey, paper and pulp laboratory KCL, IT centre for science CSC, Centre for Metrology and Accreditation Mikes, etc. All these units collaborate with Aalto and recruit many of its postgraduates.

LUT Energy of Lappeenranta University of Technology (LUT) is the largest academic research and education organisation in Finland's energy sector. It works in close cooperation with VTT and all universities associated within the field. The main application areas of energy technology research include energy production and conversion processes, and energy-efficient equipment and processes in accordance with sustainable development principles. The research operations within these areas are built primarily upon robust basic competencies in thermal dynamics, fluid dynamics and heat transfer.

The primary research area of the Nuclear Engineering Laboratory has been the experimental and computational research of nuclear safety. Several extensive test facilities have been constructed at the university research laboratory for simulation of light water reactor safety systems: PACTEL, PWR PACTEL, PPOOLEX. Unique test data has been produced using these facilities, primarily for the purposes of software validation. This data is utilised every year by various organisations in several SAFIR2014 research programme projects. Using its own test results, LUT has developed calculation codes for thermal-hydraulic and fluid dynamic safety analyses of transient and accident phenomena codes as part of several international projects, such as the ongoing EU projects and within OECD/NEA.

The COUPE project investigates phenomena related to new types of nuclear reactors and is funded by the Academy of Finland. LUT focuses particularly on coupled modelling of gas-cooled Pebble Bed Modular Reactors (PBMR), taking advantage of the institute's competence in combustion modelling. Reactor physical modelling has been carried out using VTT's SERPENT software. LUT is a member of the Sustainable Nuclear Energy Technology Platform SNE-TP.

The Laboratory of Radiochemistry of University of Helsinki is the single general university unit in Finland in its field, and is a very large one even on an international scale. Its largest area of research is final disposal of nuclear fuel. The laboratory plays a central national role especially in the study of the behaviour, retention and migration of radionuclides dissolving from nuclear fuel in bedrock and soil. The laboratory has developed an internationally unique method for determining rock porosity, and this is applied, for instance, to in-situ diffusion testing of radionuclides in Olkiluoto. The Laboratory of Radiochemistry also studies the effects of radiation on dissolving of uranium fuel.

Another important area of research related to the nuclear sector is development of inorganic ion exchangers for selective separation of radionuclides from nuclear waste effluents. Fortum Oy produces three types of exchangers developed at the laboratory in industrial scale and these have been used in a large number of nuclear facilities in several countries, the latest and so far largest utilization being the waste effluent treatment at the Fukushima plant in Japan. The Laboratory of Radiochemistry is the leading research unit in the world in this area. The third nuclear-related research field is environmental radioactivity. The most important current research focuses on dissolving and migration of radionuclides from mining mill tailings in the ground and waterways. The laboratory also develops methods for determination of radionuclide contents in nuclear waste.

Aalto University and Lappeenranta University of Technology have expressed a clear policy to support nuclear engineering education and several related tenure track slots have been filled. However, due to retirement the actual increase in personnel is modest. The new positions have involved reactor physics, nuclear safety, waste management, and materials. In addition ICT, risk and system studies, safety critical organizations, are under consideration. Tenure track recruiting with a narrow profile of expertise is uncommon, and professors´ interests usually cover both nuclear and non-nuclear applications.

Postgraduate education in all universities has the general goal of educating proper research minded students, but thereafter real expertise must be reached by "nuclearization" and further on-the-job learning. Stringent measures are being adopted to keep the graduation time short for full time doctoral students. The tenure track system enables researchers' career development, but the number of available slots is limited, salary benefits unattractive, and in particular in technical disciplines there may be too strong weight on science impact factors. Besides full-time research students paid by the university and selected by a general competition, part-time post graduate studies can also be carried out, but then external funding is needed and usually the student has to carry out project work outside his/her thesis to supplement the salary. The third path is the long one where occasional participation in academic courses, continuing education and life-long learning provide the necessary background to write the thesis. In this case the accreditation of the studies, learning portfolios, mentoring and tutoring play an important role.

3. Research networks and their role in E&T

3.1. National research programs

Strong domestic collaboration within the nuclear R&D has traditionally alleviated our limited resources available and provided dissemination of results. Nowadays, the role of international collaboration is becoming even more important. Nuclear safety research has been coordinated by several national programs: the present one is SAFIR2014 covering 2011-2014 [2]. The predecessors of SAFIR2014 have been assessed and the program format with active steering and reference groups appears to be most cost-effective. Posiva Oy carries the largest part of research on nuclear waste management, but the publicly funded KYT2014 [3] is also an important contributor. The two research programs above involve our current NPPs and waste facilities. Future nuclear energy alternatives are partly sponsored from grants and other separate funding sources. The GEN4FIN network is an example of a live collaboration forum. Fusion energy research has been extensive and efficiently coordinated by the Association Euratom-Tekes.

The mission of the SAFIR2014 research programme, derives from the stipulations of the Finnish Nuclear Energy Act: "*The objective of the SAFIR2014 research programme is to develop and maintain experimental research capability, as well as the safety assessment methods and nuclear safety expertise of Finnish nuclear power plants, in order that, should new matters related to nuclear safety arise, their significance can be assessed without delay.*" Cooperation and networking are established in order for the Finnish research on nuclear safety to reach the following standard: "*The SAFIR2014 research community is an internationally respected and* *strongly networked competence hub that has extensive expertise, equipment and methods for conducting internationally outstanding research on nuclear safety issues important to Finnish nuclear power plants."*

The SAFIR-programmes have played a significant role in educating a new generation of experts and in knowledge transfer. They have greatly contributed to the R&D resources and provided essential guidance by senior researchers. Networking between academic supervisors and instructors support the career development of part-time doctoral students and also facilitate their future employment. High-level research, international cooperation and contacts between different scientific and technical fields created in research projects contribute to deepening and broadening the know-how among senior researchers. Learning portfolios of E&T during life-long or continuous education tasks, could formally be accredited by a review committee consisting of supervising professor(s) and recommended by reference group professionals. Postgraduate education can also be used to enhance the scientific standard, the number of publications and the span of the research programmes. Doctoral studies may take several years and, therefore, full-time funding of it from research programmes has required additional funding or carrying out projects not directly involved in the completion of the thesis.

The public nuclear waste management program KYT2014 has analogous goals as SAFIR2014 but includes smaller amount of funding and while its spectrum of disciplines is very wide individual projects are relatively small. The goal of KYT2014 is ”*to ensure that the authorities have such sufficient and comprehensive nuclear engineering expertise and other facilities at their disposal that are needed for comparisons of the various ways and methods of carrying out nuclear waste management*”. In particular the law stipulates that the research projects ”*shall be of a high scientific standard and their results shall be publishable*”. In the project assessment the educational merits are one criterion. Due to the financial limitations KYT2014 has a catalytic effect but can only provide partial funding for thesis work. KYT2014 can also cover topics in life and social sciences.

The third domestic research network is called GEN4FIN. Although, it involves only money for coordination, it serves as a discussion forum for research units and other Finnish stakeholders, and disseminates information on international activities like GIF, ESNII, SNE-TP, NOMAGE4 etc. Generation 4 plans involve very long time goals and it is well suited to university driven projects. A good case is the NETNUC consortium between Aalto, LUT and VTT which was part of the SusEn sustainable energy research program in 2008-2011. NETNUC project was practically the first one of its kind funded by the Academy of Finland. Except fusion research, systematic R&D and E&T of researchers by the Academy of Finland and the Ministry of Culture and Education (MCE) is a reasonably new feature.

Fusion research in Finland has been very successful, in particular, concerning graduate education. One of the benefits has been the coordination by Euratom and of course the continuous, large enough funding. Just to mention a few significant features:

- Instead of an own plasma physics device, we have concentrated on a few large scale tokamaks in Europe, JET and Asdex UG

- The flexible mobility schemes and remote participation have facilitated efficient use of European fusion research campaigns, besides a few long-term researcher secondments.
- Basic knowledge on fusion research has been updated to know-how created.
- Our research areas have evolved to focus into computational plasma engineering, wall-materials and remote handling, and some other technology areas.
- Goal oriented training (GOT) has taken place in both computational areas GOTiT and in remote handling.

GOT provides an interesting comparison between the need of E&T of experts for ITER and DEMO and, on the other hand, similar Generation 4 facilities (cf. ENEN-III). In both regions, the number of people remains for a long time limited and very special expertise is needed.

3.2 YK nuclear safety course – a case of nuclearization

The nuclear energy sector requires a lot of various kinds of professionals, but usually their acquaintance in nuclear energy problems is limited. These people need supplementary education in nuclear safety and safety culture – the nuclearization process. The nuclear safety course, YK, is an excellent case put into practice to nuclearization of professional. The first six week long course YK1 took place in 22.9.2003 - 6.2.2004. Today, YK11 has just started and, of course, has evolved and improved during the ten years. Altogether more than six hundred people have been trained. A more detailed description of the YK courses can be found for instance in this conference's Poster sessions. It is worth mentioning that successful passing of the YK-courses has entitled the students 8 ECTS as a part of their post graduate curriculum. The YK courses providing for students a broad view on the nuclear field, is deep enough and insures excellent integration into the nuclear field. YK is also an important possibility for professionals who have done their researcher education in other fields.

3.3 National Waste Management course

In 2010 a course covering nuclear waste management (Kansallinen YJH) was launched in 2010. The course curriculum was designed based on the earlier Finnish experiences in teaching the subjects. The full six-day course has been run now since 2011 for around 20-25 students at a time. YJH credits are 1-2 ECTS. The course set-up is similar to the YK-course where the content is produced jointly by the participating organizations. To fully understand the wide range of problems in NWM the course has been favorably received.

3.4 International collaboration in education networks

The European and other international E&T schemes under EFTS and the numerous R&D fission projects strongly related to education, have been noticed and exploited in Finland. Aalto and LUT are ENEN [5] members and e.g. YTERA makes use of this network. Similarly there is YTERA connection between University of Helsinki and radiochemistry projects like CINCH, and JRC. The new PETRUS III EFTS also involves a postgraduate component and Aalto University is involved in this project together with other ENEN member universities.

Major European cooperation forums related to Education and Training and maintaining the nuclear competence include also the EHRO-N (European Human Resources Observatory in Nuclear) initiative under the Joint Research Centre in Petten, and the working groups in this field under the two technology platforms i.e. the Education, Training and Knowledge Management (ETKM) of the Sustainable Nuclear Energy Technology Platform SNE-TP and the Competence Maintenance, Education and Training Working Group (CMET) of the Implementing Geological Disposal of Radioactive Waste Technology Platform IDG-TP.

Today, most of the Euratom R&D projects are supporting participation of young scientists and training of doctoral students. This is an opportunity that could be benefitted more in the Finnish doctoral programme in the future. Also the Jules Horowitz materials testing reactor (JHR MTR) that is participated by the Finnish JHR MTR pool in realising the testing facility, is an important example of the future possibilites to make experimental research in an European facility when it is started around year 2016.

We have compared the activities of the Finnish doctoral E&T programs with analogous European programs. A case study is offered by the characterization and implementation of the education of GEN4 engineers within ENEN-III work packages. In European Fission Training Schemes harmonization and mutual recognition and accreditation of studies is an important topic that has been taken into account also in our education plans.

4. Doctoral program YTERA

Safe utilization of nuclear energy demands thorough knowledge, skills and competence regarding construction, use, decommissioning, and nuclear waste management during the long lifetime of a nuclear power plant. Finland has committed itself to nuclear power for over a hundred years due to its existing NPPs and new builds. After the recent decisions-in-principle the Parliament commitment is strengthened implying also that additional resources are needed to cover all nuclear-specific fields. Research and resources in nuclear have traditionally been scarce in Finland as compared to European standards. The public stakeholder, the Ministry for Employment and the Economy has launched initiatives like the nuclear Competence Committee and the YES strategy group to strengthen E&T and R&D in the nuclear energy sector.

As an essential part of these efforts, Aalto University, University of Helsinki and Lappeenranta University of Technology proposed long-term collaboration of postgraduate education within nuclear engineering and radiochemistry (YTERA). This collaboration originated from NETNUC consortium and GEN4FIN activities. YTERA Doctoral School of Nuclear Engineering and Radiochemistry [4] has its present funding for 2012-2015. YTERA contributes to implementing the statement of the Finnish Parliament, attached to the decisions in principle on new nuclear plants on 1.7.2010: "*The Parliament provides that the Government creates such conditions that Finnish labor, competence and enterprises can be utilized in the new nuclear projects*."

