FROM SCIENCE TO SAFETY: THE LONG WAY TO RISK MANAGEMENT ASSESSMENT IN NUCLEAR INDUSTRY

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Abstract

Non-nuclear countries started to express their interest in building electronuclear programs in the early 2000s, with the consequence of creating the "nuclear renaissance" concept. Nuclear reactors involve numerous and highly technical sciences: they cover fields from fundamental neutronics to thermohydraulics, from fuel thermomechanics to radiological gas diffusion… These sciences are in complete interactions with each other and computational tools are often required to simulate their effects on a research reactor safety. As these topics have to be examined together, with interaction between each other and in relation to the specificities of the facility, it is crucial to get a keystone engineer to manage these specialized analyses. Consequently, safety assessment requires also specific skills that are not based only on these sciences and that are not initially held by a nuclear engineer. Thus the first objective program is to define the inherent human, professional, and technical characteristics required by a safety analyst. Formalizing a safety analyst profile 0 imposes to identify a set of applicable knowledge, hard and soft skills requirements in four topics. Several routes can be explored to build a safety analyst from a nuclear engineer, such as implementing nuclear safety into universities programs 0, theoretical training programs tutoring programs; such topics can be dealt with by dedicated instances such as ENSTTI 0 and "field based" approaches emerging from case by case analysis. In this context, it is important to notice that research reactors require the same basic sciences and are not as complex as nuclear power plants. Hence holding a comprehensive set of knowledge allowing the global safety assessment of the reactor is more easily achievable by a safety analyst. Research reactors are the first object on which this set of knowledge will be applied. It would then be eventually extrapolated to any nuclear installation, and profitably nuclear power plants.

1. INTRODUCTION

Non-nuclear countries started to express their interest in building electronuclear programs in the early 2000s, with the consequence of creating the “nuclear renaissance” concept. This resulted in rising the number of power reactors under construction up to 65 according to IAEA’s PRIS 0. Therefore, the development of high-level safety analysts is a burning issue, in particular for “newcomers” who have the wish to set up independent safety authorities and/or technical support organizations’ (TSO) for risk management assessment. Some of emerging nuclear countries have planned to reach this objective by fully integrating the development of research reactors into their strategy of human resources development. For instance, for Jordan, “the research and test reactor would serve as an integral part of the nuclear technology infrastructure. It will become the focal point for a Nuclear Science and Technology Center and play the primary role in educating and training the upcoming generations of nuclear engineers and scientists” 0.

Three aspects of this topic are emphasized in this article. In a first part, it introduces a safety analyst position’s specificities. Then, this publication enlightens the French TSO’s point of view (IRSN) regarding the strategy to be set up to turn a scientific engineer into a safety analyst. Then it introduces the role that can play the construction and the operation of a research reactor in this frame. As a conclusive topic, this paper approaches the role that a nuclear country’s’ TSO can play to sustain the development of “newcomers” safety analysis skills. These three aspects could benefit any country within the step 2 of the IAEA’s Milestone framework 0.

2. SAFETY ANALYSTS SPECIFICITIES

2.1 Safety analyst missions

IRSN’s safety analyst’s main objective is to provide the French nuclear safety authority with technical and argued advices. This goal can be divided into three missions: evaluating any nuclear operator’s request regarding a creation or a modification of a nuclear installation from a technical point of view, leading the ten-year periodic safety reviews planed for each nuclear installation and define the needs regarding research and development for the two first missions.

Whether the kind of nuclear installation is a PWR, a research reactor or a nuclear cycle installation, whether the field is nuclear safety or radiation protection, safety analysts common activities have been identified; they can be divided into three main sub-activities and can be related to specific skills:

- Field based activities such as preparing and supporting the safety authority on site inspections;
- Analysis and synthesis activities:
  - Operators’ request acknowledgement and preliminary analysis, identification of specific scientific needs or specialized contributions,
  - Safety or radiological risks analysis based on safety principles,
  - Redaction of the assessment report while possibly taking into account specialized contributions,
  - Knowledge management of any installation or thematic evolution,
  - Identification and definition of future R&D needs;

— Communication and interpersonal activities:

- o Internal and external communication in ones field,
- o Management of technical relations with nuclear operators,
- o Discussions with the safety authority regarding the instruction's schedule and outline,
- o Presentation of the safety assessment conclusive elements.

