Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security

Ensuring Effective and Sustainable Expertise

Proceedings of an International Conference
Brussels, Belgium, 15–18 October 2018

ETSON EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

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CHALLENGES FACED BY TECHNICAL AND SCIENTIFIC SUPPORT ORGANIZATIONS (TSOs) IN ENHANCING NUCLEAR SAFETY AND SECURITY

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PROCEEDINGS SERIES

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ENSURING EFFECTIVE AND SUSTAINABLE EXPERTISE

PROCEEDINGS OF AN INTERNATIONAL CONFERENCE ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
HOSTED BY THE
GOVERNMENT OF BELGIUM THROUGH BEL V
IN COOPERATION WITH THE
EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK (ETSON)
AND HELD IN BRUSSELS, 15–18 OCTOBER 2018

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2021

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 26007 22529
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
www.iaea.org/publications

Printed by the IAEA in Austria
December 2021
STI/PUB/1955

IAEA Library Cataloguing in Publication Data

Names: International Atomic Energy Agency.
Title: Challenges faced by technical and scientific support organizations (TSOs) in enhancing nuclear safety and security : ensuring effective and sustainable expertise / International Atomic Energy Agency.
Description: Vienna : International Atomic Energy Agency, 2021. | Series: Proceedings series (International Atomic Energy Agency), ISSN 0074–1884 | Includes bibliographical references.
Identifiers: IAEAL 21-01427 | ISBN 978-92-0-121021-0 (paperback : alk. paper) | ISBN 978-92-0-120921-4 (pdf)
Subjects: LCSH: Nuclear industry — Security measures. | Nuclear industry — Safety measures. | Nuclear power plants — Risk assessment — Congresses. | Nuclear energy — Safety regulations — Congresses. | International cooperation.
Classification: UDC 621.039.58 | STI/PUB/1955

FOREWORD

The global nuclear safety and security framework (GNSSF) provides a conceptual structure and guidelines for achieving and maintaining a high level of safety and security at nuclear facilities and in nuclear related activities around the world. Technical and scientific support organizations (TSOs) play an essential role in sustaining the GNSSF by providing assistance to regulatory bodies in establishing and maintaining nuclear and radiological programmes with a strong safety and security component built on a sound technical and scientific basis.

Since 2007, the IAEA has held a series of international conferences examining the role played by TSOs in their support of regulatory bodies and the nuclear industry. The first conference, held in Aix-en-Provence, France, in 2007, provided a forum for TSOs, international organizations and experts to discuss — and develop a common understanding of — the roles, responsibilities, needs and opportunities of TSOs. The second conference, held in 2010 in Tokyo, focused on international cooperation and networking among TSOs, and the roles of TSOs in the regulatory process and in capacity building in Member States considering embarking on a nuclear power programme. The third conference, held in 2014 in Beijing, examined the role of TSOs in the light of the Fukushima Daiichi nuclear accident.

The fourth conference in this series, the International Conference on Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security: Ensuring Effective and Sustainable Expertise, held in Brussels in October 2018, highlighted the importance of scientific and technical capabilities to support regulatory decision making for enhanced nuclear and radiation safety and security, and explored solutions for the development, maintenance and enhancement of such capacities, especially in embarking countries. In particular, the conference promoted the self-assessment methodology developed by the IAEA to support Member States in developing their technical and scientific capabilities on the basis of the information in Technical and Scientific Support Organizations Providing Support to Regulatory Functions (IAEA-TECDOC-1835), published in 2018.

This publication includes a summary of the conference, the opening addresses and invited papers, and the Conference President's report, as well as the conclusions and deliberations of the meeting. The supplementary files, available on-line, contain the contributed papers and respective posters, the list of participants and the presentations that were submitted with the invited papers.

The IAEA wishes to thank the contributors involved in the preparation of this publication. The IAEA officers responsible for this publication were L. Guo and K. Ben Ouaghrem of the Office of Safety and Security Coordination.

EDITORIAL NOTE

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INTRODUCTION

The International Conference on Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security: Ensuring Effective and Sustainable Expertise was held in Brussels, Belgium, in October 2018, built on three previous conferences on this subject, held in Beijing, China, in 2014, in Tokyo, Japan, in 2010, and in Aix-en-Provence, France, in 2007. The focus of this fourth TSO conference was on evaluating actions undertaken to address recommendations from previous TSO conferences including achievements of the TSO Forum, facilitating experience sharing in developing TSO capacity from Member States from well-established nuclear countries or from countries intending to embark nuclear programmes experience, highlighting the role of TSOs in enhancing nuclear safety and security and exploring solutions to support Member States in developing or strengthening their technical and scientific capability.

On the basis of past TSO Conference conclusions, several developments were undertaken under the auspices of the IAEA TSO Forum:

(a) A Technical Document IAEA-TECDOC-1835 on Technical and Scientific Support Organizations Providing support to Regulatory Functions describing core characteristics of TSOs was published in March 2018.

(b) The development of a TSO self-assessment questionnaire to enable Member States to practically perform an assessment of their national TSO strategy in reference to the IAEA-TECDOC-1835.

(c) The development of a library of case studies-based methodology compiling experiences learnt from Member States on TSO related issues to support Member States in their TSO development strategies (in progress).

(d) The development of a “national TSO workshop” approach to better address needs of Member States.

The fourth conference was an opportunity to:

- Provide an overview of the current technical assessment topics to maintain a sustainable nuclear safety and security system;
- Foster dialogue and experience sharing on all relevant technical, scientific, organizational and legal aspects at the international level.
- Consider appropriate approaches to enhancing cooperation and effective networking among TSOs and beyond;

Nestor Masriera, President of the Board of Directors of Argentina’s Nuclear Regulatory Authority, served as the Conference President. Over 228 participants from 54 Member States and five organizations attended the conference. The conference programme comprised an opening session, six topical sessions that focused on challenges faced by TSOs in enhancing nuclear safety and security, and a concluding panel session that focused on future developments and future cooperation among TSOs. During the conference, two keynote presentations, 47 invited papers and 56 posters were presented. Each of the six sessions was accompanied by a panel discussion which allowed a fruitful experience sharing with the audience via the use of the ConfApp.

OPENING SESSION

The opening session began with a welcome address by M. Van Haesendonck, Director General of Bel V, the Belgian TSO that conducts inspections as well as safety assessments for nuclear projects and host of the conference, who outlined the work of his organization, explaining that its mission is to contribute towards protecting people and the environment against the danger of ionizing radiation on the basis of experience built up over 50 years.

J. Jambon, Deputy Prime Minister and Minister of Security and the Interior of Belgium, highlighted that competent safety authorities — supported by TSOs — are key to safe nuclear activities. He noted that there is a need for experts passionate about nuclear safety, who work every day to make sure that nuclear technology works for the benefit of the people, and that they do not have to worry about accidents.

J.C. Lentijo, IAEA Deputy Director General and Head of the Department of Nuclear Safety and Security, in his opening remarks pointed to the diversity of TSOs, remarking that there is no 'one size fits all' for the organizations. He noted that the Conference would discuss the wide range of formats for the organizations and their cooperation with regulatory bodies.

Other speakers at the opening session included N. Masriera, President of the Board of Directors of Argentina's Nuclear Regulatory Authority, and M. Huebel, Head of the European Commission's Unit on Radiation Protection and Nuclear Safety.

N. Masriera, as the President of the Conference, gave a welcome to the participants of the fourth TSO Conference, and highlighted the importance of promoting the understanding of the roles, functions and values of TSOs, explaining the framework focused on regulatory bodies. He also described the design of the conference structure and declared the Conference open.

Following their opening addresses, there were keynote addresses:

B. De Boeck, Belgium, President of the TSO Conference 2014, presented an update on the implementation of the conclusions and recommendations of the TSO Conference 2014.

G. Caruso, IAEA, Director of the Office of Safety and Security Coordination, presented an overview of IAEA activities related to TSOs.

WELCOME ADRESS

M. Van Haesendonck
Co-president of the Conference,
Director General,
Bel V,
Brussels, Belgium

Ladies and Gentlemen, distinguished guests,

On behalf of the IAEA, the organiser of the conference and Bel V, the local host, I would like to welcome you at this 2018 TSO Conference.

As you may know, the previous TSO Conference was organised in Beijing four years ago. It was then proposed, and later accepted, to hold the next edition in Brussels. For Belgium and Bel V, the local host, this is an honour. After many months of hard work preparing this event, we can finally say that we are happy to see you here.

Bel V, the Belgian TSO, is since 2008 a private foundation established by the Federal Agency for Nuclear Control (FANC) as a subsidiary to which the agency delegates activities in the field of nuclear safety and radiation protection. Before 2008, AVN, which then became Bel V, was in charge of the nuclear and radiation protection regulatory control since 1965.

Our mission is to contribute towards protecting people and the environment against the danger of ionising radiation on the basis of experience built up over 50 years. We fulfil our mission, on the one hand, by carrying out regulatory inspections in nuclear power plant and other nuclear installations in Belgium, and on the other hand, by performing assessments of the safety cases established by the licensees of nuclear and radiological facilities. In addition, Bel V provides support to the FANC for the development of regulatory guidance documents. We also play an important role in the frame of the Nuclear and Radiological Emergency Plan for the Belgian Territory.
Bel V is therefore an integral part of the Belgian Regulatory Body. When in 2013 at the request of Belgium the International Atomic Energy Agency (IAEA) conducted an Integrated Regulatory Review Service (IRRS mission), during which the entire Belgian Regulatory Body was audited, also Bel V’s role, our role as a technical support to the FANC and Bel V forming an integral part of the Belgian regulatory body were confirmed.

Bel V has since many years developed its own management system. The Bel V Quality Management System is certified, under the most recent ISO 9001 quality standard. Bel V’s management system aims to be an integrated management system as defined in the IAEA Safety Standard.

Since maintaining and further developing our expertise is of utmost importance there is a continuous evaluation of needs in terms of staffing, recruitment, lifelong learning, participation in working groups (e.g. R&D) and we aim to be a driving force on R&D in nuclear safety. Bel V has an R&D programme in nuclear safety research, which is regularly updated, and relies for a large part on collaboration with scientific institutions such as universities and national and foreign research establishments.

Bel V is also a founding member of ETSON. One of the activities of ETSON is the organisation of a yearly nuclear safety conference: the Eurosafe Forum. It is organised alternatively in Belgium, France and Germany. This year would have been the turn of Belgium, but the Eurosafe Forum is not held when there is a TSO conference because the audience and the objectives of the two events are too similar. This explains why ETSON is actively contributing to the organisation of the present event, which you will notice during the ETSON Side Event this afternoon. Also, today, a “TSO Café” is being organised to promote networking between the participants. It is an event which is part of the Eurosafe Forum and allows the TSOs member of ETSON to present themselves.

Finally, ladies and gentlemen, allow me to wish you a fruitful and exciting conference here in Brussels.

WELCOME ADDRESS

J. Jambon
Deputy Prime Minister and Minister of the Interior and Security,
of the Belgian Federal Government,
Belgium

Ladies and Gentlemen, distinguished guests,

As Minister of Security and the Interior I have a bit of a peculiar role regarding nuclear safety.

On the one hand I should not and cannot intervene in the assessments of the nuclear safety authority. This is a fundamental principle in nuclear safety, and I wouldn't want to have it any other way. On the other hand, I do have to answer to Parliament, answer any question they may have regarding nuclear safety.
And I can assure you, our members of parliament like to ask questions about nuclear safety.

Although they take a lot of effort, I do think these questions are a good thing. Nuclear Safety is important, and we have to show the citizens of our countries that we take it seriously. But for this, I depend on the Federal Agency for Nuclear Control, our independent nuclear safety authority. Like every country that has nuclear installations, we need a competent safety authority. We need experts, passionate about nuclear safety. Experts that work-day-in-day-out to make sure that nuclear technology works for the benefit of the people, without them having to worry about accidents.
Technical Support Organizations or TSOs are the place par excellence where we can find these experts. You are these experts.

Since the very beginning of nuclear activities in Belgium, TSOs, like Bel V, have played an important role. Not only as site-inspectors for the nuclear facilities, but as an integral part of the regulatory framework; developing, maintaining and increasing technical knowledge and experience.
With the help of TSOs, the Belgian authorities have always accorded the highest priority to nuclear safety and have never ceased to expect the highest possible level of nuclear safety in all its nuclear activities. Belgium was one of the pioneers in Europe in the use of nuclear technology. This all started in the Nuclear Research Centre (SCK-CEN), which since 1956 operated several nuclear research reactors. The BR2 remains one of the most versatile research reactors in the world, while at the same time supplying about a quarter of the global need for medical radioisotopes.

Over these past decades our country harboured several parts of the fuel cycle such as nuclear energy production, dismantling activities, waste processing and fuel manufacturing, including MOX fuel manufacturing – which I can proudly say was developed in our country – and soon we can add a waste disposal facility to this list.
Not just the past, but the future looks bright as well as we – the Belgian government – recently approved funding for MYRRHA, the next generation in nuclear research infrastructure. All of these activities have always been conducted in close cooperation with other countries.

On the regulator's side, experts from Bel V and FANC have regular exchanges with other regulatory bodies from other countries.
They are well represented in IAEA and NEA workshops; expert groups and safety standards committees and they frequently participate in peer review missions such as IRRS and IPPAS.

These activities all aim not just to learn from the experience of others, but also to share the rich Belgian experience with others.
This conference presents the ideal occasion to share your experience and your knowledge with the other participants.
All of you will take this experience and this knowledge home with you, contributing to safer nuclear installations in your countries and therefore contributing to a safer world. And that is why I am proud to open this important conference and I would like to thank Bel V and the IAEA for choosing to have this conference in Brussels.
This conference presents an ideal opportunity to develop and share your expertise. Please use this opportunity to the fullest. We all depend on you for our safety.

Thank you very much.

I wish you all a very fruitful conference.

OPENING ADDRESS

J.-C. Lentijo
Deputy Director General,
Head of the Department of Nuclear Safety and Security
International Atomic Energy Agency,
Vienna

Excellencies, ladies and gentlemen, dear colleagues, good morning!

Welcome to this important Conference, which is the fourth of its kind. I thank Belgian Deputy Prime Minister and minister of Security and Home Affairs, Jan Jambon, for joining us, and I thank our Belgian hosts, BEL-V, for their support.

Since the Agency held its last TSO conference in 2014 in Beijing, we at the Agency have intensified our work to support Technical and Scientific Organizations, or TSOs. For example, we created the TSO Forum. And earlier this year, we published a Technical Document that highlights that there is no one-size-fits-all when it comes to TSOs supporting regulators. They can be part of the regulatory body. They can be external organizations. They can form a system that draws on the expertise and competences of several national organizations. The Technical Document also emphasises that technical expertise is not only a matter of qualified staff. Technology, methodology, tools and core values also are important.
Our conference will highlight all of this. We will talk about the diversity of national contexts and the experiences of TSOs and regulatory bodies working together. We will focus on challenges, both technical and those related to conflict of interest, civil society, public communication and synergies between safety and security. And we will discuss how to build and maintain technical and scientific capability and expertise.
I hope you will take active part in these discussions. Please share your experiences during the sessions, the TSO Café and other events. Your active participation will contribute to conclusions that will influence the Agency's future TSO work.