Public funding of YTERA is from the Ministry of Culture and Education, the participating universities, and Academy of Finland. In addition, all the nuclear power companies, Fortum Oyj, TVO Oyj and Fennovoima Oy, and Posiva Oy, provide considerable private sector sponsoring for YTERA. All our Finnish stakeholders are members in the YTERA steering committee and can influence the programme. Each student is enrolled in their own university and obey the respective study regulations. The effective collaboration between the participating universities facilitates acceptance of individual studies between various partners.

YTERA employs seven full time graduate students and 27 associated students with other external funding. YTERA provides courses, seminars and other educational actions and is an important network for nuclear engineering postgraduate students. The enrolled students have actively taken part into conferences, courses and student exchange to abroad which has been secured through the possibility to receive travel grants. YTERA activities are regularly evaluated by students, supervisors and instructors, teachers, and the stakeholders. YTERA seminars enhance social and scientific networking, and the programs are planned and leveled to truly satisfy multidisciplinarity. The stakeholders have all emphasized the need to provide, besides the thesis topic issues, also sufficient breadth of the studies. About half a dozen doctoral degrees are expected to be completed within YTERA by this year.

The goal of YTERA doctoral program is to educate high-quality researchers and experts for the needs of universities, industry, authorities and other society. The program is supported by all relevant interest groups in Finland in the fields of research, education, industry and public authority. The YTERA program also utilizes international education networks for nuclear engineering and radiochemistry where the partners are already members. An essential part of the program is a 6-12 months visit at a cooperating foreign university or research center.

The principal research areas of the graduate program are related with safe utilization of nuclear installations and their development:

- Nuclear engineering, reactors of the next generation
- Geological Disposal of nuclear waste and Partitioning and Transmutation
- Sustainable fuel cycle
- Nuclear safety
- Socio-economic questions and environmental impact of nuclear energy.

Themes for research are long-term applications of nuclear energy and demanding development projects for current plants. This kind of challenging work creates both future teachers and researchers and broad minded top experts that are indispensable for assuring safety and competitiveness of nuclear energy.

5. Discussion

Many more issues should be considered:

- How to enhance R&D in areas where acute demand is high but only a few critical persons are available (ICT, several areas in materials, …)
- Practical realities: personnel cannot be obtained as JOT (just on time) and stakeholders cannot keep reserve personnel.
- How to integrate science in socio-economic areas
- Head-hunting of most promising students?
- The market prospects for narrow-band experts for very long time prototypes (ITER etc.).
- The nuclear taxonomy: a comprehensive, detailed curriculum versus general and flexible course lists?

- How to encourage cross-disciplinary attitudes?
- General ideas of Bloom´s taxonomy are very useful (emphasized e.g. in ENEN-III)
- How to assure long-term funding for full-time research.
- Etc.

To repeat: Nuclear postgraduates with fundamental researcher skills and proper attitudes are needed for R&D tasks involving a wide range from basic studies in the field to the continuous improvement of our running nuclear facilities. Besides innovativeness and an ability to tackle new problem areas the expert is assumed to have particular competences concerning safety and safety culture. In a small country one must to some extent make compromises between special expertness and on the other hand the profound knowledge real generalists´ have to possess.

The time span in achieving reasonable expertise is long – to reach a M.Sc. is typically five years, a D.Sc./Ph.D.-level adds five years and a further five years is needed to obtain a tenured position at a university. In practice, doctoral level research careers in Finland have been pursued during on-the-job training in nuclear industry, universities, and/or research institutes together with a ´light´ university level supervision and tutoring. Presently, the general trend is to have a stricter formal control on post-graduate studies and thus shorten the graduation times, but at the risk of less-mature skills and knowledge. The economic competitiveness of various R&D paths is an important issue in which also the added value of a formal graduation has to be assessed. Several means, e.g. an "inverse sabbatical", are worth trying to improve completion of doctoral studies at the research institutes or industry.

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REVISITING THE SLOVENIAN PH. D. THESES IN NUCLEAR ENGINEERING: IS USE-INSPIRED BASIC RESEARCH AN APPROPRIATE GOAL?

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ABSTRACT

Slovenia is the smallest nuclear country in the world. The scarce resources available for the national research activities are additionally affected by the somewhat contradictory but well established concepts of basic and applied research, stipulated by the public research funding agencies and industry, respectively.

To progress strategically towards the use-inspired basic research may be therefore perceived as an adequate option for a sustainable development of a nuclear engineering and safety research group.

An analysis of Ph.D. theses proposed and defended during the 25 years of the Nuclear Engineering Programme jointly operated by the University of Ljubljana and Josef Stefan Institute has been performed to evaluate the main drivers directing the research in the past. More than 20 Ph.D. theses in the fields of thermal hydraulics, integrity and ageing, probabilistic safety assessment and severe accidents were included in the analysis. The evaluation has been performed by the supervisors and authors by answering a set of questions related to the input data, research methods and results.

The results indicate that both students and supervisors largely agree that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses.

1 Introduction

Slovenia is the smallest nuclear country in the world. The single unit nuclear power plant located at Krško, Slovenia, is jointly owned by the utilities from Slovenia and Croatia. The electricity produced is shared in the 50%-50% fashion by both owners.

Such arrangement brings a full national responsibility towards the nuclear safety to Slovenia and at the same time poses rather strict limits to the resources available for the Slovenian national research. The scarcity of the research resources is furthermore affected by the traditional but somewhat contradictory concepts of basic and applied research, stipulated by the public research funding agencies and industry, respectively.

The dichotomy of the basic and applied science has recently received a wide attention in the literature. Mavko in Kljenak [1] reviewed the doctoral theses in the fields of nuclear reactor thermal hydraulics and severe accidents, from the point of view of “basic” vs. “applied-oriented” They limited the review to the theses completed at the Reactor Engineering Division of the Jožef Stefan Institute within the graduate studies of nuclear engineering at the University of Ljubljana, Slovenia. They showed a preponderance of the basic theses over applied-oriented ones and concluded by survey of the later positions of the holders of doctoral degrees, that the work on basic thesis may still be an adequate basis for future careers in the nuclear or other industries.

Other interesting examples include Tijssen [2], who derived a comprehensive system for the classification of the scholarly journals according to their “application orientation” and Evans [3], who noted that the “industry partnerships draw high-status academics away from confirming theories and toward speculation”. It has to be noted however that it is far beyond the scope of this paper to make a thorough review of such studies.

Stokes [4] on the contrary argued that the basic and applied research may coexists. Louis Pasteur was identified as typical example, since he made a purely basic discovery of the microorganisms while on the mission to improve the brewing process. Stokes’ further examples included Niels Bohr, who pursued basic research without any considerations of use. On the other hand, Thomas Edison was known for his passion for application in the absence of a need for deeper understanding of the causes.

Stokes proposed to visualize the coexistence of the basic and applied research in a two dimensional space with the “Quest for fundamental” understanding” spanning the abscissa and the “considerations of use” the ordinate (see Fig 1). Three quadrants appeared in this visualization scheme: the top left quadrant is dedicated to the pure basic research and is named after Bohr. The bottom right quadrant is dedicated to applied research and is named after Edison. The upper right quadrant accounts for the use-inspired basic research and is named after Pasteur. It is the Pasteur’s quadrant, which was used by Stokes also as the title of his book [4].

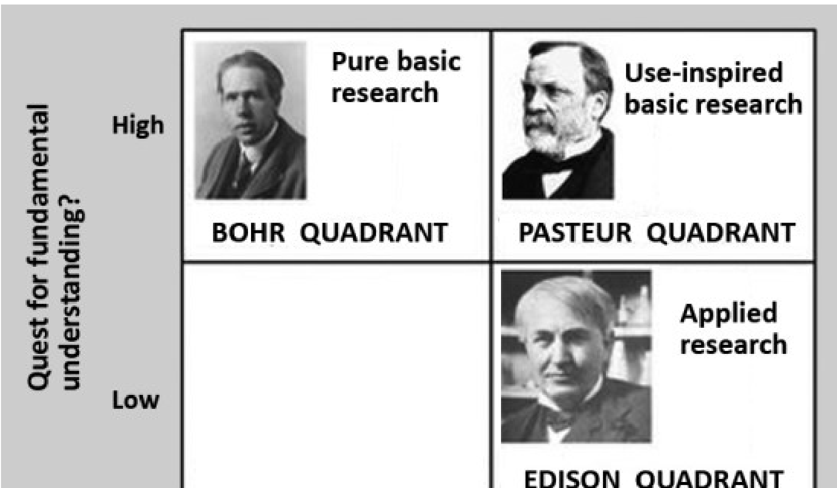

Fig 1: Pasteur's Quadrant [4]

The concept of the Pasteur's quadrant has not yet been widely accepted by the funding agencies worldwide. It has however already been reported as a successful framework to analyze scientists who have committed themselves to the collaboration between academia and industry [5]. Furthermore, a Brazilian research group active in nuclear energy has already implemented the Pasteur's quadrant to assess the basic and applied dimensions of a set of Ph. D. theses [6].

The Ph. D. theses produced within the 25 years of the Nuclear Engineering programme jointly operated by the University of Ljubljana, Faculty of Mathematics and Physics, and the Jožef Stefan Institute, were re-evaluated in the view of the use-inspired basic research. The methods and results of this re-evaluation are outlined in this paper.

The re-evaluated theses address the topics of thermal hydraulics, ageing and integrity, severe accidents, probabilistic safety assessment and radiation protection. Part of those theses have been evaluated as basic or applied-oriented by Kljenak and Mavko [1].

Input: Nature of the problem	
Which of the answers below most closely describes the nature of the problem investigated in the Ph. D. Thesis)?	
1	Totally theoretical
2	More theoretical than practical
3	Balanced between theoretical and practical
4	More practical than theoretical
5	Totally practical
Process: Nature of the performed research	
Which of the answers below most closely describes the nature of the reseach performed to complete the Ph.D. Thesis?	
1	Pure basic research without aiming for immediate economic and/or social benefits or for solutions to the practical problems
2	Basic research aiming at knowledge construction for use in an undefined future
3	Basic research aiming at knowledge construction for use in the near future
4	Applied research to solve problems defined in the present
5	Development to obtain new products, processes etc. or their improvement in the present
Output: Perspective of immediate use	
Which of the answers below most closely describes the perspectives of immediate use of results of the Ph.D. Thesis?	
1	Theoretical foundations for other theoretical studies
2	Theoretical foundations for other theoretical and experimental studies
3	Incorporation in technologies on the laboratory scale
4	Incorporation in technologies on a pilot scale
5	Incorporation in technologies for commercial use

Tab 1: Variables and questions for the »Consideration of use«.
All three variables are weighted equally.

2 The Method

The method implemented in this paper is based on the paper by Hoppe de Sousa et al [6], which has been derived while putting in practice the Pasteur's quadrant assessment of the Brazilian Ph. D. theses in nuclear energy. The method is for the sake of completeness briefly outlined below. Please note that some minor adaptations, mainly in the wording of questions and predefined answers, have been developed for the purpose of this analysis.

Hoppe de Sousa et al [6] broke down each of the axes in Fig 1 in three separate variables, describing the three stages of the creative research process: input, processing and output, respectively. These variables were then evaluated through questionnaires with predefined answers. Each of the answers assumed an integer value, as outlined in Tab 1 for the Consideration of use and Tab 2 for the Fundamental understanding.

Input: Knowledge requisites	
Which of the answers below most closely describes the knowledge requisites required to initiate the research in the Ph. D. Thesis?	
1	No theoretical and in-depth knowledge in many knowledge areas
2	Limited theoretical and good practical knowledge in few areas
3	Limited theoretical and practical knowledge in some specific knowledge areas
4	Good theoretical and practical knowledge in some specific knowledge areas
5	Profound theoretical-practical knowledge in a specific area
Process: Knowledge generation process	
Which of the answers below most closely describes the knowledge generation process utilized to complete the Ph.D. Thesis?	
1	Experimentation and aggregation of new knowledge to a broader knowledge base as the initial research problem
2	Experimentation and aggregation of existing knowledge to the same knowledge base as the initial research problem
3	Integration and/or classification and/or systemization of existing knowledge
4	Deepening the existing understanding and knowledge on the wider knowledge base than the initial research problem
5	Deepening the existing understanding and knowledge on the same knowledge base as the initial research problem
Output: Knowledge progress	
Which of the answers below most closely describes the contribution(s) of the Ph.D. Thesis?	
1	Extraordinary technological advancement (e.g., change in the quality of life)
2	Significant technological advancement (e.g., publications in the upper half of the SCI journals, international patents)
3	Moderate scientific and/or technological advancement (e.g., publications in the lower half of the SCI journals, national patents)
4	Significant scientific advancement (e.g., publication in the upper half of the SCI journals)
5	Extraordinary scientific advancement (e.g., publications in top journals, for example Nature)

Tab 2: Variables and questions for the »Fundamental understanding«.
All three variables are weighted equally.