2.2 Safety analyst skills

As a skill can been defined as the "mastering of an operational know-how needed to fulfil a determined objective while relying on dedicated knowledge and behavioural competences", IRSN defined, taking into consideration safety analysis activities, a set of key competences and their required level:

TABLE 1: SKILLS AND LEVEL REQUIRED

Skills	Types	Level required
▪ Know-how	▪ Analyse with a critical point of view operator's hypothesis, demonstration and solutions ▪ Identify and organize issues ▪ Write scientific and technical advices intended to safety authority ▪ Public speaking	▪ Proficiency ▪ Proficiency ▪ Proficiency ▪ Proficiency
▪ Knowledge	▪ Engineering sciences ▪ Safety analysis ▪ Risk analysis	▪ Detailed ▪ Operational ▪ Operational
▪ Behavioural competences	▪ Communication ▪ Relational dynamics ▪ Analytical skills ▪ Ability to synthesize ▪ Ability to coordinate	▪ Very high ▪ Very high ▪ Very high ▪ Very high ▪ Very high

2.3 Shaping a safety assessors team

The earlier mentioned (Table 1) skill profile is considered as the reference model in order to build a safety analysts team. Regarding recruitment or career management, the human resources manager evaluates the candidate level as regard to its position requirements. The gap analysis enables to select adequate candidates and to define a candidate-specific training program when needed.

2.4 IRSN practice regarding research reactors' safety assessment

IRSN research reactors safety assessment is based on a collaborative process headed by a safety analyst in order to achieve the three missions mentioned in 2.1. Each safety analyst can mobilize, when required, specialized engineers for science to support safety assessment construction. Hence can be used the "From science to safety" concept. The concepts used by safety analysts relies more on defence in depth and containment barriers principles than on any scientific knowledge.

As Gregory Rolina mentioned in 0, the French historical approach regarding safety assessment is based on technical dialog whereas regulation has quite a low weight (it has been at some point conceptualized as "French cooking"). Thus, if safety can only rely partly on regulation, safety analysts necessarily hold rules and doctrine. A clear distinction is made between this set of skills and specialized scientific knowledge (neutronics, thermohydraulics, mechanics, etc.).

Practically, each research reactor is followed up by an IRSN dedicated safety analyst, the latter holding the complete understanding of the installation safety demonstration. Moreover, such a safety analyst can be mobilized whenever it is required in case of accident on this reactor, as crisis exercises are to be set up regularly.

3. FRENCH EXPERIENCE RELATED TO WAYS OF SHAPING SAFETY ANALYSTS

This paragraph focuses on French identify methodology that are encountered in order to turn a scientific engineer into a safety analyst.

3.1 Available engineers profiles

Historically, the reference programme related to nuclear sciences is the Engineering degree from the National institute for nuclear sciences and technologies, associated with the Atomic and alternative energy commission. Though nuclear sciences were taught in French universities and engineering schools, nuclear safety did not get any dedicated programme. Since the late 90s and increasingly since 2005, specialized masters or engineering degrees have been instituted 0:

- Specialized master in nuclear safety from Arts & Métier ParisTech Engineering school;
- Engineering diploma in nuclear safety, technology and environment from Ecole des Mines de Nantes Engineering school;
- Specialized master in nuclear safety and security from Bourges ENSI Engineering school;
- Nuclear safety master from Grenoble Joseph Fourier University.

As most of these education programmes are newly built, the scientific background of existing nuclear safety analyst often relies on traditional nuclear sciences. Thus, tutoring programmes have been set up to emphasis on nuclear safety skills (see 3.3, 3.4 and 3.5).

3.2 Building safety analysts: An engineering school point of view

Directly administered by the French Ministry of economy, industry and employment, the Ecole des Mines de Nantes (EMN) has a clearly stated purpose: “to train high level professionals to meet and anticipate the needs of the corporate world.” EMN has focused its education programmes towards two main fields: information technology on one hand and energy and environment on the other hand, the latter including a dedicated course to safety, technology and environment.

The safety culture taught in an engineering school such as the Ecole des Mines de Nantes, is built on the previously mentioned technical, human and organizational arrangements and is a common denominator in each syllabus. The safety analysts are built by mixing technical skills in the nuclear technology with skills in the safety culture and safety management. Experience in the risk assessment for nuclear facilities is gained from studying other complex high-risk systems, such as the chemical installations. Design practices and design organization in the safety management are enhanced.