Ladies and gentlemen,

This wide participation in this conference - 228 participants from 65 Member States and 4 International Organisations, and more than 120 papers and 80 posters - is a recognition of the important role TSOs perform in promoting safety.

Thank you all for being here. I particularly thank Conference President Nestor Masreira, our panellists, speakers, presenters and all others that made this conference happen. This includes our Scientific Secretaries, Lingquan Guo and Karim Ben Ouaghrem, and from the Agency's Conference Services Martina Neuhold and Javlon Dusimatov.

I wish you a successful conference. I look forward to hearing about its outcome.

Thank you.

OPENING ADDRESS

M. Hübel

Head of Unit Radiation Protection and Nuclear Safety
European Commission

On the behalf of

M. Garribba

Director of Direction of Nuclear Energy, Safety and ITER (DG ENER)
European Union

Ladies and Gentlemen,

On behalf of the European Commission, Directorate-General Energy, I am pleased to address this important international conference on the Challenges faced by TSOs in Enhancing Nuclear Safety and Security. I am replacing Massimo Garribba, Director for Nuclear Energy, Safety and ITER, who unfortunately cannot be here today.

In my intervention, I would like to focus in particular on the challenges and opportunities in the role of TSOs under the Euratom Nuclear Safety framework.

Since decades, nuclear energy has been playing an important role in the energy mix of half of EU Member States. But nuclear safety concerns us all: countries which use civil nuclear power as well as those that do not. We share a common understanding to enhance nuclear safety, building upon technical experience and scientific progress. Lessons learned from the Fukushima Daiichi Nuclear accident have had a strong influence on the reinforcement of nuclear safety worldwide and will continue to do so in the future.

This is certainly the case in the European Union. The EU legislative framework has been significantly strengthened in the recent past:

- a Council Directive for the responsible and safe management of spent fuel and radioactive waste was adopted in 2011;
- a revised Directive establishing basic safety standards to protect the health of workers and the general public against ionising radiation in 2013;
- and a revised Nuclear Safety Directive in 2014 – which is currently being transposed and implemented.

Altogether, this represents the most advanced legally binding and enforceable regional legal framework which is applicable to all EU Member States.

At the same time, it is important to keep in mind that nuclear safety is a national responsibility, within an EU framework. Decisions concerning safety actions and the supervision of nuclear installations remain with the operators and national authorities.
Nuclear is – we all know - a very highly regulated industry and nuclear states have highly sophisticated sets of national technical requirements and licensing processes which vary from country to country. This is why the Nuclear Safety Directive highlights the importance of

having expertise available. In fact – and in line with the conclusions of previous conferences – regulatory bodies need constant access to supporting expertise and scientific knowledge.

The role of TSOs in the development of safety standards and in their support to safety regulators is clearly acknowledged in the Nuclear Safety Directive.

The work of TSO's in Europe through ETSON – for example by developing generic methodological guidance for safety assessments - is valuable for promoting consistency of safety approaches at the European level. This is why the Commission has strengthened links with the TSO's, for example, with the Commission's Joint Research Centre in the area of operating experience feedback, and with DG Energy for implementation of the nuclear safety objective.

The work by TSO's on the nuclear safety objective supports a priority activity in identifying practical strategies and measures aimed at preventing accidents and avoiding large radioactive releases.

The revised Nuclear Safety Directive introduced a European system of regular Topical Peer Reviews, to examine topics of common interest to nuclear safety and to share national experience. The first topical review which commenced in 2017 addressed the important subject of the 'management of ageing of reactor components, and structures'. The nuclear regulator's group - ENSREG – will publish its report shortly, and many countries have indicated that improvements have been identified as a result of the national assessments. A large amount of effort was required both in carrying out national assessments and in the peer review of the findings. The input of experts from the national TSO's was invaluable in this review process. However, the work is not finalised. Challenges have been identified that require EU-wide efforts to resolve them. Each country must also prepare a national action plan.

In addition, many of the European TSOs have been strongly involved for many years in R&D projects related to the improvement of safety of the European NPPs, under EU-funded projects. These projects have provided valuable insights, and it is necessary that these research and development activities continue with a focus on nuclear safety and results that contribute to the effective implementation of the Nuclear Safety Directive.

Nuclear activities are also an important part of the EU's external action. Since 2007, the Commission has been supporting non-EU countries, particularly neighbouring countries through the Instrument for Nuclear Safety Cooperation to ensure a high level of nuclear safety, safe management of spent fuel and radioactive waste, radiation protection and safeguards. Through these actions the Commission has also been supporting the activities of TSO's.

In June 2018, the Commission proposed a new Council Regulation for a 'European Instrument for Nuclear Safety' which would replace the INSC. Under this proposal, 300 million Euros would be allocated to activities in the period 2021 -2027.
The objective of the new European Instrument for Nuclear Safety would be to promote the establishment of effective and efficient nuclear safety standards in third countries building on the experience of nuclear safety activities within the Euratom. However, the challenge remains on how new projects can better benefit from the transfer and exchange experience and good practices in capacity building and international cooperation.

Let me mention also the application of nuclear technologies in the non-power areas. In March of this year, the European Commission organised an international conference to support the advancement of nuclear and radiation sciences and technology in fields such as medicine, industry and research.

The conference, together with the on-going study on the subject, will underpin the development of an action plan, the EU Strategic Agenda for Medical, Industrial and Research Applications of nuclear and radiation technology (SAMIRA). The input of TSO's to this initiative is vital to address the challenges ahead.

In conclusion, Mr Director General, Minister, distinguished guests, Ladies and Gentlemen, let me say that securing the most effective implementation of the EU nuclear legislative framework and related instruments is a priority for the European Commission. A strong partnership of all stakeholders is a key element in this process.
TSO's have a well-established role and are essential to a robust scientific-based evaluation of nuclear safety. It is important that through events such as this conference, the TSO community, regulatory bodies and other stakeholders have the opportunity to reflect on the achievements of the past – but also to deliver their views to the wider community on the priority areas for future actions.

I thank you for your attention and wish you every success with this event.

OPENING ADDRESS

N. Masriera

President of the Conference,
President of the ARN,
Argentina

Excellencies, ladies and gentlemen, dear colleagues, good morning!

Welcome to the fourth TSO Conference. I would like to thank the International Atomic Energy Agency with the support of all Programme Committee members for organizing this important conference and of course, our host, the Government of Belgium via Bel V.

Since the last TSO conference in 2014 in Beijing, the Agency has intensified its work to support Technical and Scientific Organizations, or TSOs. Benoit De Boeck will present the follow-up of the recommendations from the last TSO Conference.
Gustavo Caruso will provide you with some highlights on the main achievements related to the TSOs and especially the IAEA-TECDOC-1835 on TSOs providing support to regulatory functions.

This fourth conference has been thought and designed to provide you with examples of the various national contexts of TSOs supporting regulatory functions. This will be covered by the session 1. But also, examples on the TSO contributions to safety assessment, radiation and waste management safety and via international cooperation as planned in session 2, tomorrow. TSO contribution may also include Emergency Preparedness and Response, see the session 3 on Wednesday morning. Other challenges, like security, physical protection, concern of the civil society may be faced by TSOs, see the session 4 on Wednesday afternoon. The last day will address capacity building and the ways to develop strengthen TSO capacity: these will be addressed in the sessions 5 and 6, respectively. Especially in the session 6, you will get insights of the TSO initiative plus an interactive quiz. As you see the recommendations of TSO conferences provide a driving force for the Agency to support the needs of the Member States, our need as Regulatory bodies and TSOs, so, I invite you to discuss together, take benefit of the TSO Café organised today during lunch time, to raise questions during the sessions and to contribute to the concluding session till the end.

Ladies and gentlemen,

Thank you all for being here. I would like to address a specific thanks to our panellists, speakers, presenters and session chairs and rapporteurs and all others that made this conference happen. This includes our Scientific Secretaries, Lingquan Guo and Karim Ben Ouaghrem, and from the Agency's Conference Services Martina Neuhold and Javlon Dusimatov.

I wish you a successful conference and I declare this conference open.

Thank you.

KEYNOTE ADDRESS

CONCLUSIONS OF THE TSO CONFERENCE 2014

B. De Boeck

President of the TSO Conference 2014,
Belgium

Abstract

The focus of the Beijing TSO Conference 2014 was on strengthening the cooperation among TSOs and improve their capabilities to provide nuclear and radiation safety and security expertise to both regulators and operators. 11 conclusions and 9 recommendations were drawn from the discussions. The paper reviews the progress achieved on meeting those recommendations.

All recommendations were taken into account and most were satisfactorily resolved. Some will need more work. Writing a Safety Guide on the performance of TSO functions as part of the IAEA Safety Standards Series is not possible at this stage, and a Technical Document (TECDOC) was developed instead. The IAEA-TECDOC-1835 on TSOs supporting regulatory functions was published in 2018. The absence of a Safety Guide makes the inclusion of the TSO function in the IRRS difficult, and discussions are still ongoing within the TSO Forum on the basis of the recently published GSG-12: "Organization, Management and Staffing of the Regulatory Body for Safety".

In conclusion, it can be stated that the IAEA TSO Forum is very active, with useful outcome. Good progress has been achieved in implementing the recommendations of the 2014 TSO conference. The importance of TSOs in nuclear safety is more and more widely recognized. More work remains to be done on some key issues.

This paper was not available for publication but the full presentation is included in the online supplementary files, for reference, and can be found on the publication's individual web page at www.iaea.org/publications.

KEYNOTE ADDRESS

OVERVIEW ON IAEA ACTIVITIES RELATED TO TSOs

G. Caruso, IAEA

Director of the Office of Safety and Security Coordination
Department of Nuclear Safety and Security
International Atomic Energy Agency,
Vienna

Abstract

To support Member States in developing and strengthening their Technical and Scientific Capacity, the IAEA assists Member States in developing and strengthening TSO capability by, inter alia, organizing national and international workshops, and preparing several case studies and a modular TSO self-assessment.

The IAEA published in March 2018, the TECDOC-1835 on Technical and Scientific Support Organizations Providing Support to regulatory Functions, providing various organizational models of TSOs (internal, external, others), key core values and characteristics of TSOs supporting regulatory functions and the nature and scope of technical and scientific activities.

It was recognized the need for clear leadership when establishing TSOs, for the safety of nuclear facilities and activities. In this regard, the IAEA established the Leadership school for early to midcareer professionals, to develop their Safety leadership potential through a better understanding of what leadership means in practice, in nuclear and radiological working environments, such as in TSOs, with their inherent complexities and often competing considerations.

This paper was not available for publication but the full presentation is included in the online supplementary files, for reference, and can be found on the publication’s individual web page at www.iaea.org/publications.

TOPICAL SESSION 1

ROLES OF THE TSOs SUPPORTING REGULATORY FUNCTIONS

Chairperson
U. STOLL
Germany

Co-chairperson
N. Masriera
Argentina

The first topical session presented the roles of the TSOs supporting regulatory functions and included various examples of roles and models of cooperation between regulatory bodies and TSOs, their experience, challenges and opportunities. To ensure successful cooperation with domestic and international TSOs, the existence of core capabilities/technical expertise within the regulatory bodies is a key component. The challenges for modalities of cooperation between the regulators and TSOs, was highlighted during the session, with special emphasis on the needs of embarking countries seeking international cooperation to strengthen regulator and domestic TSO capabilities. One of the main lessons learned from the first topical session was the importance of increasing the dialogue between civil society and technical experts to contribute to the trust and confidence in the technical basis supporting regulatory decisions.

This paper was not available for publication but the full presentation is included in the online supplementary files, for reference, and can be found on the publication's individual web page at www.iaea.org/publications.

THE EXPERIENCE OF THE ARGENTINA NUCLEAR REGULATORY BODY USING EXTERNAL TSOs FOR LICENSING NUCLEAR POWER PLANTS

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Abstract

At present, Argentina has three PHWR (pressurized heavy water nuclear power plants) with diverse technology, is constructing an SMR and has signed a general contract for two others more NPPs. The structure of ARN dedicated to the regulation of NPPs features specialized divisions with an adequate qualified competence. The divisions are focused on regulatory follow up of operating nuclear power plants; engineering evaluations and safety assessments; inspections of components and plants; and coordination of regulatory documents. When the complexity or the specialization of a task exceeds ARN assessment capability, the support from domestics or international organizations (TSO) is arranged. This support helps in the assessment process but does not relieve the regulatory body of its assigned responsibilities. Specifically, in the last completed NPP project ARN used TSO services from foreign institutions as GRS (Germany), Universities (Purdue and Michigan, USA), Battelle (USA), and also domestic institutions as national universities (del Litoral, San Juan), INVAP company, among others. This work presents some relevant aspects of the experience gained using mainly international TSOs, going beyond results into the lessons learned in terms of organizing the assessment tasks into work-packages. ARN methodology allows retaining the regulatory responsibility by defining for each task the specification of the objectives, the scope and the applicable framework of codes and standards.

1. INTRODUCTION

The Nuclear Regulatory Authority (Autoridad Regulatoria Nuclear or ARN by its acronym in Spanish [1]) is the competent Argentine national agency for the regulation of radiological and nuclear safety, safeguards and physical protection. The ARN was created in 1997 by the National Law No. 24,804 of Nuclear Activity [2], as an autonomous entity within the jurisdiction of the National Presidency. The abovementioned law assigns to the ARN some functions that could be summarized as:

- To issue regulatory nuclear and radiological safety standards and to establish mandatory requirements and license conditions.
- Grant, suspend and revoke licenses, permits or authorizations involving nuclear and radiative facilities, regarding the installations and the personnel in charge.
- Perform regulatory inspections and assessments on the facilities subject to regulation by ARN.
- To enforce the compliance of standards and requirements in a gradual approach reaching sanctions which may lead to the cancellation of permits or authorizations.

Previous functions are performed in ARN by two regulation departments: one regulating nuclear reactors, and another regulating other nuclear facilities and radioactive medical and industrial applications. A third technical department is in charge of specialized radiological assessments, covering environmental impact, monitoring, and occupational dosimetry.

2. THE NUCLEAR REACTORS DEPARTMENT INFRASTRUCTURE

The regulation of nuclear reactors should cover all the activities from the early stages licensing of projects, the issuance of constructions permits, commissioning and operation licenses, the control of nuclear reactor in operation, the licensing of modifications and long-Term Operation of reactors, etc.

The overall regulatory approach implies the elaboration of a “licensing basis” in the demonstration of safety beginning in the design and the development of safety design requirements, and then deriving specific

engineering requirements covering all the phases of a project [3]. Once the plant is in operation, the regulatory task is essentially the re-assessment of the maintenance of the licensing basis.
To accomplish these tasks, the department is divided in 5 divisions with specific functions. Two of them are dedicated to the interaction with regulated facilities and their Responsible Entities:

- A Regulatory Documents Division, handling of regulatory and licensing documents, coordinating the interchange of documents as Safety Analysis Reports, and mandatory documents related to operation, maintenance, radiological protection, communication of events, assessment of modifications, Periodic Safety Reviews, etc.
- Coordination of regulatory control of operating NPPs, based on Resident Inspectors and a support structure. This control implies inspection, review and assessment in a basic level of the operation, interventions, modification and handling of events.