The values of the two sets of three variables are therefore defined by the person answering the questionnaire. The final values are summed (with equal weights) resulting in a point in the two dimensional space limited by the points (0, 0) and (0, 15). Equal spacing has been chosen for the quadrants: the Pasteur's quadrant is therefore limited by the points (7.5, 7.5) and (15, 15).

Both students and supervisors have been asked to evaluate each of the dissertations independently.

3 The Data

Thirty tree (33) Ph. D. theses have been completed in the 25 years being supervised by 11 supervisors.

For 21 theses, both the student and the supervisor answered the questionnaire independently of each other. These 21 theses have been further analyzed in this paper.

Nine (9) supervisors answered the questionnaire. Four (4) of them supervised 1 thesis, 4 supervised 2 theses and 1 of them supervised 9 theses.

The time span of the theses is as follows: 1 in 1993, 2 in 1998, 3 in 1999, 2 in 2001, 1 in 2002, 3 in 2003, 3 in 2004, 1 in 2005, 3 in 2008, and 1 in 2011 and 2012, respectively.

4 Discussion of Results

The results (answers) obtained from the students and supervisors are summarized in Fig 2.

The top row of figures depicts the answers obtained by the students. The three leftmost figures depict the positioning of the individual dissertations in the Pasteur's quadrant by each of the creative phases, input, process and output, respectively. The rightmost figure places the whole dissertations (non-weighted sums of input, process and output) in the Pasteur's quadrant.

The middle row of figures depicts the answers obtained by the supervisors. The three leftmost figures depict the positioning of the individual dissertations in the Pasteur's quadrant by each of the creative phases, input, process and output, respectively. The rightmost figure places the whole dissertations (non-weighted sums of input, process and output) in the Pasteur's quadrant.

The bottom row relates the assessments of the students and supervisors. The arrows point from the estimate provided by the student to the estimate proved by the supervisor. The structure of the figures is the same as in the upper rows: depiction of individual creative phases on the left and total placement on the right.

The following observations are noted in Fig 2:

- The vast majority of the points in the combined (rightmost column) figures fall into the Pasteur's (use-inspired) quadrant. This goes for both students and supervisors.
- A few points can be found in the Bohr's (pure basic research). This goes for both students and supervisors.

- The Edison's quadrant seems to be the very least populated: only one among the students felt that there is more applied than basic research added value in his or her thesis. Supervisor and student disagree in this particular case.
- The generation of the new knowledge (basic science) was seen among the main incentives for the Ph. D. research by both students and supervisors. This probably explains the fact that virtually all of the analyzed theses lye in the upper half of the figure indicating contributions to the basic science.
- Supervisors generally tend to assess the contributions of the theses more in the basic and less in the applied science than students do.

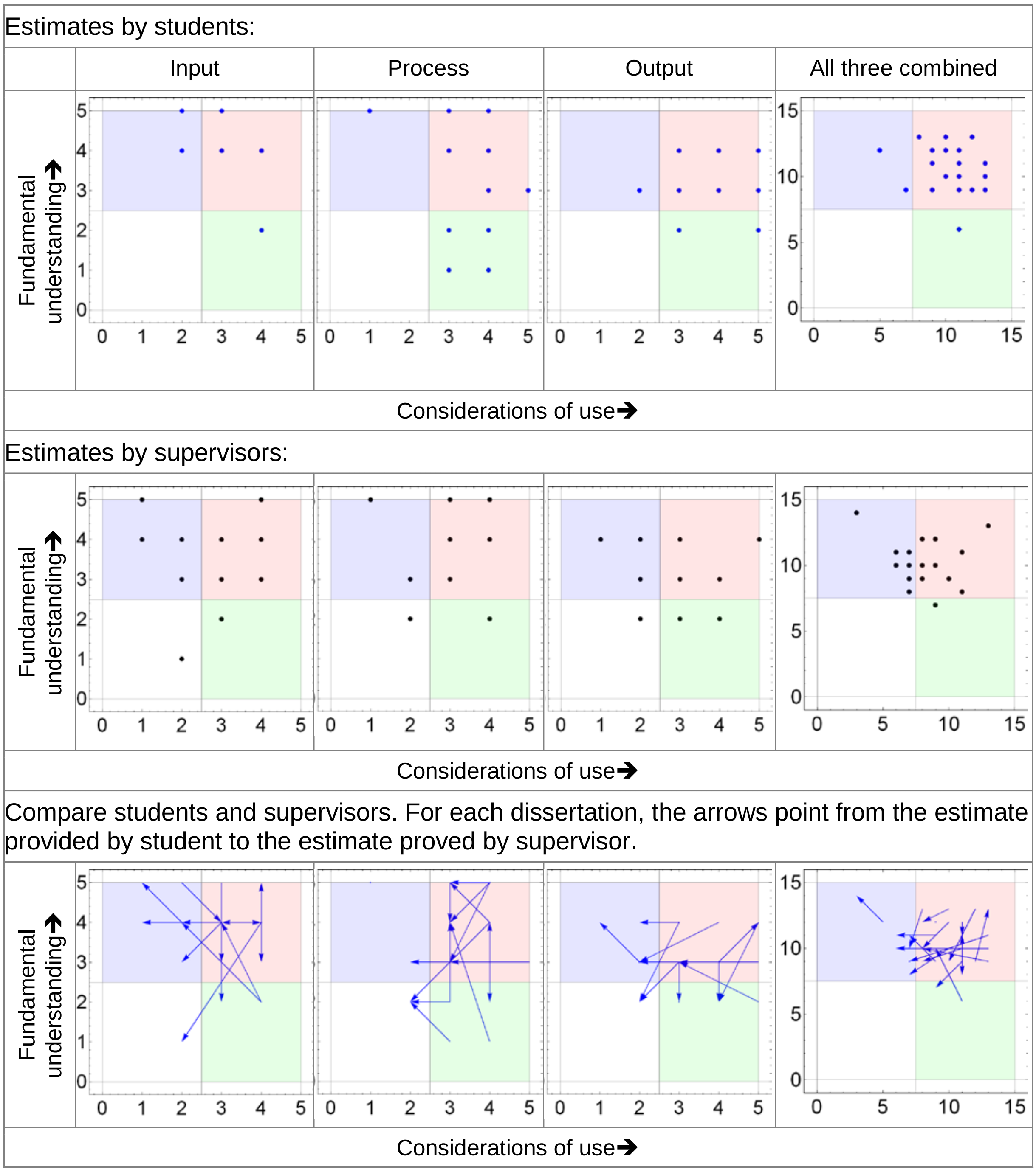

Fig 2: Summary of results

The quest for fundamental understanding is therefore not to be seen as an obstacle to the considerations of use or vice versa. On the contrary, there seems to be a tacit agreement between the students and supervisors that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses.

No data clustering by supervisor or by the year of Ph. D. dissertation has been noted in the analysis.

5 Conclusions

The results indicate that both students and supervisors largely agree that the use-inspired basic research is the dominant form of the research in the analyzed nuclear engineering Ph. D. theses. The quest for fundamental understanding is therefore not to be seen as an obstacle to the considerations of use or vice versa.

To progress strategically towards the use-inspired basic research may be therefore perceived as an adequate option for a sustainable development of a nuclear engineering and safety research group.

6 Acknowledgement

The authors would like to express the gratitude to the European commission, Slovenian Ministry for Science, Research Agency and the Nuclear power plant Krško, who funded the Ph. D. research analyzed in this paper. The authors are also greatly indebted to all students and supervisors who took time and evaluate the questionnaires.

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COLLABORATIVE TRAINING DEVELOPMENT IN NUCLEAR WASTE MANAGEMENT IN FINLAND

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ABSTRACT

In 2010 a course covering nuclear waste management ("Kansallinen YJH course" or National YJH course as used in the following) was launched. The impetus for the course development resulted from an evaluation of the KYT2010 programme (Finnish Research Programme on Nuclear Waste Management) pointing out the need to address competence maintenance also by the means of training not only in research projects. The National YJH course curriculum was designed based on earlier Finnish experiences in teaching the nuclear waste management subjects. The current course with a six day curriculum has been running since 2011 for around 20-25 students at a time and equalling 2 ECTS. The course set up is similar to the Finnish YK-course in nuclear safety, where the content is produced also jointly by the participating organizations. The practical course coordination has been carried out by Aalto University, first with the KYT2010 assistance and later based on a cost sharing principle by the participating organizations. The course has been favourably received both by the participating new staff members and by their employers since the course provides a basis for the new professionals to fully understand the wide range of multidisciplinary issues that need to be addressed in nuclear waste management.

1. Introduction

Nuclear Waste Management is a multidisciplinary field. Traditionally the professionals in the field have a basic education in some technical or scientific discipline prior entering the field of nuclear waste management. In Finland, the personnel working in this field are employed by the nuclear waste management company Posiva Oy, the authorities (MEE and STUK), the utilities, universities and research organisations, and by consulting companies.

In the nuclear energy sector it has been customary to invest to the development of personnel by internal training that is complemented with on the job training /1, p. 65 /. In the nuclear safety field the YK course on Nuclear Safety was set up in collaboration in 2003 with the various stakeholders in the field (1, pp. 67-68) and (2). In the field of waste management, the critical mass of participants was smaller. Training was carried out mainly by the main organisations themselves or in limited cooperation. No general curricula models either existed for such training. However, cooperation had existed for several years since the 1980s between STUK and the Geological Survey of Finland and VTT, and between Posiva Oy and

VTT (1, p. 68) since 2003. These have formed the first basis for the course curriculum development, too.

A new staff member independent of whether he or she is a recent graduate or a more experienced specialist in his or her field is often very dependent on one's superior and on one's colleagues in the discovery process of the core new knowledge about nuclear waste management and all of the activities that have been carried out during the last 30-40 years in Finland. A new entrant does not necessarily possess such a large network of contacts in the nuclear waste management community, or the wider picture of this multidisciplinary field of research and technology has not yet dawned on the newcomer. Often the other organizations and stakeholders working in the field are also unknown.

In 2006, a Finnish Research Programme on Nuclear Waste Management KYT2010 was established. In the independent review report of this first programme phase (3, pp. 17-18) attention was paid to the lack of a national training initiative in the field of nuclear waste management. Resulting from these review findings a preliminary planning group and the writers of this paper consisting of a representative from the Ministry (MEE), STUK and Posiva Oy started talks in 2008 on how to address this training needs issue. Further organisations were engaged into the process and a pilot course was organized with Aalto University as the course coordinator with KYT2010 support.

2. A National YJH Course Kicked-off

The pilot course run in 2010 was two and half days long. In 2011, the National YJH course curriculum was extended and repeated in 2012 and 2013. The third full length 6-day course took place in October 2013. The main extensions to the content included an overview of the legal and regulatory framework applicable in Finland and a more in-depth look at the different components of Posiva's Safety Case as a part of the construction license application for a deep geological repository.

The underlying idea of the course is to provide an overview of the nuclear waste management as a whole. The course is complementary to the YK course that has run since 2003. In its current form the National YJH course replaces Posiva's specific induction course for new staff that run until 2011. A new National YJH course is under planning for 2014 with new participant organisations desiring to join the consortium producing the course.

Almost 100 professionals have now participated in the course and the feedback has been favourable from all stakeholders. Feedback has been collected both from the participants and from the organisations providing the course content (lectures, excursions and exercises) and sending participants to the course. National YJH course has now been run successfully for four years and this paper and a poster discuss the course organization, curriculum development and its implementation (4, pp.14-16).

The course planning group has extended and in 2013 Ms. Jaana Avolahti from TEM continued to chair the group. The other group members are Marjatta Palmu from Posiva, Kari Rasilainen from VTT; Jari Tuunanen from Fortum; Anssu Ranta-aho from TVO; Mia Ylä-Mella from Fennovoima; Kaisa-Leena Hutri from STUK; Risto Harjula from Helsinki University, Laboratory of Radiochemistry; Timo Saanio from Saanio & Riekkola Engineering Consultants; and Jussi Leveinen from Aalto University, who have contributed to the course development and its content. These organisations are also the ones who can in exchange to their input to the delivery of the course send their staff members to the course as students. The coordinators have come from the Aalto University. An approval was made by the planning group to include the University of Jyväskylä and Pöyry consulting company to the consortium and discussion on their role in the consortium has been initiated.