Engineers must also increasingly mobilize their technical expertise in situation of uncertainty in a world with redistributed responsibilities. They must also develop capacities of analysis of controversy for which there does not exist consensus and which induces nevertheless “hot decisions:” they have to choose the optimal technical solution following arbitrations in a range of possible solutions, by anticipating the social reactions, morals, economic and organisational that they can induce. Risk and uncertainty are important issues in a growing amount of societal areas and particularly for environmental and technical issues. That is why the management and negotiation of risk, its socio-cultural production in media coverage and discourses and the conflicts on its unequal allocation are focal themes in the engineering courses.

Safety analysis may be organizational, social or equipment-related. Experts opinions, theory and practical approaches are mixed and multiplied to sharpen the safety culture. For instance, a newly set up half-day exercise is organized each year by IRSN at the Ecole des Mines de Nantes Engineering school (EMN). A first team of students has to submit an application file for design approval and safety certification of a Generation IV reactor. A safety assessment is then performed by a second team of students. Exchanges between “safety assessors,” “designers” and IRSN experts provide a natural environment to identify safety issues and understanding of what a safety evaluator is. Moreover it enables students to “fill the gap” between theoretical concepts and practical safety assessments.

Numerical simulation tools (MCNP, CATHARE, etc.) and reactor simulators are also support tools used to understand the links between scientific subjects taught at EMN, i.e neutronics, thermohydraulics, reactor operations, ergonomics, human factor, safety and their links. In other side, the students, after having observed an emergency drill, must analyze the elements of coordination and cooperation which they could identify. This experience feedback, framed by the teachers, enlightens the collective dimension of safety. The lecture also aims at understanding the institutional construction of safety, with a particular attention drawn on the relationships between the Safety Authority (backed by its technical support organization IRSN) and the main nuclear licences and operators.). In other words, through the analysis of various interactions (cooperation, coordination but also conflict) between the people and between the entities (services, organizations), the students are aware of the collective support of the facilities safety.

3.3 IRSN internal “school of expertise”

The newly created “School of expertise” has two main goals:

- Integrating newly recruited safety analysts. As a complement to existing tutoring programmes, the School of expertise will provide young safety analysts with better understanding of ones role and job requirement;
- Develop an IRSN safety and assessment culture, defining a proper IRSN meaning of “expertise” and structuring the stages and methods of a safety instruction while emphasizing on safety analysts debates. In the meantime, training to redaction and IRSN specific vocabulary will be given.

This specific training programme is divided into three sessions. At the end of the first of them, and as an introduction to assessment, safety analysts and researchers should be able to answer questions such as “Why assessing?”. Moreover, they are given a common vocabulary regarding safety, radioprotection and security and they approach the link between assessment and research.

The second session is dedicated to safety assessors. It is aimed at defining assessment process in order to build a common methodology. For instance, the following aspects are gone through:

- Assessment process: organisation and skills;
- Preliminary analysis: goals and skills;
- Technical instruction;
- Writing and validation of IRSN assessment;

— Specific assessment for specific themes.

The third session is aimed at personal development in order to give safety analysts capability to argue technical points of view publicly. Media-training is used in this case.

3.4 An example of European cooperation: ENSTTI

As identified in the firsts parts of this article, the construction of expertise in nuclear safety is more than a matter of formal education as it involves transfer of non-formal knowledge, practical experience and culture. Non-formal education in nuclear safety was only globally discussed at the 2010 IAEA conference on the challenges faced by Technical Safety Organisations (TSO) in enhancing nuclear safety and security. The conference conclusions recognized that the quality of training in safety and security assessment depends upon the practical expertise of the trainers 0. This issue was further discussed at the last EUROSAFE conference through a workshop devoted to European cooperation in education on nuclear safety. It was again emphasized that safety training has to be implemented in educational planning through TSO-informed teaching programmes 0.

The major part of the non-formal education received by European TSO staff comes from in-house training programmes. One of the concerns raised in European Commission forum was the possibility for some small safety organisations or newcomers in the nuclear energy field with still limited infrastructure to deliver training to their staff without building their own training school. To answer these concerns and enhance the harmonisation of curriculum within the EU, the European TSOs took in 2010 the initiative to create the European Nuclear Safety Training and Tutoring Institute, ENSTTI, in association with the European Union and the IAEA, to drive the vocational training of the present and coming generations of professionals in nuclear safety, nuclear security and radiation protection.