There is a third division, the Research Reactors Division, in charge of performing a role similar to the latter, for the regulatory control of research reactors, based on a “batch” / visits approach rather than residents’ inspectors.

For the regulatory control of early stages of projects involving complex reactors, a “Project Coordinator” is nominated, in some cases with a small support group.

In all cases described up to this point, there are review and assessment capabilities in a basic level, with a view on the integral safety approach, and the licensing basis. In case there is a need of specialized topical knowledge for assessment, review or inspections, they elaborate work-packages to be handled by specialists. The responsibility on the “general” issue is kept by defining the review scope, acceptance criteria, expected content, framework of safety standards and the insertions on the overall safety approach (e.g. safety classification and derives safety engineering requirements).

For specialized assessment, inspections or reviews, there are two divisions handling specialized knowledge:

- The Engineering Evaluations Division, focused on the elements of the safety analysis of a design, with groups dealing with deterministic assessment (thermal hydraulics, reactor physics, plant simulation), probabilistic assessments (at the three levels) and process assessment (on systems design, mechanics, I&C, electrical and civil works).
- The Inspections Division, focused on the specialised review of components (handling of industrial standards in all the stages of a project) and on the review of plant intervention (during outages, repairs or design modifications). In all cases, the inspections are mainly performed focused on different areas, as mechanical, I&C or electrical.

2.1 Licensing and control of nuclear reactor department capabilities

As mentioned previously, the overall approach of ARN on the regulation on NPPs implies the elaboration of a “licensing basis” based on the demonstration of safety as the key issue of the regulatory control.

ARN institutional approach implies having qualified personnel for performing the regulatory control of nuclear reactors facilities and projects in a basic level. This implies mastering the elaboration and maintenance of the licensing basis and the overall safety approach.

It is on specialized area of inspection, review and assessment that ARN might contract TSO services, when the workload exceeds the capabilities of the divisions or the specialized knowledge, when there is a tight schedule or when the need of the specialized knowledge is for non-periodical tasks.

Therefore, only two divisions of the department are entitled to contract TSO services: The Engineering Evaluations Division, and the Inspections Division. Following ARN approach, the framework for contracting the inspection, review or assessment is based on the definition of the review scope, acceptance criteria, expected content, framework of safety standards and the insertions on the overall safety approach (see previous section). The specialized division is also responsible for added detailed information to these working packages, as the framework of industrial standards and its follow up during the contract.

This approach ensures that ARN does not release any of its responsibilities, and that it has permanent staff with sufficient competence to manage the work of contracted TSOs and to evaluate the quality and results.

As an example of the core of regulatory control tasks of basic level which should be kept under the direct responsibility of ARN personnel, let’s take the broader assessment of a licensing process, the review of sections of a SAR. The safety approach of a NPP project is reflected in the classification of Postulated Initiating Events, defining the limits of the Design Bases scenarios, and the consideration of the NPP systems within a Defence in Depth scheme. It is necessary to have the basic understanding of the plant design and how the safety analysis provides a demonstration of the functional adequacy of the design. It is particularly important in the safety approach to produce a clear methodology for classifying the safety relevance of all the Structures, Systems and Components (SSC) according the role they play in the functional safety analysis. This safety classification allows to produce a specific set of engineering requirements to be complied by SSCs of each safety class, in order to sustain the demonstration of safety.

Among the documents that may be subject to be reviewed by an external TSO, under working packages could be mentioned: the chapters of the SAR describing the engineering of specific systems of relevant references; the commissioning planning; the implementation of Operational Limits and Conditions and operational procedures, the quality management system and the approach to decommissioning.

In some situations, there may be a need of contracting TSO services in order to develop ARN capabilities or to perform confirmatory and independent simulations for specific issues. Furthermore, a TSO might be contracted to perform analyses or research on innovative issues.

It has to be stressed that the support helps in the assessment process but does not relieve the regulatory body of its assigned responsibilities, and because of that, ARN retains the key role in the connection between the support organization and the licensee. This means, all communications and decision are made by the regulator who selects and prioritizes potential recommendation.

3. ARN´S EXPERIENCE WITH TECHNICAL SUPPORT ORGANIZATIONS

When the delayed Atucha II project was relaunched in 200, its licensing implied a huge challenge due to the particular situation of the project after almost thirty years of delay since the Construction Licence was granted. The licence was based on a plant concept developed in mid-seventies and the state of the art had evolved in several waves since then. There was a risk that the plant, as planned previously, did not comply with the current approaches and standards.

In order to reduce such risk, ARN contracted different TSOs for support on identifying the key issues for updating the Construction License. The Critical Issues identified were:

(a) Reassessment of the pipe break concept used for the analysis of loss of coolant accidents,
(b) Verification of the core design considering neutronics – thermal-hydraulic coupling, particularly for big loss of coolant accidents. This implied potential design changes.
(c) Verification of the effectiveness of safety systems for fast reactor shutdown considering the update of the break concept and of the safety assessment.

ARN decided to have a proactive and goal-oriented approach in the Atucha II licensing, and there was a need to develop an understanding on the Critical Issues independently from the Licensee. This required some specialized knowledge and calculation tools, which were not available at ARN by that time. Moreover, ARN had limited capabilities for defining the terms of reference for the assessments needed, i.e. for defining work-package, stating review scope, acceptance criteria, etc. This limitation was compensated by involving more than one TSO on each task, developing a broader understanding by the comparison of approaches. In this scheme GRS, Purdue University and DOE - Battelle Memorial Institute were contracted to perform independent calculation and assessments on critical issues following an orderly distribution according to the expertise of each one of the institutions.

This working scheme allowed ARN´s personnel to gain experience on how to work with TSOs defining work-packages for specialized controls, while retaining its responsibility in the licensing project.

The experience of German institutions GRS and TUV on the original Atucha safety approach, on the design concept and industrial standards framework (as KTA) was particularly valuable. In the case of GRS, it was contracted for review and assessment of reports covering the following main topics:

(a) Mechanical design of structures, components, systems and equipment,
(b) Preliminary Risk Analysis / Probabilistic Safety Analysis,
(c) Reactor Physics,
(d) Reactor Thermal hydraulics.

As an example, for the first topic GRS assessed the break concept as applied in Atucha II against the German Break Preclusion Concept. The activities were focused in the fulfilment of the prerequisites for the application and completeness of the steps of the deterministic Leak-Before-Break (LBB) demonstration, and the consideration of measures for safeguarding the LBB concept application. From the results of this assessment, several recommendations to be implemented in the plant were identified, not only for construction stage, also for commissioning and control of operation (e.g. a feedback in the In-Service Inspection Programme).

During the construction and assembling activities, ARN contracted a TÜV NORD/SÜD Consortium as a TSO for on-site inspections and review. Different work-packages were specified according to a process-oriented approach allowing ARN to verify the qualified fulfilment of safety requirements connecting the design and erection stages.

In all cases, besides the technical aspects, the terms of the contract included on-the-job training of ARN personnel, as a means to recover technical capabilities after many years without licensing projects of NPPs.

4. LESSON LEARNED

The lesson learned from the use of TSO mentioned previously include:

(a) **Work packages specification.** There is a qualitative difference when the scope of an assessment is particularly broad in technical aspects and “size” e.g. for assessing a complete Safety Analysis Report or assessing the application of the Break Preclusion Concept featuring several interlinked topics. The overall assessment could be “divided” in specifics tasks of limited scope, only of the responsible of the work-package is in condition to produce an integration of the “sections” ensuring the consistency of the review, assessment and inspection activities. To accomplish this “integration”, it is required to have an understanding of the several interlinked topics (design and the licensing basis of the plant, safety approach, framework of codes and standards to be applied, etc.). So, the work-package specification of broad scope may include an additional task related to familiarization with interlinked topics.

(b) **Definition of project manager.** The contract with a TSO has to specify contact persons from both institutions. From TSO side, he should be a senior technical expert involved in the task, while from ARN side the nominated person must act as technical project manager responsibility capable of integrating the outcomes into the overall licensing or control process. Due to the dedication and communication needs, the selected contact persons should not be in a very high institutional position.

(c) **Schedule**. It is extremely relevant to include in contract terms the schedule for completion the tasks in accordance to the requirements from the licensing and control processes in which they fit.

(d) **Payments and deliverables**. Depending on the institutional framework of a regulator TSO payments may involve authorisations by government administration officers, turning the process more complex and time consuming. In order to better cope with this ARN tried several approaches of linking payment to deliverables (by hours of advance, by period of time and by completion of work packages). The challenge is always to effectively meet the regulatory project requirements in scope and schedules, while not threatening the compliance of the terms of the contract for the TSO.

(e) **Flexibility:** In ARN experience, a contract should consider an amount of hours for interchanges ensuring beyond doubts both parties understanding on the works, and to allow for unforeseen issues such as delayed documentation, lack of information or references.

(f) **Communication.** The contract should include, when possible, a clause related to the effective knowledge transfer to ARN personnel. This can be achieved by a range of means, from a single meeting for discussing results and outcomes, up to ARN personnel participation in the works for on-the-job training.

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LEADING NUCLEAR SAFETY AND RADIATION PROTECTION EXPERT ASSESSMENT IN FRANCE

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Abstract

The organization adopted by France for the oversight of nuclear safety and radiation protection is built around an authority, ASN, with a main technical support organization, IRSN. It can also call on other expert bodies to deal with particular subjects. ASN oversees technical investigations, to which IRSN contributes its own expert assessments. The first part will present a reminder of the legislative and regulatory framework, in particular ASN's role with regard to the IRSN, fundamental framework documents such as the ASN-IRSN convention and the annual protocols defining the expertise priorities, the organization and the methods for exchanges between the two entities and the formalization of ASN's appraisal of the quality of IRSN's expert assessments. ASN will underline the high-level quality of technical support works provided by IRSN. The role recently entrusted to ASN concerning nuclear safety and radiation protection research orientations and the implications of this role for relations with the TSO will also be examined. The second part will mention a few of the issues linked to the relation ASN-IRSN:

- The need to reinforce the evaluation of the IRSN (topic identified by the IRRS mission in November 2014).
- The respective positions in the management of emergency situations, as both ASN and the TSO provide the public authorities with support.
- The search for improved efficiency and synergy in their actions on behalf of nuclear safety and radiation protection.
- Reinforcement of ASN's role with respect to the IRSN as a member of the Board of Directors with the ability to influence the choice of strategic orientations.

The conclusion will be illustrated by some of the broad outlines of the ASN multi-year strategic plan as well as the prospects for greater collaboration at European level between authorities and between TSOs when conducting expert assessments.

1. INTRODUCTION

Oversight of nuclear safety and radiation protection in France is ensured by ASN (Autorité de Sûreté Nucléaire), the French nuclear regulator, which has had the status of an independent administrative authority since 2006. To guide its decisions and resolutions, ASN consults internal and external experts whenever necessary. However, its main technical support organisation (TSO) is IRSN, the French Institute of Radiation Protection and Nuclear Safety, a public body with industrial and commercial activities, which exercises expert assessment and research functions in the fields of radiation protection, nuclear safety and protection against malicious acts.

The extent of the relations between ASN and IRSN is reflected in a number of figures. Out of a total budget of €216 M in 2017, IRSN devoted €85 M to technical support for ASN, which corresponds to the work of about 400 of the institute's 1700 employees. By way of comparison, ASN's own budget for 2017 was about €84 M for a headcount of slightly over 500 employees. During the year 2017, IRSN provided ASN with more than 500 opinions or reports and accompanied some 300 ASN inspections (out of a total of about 1800). In addition to this, IRSN fulfils other recurrent missions in the areas of training, experience feedback analysis, preparation of meetings of the Advisory Committees of Experts placed under the authority of ASN, and participation in emergency exercises. In view of the extremely close ties between the two entities, an extensive system of coordination, communication, cooperation and appraisal has been put in place.

2. THE FRAMEWORK GOVERNING EXPERT ASSESSMENT REQUESTS

2.1 Legislative and regulatory framework

Created in 2006 through the TSN Act relative to transparency and security in the nuclear field, ASN is an independent administrative authority which participates in the oversight of nuclear safety, radiation protection and nuclear activities (in the medical, industrial, veterinary and research sectors). Its missions consist in regulating, licensing, inspecting, assisting the public authorities in emergency situation management, contributing to informing of the various audiences and to ensuring transparency in its areas of competence. In

addition, Ordinance 2016-128 of 10th February 2016 *introducing various provisions concerning nuclear activities* gave ASN competence with regard to the identification of research needs in nuclear safety and radiation protection.
IRSN was created by Act 2001-398 of 9th May 2001 and by Decree 2002-254 of 22nd February 2002 within the framework of the national reform of the oversight of nuclear safety and radiation protection with a view to pooling public expert assessment and research resources in these areas. These texts have since been modified, more specifically by Act 2015-992 of 17th August 2015 *relative to Energy Transition for Green Growth* and Decree 2016-283 of 10th March 2016 *relative to the Institute for Radiation Protection and Nuclear Safety*. IRSN is placed under the authority of the Ministers responsible for the Environment, Defence, Energy, Research, and Health.
IRSN's dual mission of research and expertise is a factor that contributes to the technical excellence of the IRSN opinions.

2.2 Documents underpinning the ASN-IRSN relationship

The collaboration between ASN and IRSN is governed by a five-year agreement, several framework documents and an annual protocol.
The agreement, renewed in 2017 to take into account the latest regulatory changes in particular, establishes the field in which ASN can call upon the expertise of IRSN. It defines the type of actions carried out for ASN and sets the procedures for coordinating and monitoring these actions. One article specifically addresses the joint communication strategy, insofar as IRSN publishes all its opinions. It also broaches the financial issues, insofar as ASN awards grants to IRSN. Framework documents drawn up by type of action or by technical domain clarify the framework agreement by defining the responsibilities and the mutual expectations of the two parties. Lastly, an annual protocol defines the actions that IRSN must carry out in priority and the corresponding budgetary resources. The protocol lists more specifically the main files in which IRSN involvement is requested. ASN ensures that IRSN's expertise is called upon for the most technically complex subjects in order to optimise the use of the Institute's skills.

2.3. The coordinating meetings

Several types of meetings are held to monitor application of the agreement and the annual protocol between ASN and IRSN. The ASN Director General and Chairman have a meeting with the IRSN Director General and Chairman of the Board of Directors twice a year to address strategic matters. These meetings may be supplemented by seminars and meetings of the senior management of the two organisations, including the technical departments.
The progress of the technical examinations entrusted to IRSN is monitored twice yearly at meetings of the GEAS (Safety Assessment Analysis Group). After preparatory discussions between the technical departments of the two entities responsible for a given area, a wrap-up meeting chaired by the two directors general is held to adjust the work priorities according to the stakes, the work load, or topical issues which may have emerged since the protocol was established.
In practice, contact points are designated for both parties as the single point of entry for monitoring the convention.