3. Curriculum and Delivery of the Course

The course content covers topics from the legal and regulatory framework internationally and in Finland. The nuclear fuel cycle is covered from the origin of the uranium to the geological disposal of all types of nuclear waste. Radioactivity and waste classification and international developments in both LILW and HLW and spent fuel are covered. Decommissioning and interim storage solutions and the contents of Posiva's Safety Case are addressed. Advanced reactors and alternative concepts for final disposal are presented as shown in Tab 1.

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Course objectives (Group exercise)	Nuclear Fuel cycle Radiation and radiation safety	Low and intermediate level waste: Operating waste and decom-missioning; Safety case for operating waste	EBS: Buffer and Backfill Site selection Processes of geological disposal of SF	VTT waste laboratories and FIR1 research reactor	Special topics: Transport Safeguards Retrievability
Legal frameworks and licensing	Nuclear safety principles Waste classification	Spent fuel management: Fuel properties; Interim storage Geological disposal:	Safety case for spent fuel (TURVA 2012) Repository evolution and scenarios	Radionuclide release and transport. Biosphere assessment and radiological impacts.	Advanced fuel cycles Natural analogues and safety indicators
Regulatory requirements	Nuclear waste management outside Finland	KBS-3 disposal system. Engineered barriers (EBS): Canister	VTT and Aalto underground research laboratory facilities	Group exercise on argumentation for safety	Feedback discussion

Tab 1: National YJH course curriculum in 2013.

Besides lectures provided by thirty different experts and tutors, the students are engaged in group work around their own objectives for the course and in preparing arguments for safety (Fig 1). The timing of the activities is depending also on the constraints posed by the length of each day and earlier also on the possible access times to the research reactor, which was used for medical radiotherapy.

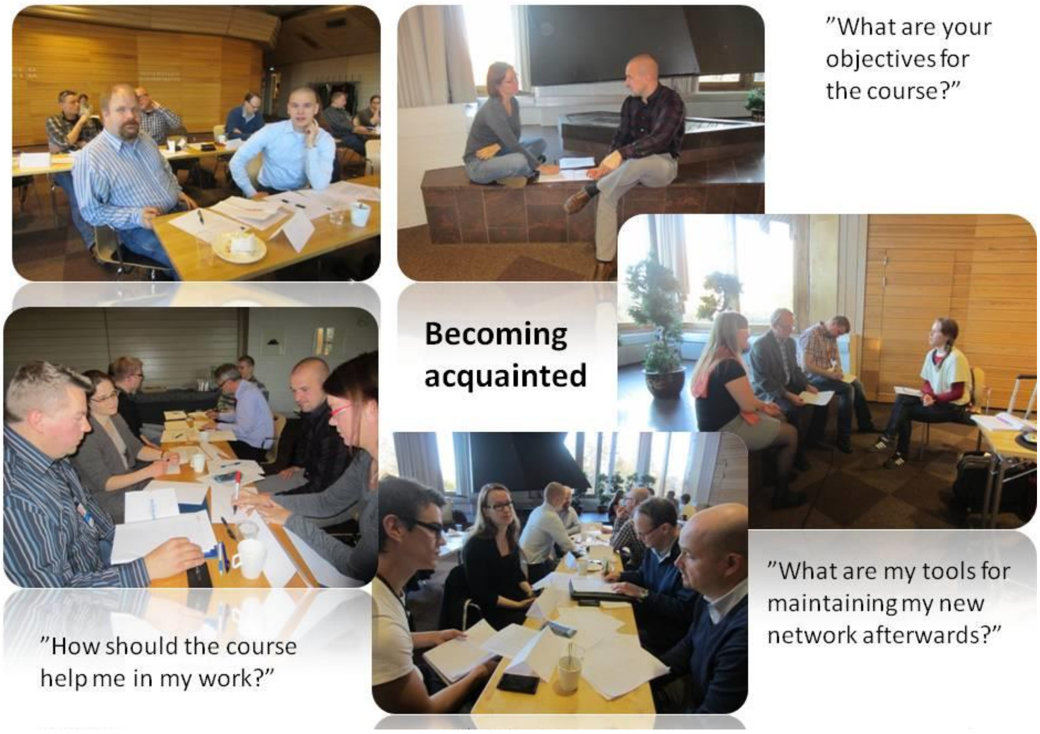

Fig 1: Getting acquainted and sharing learning objectives (Photos: Marjatta Palmu 2012)

Within the 6 days also excursions are included: to the Triga research reactor FIR1 in Otaniemi and to the laboratories of VTT's nuclear waste management team studying various long-term safety related phenomenon and processes. A further set of excursions take the students underground to the geosciences excavation test tunnel of Aalto University (Fig. 2) and to the underground research hall of VTT.

Fig 2: Excursion to Otaniemi Underground (Photo: Lauri Uotinen, Aalto University 2012)

4. Experiences from the Course

Even though the course length in days is 6 days, the course days range from 8:30 am to 5 p.m. The course includes a total of 40 hrs of learning activities for the participants and responds to around 2 ECTS at the Aalto University depending on the final exercise input by the students desiring academic course credits.

The students are also encouraged to maintain their newly created network of radioactive waste management professionals. Several networking opportunities are covered both nationally and internationally starting from the ENS Young Generation networking events to the ENEN association, and the IGD-TP opportunities. A LinkedIn group has been set up for the students, course alumni, and lecturers.

From each course a feedback is collected from the participants both orally in a feedback discussion and by a feedback questionnaire. The feedback is then compiled and discussed in a feedback meeting right after the last course days by the planning group. The lecturers and organisers of the course are also asked for their oral feedback during the planning meeting. The feedback is included into the content and to the delivery methods of the course when the next course is carried out. At the moment, it is not possible to extend the scope of the course beyond the six days. Thus the students are encouraged to network and to participate in other events that complement the knowledge and skills received during the course.

The National YJH course is also one of the arrangements for education and training of staff on the national level in waste management as required by the new Waste Directive 2011/70 (5, p. 54).

In the 2012 evaluation of the on-going Finnish Research Programme on Nuclear Waste Management KYT2014 the review team regarded the National YJH course as successful. It offers opportunities for many to become familiar with the subject and it also clearly promotes networking among its participants with different backgrounds (6, p. 17).

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DEVELOPMENT AND ACTIVITIES OF THE PROJECT "ENGINEERING RESEARCH AND EDUCATION ON SAFETY AND SECURITY UNDER LOW-LEVEL RADIATION ENVIRONMENT"

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ABSTRACT

For the future generations, it is needed to cultivate a steady and sustainable culture of safety in the field of nuclear engineering. It is imperative to introduce a structured knowledge in the field of nuclear education and research. Okayama University is one of the leading universities in Japan, and we have run an education and research program related to nuclear engineering and radiation health problems since October 2008. The major object of this programme is to supply human resources who possess not only high level skill and knowledge on nuclear problems but also ethics as a professional engineer. It has been made much effort to establish a graduate program in this field. In addition, we have keenly joined an engineering project for closing a uranium mine, which has been managed by the Ningyo-toge Environmental Engineering Center of the Japan Atomic Energy Agency (JAEA), and these experiences strictly help to develop our research and education programme. Cultivating human resources in the field of safety and security management is of a prime concern in nuclear engineering. Okayama University is the only one institution that provides a higher educational and research programme, especially on a low-level radiation environment. We have exchanged information for research and education with domestic institutes and international organizations. Above all, the universities joined to the Japan Nuclear Education Network have been cooperating. An open seminar and international joint workshop were arranged under this program. We provided an atmosphere to the participants with open-minded discussions and then established deeper cooperation beyond organizations. Eventually students started to think critically and logically. The new environment after the Great Eastern Japan Earthquake and Tsunami should be taken into consideration for our future educational activities. Indeed, the lack of experienced engineers in the field of nuclear waste management becomes obvious because of the severe accident of the Fukushima-Daiich nuclear power plants. The Ningyo-toge area which is located in Okayama prefecture is now important related to nuclear waste treatment and disposal. The Ningyo-toge project contributes to the progress of research and education on the safety and security management of radioactive wastes (henceforth, radwastes). Now we aim to extend our program to cover mitigation of natural disasters and human behavior when committing a severe natural disaster. It will help the international nuclear community which requires a new challenge after the Fukushima accident.

1. Introduction

After the severe accident of the Fukushima nuclear power plants due to the Great East Japan Earthquake and Tsunami, the safety management must be reconsidered. Obviously we have not the sufficient number of experts in the field of nuclear waste management. In the site a massive amount of radioactive wastes are daily produced, and the wastes must be treated and disposed. It should be noted that the radwastes are a negative heritage of nuclear use. In this paper we show research and education project "Engineering Research and Education on Safety and Security under Low-level Radiation Environment" in Okayama University. Now the aim of this project is to enhance the tolerance ability of our human society against severe natural disasters. We understand that one of the important roles of the university is to challenge the keen social issues. Without question the radwaste management due to the Fukushima accident is such the keen problem. The cleanup work will last more than 30 years, and we are obliged to supply well-educated professional engineers and technicians continuously.

2. The project "Engineering Research and Education on Safety and Security under Low-level Radiation Environment"

Its main aim is to give a solution to the urgent requirement of human resources with high level skill and knowledge on low-level radiation environment. Master and Doctoral education course programme on this topic was already established. The development of human resources is of prime importance for safety and security management of worldwide nuclear environment. Okayama University is the only one that provides a higher educational and research programme on low-level radiation environment in Japan. The duration of the project is 4.5 years (Oct. 2008 – March 2013). This project was granted by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan and Okayama University. 1.5 years (Oct. 2008 through March 2010) was for preparing Master Course and 3 years (April 2010 through March 2013) for Doctoral Course. These courses were in 3 graduate schools of Okayama University, i.e. Graduate School of Health Sciences, Graduate School of Environmental and Life Sciences and Graduate School of Natural Science and Technology. Teaching staffs were not only from Okayama University but also from other Japanese Universities (TITEC, Osaka Univ. and Fukui Univ.), Chugoku Electric Power Company and JAEA. Also foreign professors and researchers were invited for this education programme. Lectures prepared by JNEN (Japan Nuclear Energy Network supported by JAEA) are offered to students by use of private network education system.[1]

The research plans have been started to find solutions for the Ningyo-toge former uranium mining site problem. Ningyotoge is in a north region of Okayama prefecture of Japan, the JAEA developed a uranium mine, which was already closed. We have discussed the tailing problem of that mine. Note that the tailing is a Naturally-Occurring Radioactive Materials/Techno- logically-Enhanced ones, called as NORM/TENORM. Because of world-widely increasing demands of nuclear energy, the radwastes become more serious problem including these NORM/ TENORM and the radwastes produced by nuclear accidents.

Fig.1 shows an outline of this project.

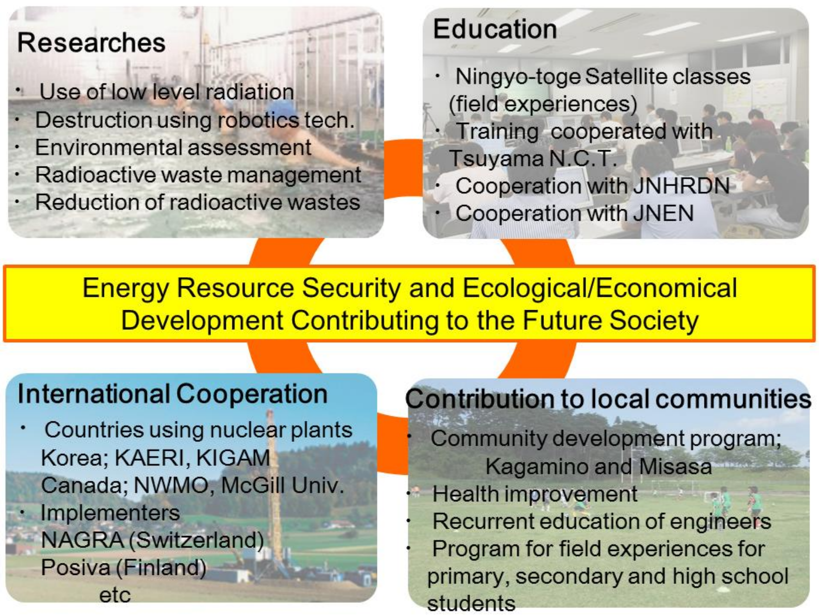

Fig.1 Outline of the project "Engineering Research and Education for Safety and Security under Low-level Radiation Environment"

2.1 Steering Committee

To manage this project Okayama University prepared Steering Committee, chaired by Vice President (in charge of Education). This committee was organized and started its function to check curriculum for the improvement for Master and Doctor Courses and to verify progress of research plan. This project is approved by MEXT,Japan and offered financial support with Okayama University. The enrolment in the masters program has increased, starting with 7 students in 2008 to 22 students in 2012. The enrolment in the doctoral graduate program was 2 in 2010 and 6 in 2012. The largest participation at the master's level was in the Natural Sciences and Technology area, which had the highest potential for employment both within the Nuclear Energy production sector and the Regulatory Sector. The educational background of the students tended to vary from the pure sciences to engineering and both governmental and private sector businesses could benefit from the graduates.