The main goal of ENSTTI is to train European TSOs' technical staff throughout their professional life in TSOs' state-of-the-art assessment methods and to raise the overall assessment technical level. Leverage of nuclear safety expertise and harmonization of assessment methods are goals beyond the European Nuclear Safety framework and ENSTTI opens its training activities to participants from nuclear safety organizations from other regions of the world.

ENSTTI offers short applied training sessions and longer tutoring periods both for young professionals and for those with some professional experience in the nuclear sector. All course programs include working groups, simulator sessions, technical visits and open discussions. The ENSTTI formation curriculum is made up of three parts: the "Induction to Nuclear Safety" course, where during a four-week course trainees approach the bases and culture of nuclear safety, nuclear security and radiation protection; tutoring periods where trainees are integrated into TSOs' operational units; and short training modules for specialists, where TSO experts and other safety specialists are briefed in-depth on a particular safety or security topic. During the tutoring periods customized to each applicant's future work, trainees work alongside an expert with safety responsibilities within its own organization. The content and duration of tutoring periods are adapted to the profile of each individual. The personalized support is continued through regular contacts with safety experts once the trainee returns to work.

ENSTTI relies primarily on its TSO members to provide professors and facilities for the organisation of its activities. ENSTTI lecturers and trainers are experts in their technical domain. Through its activities, ENSTTI aims at contributing to the harmonization of nuclear safety and security practices and to the networking of today and future nuclear safety experts in Europe and beyond.

3.5 Tutoring and case by case analysis

As a young nuclear analyst with scientific background, one can be confused with the methodology of safety assessment and the gap between “hard sciences” and soft skills which are at the heart of the French nuclear assessment process. Thus, as identify at IRSN, one of the best way to integrate these aspects can be case-by-case analysis topped by close tutoring. In this case, instructions have to be chosen carefully as they have to be as educational as possible. This methods assumes that the safety analyst is yet in position and its potential misconducts would be corrected by an expert identified for tutoring purposes. It develops safety assessors responsibility as well as being highly practical.

3.6 Conclusion

This third paragraph enlightens the methodologies found in France to shape safety analysts teams. These tools (engineering programmes, external/internal tutoring, internal school) are not to be used all together but to be carefully chosen as a mean to raise a profile to a better suited level taking into account specific human characteristics such as the candidate personality.

Once the set of theoretical knowledge, know-how and behavioural skills is satisfyingly held by a nuclear analyst, i.e. the gap between science and safety if filled, it has to be practically applied on a nuclear installation safety assessment. Once again, as the risks are often growing with the complexity and the power of nuclear installations, it has to be chosen carefully to be in adequacy with safety analysts capabilities. A first step can be research reactors safety assessment.

4. A RESEARCH REACTOR: A SAFE STEP TOWARDS AN ELECTRONUCLEAR PROGRAMME?

Historically and for numerous reasons, most of major nuclear powered countries have started their programmes with the design and the operation of research reactors. For some of them, these research reactors were real prototypes of industrial installations 0. This approach led numerous countries, through decades, to build research reactor as a first step into a nuclear programme. Thus, 375 research reactors were in operation around the globe in 1975 0. Such a process allowed, at that time, nuclear countries to built high level scientific teams but also to experiment “hand-made” safety 0 even if this concept was not associated to a dedicated institution. Nowadays, countries such as Jordan 0 or Poland have explicitly indicated that their existing (for Poland) or future (for Jordan) research reactor is a key stone in their training programme.

From a safety analyst point of view, as such a reactor is far less complex than a nuclear power plant, holding a comprehensive set of knowledge related to its safety demonstration being much more achievable. As an example, the application of the defence in depth principles to a research reactor and to its components can be made with a lot less ambiguity than what would reveal a NPP.

Simultaneously as the technology transfer that would lead newcomers to gain access to NPPs, the knowledge management system can rely on training applied on research reactors.

5. CONCLUSION

Examples of French practices related to knowledge management in terms of safety analysis have been given in this article. They may constitute a tool for a newcomer to build its human resources program, while having to be adapted to local specificities.

As a complementary example, TSO can have a direct assistance in terms of building a newly created TSO identity and expertise, as mentioned in 0. In this case, a dedicated team of IRSN experts acted as consulting agents focusing on safety analysis methodology as well as organisational aspects and managing issues.

Undeniably TSOs can play a significant role to sustain the development of "newcomers" safety analysis skills and support harmonization in terms of practices and safety requirements.

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