3. SOME CHALLENGES IN THE RELATIONSHIP BETWEEN THE REGULATORY BODY AND THE TSO

3.1 Appraising the expert assessment

A determining aspect in the relationship between the regulatory body and the TSO is the organisation adopted to appraise and improve the quality of the expert assessment. As was stated earlier, a robust organisation enables ASN and IRSN to very regularly discuss, at all levels of the hierarchy, the needs for expert assessments and how they are carried out. ASN and IRSN have developed a system for appraising the IRSN deliverables. It has been decided that only the opinions which met with difficulties will undergo an appraisal based on a joint analysis matrix. The identified criteria focus primarily on compliance with deadlines, the technical quality of the resulting deliverable, its appropriateness with respect to the initial order and the quality of relations during examination of the case. The identified cases are discussed during pre-GEAS meetings and, if necessary, at the GEAS meetings. ASN is on the whole highly satisfied with the quality of the expert assessments and it issues few appraisal reports of this type.

Nevertheless, communicating on an almost daily basis does not obviate the need to stand back and take an objective view of the situation from time to time. As was underlined by the IRRS missions hosted in France in 2006 and 2014, ASN can improve its appraisal of IRSN's expert assessment services. In 2015 it was decided to put in place an original audit system, comprising an appraisal of the application of the convention binding ASN and IRSN and of the other texts that govern the expert assessment service that IRSN provides for ASN. The audit was led by a high-ranking official external to both ASN and IRSN, and the audit team comprised staff from various ASN departments. For the first audit, held in 2016, the auditor - in consultation with ASN - decided to limit the scope of the audit to the expert assessments of nuclear power reactors. The audit revealed no shortcomings or significant deviations with respect to the reference texts binding ASN and IRSN and concluded that *"The processes have reached a good level of maturity and the minor deviations already identified by IRSN and confirmed by the audit have been analysed and appropriate corrective actions have been taken"* and that *"The question of meeting deadlines is more complex and demands efforts over the long term"*. The recommendations made to ASN and IRSN more specifically concern the rules of professional ethics, the harmonisation of practices between the various ASN entities for requesting the services of IRSN and reducing certain time frames, the improvement of the content of the examination tracking documents and stepping up the technical interchanges between ASN and IRSN during expert assessments and the interchanges between ASN and IRSN when the opinions of IRSN are only partially taken into account. Several good practices and areas for improvement of lesser importance were also identified. The actions implemented are monitored at the coordination meetings between the two entities. A new audit is planned for 2019.

3.2 ASN's relationship with the other authorities and government departments

Another issue is the relationship between ASN and the other authorities or government departments that supervise IRSN or order expert assessments from IRSN. ASN thus worked in 2018 - in collaboration with IRSN and its five supervisory ministries and with ASND, the defence nuclear regulator and the departments responsible for protecting nuclear installations against malicious acts - on the development of the next multi-year objectives agreement between the State and IRSN. Among the subjects associated with leading the expert appraisals, which is assumed jointly by ASN and the other authorities and government departments involved, one can mention:

- The particular position in the management of emergency situations, where the regulatory body and the TSO are both involved in assisting the public authorities, which makes it all the more important to clearly define the division of roles (the entity responsible for emergency management needs to have a clear and unambiguous recommendation);
- The consideration of the expectations of the stakeholders in the expert assessment and decision-making process. Indeed, even though IRSN contributes to informing the public, the relations with the stakeholders in the context of expert assessments of the licensees' files must be organised so as to optimise the contribution to the decision-making process. ASN proposed increasing the level of consultation with IRSN to define the needs on the basis of a joint analysis of the issues, and to take into account any expectations expressed by civil society as from the work request phase, so that IRSN's expert assessment work always fits into a clearly defined framework set by the ASN work request.
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3.3 The search for efficiency

Over and beyond the questions of coordination, in a restricted budgetary context, the two entities - the regulatory body and the TSO - must work together to ensure the efficiency of their actions to enhance nuclear safety and radiation protection.

ASN and IRSN have opted to put in place tightened coordination in terms of human resources and skills: first of all, short-term internships between the two entities will be developed more systematically, followed by a reflection and broader measures concerning the forward-looking management of jobs and skills. Increased vigilance shall be exercised to better identify the bottlenecks - which could be a long-term phenomenon - associated with skills that are critical for the expert assessments.

The Act of 17th August 2015 recently stepped up ASN's role with respect to IRSN: the ASN Chairman is now a member of the IRSN Board of Directors, and ASN plays a greater part in defining the strategic directions of IRSN. One of the aims of the ASN multi-year strategic plan, which sets out the broad strategic guidelines for a 3-year period, is to clarify the responsibilities of the two entities and achieve efficiency thanks to more closely targeted use of the expert assessments. ASN leads the technical investigations, to which IRSN contributes through expert assessments. Consequently, ASN plans to step up its prior analyses of the files in order to better define and target the external expert assessments, and then to monitor them as they progress. The procedures for informing and ensuring the participation of the public and stakeholders must also be clarified, as mentioned earlier.

4. CONCLUSION

The French system for ensuring the oversight of the nuclear safety and radiation protection of civil nuclear facilities and activities, which is based on an independent administrative authority - ASN, and a main TSO - IRSN, is a system that works well and ensures high quality decisions.

ASN leads the technical examinations, relying in particular, when necessary, on IRSN's expert assessments, which are essential to enable informed decisions to be made on the subjects that have the most significant potential implications. ASN and IRSN interchange regularly to control the workload, prioritise the expert assessments and reach agreements on the way they exercise their respective responsibilities.

In the context of the reinforcement of the European framework for nuclear safety and radiation protection, ASN supports the actions of ETSON (European Technical Safety Organisations Network), in which IRSN plays a major role. ASN considers that the WENRA and ETSON networks could work together more closely to identify expert assessment needs common to several national nuclear regulators and entrust the performance of these assessments to the ETSON experts. The setting up of a joint European mechanism for identifying expert assessment needs and carrying out the assessments would enhance the credibility and legitimacy of the positions adopted by the regulators to improve nuclear safety and radiation protection, by moving towards greater harmonisation.

THE MISSION OF A TECHNICAL SUPPORT ORGANIZATION: PERSPECTIVES OF THE U.S. NUCLEAR REGULATORY COMMISSION

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Abstract

The authors have presented a brief overview of functions and activities of the Office of Regulatory Research (RES) as an internal TSO within the Nuclear Regulatory Commission (NRC) (also referred to as the Agency). Because RES is an integral part of the agency, RES strategies and vision are necessarily aligned with those of the agency at large. Thus, the paper describes the NRC's strategic plan and the challenges it faces in the near-term and in the future. The implications of these challenges to RES is also discussed. In order to better prepare for the future, the staff, at the direction of the Executive Director of Operations, has proposed several strategic initiatives. These strategic initiatives and their impact on RES are discussed in the paper.

1. INTRODUCTION

The Energy Reorganization Act of 1974 [1] established the U.S. Nuclear Regulatory Commission (NRC or Agency) as an independent agency responsible for licensing and regulating the commercial use of atomic energy in the United States. These responsibilities were previously held by the Atomic Energy Commission, along with research, development, and nuclear energy policy functions that have since been assumed by the U.S. Department of Energy (DOE). The same Act also established the fundamental role of the Office of Nuclear Regulatory Research (RES) to engage in or contract for research necessary for licensing and related regulatory functions of the NRC. Further, the law states that the Commission shall appoint a Director of RES. The law requires the RES Director to develop recommendations for research and to engage in conducting research, which the Commission deems necessary for the performance of NRC's licensing and related regulatory functions. The Joint Explanatory Statement of the Committee of Conference on the Energy Reorganization Act of 1974 states that

"…the Commission would have an independent capability for developing and analyzing technical information related to reactor safety, safeguards, and environmental protection in support of the licensing and regulatory process."

In 1977, the Energy Reorganization Act was amended to direct the Commission to develop a long-term plan for projects for the development of new or improved safety systems for nuclear power plants.

The role of RES is further promulgated in Title 10, "Energy," of the Code of Federal Regulations (10 CFR) Part 1, "Statement of Organization and General Information" [2], which states that RES:

(a) Plans, recommends, and implements programs of nuclear regulatory research, standards development, and resolution of generic safety issues for nuclear power plants and other facilities regulated by the NRC;
(b) Coordinates research activities within and outside the NRC including appointment of staff to committees and conferences; and
(c) Coordinates NRC participation in international standards related activities and national volunteer standards efforts, including appointment of staff to committees.

RES supports the regulatory mission of the NRC and executes the following strategies to help achieve NRC's safety and security strategic goals:

- Provides expert technical advice, state-of-the-art tools, and information to make safety and security decisions, and issue regulatory requirements and guidance.
- Conducts research activities to independently confirm the safety of licensees' operations and enhance the regulatory framework by addressing changes in technology, science, and policies.
- Conducts independent confirmatory and anticipatory research to resolve potential safety and security issues and confirm the safety and security bases and margins associated with the use of radioactive materials.
- Conducts long-term research to understand any potential safety issues associated with current and emerging technologies.
- Performs independent analyses of operational data and assessments of operating experience that are used to estimate and monitor the risk of accidents at NRC licensed facilities and inform NRC's strategic plan goals.
- Develops and revises regulatory guides in light of knowledge gained from licensing reviews, inspections, operating experience, and research activities.
- Exchanges information, expertise, operating experiences, and research with domestic and international counterparts to increase awareness of, and respond to, emerging technical issues; to participate in the development, evaluation, and implementation of harmonized standards; to seek common approaches to resolving technical issues; to promote best practices; and to leverage resources through shared research programs.
- Incorporates insights gained from research activities, including interactions with international, academic, and other Federal agencies, into the regulatory infrastructure.
- Maintains critical technical expertise to support regulatory functions such as licensing, oversight, rulemaking, policy development, and research.

It should be noted that the responsibility for the safety of nuclear power plants and for the safe use, storage, and disposal of radioactive material lies with the licensees. Accordingly, the industry and related organizations must develop and provide the necessary data and information to support their safety assessments. RES, on the other hands, generally conducts a more limited scope of confirmatory research, to examine key uncertainties and assumptions in those safety assessments. The research can be directed expressly by the Commission in the case of certain issues that relate to safety and security policy issues, but more frequently is performed at the request of the NRC offices responsible for licensing and inspection.

The Energy Reorganization Act permits RES to enter into cooperative research agreements with international and domestic organizations, provided that the agency maintains its independence and remains free from the perception of conflicts of interest with licensees. Through such agreements, RES can share the costs of experimental programs, acquire data, and develop and verify analytical tools to fully understand and characterize the safety and security of nuclear facilities and nuclear materials users. International and domestic cooperative programs have been developed in many research areas to minimize duplication of effort. This enhances the NRC's ability to make sound regulatory and safety decisions based on worldwide scientific knowledge that promotes the effective and efficient use of agency resources.

A more detailed overview of the role and functions of RES as an internal TSO was provided in the NRC paper from the 2014 IAEA TSO Symposium [3].

2. NRC STRATEGIC PLAN 2018-2022

As a TSO internal to the NRC organization, RES strategies and vision are necessarily aligned with those of the agency at large. NRC's Fiscal Years (FY) 2018-2022 Strategic Plan [4] defines its two strategic goals as: (1) ensure the safe use of radioactive materials, and (2) ensure the secure use of radioactive materials. The Strategic Plan provides an overview of the NRC's responsibilities and lays out the plans, strategies, and key activities that will be used to achieve the agency's strategic goals.

As outlined in the Strategic Plan, the NRC's mission is to:
"License and regulate the Nation's civilian use of radioactive materials to provide reasonable assurance of adequate protection of public health and safety and to promote the common defense and security and to protect the environment."
The phrase "reasonable assurance of adequate protection" was introduced into the mission statement in the current version of the Strategic Plan.

The NRC's main regulatory functions are to:

- Establish standards and regulations.
- Issue licenses, certificates, and permits.
- Ensure compliance with established standards and regulations.
- Conduct research, adjudication, risk and performance assessments to support regulatory decisions.

The current strategic plan also introduces a new Vision statement: "Demonstrate the Principles of Good Regulation (independence, openness, efficiency, clarity, and reliability) in performing our mission".

As noted in a companion paper [5], the Commission established the NRC's Principles of Good Regulation (PGR) in 1991 to focus the agency on implementing our safety and security mission while appropriately considering the interests of the NRC's stakeholders, including the public and licensees. The PGR serve as guideposts enabling both the agency's decision-making and staff behaviors. The current Strategic Plan clearly articulated the importance and implications of these principles, as given below.

INDEPENDENCE
Nothing but the highest possible standards of ethical performance and professionalism should influence regulation. However, independence does not imply isolation. All available facts and opinions must be sought openly from licensees and other interested members of the public. The many and possibly conflicting public interests involved must be considered. Final decisions must be based on objective, unbiased assessments of all information and must be documented with reasons explicitly stated.

OPENNESS
Nuclear regulation is the public's business, and it must be transacted publicly and candidly. The public must be informed about and have the opportunity to participate in the regulatory processes as required by law. Open channels of communication must be maintained with Congress, other government agencies, licensees, and the public, as well as with the international nuclear community.

EFFICIENCY
The American taxpayer, the rate-paying consumer, and licensees are all entitled to the best possible management and administration of regulatory activities. The highest technical and managerial competence is required and must be a constant agency goal. The NRC must establish means to evaluate and continually upgrade its regulatory capabilities. Regulatory activities should be consistent with the degree of risk reduction they achieve. Where several effective alternatives are available, the option which minimizes the use of resources should be adopted. Regulatory decisions should be made without undue delay.

CLARITY
Regulations should be coherent, logical, and practical. There should be a clear nexus between regulations and agency goals and objectives, whether explicitly or implicitly stated. Agency positions should be readily understood and easily applied.

RELIABILITY
Regulations should be based on the best available knowledge from research and operational experience. Systems interactions, technological uncertainties, and the diversity of licensees and regulatory activities must all be taken into account so that risks are maintained at an acceptably low level. Once established, regulation should be perceived to be reliable and not unjustifiably in a state of transition. Regulatory actions should always be fully consistent with written regulations and should be promptly, fairly, and decisively administered so as to lend stability to the nuclear operational and planning processes.

3. NRC'S ORGANIZATIONAL VALUES

In addition to the PGR, the NRC adheres to seven organizational values to guide its actions: integrity, service, openness, commitment, cooperation, excellence, and respect. As a learning organization, the NRC continuously evaluates and upgrades its regulatory capabilities. Its regulations are coherent, logical, practical, and based on the best available knowledge from research and operational experience. The NRC also views nuclear regulation as a service to the public and, as such, it must be transacted openly. The NRC's Open Government Plan, first published April 7, 2010, is a reflection of the agency's long history of, and commitment to, openness with the public and transparency in the regulatory process. The agency's goal to ensure openness explicitly recognizes that the public must be informed about, and have a reasonable opportunity to participate meaningfully in, the regulatory process. Except for proprietary information, security-related information, predecisional information, and information supplied by foreign governments that is deemed to be sensitive, the NRC makes the documentation that it uses in its decision-making process available in the agency's Public Document Room in Rockville, MD, and on the agency's public Web site at http://www.nrc.gov . Over the past several years, the NRC also has embraced social media as an important new tool for reaching a wider public audience. As a result, a significant amount of information about nuclear activities and the national policy regarding them is available to everyone.