2.2 Education

We prepared these education courses for Master and Doctor as to reflect new knowledge and technology obtained through wide-range researches on 1) risk communication with local community neighboring nuclear and its relating facilities, 2) accident prevention based on risk management, 3) safe and secure management of nuclear facilities and development of destruction technology after its closure. The graduate courses consist from the cooperation of four existing graduate schools (Graduate Schools of Natural science, Environmental and Life Science, Human Health Science and Humanities and Social Science) of Okayama University. By suggestions from supervisor students can select lectures from these four graduate schools and also from lectures offered by JNEN, which are sent to 6 universities as Tokyo Institute of Technology, Ibaraki University, Kanazawa University, Fukui University, Osaka University and Okayama University via network. The universities of JNEN have cooperated with related organizations to educate students as professionals with a higher sense of ethics.

2.3 Cooperation with JNEN

JNEN has been initiated in 2007, lectures are provided through the system at real time to the students at various universities. JNEN is a real-time and interactive remote education system using internet (Virtual Private Network) [1], as illustrated in Fig. 2.

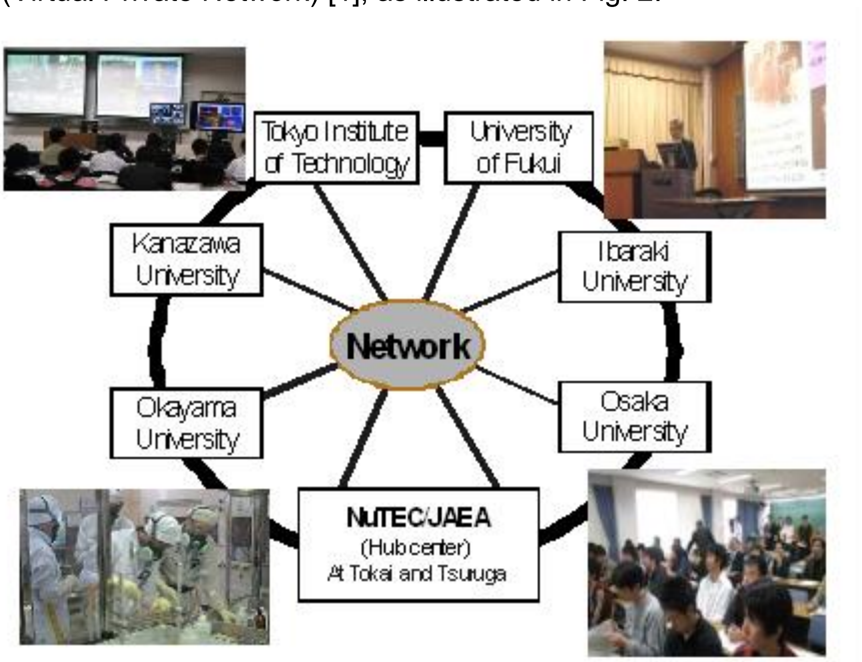

Fig.2 Japan Nuclear Education Network (JNEN)

The students and the professors of 6 universities can make Q&A and discussions through wide monitors multi-directionally on the real time. The students can also review by the e-learning system after the lectures.[2] Since 2010, Okayama University have provided for New Lecture “Environments and Human Activities”. This lecture is a summer session gathering students and teachers from the universities of JNEN to Okayama University in Fig.3. It is organized as a 5-day intensive course including lectures, group discussion, presentation and debate. Active learning is important for students to develop a broad vision and to think for themselves.

Fig.3 The Lecture “Environments and Human Activities”

3. COOPERATION WITH STAKEHOLDERS

Safety culture [3] is essentially important in nuclear engineering because the use of nuclear energy is inevitable for our future generations. After the Fukushima accident, most Japanese people feel anxiety not only to nuclear engineering but also to science and technology. In order to build up a believable safety culture into all persons concerned with the nuclear engineering, the followings are particularly important.
1. Involvement of individual/organization responsibility into safety culture
2. Mutual understanding and sharing of safety information between organizations
3. Inheritance of technology and safety knowledge

Safety culture is the whole of the attitude and characteristics of organizations and individuals. When committed to a crisis, a quick decision is required. The information including risk must be shared by all stakeholders. An accident of a nuclear power plant causes profound effects on the broad region. As stated previously we live in the era after the Fukushima accident. It is our essential purpose to cultivate the safety culture in each engineer and stakeholders through our education programme.

3.1 International Symposium, Seminar and Workshop

We have already started to cooperate with domestic and international organizations. It is also our scope to contribute to local social and economic bodies such as local governments, NPOs, Okayama-based corporations and Ningyotoge Environmental Center of JAEA. Since 2008 Okayama University held a series of international and domestic symposia on nuclear safety and radwaste management. The symposia were open for citizens. We also organized international seminars to educate young scientists and engineers. In 2012, The 5th Environmental and Energy Symposium & International Workshop (Co-sponsors; Tokyo Institute of Technology) were held at Okayama and Tokyo. The graduate program has benefited from international events such as the International Joint Workshop on Nuclear Energy and Radioactive Waste Management Activities. Efforts could be made to include other International Meetings and Special Sessions organized by the Japanese and international scientists involved in management of nuclear wastes, with special emphasis on aspects of the Fukushima event. Younger faculty and graduate students should be encouraged to participate at these events as shown in Fig.4.

A Speciall Seminar of scientists and engineers working to develop waste management strategies could be a useful activity.

Fig.4 Workshop “What happened in Fukushima?” and
The 5th Environmental and Energy Symposium & International Workshop

3.2 Networking

The project has successfully contributed to the progress of cooperate with domestic and international organizations. The exchange of students and researchers related the present effort have lead to positive result of interactions and networking. This should be strengthened through scientific exchanges of both students and younger faculty. It has been shown that multidisciplinary discussions on the issues to nuclear power are very fruitful and promote common understanding.

4. For the Future

Nuclear power is utilized in many countries, and the safe use of nuclear energy is our common interest. The final and most difficult problem is the radwaste disposal. This project was inaugurated before the Fukushima accident. The primary social concern at that time was how to reduce the emission of carbon dioxide. It was the era of ‘nuclear Renaissance’.
We now inhabit the post-Fukushima era. Under this altered circumstance,we focus on the following four fields of nuclear engineering.

Field 1; Environmental security and management after the accident
Field 2; Radiation safety and healthcare
Field 3; Safe decommissioning of the power plant
Field 4; Risk assessment/management and risk communication

In order to contribute to the radwaste problem, we have initiated a new Project for Disaster-Resistant Nuclear Facilities and Radwaste Management, called as DiRaM, in FY2013 under the support of MEXT. We will establish a R&E center in Okayama University under support of IAEA and JAEA.

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INSTN: THE CEA INSTITUTION COMMITTED TO NUCLEAR SCIENCE EDUCATION IN FRANCE

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ABSTRACT

As part of the French Alternative Energies and Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) stands out as a specifically nuclear-oriented higher education institution in France. Under the joint supervision of the Ministries in charge of Education and Industry, the INSTN offers advanced courses to engineers, university graduates, technicians and professionals in the applications of nuclear physics, from power generation to the use of radionucleides in biology and medicine.
High quality and up-to-date knowledge and know-how is provided by cutting-edge scientists from CEA but also university staff as well as experts from the industrial sector, from the medical area and from regulatory authorities. In all, over 1400 specialists participate in the education and training programs offered by the INSTN. National and European academic and vocational courses cover the full spectrum of nuclear education ranging from nuclear engineering, science and economics, nuclear medicine and radiopharmacy, molecular imaging and instruction for nuclear technicians. The courses are delivered in a modern setting and make use of specific infrastructures and tools such as a training reactor, reactor simulators for normal and accidental operating conditions, research and industry codes, radiation protection facilities, electronic microscopes and a Van de Graaff accelerator. Presently, online courses on a research reactor are also being developed.
At the international level, the INSTN is involved in several European projects aimed at the implementation of nuclear education and training on nuclear engineering (ENEN III), radiation protection (ENETRAP II) as well as, in the new Framework Program 7, on radioactive waste (PETRUS III) and sharing and growing nuclear safety competences (NUSHARE). The INSTN is also the founding member of the European Nuclear Education Network (ENEN), a nonprofit association with 64 members, including academia, research centers and industry, from 18 EU countries plus South Africa, Ukraine, Japan and Russian Federation. With a wealth of experience in international collaboration for many years, the INSTN is committed to the development and harmonization of the European higher educational area in all domains of nuclear science.

Introduction

The Institut National des Sciences et Techniques Nucléaires (INSTN) has been created in 1956 within the French Alternative Energies and Atomic Energy Commission (CEA) when France decided to launch the civil nuclear program. Originally designed to train mainly EDF professionals and engineers to acquire a high level of scientific and technological qualification in nuclear energy, the INSTN has now set up a broad range of further education in cutting-edge disciplines (nuclear engineering, material science, health science, nanoscience) relying on the skills available at the CEA and in other institutions and companies such as, for the nuclear power sector, EDF, AREVA, and IRSN the French TSO. The institute has also invested in the development of innovative pedagogy with the implementation of new distance learning courses on nuclear reactor operation as well as radiation protection courses and serious games. Experimental facilities such as training reactor, ICT facilities including new generation PWR simulators, field school for decontamination and radiation protection, laboratories for the practical training in radiochemistry, radiation protection, detection and measurement of β, γ, neutron and X rays are available for trainees. In addition, its location allows an easy access for students and professionals to the extensive facilities of CEA laboratories.

With a permanent academic and administrative staff of about 110, plus the backing of some 1400 experts from national and foreign academic and scientific institutions as well as industries (EDF, AREVA, Siemens…), regulatory bodies and hospitals, the INSTN hosted in 2012 about 8000 trainees for continuous education and 800 students for academic degree programs.
Over the past years the involvement of the INSTN in education and training at the international level has strongly increased with the development of both academic and vocational programs. Presently up to 30% of our students are foreigners. A large panel of international courses lasting one to two weeks has also been implemented on a yearly base and covers neutronics, thermo-hydraulics, nuclear materials, principles and operation of nuclear reactors as well as fuel cycle and reactor dismantling topics. In addition, international tailored made trainings have been developed on demand and delivered at the INSTN for the specific need of the nuclear sector. INSTN experts have also been providing training and support in various fields, including radiation protection and radiopharmacy, at customer's location. At the European level the INSTN has strengthened its cooperation's with universities and companies of the nuclear sector from the European Union by participating at several European projects of the Framework Program 7 aimed at developing nuclear education and training in nuclear engineering (ENEN III), radiation protection (ENETRAPII) as well as on radioactive waste (PETRUS III) and the enhancement of safety culture (NUSHARE).
To tackle the growing need for a high level education and training in the nuclear field, the INSTN developed different training modalities, including widening the initial and continuous training offer. The following sections will present each training mode and illustrate some of the most fruitful examples of actions undertaken at the national and international level.

1. Initial training

Over 40 academic degrees, including Higher Technician Diplomas, Bachelors, Masters and engineering degrees are issued by the INSTN.

Higher Technician Diploma (BTS) in radiation protection
This course teaches students all about the requirements for working in an irradiated environment. They learn to implement all the techniques for radiation control and to apply radiation and contamination protection rules in compliance with applicable legislation. Students are selected on the results of a knowledge test in mathematics and physics. A B2 level in French is required for attendance.
Masters and engineering degrees
More than 30 Master degrees, delivered in cooperation with Universities and Engineering Schools, are mainly addressed to M2 students and cover a wide range of topics developed within CEA research laboratories such as nuclear energy (fission and fusion), functional and structural engineering of proteins, radiobiology, materials for structures and energy, nanophysics, nanobiology and nanobiotechnologies, innovation and technology management, astrophysics, radiation protection…
Most of those Masters are taught in French but a few of them are in English. They are all open to foreign students who represented in 2011 more than 23 % of the INSTN student population (Figure 1), coming from 58 countries, mainly non-EU (Figure 2).