4. CHALLENGES AND STRATEGIC INITIATIVES

Over the past several years, primarily economic factors have contributed to a number of reactor closures and present challenges to the long-term sustainability of the domestic reactor fleet (Figure 1). The figure also illustrates potential opportunities for recovery and growth. These external factors, among others, will impact the regulatory environment as well as the resources needed to fulfil NRC's mission. The Commission has long recognized the need to adapt to such changes. Thus, the NRC must use its resources efficiently, revise the regulatory framework as appropriate to disposition existing or emerging issues, and provide adequate infrastructure to maintain staff competence and readiness.

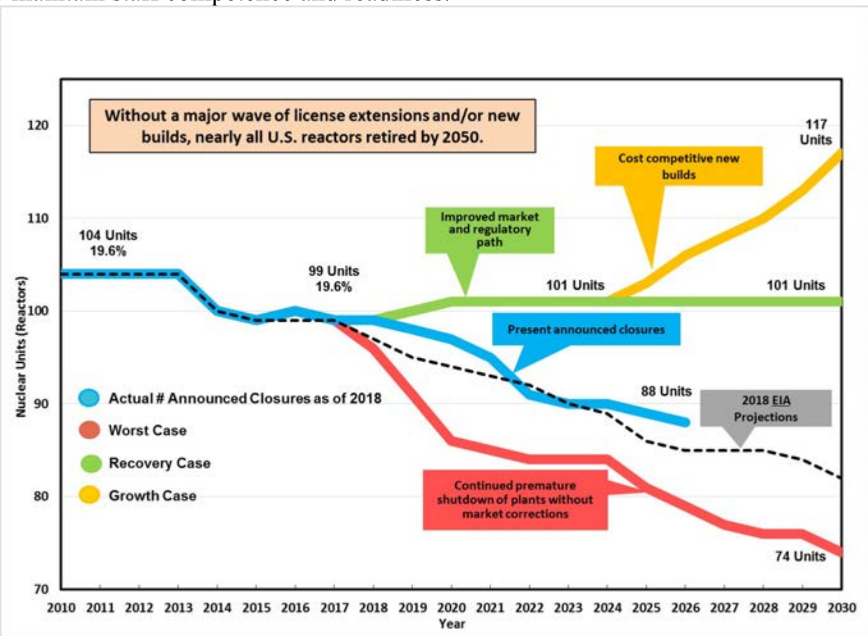

FIG. 1. U. S. Civil Nuclear Status and Projected Outcomes. (Adapted from R. Furstenau,, "U.S. Nuclear Energy and Its Future," INMM Spent Fuel Management Seminar, January 23, 2018. https://www.inmm.org)

In the Strategic Plan for FY 2014-2018, the NRC identified major challenges for the future [6], including

- continual learning and adaptation of the regulatory framework to address knowledge of and response to the specific hazards, uncertainties, and risks associated with each nuclear site,
- continued readiness to review applications involving new technologies such as small modular reactors, medical isotope production facilities, and rapidly evolving digital instrumentation and control systems
- changes in the demographics, experience, and knowledge of the workforce,
- changing economic conditions in the energy market affecting current and planned applications to construct and operate new nuclear facilities or licensee decisions to decommission existing ones, and
- continuous monitoring of the threat environment to ensure the security of nuclear facilities and radioactive materials.

In the current NRC Strategic Plan for FY 2018-2022 [4] there was a recognition of many of the challenges listed above with an increased emphasis on risk-informing the regulatory framework. Specifically, the current Strategic Plan calls for the:

- Use of risk-informed and performance-based approaches to enhance the effectiveness and efficiency of the regulatory framework that appropriately consider defence-in-depth, risk insights, and margins of safety, and

- Development and implementation of a risk-informed regulatory infrastructure to conduct effective and efficient licensing activities for applicants developing new reactors, small modular reactors, advanced reactors, fuel cycle facilities, and domestic medical isotope production facilities

As stated in the current Strategic Plan [4], the following key external factors could affect the agency's ability to achieve its strategic goals:

- market forces
- incidents and threats
- globalization of the nuclear technology and the nuclear supply chain
- legislative and executive branch initiatives
- international treaties and conventions
- workforce dynamics, and
- information technology advances.

Since 2014, the NRC took several significant initiatives to address and prepare for the challenges with agility, effectiveness, and efficiency. A few key initiatives are described in the following.

4.1 Project aim

Project Aim was an NRC initiative to improve agency efficiency, effectiveness, and agility, driven largely by the need to align agency regulatory work environment, structure, and processes with numerous fact-of-life changes. The agency had grown significantly to enhance security and incident response (subsequent to the September 11, 2001, terrorist attacks) and to prepare for projected growth in the use of nuclear power in the U.S. The forecasted growth did not occur because of market conditions in the nuclear industry that resulted in fewer new nuclear facilities and the early closure of existing plants. The NRC's Executive Director for Operations established Project Aim in coordination with the Chief Financial Officer in June 2014 to enhance the agency's ability to plan and execute its mission while adapting in a timely and effective manner to a dynamic environment. The project team gathered perspectives from internal and external stakeholders to forecast the future workload and operating environment. Based on analysis of these perspectives, literature review, and the evaluation of the NRC's current state, the team and NRC senior leadership identified key strategies to transform the agency to improve the effectiveness, efficiency, and agility of the NRC. These strategies would better position the NRC to respond to new safety and regulatory challenges without compromising our important mission and without affecting our ability to demonstrate organizational values and Principles of Good Regulation. In late January 2015, NRC staff provided a number of recommendations to the Commission [7]. The staff's report proposed that the NRC could function more efficiently by performing the following:

- right sizing the agency while retaining appropriate skill sets needed to accomplish its mission,
- streamlining agency processes to use resources more wisely,
- improving timeliness in regulatory decision-making and responding quickly to changing conditions, and
- promoting unity of purpose with clearer agency-wide priorities

On June 8, 2015, the Commission approved many of the recommendations presented by the staff's report [7]. A wide range of implementation activities underway are being tracked as 19 discrete tasks. The implementation of the project recommendations establishes the foundation to improve NRC's operational excellence, efficiency, and agility, while also refining the basis for agency planning through 2020 and beyond. Among the Project Aim activities, the Commission directed the staff to undertake a "re-baselining" effort to identify work that can be shed or eliminated, deferred, or done with fewer resources. This task, which involved a broad review of the agency's workload, resulted in recommended efficiencies for Commission consideration as documented in [8]. The Commission approved almost all of those recommendations in the Staff Requirements Memorandum (SRM)- SECY-16-0009, which was issued on April 13, 2016. The staff began developing implementation plans to achieve these approved efficiencies in an open, collaborative, and transparent manner. While all of major deliverables for each of the 19 tasks were completed in 2017, most Project Aim tasks involve ongoing actions to implement recommendations.

In response to Project Aim, RES took initiatives to streamline its operations and activities, without compromising its commitment to the NRC mission. Some of the implications and impacts to RES, as a result of Project Aim, include:

- Shedding work as part of re-baselining
- Strategic Workforce Planning to ensure maintenance of existing critical skills and developing new ones

- Changing the culture to boost efficiency, agility, and responsiveness
- Standardizing Contracting Officer Representative (COR) functions
- Staff remains committed to continuous enhancements in process efficiency and effectiveness and the development of tools to systematically enable innovation and to leverage employee creativity.

4.2 Innovation and leadership

Recognizing the need for increased employee participation in successfully fulfilling NRC's safety and security mission, the Executive Director of Operations (EDO) issued a change management strategy in 2016. The strategy, which was shared with all NRC employees, identified specific activities covering three broad areas: (1) encouraging employee growth and development; (2) enabling innovation; and (3) fostering a work environment in which people are engaged and embrace change. During April 2017, via a tasking memo, the EDO further elaborated on the idea of fostering innovation and strengthening employee engagement by establishing a new Agency Innovation Forum ("InnovateNRC") to be managed and sustained by the staff. The memo also provided some examples of staff innovation. These examples showed that by leveraging the natural creativity of our employees, the NRC can identify and adopt new and improved approaches to our regulatory and business processes.

An organization's strength and success largely depend on its human capital. In the case of the NRC, the staff is also its most valuable asset. With the recognition that through behaviors and attitudes, every NRC employee, regardless of title or position, provides leadership by influencing work products and others, with whom the staff interacts. Thus, the staff should have clear expectations to understand how they can individually and collectively demonstrate leadership in fulfilling the NRC mission. To enable this understanding, the NRC Leadership Model was developed as a roadmap. The NRC Leadership Model complements the Principles of Good Regulation) and NRC Organizational Values by elaborating upon six fundamental characteristics, which are not explicitly addressed by the either the Principles or Values. Specifically,

- Participative Decision Making

All employees have a role in the decision-making process, consistent with their assigned responsibilities. This work entails gathering facts and soliciting diverse viewpoints of those involved in the process. To make the most informed and soundest decision, the decisionmaker(s) should consider as many viewpoints as practical and critically assess the merits of each position. Once a decision is made, the person or organizational unit responsible should explain that decision and ensure that it is implemented accordingly.

- Receptivity to new Ideas & Thinking

We recognize that a key measure of our organizational agility is our ability to respond to change promptly and effectively. All employees are open to a broad range of possible solutions to resolve problems or find new ways of working.

- Empowerment and Shared Leadership

Each supervisor is expected to give his or her employees the support, access to information, and discretion to perform work consistent with their assigned roles and responsibilities. Each employee is expected to display leadership and initiative while engaging others in a manner that supports the mission and reflects the NRC organizational values and Principles of Good Regulation.

- Diversity in Thought

At the NRC, decision-making is enhanced when it incorporates a variety of viewpoints. For this reason, we cultivate a positive environment for the expression of diverse views, alternative approaches, critical thinking, collaborative problem-solving, unbiased evaluations, and honest feedback.

- Innovation and Risk Tolerance

All employees are encouraged to actively identify new ways of doing the work of the agency. We embrace failures as learning opportunities that build personal and organizational character, and despite the possibility of falling short of our goal, we persevere in seeking ways to improve.

- Collaboration and Teamwork

We are inclusive when employees deliberately work together with others internally and externally on a shared goal. This work involves collective brainstorming, debating, and developing possible solutions to inform a decision. Team members share the recognition that the best solutions often come not from a single individual, but through the team working together.

FIG. 2. The NRC Leadership Model

The Model describes the specific leadership behaviors associated with these characteristics that are expected from individuals, supervisors, and team members. It also describes the NRC programs and activities that contribute to, implement, and allow the staff to hold each other accountable for the concepts and ideals presented in the Leadership Model.

4.3 Transformation

As outlined in the FY 2018-2022 Strategic Plan [4], further enhancements to regulatory infrastructure incorporating risk-informed and performance-based approaches for reviews related to current operating plants and the development and implementation of a risk-informed regulatory infrastructure for advanced reactors and nuclear facilities are needed. In this spirit, the NRC staff, at the direction of the EDO, provided a SECY paper on “Achieving Modern Risk-Informed Regulation” [9] for Commission approval. In the paper, the staff outlined several significant and specific revisions to the regulatory framework and approaches to better enable the safe and secure use of new technology in civilian nuclear applications. A Transformation Team, established by the EDO, identified potential transformational changes to NRC’s regulatory framework, culture and infrastructure to further enhance our effectiveness, efficiency and agility. The Team harvested techniques, ideas, and information relating to novel technologies from internal and external stakeholders that, when implemented, would be transformational. Based on the information and feedback, the team identified specific areas to initiate transformation at the NRC. Based on this work, the staff recommended that the Commission direct the staff to:

- develop an agency wide process and organizational tools to expand the systematic use of qualitative and quantitative risk and safety insights; thereby, enabling staff to scale the scope of review and the level of detail needed in licensing to make a finding of reasonable assurance of adequate protection of public health and safety, beginning with licensing reviews for reactors;
- revise Title 10 of the Code of Federal Regulations (10 CFR) 50.59, “Changes, Tests, and Experiments,” and comparable sections, as needed, to allow licensees additional flexibility to make facility changes without prior NRC approval while ensuring safety and security;
- develop a performance-based, technology-inclusive regulation as an alternative approach for licensing for non-light-water reactors; and

- develop a new regulation to define high-level performance based I&C safety design principles and associated regulatory guidance that documents the acceptable standards that may be used to meet these principles.

The Commission is currently reviewing the Transformation SECY paper.

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TSO SYSTEM DEVELOPMENT IN THE REPUBLIC OF BELARUS

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Abstract

The paper is dedicated to the specific approach of the Republic of Belarus on establishing a national TSOs system and describes a relatively short way of its establishment (2015-2017) by using scientific, statistic and functional methods. The used approach on the TSO system establishment is realized on the basis of recommendations of IAEA INIR (2012) and IRRS (2016) peer review missions and assistance of the Permanent mission of the European experts from Germany and France in the frame of the EC technical cooperation project, project's experts from Finland, Ukraine and Lithuania as well as international expert power in the field, Director of IRSN Mr. Jacques Repussard.

1. INTRODUCTION

The Republic of Belarus took the decision to implement its first nuclear programme in 2007 by constructing Belarussian NPP in Ostrovets site, Grodno region. Since that period, as an embarking country, the Republic of Belarus started and continues to develop necessary nuclear and regulatory infrastructure to ensure its compliance with the IAEA requirements and best international practices in nuclear safety.

As the construction program of the Belarusian NPP is under implementation, the country has been undertaking various actions recommended by the IAEA at the main phases of safety infrastructure development over the lifetime of a nuclear power plant [1]. With regard to the establishment of the regulatory framework at the first phase, the regulatory body was identified (Ministry for Emergency Situations of the Republic of Belarus, MES) and relevant executive body was created (Department for Nuclear and Radiation Safety of MES, Gosatomnadzor) in 2007 and at the second one, in 2012, the organization to provide scientific and technical support to the regulatory body the SSE "JIPNR-Sosny" was defined by the Government [2].

Along with the development of the regulatory infrastructure in Belarus the external peer review took place. In particular, in 2012 the INIR mission produced a recommendation regarding TSO to the RB by advising the country to establish an independent TSO [3]. IRRS mission recommendation "to ensure that adequate technical support is available to the regulator for all applicable disciplines. Gosatomnadzor should continue to implement the training and development plans to enhance its staff competencies" [4].

The implementation of the INIR and the IRRS recommendations as well as the interaction with the European experts within the framework of the European Commission technical cooperation project BY3.01/13 "Support and assistance to strengthen the capabilities of the Belarusian Nuclear Regulatory Authority MES/Gosatomnadzor in the field of licensing and supervision of construction of the Belarusian Nuclear Power Plant (NPP)", allowed to elaborate a specific approach to providing scientific and technical support - the establishment of a system of scientific and technical support organizations. The analysis of the approach applied in the Republic of Belarus showed its compliance with the latest IAEA recommendations [5].

2. NATIONAL CONTEXT

Before taking decision in principle to embark on nuclear energy, the Ministry for Emergency Situations of the Republic of Belarus (MES) was the National Regulatory Authority (NRA) in the area of nuclear and radiation safety. After the decision in principle MES remains the authority responsible for arranging and performing state regulation in this area. Within the structure of MES the Department for Nuclear and Radiation Safety was created in 2007 as a separate legal entity.

The main objective of Gosatomnadzor is control over the execution of the legislation and supervision in the field of nuclear and radiation safety.

In the frame of the regulatory infrastructure development and following the IAEA safety requirements of access to the technical expert support to the regulatory decisions it was decided to mandate the SSE "JIPNR-

Sosny” with this role [2]. The decision was sound given the existing knowledge and experience in the country in the field of nuclear and radiation safety.

The SSE “JIPNR-Sosny” is a scientific institute of the National Academy of Sciences of Belarus and is the legal successor of the Nuclear Power Engineering Institute of the BSSR Academy of Sciences. Since the foundation of the SSE “JIPNR-Sosny” and until the Chernobyl accident, the Institute primarily specialized in such basic and applied research areas as material-radiation interaction, development of gas-cooled slow- and fast-neutron nuclear reactors and application of ionizing radiation sources in the national economy. The basic scientific competencies in the field of the peaceful using of atomic energy had been concentrated here at that moment. A feature of the SSE “JIPNR-Sosny” is its focus on the carrying out of the fundamental academic research.

With that, the development of the construction of the first nuclear power plant has been setting new challenges for the regulator. The field of questions for the provision of scientific and technical support to the regulatory body has been expanded and gone beyond the competence of nuclear physicists from SSE “JIPNR-Sosny”: welding, seismic stability, reliability and strength of buildings and structures and others.

In this situation the regulatory body took a decision to order the support on the associated spheres from the TSO of the technology provider country - VO “Safety” of Rostechnadzor. There are advantages and disadvantages of this approach. The main advantage is getting assistance from experienced experts without a doubt in their competence for the regulator as well for professional society as a whole. Certainly, this is very important for the first steps of an embarking country. Disadvantages of such an approach consist in lack of promptness because of issues related to contracts making to get assistance, absence of competences growing in the country developing its first nuclear programme and as a result, inability to get technical support in case of unexpected conditions.

At the same time, the Republic of Belarus possesses a large and well developed scientific and technical community including the legacy of the Soviet Union.

3. MATERIALS AND METHODS

The materials for this research are activities of Belarusian organizations experienced in commissioning of scientifically and practically applied studies in the fields which are not directly related to the issues of nuclear and radiation safety but influence them as well as different practices of existing TSO’s in Finland, France, Germany, Ukraine and Lithuania presented under the a special Note comprising possible options of TSO establishment in Belarus prepared by the Permanent mission of the European experts in the frame of the EC technical cooperation project BERA08 (BY3.01/13 “Support and assistance to strengthen the capabilities of the Belarusian Nuclear Regulatory Authority MES/Gosatomnadzor in the field of licensing and supervision of construction of the Belarusian Nuclear Power Plant (NPP)”) and submitted to Gosatomnadzor for decision making process.

Statistics and functional analysis have been used as methods for this research.

3.1 Analysis of Belarusian organizations activities

In the frame of statistics analysis at the first stage the topical field of scientific and technical support was identified. In this regard in close interaction with the European experts of the Permanent mission within BERA08 (BY3.01/13 “Support and assistance to strengthen the capabilities of the Belarusian Nuclear Regulatory Authority MES/Gosatomnadzor in the field of licensing and supervision of construction of the Belarusian Nuclear Power Plant (NPP)”) the list of required relevant competences was set up.

Based on experience gained by the countries with well-developed nuclear infrastructure the conclusion of the necessity and on importance of scientific component of technical support to the regulatory body was made. Despite the considerable differences between safety assessment conduction resulted by confirmation of compliance of the expertise object with the safety requirements from pure scientific studies related to the scientific search and getting of new scientific knowledge, it was decided to set the requirements to the potential organizations depending on the availability of scientific studies experience.

There are several reasons for such a decision. The first, implementation of such scientific studies allows forming and growing the necessary scientific background of the experts, to contribute to the development of analytical skills and by that to form required expert competences. The second, in the frame of scientific studies different scientific hypotheses could be verified, relevant corrections to the existing safety criteria could be implemented and as the result the regulatory base is continuously developing. Thus, availability of scientific studies conduction has become the first criteria to identify organization-candidate to provide support to the regulatory body. As the next step the functional analysis of existing scientific competences presented in the Table 1 and existing in the Republic of Belarus was done.

In the frame of the mentioned analysis conduction existing scientific organizations were considered as complex of implemented by them functions without taking into consideration their organizational structure. The attention was given not only to main organization's functions but to the functions of divisions and sub-divisions making part of such an organization.

The Analysis was done in two stages. At the first stage the declared organizations' functions were studied as well as the functions of their divisions and sub-divisions and at the second stage the individual readiness of these organizations to enlarge functions of nuclear and radiation safety insurance. The result of such a two-steps analysis is presented in Table 1.

TABLE 1. RESULT OF ORGANISATIONS' FUNCTIONAL ACTIVITIES

Fields of technical competences	Organizations
General requirements and technical means of NPP safety	The SSE "JIPNR-Sosny", Belarusian National Technical University
Neutron calculations	The SSE "JIPNR-Sosny", Belarusian State University, Institute for Nuclear Problems of Belarusian State University
Heat hydraulic calculations	The SSE "JIPNR-Sosny", A.V. Luikov Heat and Mass Transfer Institute of the National Academy of Sciences of Belarus
Evaluation of emergency regimes (beyond design basic and sever accidents)	The SSE "JIPNR-Sosny"
Evaluation of materials features and technologies of equipment manufacturing including issues of welds, non-destructive control	Belarusian National Technical University, State Institution of Higher Professional Education "Belarusian-Russian University", State Scientific Institution "Powder Metallurgy Institute",
Probabilistic safety assessment	The SSE "JIPNR-Sosny", Belarusian State University, Belarusian National Technical University
Reliability of personal	The SSE "JIPNR-Sosny", Belarusian State University, Belarusian National Technical University
Risk-oriented approach	The SSE "JIPNR-Sosny", Belarusian State University
Assessment of equipment solidity and issues related to the materials ageing	State institution of higher professional education "Belarusian-Russian University", State Scientific Institution "Powder Metallurgy Institute"
Analysis of solidity of engineering structures	State Scientific Institution "Institute of Applied Physics of the National Academy of Sciences of Belarus"
Assessment and accountability of external impacts	Centre of Geophysical Monitoring of the National Academy of Sciences of Belarus
Analysis of stability of systems and elements	Belarusian National Technical University
Assessment of meteo conditions and estimation of environment impact	State Institution "National Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring"
Measurement equipments' and automatics including automatic control system(I&C). Protective automatics	Belarusian State University of Informatics and Radioelectronics
Issues related to the verification and validation of software products	Belarusian State University of Informatics and Radioelectronics
Fire protection	The Institution "Research Institute of Fire Safety and Emergencies" of the Ministry of Emergency Situations
Assessment of radiological impact on personal and population	International Sakharov Environmental Institute of Belarusian State University, The Republican Scientific Research Unitary Enterprise "Institute of Radiology"
Emergency Preparedness and Response	University of Civil Protection of the Ministry for Emergency Situations of the Republic of Belarus"

Radioactive waste management and spent nuclear materials	The SSE “JIPNR-Sosny”
Issues related to water-chemical regime	The SSE “JIPNR-Sosny”, Belarusian State University

Thus, the used approach allowed forming a pull of organizations with relevant technical competences to start providing the support to the regulatory body to facilitate decision-making process.

3.2. Development of the system of scientific and technical support the Belarusian regulatory body

The most significant outcome of the undertaken actions is the transition from one technical support organization to a TSOs system.

The mentioned organizations didn’t see application of their existing scientific and technical competences in the field of nuclear safety. The turning point and step ahead was a workshop in May 2015 arranged in Belarus, where the method of “Expert Power Using” was applied. Director of IRSN (France) Mr. Jacques Repussard was a special invitee to share his vision of the TSO role, responsibilities, competences as well as assurance of its sustainability with Senior leaders of 20 organizations and European technical cooperation project experts from Ukraine, France, Germany, Lithuania. The importance and encouraging message of Mr. Jacques Repussard to Belarusian specialists was that we, in Belarus, have a great soviet scientific and technical heritage and it would be relevant and wise to use it for TSO functions by developing and reinforcing.

To this end, in the first stage the special Governmental resolution of TSOs system for technical support provision to the regulatory body was signed on 02 December of 2016 # 991 [6]. 16 organizations were defined for this purpose and 64 safety assessment experts in the field of nuclear energy were identified for different areas in these 16 TSOs. The second and crucial stage was the creation of TSOs system-coordinator within the Ministry of Emergency Situations – State Scientific and Technical Organization “Nuclear and Radiation Safety Centre (NRSC)” according to Presidential Decree of 05 October 2017 #361 [7].

The current priority task of NRSC is staff recruitment, preparation of a short-term work plan, working-out of a concept of NRSC strategic development.

4. CONCLUSION

In the Republic of Belarus as an embarking country on nuclear energy the specific approach has been applied in regard to TSO establishment – creation of the national TSOs system comprising 17 relevant organizations – 10 scientific institutes, 6 universities and one coordinating body subordinated to the Regulatory Body. For a relatively small country as Belarus it was decided to gather all existing scientific and technical experience in the field of nuclear and radiation safety under one umbrella of the national TSOs system and legitimate it by the Governmental resolution. The challenging and ambitious task is to maintain the effectiveness of such a system and to develop it in a relatively short period of time.

Such an approach has become possible due to the effective and rich exchange of experience brought to Belarus by the IAEA experts and European Union nuclear countries experts. Series of the mentioned in the article international events have contributed to the feasibility of such a way of TSOs system creation and become a great example of international scientific society homogeneities and its readiness to open the door to the Belarusian experts for raising their competence to ensure high standards of safety.

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TECHNICAL SUPPORT ORGANISATIONS IN POLISH NUCLEAR POWER PROGRAMME

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1. INTRODUCTION

The subject of the presentation is to emphasize that the Polish nuclear R&D institutes - strongly involved in developing nuclear technologies with one of the leading National Centre for Nuclear Research operating the MARIA nuclear research reactor - have a high competences and involvement in nuclear power research programmes with numerous achievements and awards to provide expert support for the nuclear regulatory and the government administration in the process of granting permits for construction, commissioning, operation, and decommissioning as well as in the course of their construction, operation, and decommissioning. The presentation is providing, in connection with the implementation in the coming years first nuclear power plant in Poland, the background information about the government's intended actions towards to organizing the Technical Support Organisations under the Polish Nuclear Power Programme using the potential of Polish nuclear scientific and research units.

2. POLISH NUCLEAR POWER PROGRAMME

Polish Nuclear Power Programme (PNPP) was approved on 28 January 2014 by the Council of Ministers. Its key goals resulting from the Energy Policy of Poland until 2030 are following:

- assuring long-term security of electricity supply
- maintaining electricity prices at levels acceptable by the national economy and the society
- reducing emissions of CO_2 and other air pollutants
- implementing nuclear power plants

Under the PNPP implementing of first nuclear power plant in Poland should provide scientific and research nuclear infrastructure to ensure support for the nuclear regulatory and inspection functions, and the government administration in the process of granting permits for construction, commissioning, operation, and decommissioning.

3. POLISH NUCLEAR POWER R&D

Poland since 1955 has developed a high level, active and multilateral scientific and research base in the field of nuclear science with support the MARIA research reactor. Poland has 4 Institutes, subordinate to the Minister of Energy, with high competences and involvement in the field of nuclear power R&D programmes:

3.1 The National Centre for Nuclear Research (NCBJ) since 1955:

- come into existence in effect of merging the Institute of Atomic Energy POLATOM and the Andrzej Soltan Institute for Nuclear Research
- leading research centre in Poland for basic and applied research, including interdisciplinary research
- the only Polish research institution operating the nuclear research MARIA reactor
- actively collaborates with leading global and European research institutions
- participates in numerous research projects and programmes
- young and talented researchers in the domain of nuclear medicine, nuclear power and risk modeling and risk mitigation
- carries out third level studies (PhD studies and post-doctoral)
- research focuses on nuclear power-related studies with various fields of sub-atomic physics (elementary particle physics, nuclear physics, hot plasma physics etc.)
- offers services unique in the national market (electron beams, radioisotope production)
- strongly involved in developing nuclear technologies and promoting practical applications of nuclear physics methods
- actively cooperates with national industry, inter alia, in such fields as:
  - development, research and production of radiopharmaceuticals

- materials and R&D studies related to the development of fourth generation nuclear reactors technology, including HTR high temperature reactors, GFR gas-cooled fast reactors

NCBJ with MARIA nuclear research reactor:
- the sole research reactor in Poland, located in NCBJ near Warsaw reached for the first time its critical state on 1974
- one of the best research nuclear reactor in Europe
- currently MARIA's power amounts to 30 MW
- MARIA produces radiopharmaceuticals, special materials/radioactive sources for industry environment protection and healthcare
- provides trainings in the field of reactor physics & technology

3.2 The Institute of Nuclear Chemistry and Technology (ICHTJ), since 1955:

Is the one of the most advanced centers in the field of radiation chemistry and technology, application of nuclear methods in material engineering and process engineering, design and production of instruments based on nuclear techniques, radio analytical techniques, environmental research. Research is focused on:
- radiochemistry
- chemistry of isotopes
- physical chemistry and engineering of separation processes
- cellular radiobiology and radiation chemistry
- particularly that based on pulse radiolysis method

The Institute:
- participates in international research projects and programmes
- actively collaborates with leading global and European research institutions
- the Institute has four pilot plants equipped in six electron accelerators: for radiation sterilization of medical devices and tissue graft, for radiation modification of polymers, for removal of SO2 and NOx from flue gases and for food hygenization
- the results of its works have been implemented in national economy, particularly in industry, medicine, environmental protection and agriculture
- the I cahtegory scientific institutions group in accordance to the Ministry of Science and Higher Education
- carries out third level studies (doctorate) in the field of nuclear and radiation chemistry

3.3 The Central Laboratory of Radiological Protection (CLOR), since 1957:

Polish research center focused on protection of general population and occupationally exposed persons against the hazards of ionizing radiation. Its duties comprise of:
- monitoring of radioactive contamination in foodstuffs and environmental components
- around-the-clock radiological emergency service assistance
- support the countermeasures against illegal trafficking in nuclear and radioactive materials
- monitoring of personal radiation doses
- calibration and attestation of radiation measurement instruments
- research on matters dealing with radiation, radiation protection, radiobiology and radioecology
- professional training in radiation protection

3.4 The Institute of Plasma Physics and Laser Microfusion (IFPiLM), since 1976:

Polish research center focused on basic plasma physics studies and its implementation in the area of magnetic confinement *fusion inertial confinement fusion and pulsed high-power technology.* The Institutes contains two Research Divisions: Division of laser plasma and Division of magnetized plasma.