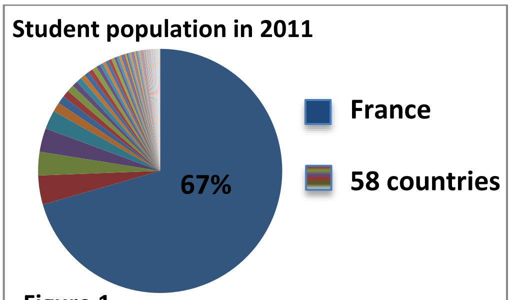

Figure 1

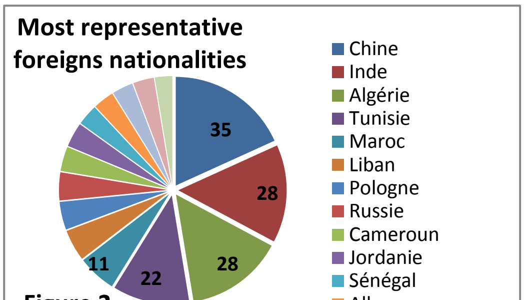

Figure 2

INSTN main pedagogical efforts are focused on the design and implementation of specifically nuclear-oriented educational programs as required for the maintenance and development of the nuclear sector, some of them being accredited exclusively by the INSTN (Figure 3). They include a medical physicist degree (DQPRM) as well as specialities for medical doctors and radiopharmacists, in accordance with the French directives on health, and two specialised educational programs on nuclear engineering: the Master in nuclear energy and the “Génie Atomique” course.

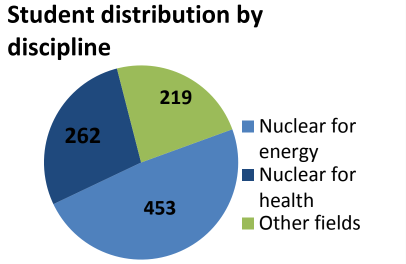

Figure 3

The **Master in nuclear energy** is a two-year program fully taught in English by a large consortium of universities, engineering schools and key industrial partners such as AREVA, EDF, GDF SUEZ. It aims to teach both French and international students the principles and knowledge required for the nuclear industry. The M1 is aimed at acquiring compulsory “Core Syllabus” of a general basic knowledge in almost all the domains in nuclear energy. The five Majors offered at the M2 level cover a wide variety of careers in the nuclear industry as either experts or managers in fields such as:

- Design and construction
- Operation and Maintenance
- Nuclear plant decommissioning and waste management
- Fuel cycle

The programme also aims to prepare students for a career in research and education for those continuing with a doctoral scheme.

The **Génie Atomique** is a specialized engineering degree (Master after master degree in nuclear engineering) delivered by the INSTN and aimed at educating talented engineers in the nuclear engineering field. Students learn basic sciences and technology and its application to research, design, operation, and optimization of nuclear power plants. The curriculum last one calendar year and is organized in 2 phases:

- A 7 months academic part of courses, conferences, exercises and laboratory sessions to acquire a systemic view in the nuclear engineering field
- Followed by a 5 months internship in research centres, universities, industry in France or abroad to apply the knowledge and concepts acquired during the first phase to concrete research or industrial situations.

This educational scheme is unique in France in terms of number and volume of the courses (more than 500 hours) and facilities involved in the training. Since its inauguration in 1955, INSTN has graduated more than 5000 nuclear engineers, some are active today in all the major organizations of the French and International nuclear sector. As illustrated in Figure 4, the higher student enrolment occurred at the creation of the curriculum, between 1958 and 1970, when France decided to launch the nuclear civil program. The following years about 60 to 100 students per year enrolled in the programme, depending on the French and world perspective of the nuclear sector. In the past few years an increasing number of foreign students attended the “Génie Atomique” course, mainly from China and North-Africa (Figure 5).

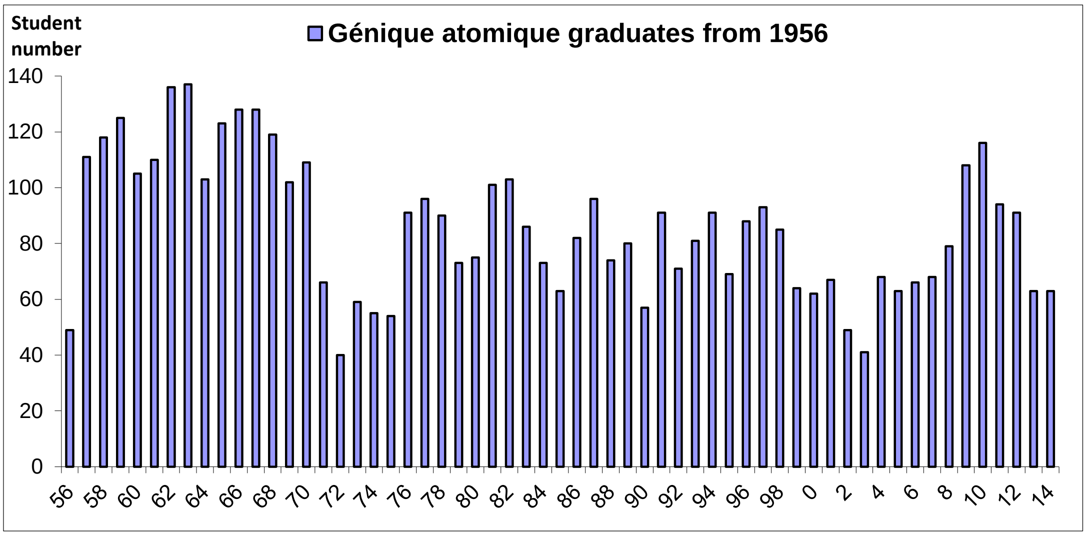

Figure 4

Year	Foreing students	%	Countries of origin
2010-2011	23	31	11 Tunisia, 4 China, 2 Belgium, 1 Spain, 1 Canada, 1 Cameroon, 1 Russia, 1 Malaysia, 1 Vietnam
2011-2012	11	15	6 Tunisia, 3 China, 1 Lebanon, 1 Netherland/Japan
2012-2013	12	26	6 China, 2 Italy, 1 Belgium, 1 Czech, 1 Morocco, 1 Bahraini
2013-2014	8	17	4 China, 2 Morocco, 1 Spain, 1 Tunisia

Figure 5

2. Continuous professional training offer on catalogue

Continuous education constitutes another important panel of the INSTN activity aimed at up-dating knowledge of those who already have a strong background in the applied field (professionalization program) or initiation into new techniques for those specialized in other fields (retraining program). Training sessions, lasting a few days to a few weeks, are organized all year around for professionals, researcher or qualified technicians. The courses available cover nuclear engineering, all the stages in the nuclear fuel cycle, radiation protection, imaging in nuclear medicine, micro and nanotechnologies, new energy technologies as well as soft skills such as patenting and intellectual property rights. All the vocational training is under quality assurance procedures, the INSTN being certified ISO 9001 since 2001. The INSTN course catalogue presently includes an offer of more than 200 trainings that take place at the INSTN and are mainly run in French. Over the past 10 years the INSTN has developed an international offer in nuclear engineering taught in English, which cover the following topics:

- Principles and operation of nuclear reactors
- Neutronics for Light Water Reactors
- Thermal hydraulics for Light Water Reactors
- Operation and safety of pressurised water reactors
- Criticality-Safety
- Nuclear fuel cycle
- Nuclear materials for pressurised water reactors
- Metallurgy and properties of Zirconium alloys for nuclear applications
- Introduction to the use of plutonium

- Nuclear waste management
- Nuclear facility dismantling experience
- Generation IV: nuclear reactor systems for the future
- Basic operations on nuclear reactor

Overall in 2012 the INSTN delivered 644 training session for a total of 3371 training days to more than 7000 trainees. Despite the economic crisis, the difficult post-Fukushima context and the debate on the energetic transition the number of training days delivered in the nuclear field remain constant. Over 85% of the training delivered was in the nuclear field, with 7% being international (Figure 6). The need of training in radiation protection and nuclear for health is noticeable with more than 50% of the total training delivered in this field (Figure7).

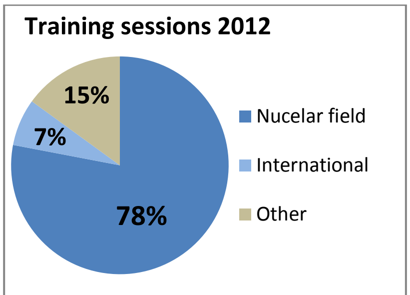

Figure 6

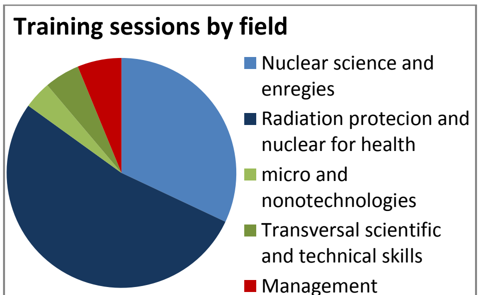

Figure 7

For PhD students and young researchers a dedicated international offer of six advanced courses has been also developed. Each course, lasting one week, is dedicated to a specific aspect of nuclear reactor design and operation: (i) Thermal Hydraulics and Safety, (ii) Nuclear Fuels for Light Water Reactors and Fast Reactors, (iii) Reactor Core Physics and Monte Carlo Methods, (iv) Materials for Nuclear Reactors, Fuel and Structures, (v) Nuclear Fuel Cycle and Reprocessing, (vi) Nuclear Waste Management.
Recently, under the auspices of the IAEA, an Internet Reactor Laboratory (IRL) project will be developed. A virtual research reactor will be made available to access to countries that have no installed facilities, but need to train students & professionals in experimental nuclear physics and reactor operation. The IRL works by creating a virtual reactor in a remote location via an internet link. Using hardware and software installed in the research reactor, signals are sent over the internet to the training institution, where a real-time display of the reactor's control room is visible to trainees. Then, using videoconference equipment, trainees can interact to "conduct experiments" by asking the reactor operators to change reactor settings and seeing the real-time displays change accordingly. The IRL distance learning course will be launched by end of 2014.

3. Training on demand

The INSTN is also keen in designing, implementing and organizing basic to advanced flexible, tailored training on its field of expertise on demand. Those customized national or international trainings can be delivered either at the INSTN or at clients' location. Examples of training on demand delivered at the INSTN includes Safety Culture for Rolls Roys (FR), Energetic Transition and Sustainable Development for Renault (FR), Operation of Pressurized Water Nuclear Plant for EDF (FR), as well as Principle and Operation of Nuclear Reactors for ENEL (IT) or Practical training on ISIS reactor addressed to university master students from Sweden and Finland. Those training, lasting from 2.5 days to 2 weeks, are mainly dedicated to provide new or up-dated skills and knowledge to trainees. More interestingly, the INSTN has also been active in serving new comers in the field to develop their own nuclear engineering educational program. A 12 weeks "Train the Trainers" program, to train future trainers in science and technologies, has been thus conceived in 2010 for university professors and researchers on the demand of Polish Universities. The objective of this training session was to provide the trainees the necessary knowledge to

build up an educational program to ensure a proper implementation of the nuclear power program that Poland is willing to develop by 2020. In addition to conferences and lectures, technical visits of CEA as well as industrial facilities have been organized including the visit of the EPR construction site in Flamanville, a fuel reprocessing unit in La Hague and a nuclear power plant in Doel (BE). Shorter effective sessions for tutoring decision-makers to address energy-related issues, are also offered. A course of this type have been developed for the Electricity of Vietnam (EVN) Company to train future project managers for Vietnam's first nuclear power plant.
Finally, INSTN experts have been supporting the creation of several programs at customer's locations such as the development and implementation of the Master on radiation protection (University of Kenitra) as well as a vocational training offer on radiation protection in Morocco or the development of radiopharmacy initial training in Tunisia. An introductory course on nuclear energy has also been provided to students of the National school of engineers of Tunis (ENIT) as well as assistance for the development of human resources to the Tunisian electrical supplier STEG.
Traditionally INSTN organizes also courses exclusively intended for specialist from foreign countries under the International Atomic Energy Agency (IAEA) umbrella.