3.5 Poland has also more than 10 Universities with research and education in nuclear engineering, nuclear chemistry, nuclear safety and radiological protection, nuclear technology and physics, such as:

- Academy of Mining and Metallurgy, Krakow
- Gdansk University of Technology
- University of Warsaw
- Warsaw University of Technology
- Wroclaw University of Technology

4. INSTITUTIONAL FRAMEWORK FOR R&D

National Atomic Energy Agency Ministry of Energy Ministry of Science and Higher Education

Nuclear Regulatory oversight administrative financial oversight scientific oversight

NCBJ
National Centre for R&D ICHTJ
CLOR
IFPiLM

5. STRENGTHS AND CHALLENGES OF POLISH NUCLEAR R&D CENTRES IN DEVELOPING TECHNICAL SUPPORT ORGANISATIONS

Strengths
- high level of basic and applied research
- experienced scientific and technical staff,
- international collaboration, joint projects
- excellent scientific base (research reactor, research and manufacturer Center of Radioisotopes)
- competences in the field of production of linear accelerators (3-4 companies in the world), nuclear energy, new reactor technologies and safety analysis,
- supercomputer and good IT team,
- physical protection in NCBJ
- good efficiency in obtaining grants and projects

Challenges
- institutional and thematic dispersion
- fragmentation of scientific potential
- duplication of R&D works
- no possibility of effective integration by the State of conducted research for the own needs
- participation of Polish scientists in a large number of small EU projects, while in developed countries research institutes focus on fewer large projects
- funding problems
- the age structure of employment
- lack of support for the commercialization of innovative products

6. CONCLUSIONS

Poland has a network of research institutes in the field of nuclear sciences with research infrastructure and human resources carrying out scientific and research activities in most areas of nuclear sciences for many sectors of science and economy.

To meet the challenges facing the Polish TSO system in implementing of first nuclear power plant in Poland:
- one National Nuclear Laboratory through consolidation of nuclear research centres would play a role of strong, more effective TSO and provide the scientific and research backup for the Polish NPP
- the legislative process of setting up the Polish NNL has been initiated and currently the project is approved by the Minister of Energy and will soon be submitted to inter-ministerial consultations
- the expected date of setting up the Polish NNL - 1st half of 2019

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CHALLENGES OF REGULATORY BODY AND TECHNICAL SUPPORT ORGANISATIONS DURING THE EXPANSION OF NUCLEAR POWER PROGRAMME IN INDIA

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Abstract

Nuclear energy remains an important element in the energy mix for sustaining rapid economic growth of the country. In addition, use of radioactive sources and radiation generating equipment for industrial, medical and research applications is essential for the welfare of the society. This has resulted in increasing demand in the country for reliable power sources and radioisotopes. India has a flourishing and largely indigenous nuclear power programme, which expects to have 14.6 GWe nuclear energy capacities by 2024 and 63 GWe by 2032. Since building the two small boiling water reactors at Tarapur in the 1960s, its civil nuclear strategy has been directed towards complete independence in the various activities related to safe use of nuclear and radiation technology. Today, India has activities encompassing all stages of nuclear fuel cycle and ionizing radiation, viz. uranium exploration and mining, fuel fabrication, heavy water production, reactor design and construction, reprocessing, waste management and safe use of radioactive sources for various applications. It is also developing technology to utilise its abundant resources of thorium as a nuclear fuel. Atomic Energy Act, 1962 provides basic regulatory framework for all activities concerning atomic energy programme in India. Atomic Energy Regulatory Board (AERB) was constituted as the regulatory body in the year 1983, under the provision of the Act. Today, safety supervision and surveillance of the huge atomic / nuclear programme in India is the responsibility of AERB. Technical and Scientific Support Organizations (TSOs), like Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Raja Ramanna Centre for Advanced Technology (RRCAT), Variable Energy Cyclotron Centre (VECC), etc. are gaining increased importance in providing technical and scientific basis for the activities regarding nuclear and radiation safety. The paper brings out the associated challenges faced by Regulatory body and TSOs during the expansion of nuclear energy programme in India.

1. INTRODUCTION

Nuclear energy is an important element in the energy mix for sustaining rapid economic growth of the country. In addition, use of radioactive sources and radiation generating equipment for industrial, medical and research applications is essential for the welfare of the society. The first nuclear reactor in the country (and also in Asia) named as “Apsara” was set up at Trombay, Mumbai for training and research. Apsara reached criticality on 4th August 1956. In addition to experiments in nuclear physics and the effects of irradiation, the reactor was used for production of radioisotopes for medical, agricultural and industrial applications. The Atomic Energy Establishment was set up at Trombay, Mumbai, in the year 1957, which was renamed ten years later as Bhabha Atomic Research Centre (BARC). Research reactors, named as “CIRUS” and “ZERLINA,” were set up at Trombay in 1960s. The twin units of Boiling Water Reactors (BWR) at Tarapur, commissioned in 1969, were the first nuclear powerstations established in the country. Since then, the Indian nuclear energy programme is directed towards complete independence in the various activities related to safe use of nuclear and radiation technology. Today, India has activities encompassing all stages of nuclear fuel cycle and ionizing radiation, viz. uranium exploration and mining, fuel fabrication, heavy water production, reactor design and construction, reprocessing, waste management and safe use of radioactive sources and radiation generating equipment, for various applications. Over the years, India has mastered all the stages and activities associated with nuclear fuel cycle and safe use of Ionizing radiation.

In India, Department of Atomic Energy (DAE) is engaged in the design, construction and operation of nuclear reactors and the associated nuclear fuel cycle and radiation facilities. DAE comprises of six research centers namely, Bhabha Atomic Research Centre (BARC), Indira Gandhi Centre for Atomic Research (IGCAR), Raja Ramanna Centre for Advanced Technology (RRCAT), Variable Energy Cyclotron Centre

(VECC), Atomic Minerals Directorate for Exploration and Research (AMD) and Global Centre for Nuclear Energy Partnership (GCNEP). Three industrial organizations namely, Nuclear Fuel Complex (NFC), Heavy Water Board (HWB) and Board of Radiation and Isotope Technology (BRIT) are part of DAE. Nuclear Power Corporation of India Ltd. (NPCIL), Bharatiya Nabhikiya Vidyut Nigam Ltd. (BHAVINI), Uranium Corporation of India Ltd. (UCIL), Electronics Corporation of India Ltd. (ECIL) and Indian Rare Earths Ltd. (IREL) are five Public sector undertakings under DAE. It has under its aegis Board of Research in Nuclear Sciences (BRNS) and National Board for Higher Mathematics (NBHM) for promoting and funding extra-mural research in nuclear and allied fields. It also supports eight institutes of international repute engaged in research in basic sciences, astronomy, astrophysics and cancer research. Those institutes are namely, Tata Institute of Fundamental Research (TIFR), Saha Institute of Nuclear Physics (SINP), Tata Memorial Centre (TMC), Harish-Chandra Research Institute (HCRI), Institute of Physics (IP), National Institute of Science Education and Research (NISER), Institute of Mathematical Sciences (IMS) and Institute for Plasma Research (IPR).

The Department is also engaged in development of radiation technologies for societal applications to improve crop production, radiation based post-harvest technologies, techniques for radio-diagnosis, radiotherapy for cancer, technologies for safe drinking water, protection of environment and industrial growth. DAE also contributes to the enrichment of knowledge domain by supporting basic and advanced research in nuclear energy and related frontier areas by interaction with academic institutions and international cooperation.

2. PROPOSED EXPANSION OF NUCLEAR ENERGY PROGRAMME IN INDIA

As of June 2018, India has 22 operating reactors, with installed capacity of 6780 MWe. Among these, eighteen reactors are Pressurized Heavy Water Reactors (PHWRs) and the remaining four are Light Water Reactors (LWRs). Another six reactors are under construction with combined generation capacity of 4,300 MWe. India has an operating Fast Breeder Reactor (FBR) with capacity 40MWt and is building a larger one of the capacity 500MWe. It is also developing technology to utilize its abundant resources of thorium as nuclear fuel. There is an increasing demand in the country for reliable power sources and radioisotopes to be used for the benefit of the society. India has a flourishing and largely indigenous nuclear power programme, which is expected to have 14.6 GWe nuclear energy capacities by 2024 and 63 GWe by 2032.

It is envisaged to start work on eight indigenous 700 MWe PHWRs, two 500 MWe FBRs, one 300 MWe advanced heavy water reactor (AHWR) and eight LWRs of 1000 MWe or higher capacity. In May 2017, ten 700 MWe PHWRs have been approved by the cabinet, as a “fully homegrown initiative” with likely manufacturing orders to Indian industry.

3. REGULATORY FRAMEWORK

Atomic Energy Act, 1962 provides basic regulatory framework for all activities concerning atomic energy programme in India. It prohibits private control of nuclear power generation. Its 2016 amendments, allowing public sector joint ventures, do not allow direct foreign investment in nuclear power, apart from the supply chain. Initially, DAE was enforcing radiological safety in the country through in-house groups or independent committees, until a formal regulatory body named Atomic Energy Regulatory Board (AERB) was constituted in the year 1983, under the provision of Atomic Energy Act, 1962. Multi-tier safety review and assessment are conducted by AERB before issuing regulatory consent to the facilities/ activities. The safety committees comprise of experts drawn from regulatory body, the Scientific and Technical Support Organizations (TSOs), reputed academic institutions and other governmental agencies. The TSOs analyse the scientific and engineering issues referred to them. However, they are not involved in decision making.

As per its prevailing practice to take decisions on merit, AERB is serving as a functionally independent organisation under Atomic Energy Commission (AEC). However, considering the anticipated growth expected in nuclear power generation and use of radiation technology in the next few years, the government has recently put up a bill for setting up Nuclear Safety and Regulatory Authority (NSRA) for further strengthening of the regulatory and safety practices in the country.

4. THE ROLE OF OPERATOR AND TSO

Nuclear Power Corporation of India Ltd. (NPCIL) is responsible for design, construction, commissioning, and operation of thermal nuclear power plants in the country. It has identified few new designs of nuclear power plants, such as EPR (French), AP-1000 (US), VVER (Russian) and ESBWR (US), for installing at new sites. As a part of development of Fast Breeder Reactor (FBR) in India, a 40 MWt Fast Breeder Test Reactor (FBTR) was commissioned in Oct 1985. Design and construction of 500 MWe Prototype Fast Breeder Reactor (PFBR) has been undertaken by Bharatiya Nabhikiya Vidyut Nigam Ltd. (BHAVINI) at Kalpakkam.

There have always been concerns over the required support to be provided to the nation's programme, through safety and regulatory research. Independent safety research is a vital component for maintaining core technical competence. Detailed safety research is conducted by multi-disciplinary organizations like, BARC, IGCAR, RRCAT and VECC, that are acting as TSOs to AERB, NPCIL, BHAVINI, BRIT, NFC, etc. In addition, AERB has established Safety Research Institute (SRI) at Kalpakkam. To expand the regulatory research, AERB also sponsors research projects in the academic institutions.

The TSOs are responsible for technical support and analysis related to nuclear physics, nuclear chemistry, nuclear engineering, metallurgy and materials science. In addition, they support risk assessment/ computational techniques, modelling and simulation, process development for demonstration, safety assessment/ analysis, etc.

5. MAJOR CHALLENGES FACED BY REGULATORY BODY AND TSO

Considering the projected growth in the nuclear and radiation facilities in the country, TSOs whether part of a regulatory body or a separate organization, are gaining increased importance in providing the technical and scientific basis for decisions and activities regarding nuclear and radiation safety. Their role and quality of technical and scientific expertise are extremely important. Plant safety and economics are largely affected by the quality of TSO's skill, combined with that of the operator. AERB is reviewing the new designs to identify potential safety issues in advance. Based on the suggestions of safety committees, the plant designers are required to make necessary changes in first of a kind system, wherever needed. The relationship between TSOs and their counterparts, such as architect-engineering firms, vendors and construction companies, is vital component for the growth of the nuclear and radiation technology. AERB has regular interaction with the private vendors participating in the nuclear programme, both of local and foreign origins. AERB is also conducting National Conferences with participation of facility operators, TSOs and private vendors to discuss the safety and security issues and associated challenges.

In the present context, the major challenges towards the safe growth of nuclear and radiation technology in the country are as follows:

- Maintaining a high level of nuclear safety and security with increasing share of work assigned to TSOs;
- Developing strategies for regulation and growth of wide variety of nuclear and radiation facilities;
- Developing the additional skilled manpower needed for the growth and expansion of the nuclear and radiation programme in the country;
- Assessing the nuclear capabilities of all stakeholders involved in design, construction and operation of the facilities, including the architect-engineering firms, vendors and construction companies;
- Developing competence of regulators to assess / review wide variety of technologies, including different designs and applications, and to detect early signs of deficiencies, if any;
- Developing capabilities of TSOs to evaluate and analyse the safety issues associated with new designs/ technologies in all related activities;
- Formulating Quality Assurance (QA) requirements for all associated stakeholders;
- Ensuring and maintaining the level of nuclear excellence of TSOs in terms of technical and manufacturing capabilities by periodic checks/ inspections;
- Enhancing safety culture among various stakeholders with different orientations towards commercial interests and commitment to safety;
- Meeting the challenges posed to the nuclear and radiation industries, due to the dynamically changing nuclear security scenarios;
- Promoting safety related research and development for the associated technologies and advanced techniques;
- Developing synergies between safety and security requirements for the associated activities;
- Developing cooperation among all stakeholders of local and foreign origins.

6. CONCLUSION

Nuclear energy programme is expanding in most of the countries in the world, including India, to meet the demand for projected energy and use of radioisotopes for societal benefits. Significant growths in foreign investment and participation of TSOs are anticipated for expansion of nuclear and radiation technology, which pose a big challenge on nuclear safety and security for all stakeholders. Though effective measures have been taken by the states, it is important to call for international co-operations to achieve high level of safety and security. It is essential to join hands on the matters related to nuclear safety and security assessment; peer reviews; manpower training; programs for public awareness; nuclear safety and security related research and development; and capacity building for the new entrants. It is extremely important to share the information on the related matters among the stakeholders.

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SUPPORT TO EUROPEAN NUCLEAR REGULATORY AUTHORITIES IN THE FIELD OF NUCLEAR SAFETY

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Abstract

The paper describes the support GRS is providing to different European nuclear regulatory authorities in the field of nuclear safety. Four examples are described here to provide the reader with an illustration of the types of services, among many, that GRS provide. Those examples are evaluation of operating experience, development of safety requirements, fault analysis studies and support in a research project dealing with specific thermohydraulic analyses - are presented.

1. INTRODUCTION

GRS is a technical safety organisation in Germany in the field of nuclear safety, decommissioning, radiation protection, nuclear security and waste management. GRS is the central expert organisation advising the German federal ministry competent for nuclear safety and radiation protection (BMU) and to a limited extent other European Nuclear Regulators (NR) on technical issues. Examples of the broad spectrum of technical support to different NRs in the field of nuclear safety are presented.

As a first example, GRS continuously evaluates national and international operating experience on behalf of the BMU. If new generic safety-relevant issues are identified, GRS prepares Information Notices (IN) on behalf of the BMU which include recommendations on how to consider these issues. Licensees are required by the supervisory authorities to react on the IN and provide feedback, e.g. on implemented measures.

In the second example, it is shown that GRS provides technical support to a European NR covering different phases within the licensing process of a nuclear facility. The spectrum of work ranges from the development of safety requirements to the support in reviewing different chapters of the preliminary safety analysis report (PSAR).

The third example represents the support work to the authority in the course of a Generic Design Assessment (GDA) for new nuclear power plants. Specifically, an analysis simulator was developed in order to perform transient analysis of specified events. Pursuing event analysis utilising the simulator allows for independent calculations and a check of the applicants' analysis. By this means, an identification of potential weaknesses or possible improvements in the design of the NPP is possible.