4. Involvement in EU projects

The INSTN is strongly committed to the development, share and harmonization of educational skills in nuclear science and technology, in particular at the EU level. It has been awarded the extended ERASMUS University Charter and, as declared in its ERASMUS Policy Statement (EPS), it promotes mobility of students and teaching staff to favor scientific exchanges, cooperation and dissemination of best practices and is open for multilateral cooperation with higher education institutions and enterprises. Indeed the INSTN is involved in several European projects aimed at implementing nuclear education and training on different topics ranging from nuclear engineering (ENEN-III), radiation protection (ENETRAP) and waste management (PETRUS III) to the enhancement of the nuclear safety culture (NUSHARE). It has also be a leading member of the European Nuclear Education Network (ENEN) since its creation in 2003.

5. Conclusions

The INSTN is the French key player in education and training on nuclear engineering and radiation protection since 1956. Sensitive to the growing educational and training needs of the nuclear sector, the INSTN has been diversifying its training offer to better respond to this national and international challenge. Presently, beside offering a large spectrum of high level educational programs, mainly at the Master level, as well as vocational training open to French and foreign students, it is also able to tackle specific training needs expressed by countries freshly acquainted to the nuclear field for civil applications and health.

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TRAINING IN AP1000®[1] NUCLEAR POWER PLANT MAIN CONTROL ROOM

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ABSTRACT

The **AP1000** Nuclear Power Plant (NPP) includes in its design passive safety systems and combines in its Main Control Room (MCR) software controls with hardware controls. Training is a fundamental tool to merge the new advanced control features with a safe plant operation. The special features of workstation soft controls represent a challenge that Tecnatom, in a partnership with Westinghouse Electric Company, is facing to teach the **AP1000** plant Reactor Operators (ROs) and Senior Reactor Operators (SROs) in China and the United States.

Human performance enhancement techniques have been used in the nuclear industry for decades. However, software based control rooms strengthen even more the need for error prevention techniques due to the fact that almost all plant components can be operated through the very same computer screen.

Additionally, traditional assessment schemes in simulators take advantage of the physical location of each component controller. Software based control rooms do not allow the instructor to identify the system or even the component the operator is handling without taking a close look at the computer screen.

This paper describes the main differences between traditional and software based control rooms from a training and performance assessment point of view. It incorporates the recent experience of Tecnatom in delivering initial training to ROs and SROs for Sanmen and Haiyang NPPs and proves that conduct of operations must evolve and adapt to the new environment provided by all software based control rooms.

1. Introduction

Besides the evolution in the nuclear industry that **AP1000** NPP materializes in its design by using passive safety systems, the new all software based MCR is another step ahead in the control of a NPP.

Vintage plants usually have all hardware controls (**Fig. 1**). This was the first type of MCR and due to the well known layout of the systems, components and alarms throughout the panels, the plant operation manoeuvres were hardly missed by the crew or the instructors. Also, all the information available and the plant parameters were collected by walking down the panels and the alarms.

In the last decade a new element for plant operation has taken its place in the MCR: software control displays. Hybrid MCR resulted from merging hardware and software controls (**Fig. 2**). In this new type of layout, effective communication tools were confirmed to be essential to not miss

[1] *AP1000 is a trademark or registered trademark of Westinghouse Electric Company LLC, its affiliates and/or its subsidiaries in the United States of America and may be registered in other countries throughout the world. It is used herein with permission. Unauthorized use is strictly prohibited.*

any manoeuvre from the software controls and also to verbalize the new set of parameters and information contained in the different displays.

By taking to a minimum the hardware controls, as it has been done in the **AP1000** plant MCR, where they are only related to a few components and signals, the newest way of operation and control of a NPP has been established.

Fig. 1 Traditional MCR: Asco NPP simulator (Spain)

Fig. 2 Hybrid MCR: Fangjiashan NPP simulator (China)

2. Materials and Methods: AP1000 NPP Main Control Room

The **AP1000** plant MCR is designed to enhance the operator control capabilities and to provide all the needed parameters of the systems' operation and equipments' performance from a single computer screen.

The MCR is laid out in two horseshoe desks, which include the operation stations, three hardware control panels and 14 Wall Panel Information System (WPIS) Displays in 65" flat screens. The WPIS provides dynamic display of plant parameters and alarm information so that a high level understanding of current plant status can be readily ascertained (Fig. 3).

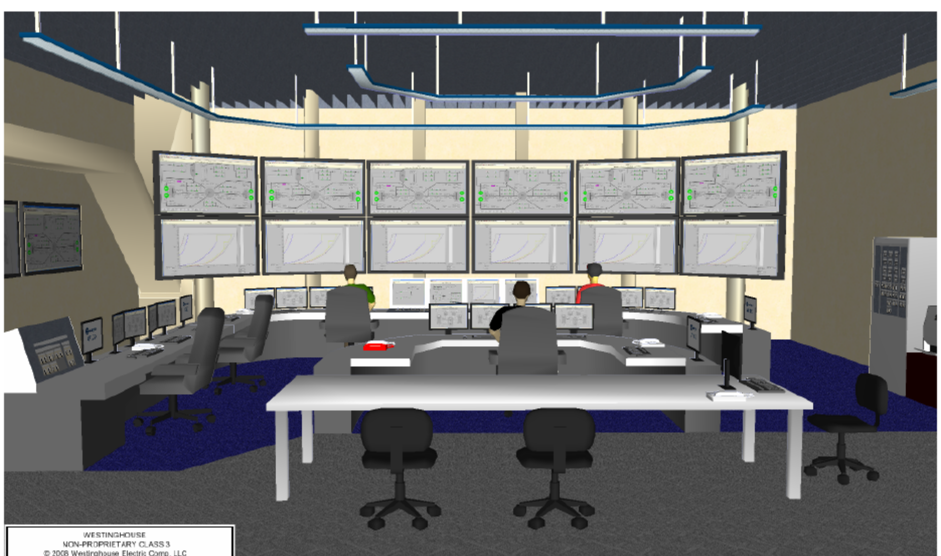

Fig. 3 **AP1000** Plant MCR layout[2]

[2] Courtesy of Westinghouse Electric Company, LLC

Each of the operation stations includes two workstation computers, each with two flat computer screens, one keyboard and one mouse. All of them are connected to the Ovation™[3] expert distributed control system software, which provides the control capability of plant equipment through multiple displays.

The SRO position is at the smallest horseshoe desk and is provided with two workstation computers. The supervisor workstation is identical to the RO workstations, except that its controls are locked-out and are used only for information and to follow and check the manoeuvres of the crew. This modified configuration maintains independent, redundant workstations. The supervisor workstation contains both internal and external plant communications systems.

The RO and Balance of Plant (BOP) Operator are located at the largest desk closer to the WPIS. They have two stations each to control the plant, facing 12 WPIS displays which contain the most useful plant information. There is a spare station facing the side wall in front of another two WPIS displays which is used for convenience by an extra operator, Shift Technical Advisor (STA) or when one of the main stations is not available.

Besides the control stations, each position is provided with a local area network (LAN) computer not connected to the Ovation™ expert distributed control system software network but with access to all the plant and operation documents.

The instrumentation and control architecture uses both discrete control switches and soft control units. The soft control units are used to provide a compact alternative to the traditional control board switches by substituting virtual switches in the place of the discrete switches. The hardware operation in this MCR is only reserved for the safety signals, systems and components. The Protection and Safety Monitoring System (PMS) and the Diverse Actuation System (DAS) are the systems which signals are actuated from the hand switches.

The switches panels for PMS are located in between the RO and BOP, at the Primary Dedicated Safety Panel (PDSP), which includes four safety screens, each for one PMS division, and at the end of the biggest horseshoe desk at the Secondary Dedicated Safety Panel (SDSP). The manual actuations for DAS are performed from a separate cabinet at the side wall.

This new all software control MCR has different software programs to support the plant operation:

- Ovation: The Ovation™ expert distributed control system software is the one controlling all the non-safety plant systems and components, providing the parameters for the plant control and the indications of the equipments status. Ovation provides useful information with a glance to one screen since it has multiple displays, not only for systems and components, but also related to actuation signals, core conditions and parameters, maintenance activities, etc. (Fig. 4 and Fig. 5). The displays provided by the plant information system are non-safety related displays, but provide information on both safety-related and non-safety related systems. Those displays can be opened at the same time from all the operation stations, which facilitate the concurrent verification of the tasks. The human system interface is designed to reduce the likelihood of operator error and provide for error detection and recovery capability for the identified critical human actions and risk important tasks (1).

[3] *Ovation is a trademark or registered trademark of Emerson Process Management Power & Water Solutions, Inc. Other names may be trademarks of their respective owners.*

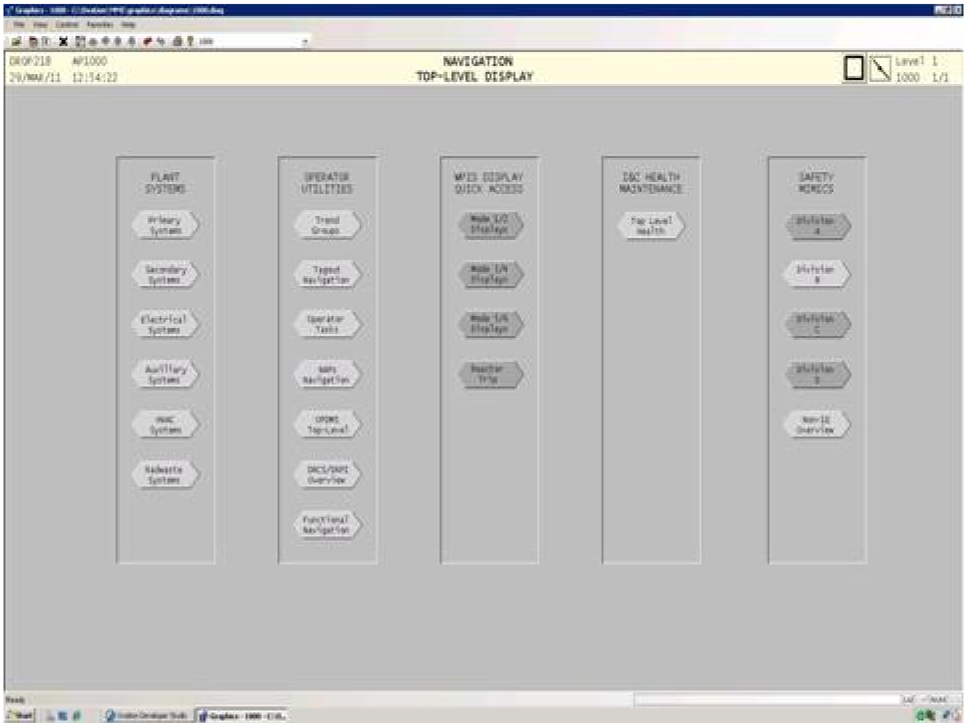

Fig. 4 Example of main menu display in Ovation [4]

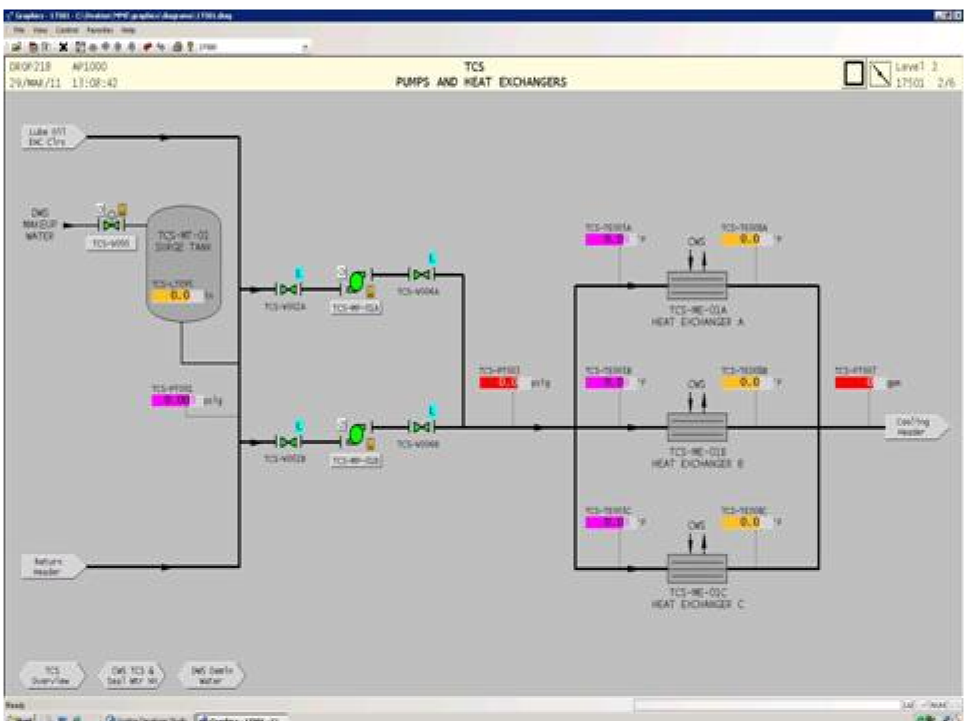

Fig. 5 Example display and indications in Ovation [5]

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[4] Courtesy of Westinghouse Electric Company, LLC
[5] Courtesy of Westinghouse Electric Company, LLC

- Computerized Procedures System (CPS): This program includes the general, abnormal and emergency operation procedures. It receives information from the plant and has its own logic to open the appropriate procedure when one entry condition is met and to provide the input with a green check when a step is met, which helps the operator with the decision making process. By using CPS the operator can follow the procedure and apply human performance tools of place keeping and three-way communication. These error prevention techniques are different when using procedures in CPS or in paper copy. Another helpful feature of this program is that, when the critical safety functions are applicable, it displays the colour code for the critical safety functions' priority and directs the entry into the appropriate critical safety function procedure when they are orange or red.
- Alarm Presentation System (APS): APS is a software application that reads alarm information from the distributed control and information system and presents it to the operators via workstation displays and wall-mounted panel displays. The system is designed to alert the plant operators to an alarm condition and to provide fast access to alarm-related information that will guide the operator in managing abnormal plant conditions. The system also provides suppression features to assist the operator in identifying and managing alarms. The wall-mounted panel displays are visible to the operators from anywhere in the MCR and are readable from the RO's console and the SRO's console. The system presents alarm information on two of the wall panel displays. The use of spatially dedicated, continuously visible graphical alarm tiles promotes early detection and fast cognitive processing by the operators. The workstation displays present alarm information using a mix of graphical alarm tiles and alarm lists. The workstation graphical alarm tiles duplicate the graphical alarm tiles on the wall panels and provide a navigational aid to viewing the alarms driving each tile. The workstation alarm lists organizes alarms into several lists that the operator can use to support the current activities. The alarm lists can be sorted by time, priority, plant area, system, point name, point description, alarm type and alarm status. One helpful feature to rapidly respond to an alarm is that all of them are linked to their associated Alarm Response Procedure.
- Reactor Operator Peer Check System (ROPCS): The new MCR configuration gives the operators the opportunity to operate and control the plant without the need of moving around, just from their own screens. This could be an advantage for the crew, but also implies a lack of supervisory oversight from the SRO. This has been a new feature from a training point of view as well, since it is not easy to follow the trainee manoeuvres unless there is an instructor looking at the very same screen. To help with this potential lack of supervision during normal plant operation and training sessions a new software tool has been developed. It duplicates at one SRO workstation the current screen in use by one operator. Thus, it allows the SRO to follow the crew manoeuvres from the SRO station.

On the one side, the benefits of these new environment and tools are compelling and should result in more efficient operations and maintenance. On the other side, it is also important to recognize that, if those new tools are poorly implemented or used, there is a potential challenge to negatively impact performance resulting in a detrimental effect on safety (2).

Therefore, training needs to be oriented to take advantage of all these new features and to apply and adapt the Human Performance Tools as well as the Conduct of Operations to comply with a safe and efficient plant operation.

3. Results

Tecnatom has participated in this training evolution and has adapted to these advanced features. The first operations training course in the **AP1000** plant simulator was successfully delivered to 48 instructors from VC Summer and Vogtle NPPs (USA) in 2011. After that, continuing with the training program for the new plants under construction, 72 operators and plant technical staff from Sanmen NPP (China) in 2012 and 72 from Haiyang NPP (China) in 2013 received the operations training as well.

Tecnatom's consolidated experience delivering initial operations training of **AP1000** plant to future operators and instructors, has confirmed the special care that needs to be taken when implementing human performance enhancement tools. Industry events support this statement and strengthen the need for an even stricter implementation of such tools.

Due to the new MCR characteristics previously described, one of the singularities found during the training was the different way of implementing some of the human performance tools compared to the traditional MCRs:

- Peer-checking: The operator performing the peer-check to an action from a display has to accomplish this task by looking at the very same control station that is being used, which implies leaving his own station since there is no shadow tool in the operators' workstations. Peer-checking is therefore done as in vintage MCRs and verifier still has to interrupt any task in progress at that moment. The ROPCS is the new capability in the **AP1000** plant MCR because of the software available at those control stations. Thus, the SRO can follow the operator's display and precisely oversee the computer mouse and peer-check the task that is being performed without leaving the command and control position.
- Decision making: Because of the MCR configuration and its full capability from all the operation stations, the SRO has more supervision capability over all the plant evolutions making the decision process easier and the communication between all the crew members more fluent. Besides that, the software operation tools also facilitate the operator's decision process thanks to the useful information provided in multiple displays, the priority of the alarms given by APS and the input for each procedure step from the logic schemes in CPS.
- Concurrent verification: The capability of opening the same displays and controllers from each of the workstations facilitates this process, being easier to create a freedom of thought between the operators and act independently.
- Three-way communication: This useful tool for an effective communication is implemented differently when using procedures in CPS. This program allows all the crew members to read and follow the same procedure, giving feedback of the step in progress and its condition (met or not met). The SRO doesn't have to read each of the procedure steps, reducing the number of three-way communications, most of them becoming two-way communications and making the process easier, shorter and more effective.
- Place keeping: The CPS is a useful tool that automatically helps the operators to keep track of the procedure step in progress in each moment.
- Signature: The capability of the operators to individually log into each of the workstations implies a change in the signature process. Furthermore, the CPS automates log keeping and the Ovation™ expert distributed control system software will keep track of every action taken by the operators and automatically record the manoeuvres in the plant historian database. The personal accountability that is necessary for creating and maintaining an effective safety culture (3) is thus fostered by the MCR design itself.

From a training point of view there are also some significant changes. Even though the basics and fundamental principles of training remain the same, adaptation of the instructors to the new learning environment is mandatory. Also, the aforementioned human performance tools and their application must be modified for software based control rooms.

Instructors have to get used to new tools when training in this simulator. For example the ROPCS, that, on top of being a useful tool for supervisory oversight during plant operations, has also revealed itself to be a valuable resource for simulator instructors. In the **AP1000** plant simulator the booth instructor uses the ROPCS to follow the crew performance and identify the components that are being operated in each moment. This information retrieved by the booth instructor is a very helpful input to the floor instructor. Sometimes it is even fundamental when several actions are taking place during a plant transient and a closer analysis of the operators' performance is needed.

However, there are also some difficulties that arise for consistently conducting a performance evaluation in software based control rooms. During traditional simulator assessments, the instructor takes into account how the operators move inside the control room. The floor or even the booth instructor can penalize operators' performance if they approach the wrong panel. In contrast, software based control rooms do not allow the instructor to identify the system or even the component the operator is handling without taking a close look at the computer screen. The need for having as many evaluators as positions are in the MCR is thus reinforced. Moreover, guidelines must be issued to standardise the assessment whenever the operators select a wrong controller or display but do not carry out any action, since this situation did not exist in vintage simulators.

Additionally, Conduct of Operations as described by the International Atomic Energy Agency (IAEA) (4) needs to evolve and incorporate the special features of the **AP1000** plant MCR design. Though this decision depends on each utility, specific paragraphs should be added to specifically address the use of error prevention techniques. These sections could include directions for using traditional performance enhancement tools in the new MCRs. Furthermore, extra clauses could be included to take into account the uniqueness of trainee's On-the-Job Training (OJT) in that type of environment. Thus, incorrect equipment operation could be prevented, likely to happen with all components being operable through a single component screen.

The plant specific Conduct of Operations is also a suitable administrative procedure to include guidelines promoting communication between the different operation team members. Due to the challenges that software control rooms poses to the situation awareness of the operators (5) there can be situations where it is beneficial to set standards for crew briefs or updates in order to keep up to date the information shared among the different crew members.

4. Conclusions

The evolution of the design and control in the **AP1000** NPP is not only a step ahead in the safety and reliability of nuclear industry; it also implies an evolution in the plant operators and instructors to keep the safety culture principles applicable in the new all software based MCR.

Human performance enhancement tools and administrative procedures, as the Conduct of Operations, must evolve and adapt to the new environment, not only for normal plant operation but also to initial and continuation training in the simulator.

However, pursuing excellence obliges to continuously monitor and improve simulator training in order to verify the effectiveness of the aforementioned measures.

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Options for an International Nuclear Training Standards Accreditation Model

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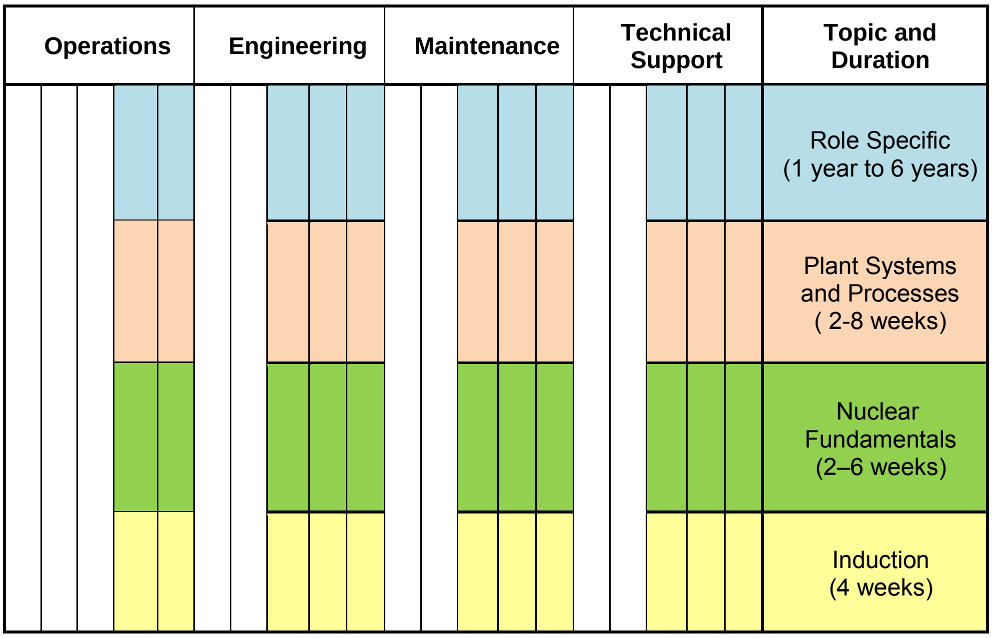
1 Introduction

With the development of new nuclear build programmes across the world and the demographic challenge facing existing nuclear operators it is essential that the industry has the capability to maintain a qualified and capable workforce. This paper proposes an international nuclear training standards accreditation model based on international best practice as a means of ensuring high quality and sustainable training and development programmes are in place for the future.

2 Description

Operators around the world are seeking to develop a sustainable training model for the current and future generations or workers. The current training models are broadly based on international nuclear curriculums (IAEA, INPO, WANO). These provide the foundations for the initial training models with some refresher and continuing training subjects.

Diagram 1: Typical Nuclear Training Model



The development of the Peer Evaluation programmes within WANO now seeks to identify opportunities for improving safety and performance for both the plant and personnel. This is recognition of the personnel development requirements in the nuclear industry of the 21st century. The peer evaluation models provide specific guidance with regard to the standards and quality of the training and qualification requirements expected to meet best practice. With the maturity of these processes the opportunity now exists to further strengthen the self-governing models with the use of an international nuclear training standards accreditation process.

The proposed structure of an international model would be based on voluntary participation, using the INPO and/or WANO peer evaluation methodology with a specific and dedicated focus on meeting the training and qualification performance objectives and criteria. The use of an international board and assessment teams based on a standardised approach to reviewing criteria requirements would be followed similar to the current arrangements experienced in the US and the UK.. This would involve direct involvement and feedback to Senior Plant Management throughout the process.

The challenges of the impact or positioning with national regulatory models, the plant diversity and the language and cultural differences would need to be carefully considered in establishing the model, and it would need to be designed to complement other peer review processes including WANO Peer Reviews and OSART Missions.

EDF Energy in the UK have developed a nuclear standards accreditation model,
Designed to meet UK needs with a 'European' flavor. The model is not regulatory driven but follows the UKs 'goal-setting' approach dependant on self-regulation. This includes a Training Standards Accreditation Board (TSAB) made up of 8 international members from Germany, Switzerland, France, UK, RSA, USA, Spain, covering a diverse expertise such as training in the nuclear industry and civil aviation. The process is very similar to the WANO Peer Evaluation but focuses on Training.

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