The final example presents the support work to a NR in terms of a research project. The aim of this project is the identification and determination of possible differences between conservative thermohydraulic analyses and best-estimate methods plus uncertainty evaluation (BEPU) in case of pressurized thermal shock (PTS) situations.

The above-mentioned examples of how GRS supports the nuclear regulatory authorities are expanded upon below.

2. SUPPORT TO DIFFERENT EUROPEAN NUCLEAR REGULATORY AUTHORITIES

2.1 Evaluation of Operating Experience for the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety

The continuous evaluation of national and international operating experience of nuclear installations presents a central task of GRS. On behalf of the competent ministries, - today the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU) -, GRS has performed this task for more than 40 years. GRS evaluates all reportable events from German plants as well as safety-relevant events in foreign nuclear power plants (received through international and bilateral networks and working groups). Learning from operating experience is an important element for preserving and improving nuclear safety. Insights obtained from these in-depth evaluations form the scientific basis for *expert statements*, *information notices* or *generic reports* on behalf of BMU.

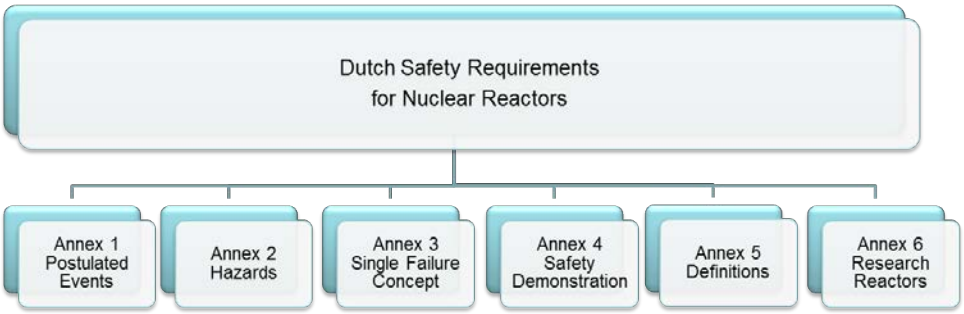
The evaluation of operating experience is a two-stage process. Firstly, all available information is screened and preliminarily assessed with respect to safety significance and applicability to other German installations. This involves interdisciplinary expert teams from areas like systems engineering, instrumentation and control, component integrity, human factors and management systems.

The screening process aims to identify new generic safety-relevant issues, which are then followed up by detailed and thorough investigations comprising, for example discussions with authorities, Technical Support Organisations (TSOs), licensees, or manufacturers and analyses with the plant-specific GRS analysis simulator. Based on the results of this assessment, GRS prepares INs on behalf of BMU which are sent to authorities, TSOs, licensees, and manufacturers after approval by BMU. Recommendations on how to resolve these issues are an essential element of the IN. Licensees are required by the regulatory authorities to react to the IN and provide feedback (e.g. on the measures implemented to prevent similar events) which is also assessed by GRS on behalf of BMU for further generic insights.

For example, there were findings of increased thickness of oxide layers on fuel rod claddings in a German PWR during refuelling in February 2017. The upper end of the active zone and the area of the upper plenum of M5 fuel rods were affected. For several fuel rods, operational limits for oxide layer thickness were reached or exceeded. Because it could not be excluded that this phenomenon occurs also at other German PWRs, GRS has written an IN with respect to this event including among others the recommendation of extended inspections of fuel assemblies with M5 claddings which was distributed in April 2017. Conclusive clarification of contributing causes is still underway, with discussions in a working group of the Reactor Safety Commission and different research projects with GRS involvement. This event has also been reported via the International Reporting System for Operating Experience (IRS 8628).

2.2 Development of safety requirements, technical review plan and review of PSAR for the nuclear regulatory authority of The Netherlands (ANVS)

The nuclear regulatory authority of The Netherlands (ANVS) is supported by GRS in the field of nuclear safety. Notably, GRS supported ANVS in the development of the Dutch Safety Requirements (DSR) as part of the "Veilig Ontwerp en het veilig Bedrijven van Kernreactoren" (VOBK). The DSR, which represent a modern set of safety requirements for NPPs and research reactors, together with an introduction to the application of the DSR form the so-called VOBK. In developing the DSR, ANVS and GRS considered the most recent state of the art of science and technology. As an integral part of the DSR, the defence-in-depth concept proposed by WENRA was implemented. The VOBK were published [1] in October 2015 following a positive review by the IAEA. The structure of the DSR is depicted in Fig. 1 below.



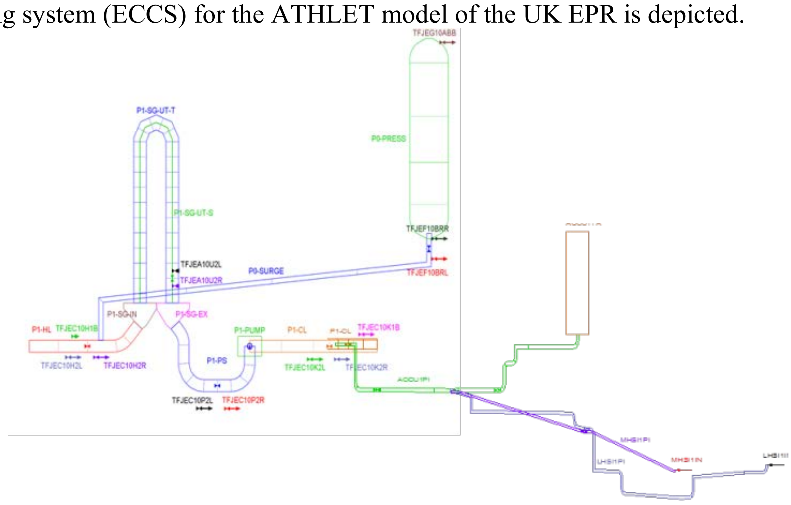
The DSR contains the main document supplemented by six annexes. A clear distinction between postulated initiating events (PIEs, e.g. pipe break, loss of off-site power, power excursion, etc.) in annex 1 and hazards (e.g. flooding, earthquake, fire, explosion, load drop, etc.) in annex 2 was made. The single failure concept, the safety demonstration and all definitions are summarised in the annexes three to five. Annex 6 contains specific requirements only applicable for research reactors and a structured method to grade requirements for nuclear power plants according to the specific hazard potential of research reactors.

In addition, ANVS and GRS developed a technical review plan (TRP) to ensure an effective, comprehensive and transparent review of the SAR in which the DSR are applied appropriately. In line with the DSR, this review plan includes a goal-oriented review approach that is strictly based on safety importance [2]. The main three parts of the TRP are 1.) "Basic review recommendations" including recommendations on issues that need to be addressed before the start of the detailed technical review process, 2.) "Common review steps", where a stepwise and systematic review approach to contribute to a technical review is introduced and 3.) "Specific review recommendations" containing review recommendations for 22 specific review areas.

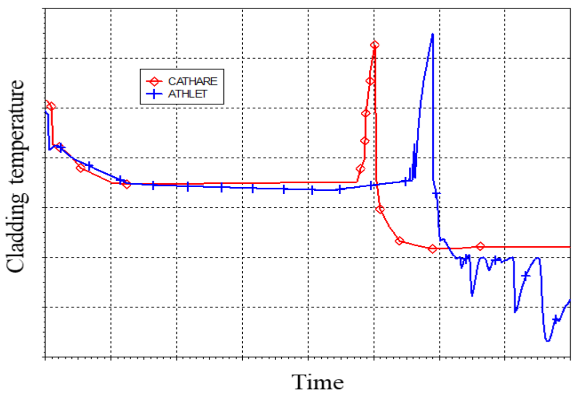
Both the new requirements and the review plan are currently applied during the review of a research reactor licensing process.

2.3 Fault studies assessment of the design basis analyses for the UK EPR reactor by order of the Office for Nuclear Regulation (ONR) in UK

GRS has supported the British authority's (ONR) Generic Design Assessment (GDA) process for several new nuclear power plants such as the UK-EPR. A UK-EPR analysis simulator was developed in order to perform transient analysis of specified events. These simulations are used as independent confirmatory calculations of the applicants' analysis. By this means, an identification of potential weaknesses or possible improvements in the design of the NPP is possible. In Fig. 2, the thermal hydraulic representation of the emergency core cooling system (ECCS) for the ATHLET model of the UK EPR is depicted.



In Fig. 3, the comparison of the applicant's analysis results (CATHARE) for the peak cladding temperature (PCT) and those of GRS (ATHLET) are presented. Whilst both simulations result in similar maximum PCTs, there is a marked difference in the timing of these events These differences were found to be due to different leak discharge rates which lead to a different pressure vs. time dependence on the primary side, which in turn lead to a different start time of the accumulator injection.



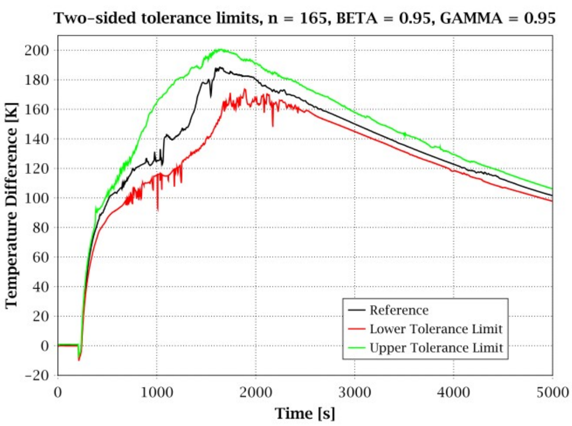
2.4 BEPU Analysis of Generic Pressurised Thermal Shock Investigations

GRS is supporting the Swiss Federal Nuclear Safety Inspectorate (ENSI) addressing scientific questions to nuclear safety related issues. A research project was initiated in 2016, in order to identify and determine the possible differences in safety margins when conservative thermohydraulic analyses are compared to best-estimate methods plus uncertainty evaluation (BEPU) in the application-oriented investigation of pressurized thermal shock (PTS) relevant accidental situations. The work investigates thermohydraulic simulations of PTS endangering events for a generic pressurized water reactor (PWR) model with the system code ATHLET [3].

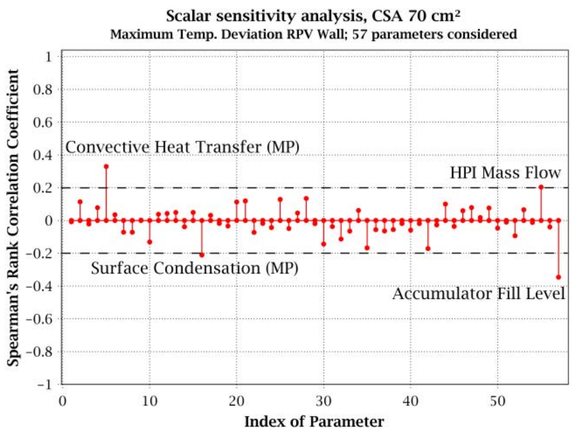
In 2009, the IAEA addressed four options for the application of deterministic safety analysis (DSA) as combinations of conservative or best-estimate calculations with conservative or realistic initial- and boundary conditions [4]. Conservative options (option one and two) have been predominantly used in the past for licensing purposes and are still widely used today. However, these approaches are subject to certain limitations. For example, comprehensive assessments of conservative simulation results revealed, that boundary conditions which were so far considered conservative do not necessarily lead to conservative results. In order to overcome such limitations and to utilize current understanding of important phenomena, best-estimate codes and data together with an evaluation of the respective uncertainties and sensitivities are used in modern safety assessment studies.

The safety analyses carried out in this project in order to quantify the uncertainties during PTS situations are based on a generic model of a pressurized water reactor with a detailed nodalisation in the relevant regions of the downcomer. By performing a large number of simulations with varying accidental configurations, the most unfavourable initial conditions for PTS were identified. It was found that loss of coolant accidents (LOCA) with small to medium break sizes of ~70 cm² lead to the highest thermohydraulic loads as a result of a strong temperature drop at the reactor pressure vessel (RPV) surface and a high remaining pressure level. The temperature deviation over the RPV wall at a postulated crack position was determined as reference parameter, since it is accessible by the thermohydraulic system code and it shows a strong correlation with mechanical loads on the structure material. By performing a total number of 165 LOCA simulations considering 57 uncertain parameters the upper and lower tolerance limits for a 95/95 confidence level for this temperature deviation were determined as shown in Fig. 4(a).

To obtain information about sensitivities of the varied uncertain parameters, the spearman rank correlation coefficients (SRC) for each parameter were determined and the results are depicted in Fig. 4(b). It provides an indication of how strongly and in which direction a variation of a certain parameter influences the maximum value of the investigated determination factor. The influence of parameters with an SRC of less than 0.2 is assumed to be stochastic noise. The sensitivity analysis reveals that the most influencing uncertain parameters for the investigated PWR model are: the accumulator fill level; the mass flow of the HP-ECC injection; and the model parameters for condensation and heat transfer.



(a)



(b)

Future conservative simulations will be performed using knowledge raised from previous project steps for comparison with the applied BEPU-method, in order to quantify differences in safety margins.

3. SUMMARY

The broad spectrum of support that GRS is providing to different European nuclear regulatory authorities in the field of nuclear safety covering the pre-licensing, licensing and operational phase of NPP as well as research reactors was presented. Four examples – development of safety requirements as well as technical review plan and review of the PSAR, fault analysis studies in the framework of a GDA process, support in a research project dealing with specific thermohydraulic analyses and evaluation of operating experience – were discussed.

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DIVERSIFICATION OF SERVICES OFFERED BY NUCLEAR REGULATORY ORGANIZATIONS THROUGH THE USE OF TECHNICAL SUPPORT ORGANIZATIONS: LESSONS LEARNT FROM SOUTH AFRICA

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Abstract

There is an emerging need in the nuclear industry for regulatory bodies to process applications for licenses/permits in order to allow nuclear license applicants to prepare a nuclear site by undertaking early construction activities before the issuance of a construction permit by the regulatory organization or the selection of a specific facility design. This is proving to be a challenge as most regulators have no experience in dealing with this issue. Furthermore, there are no explicit IAEA guidelines addressing the issue. Some countries such as Canada, UK and USA have established local practices based on current projects they are engaged in. However, such practices are both country and project specific. This challenge presents increased opportunities for TSOs to participate in licensing activities for which regulatory bodies are not routinely structured to undertake. It also presents an opportunity for regulatory bodies to diversify their organizational structures in order to meet increasing industry demands and expectations.

The aim of this paper is to disseminate information on the process currently being followed by the National Nuclear Regulator (NNR) of South Africa to address the challenge highlighted above in a country and project specific context. The paper presents the operational model chosen by the NNR to address the issue, provides a summary of the project deliverables accomplished so far in order to formalize their acceptance and closure, highlights lessons learnt, outlines the strategic objectives for future deliverables. Major risks for mitigation are also outlined to ensure that subsequent phases of the project remain on track. The successful completion of the phases of the project completed so far, despite some challenges, serves as an important demonstration that similar projects can be planned and completed with products that have direct use by other regulatory bodies.

1. INTRODUCTION

South Africa has one operating twin-reactor unit nuclear power plant, the Koeberg Nuclear Power Plant, consisting of two pressurised water reactors with a thermal power of 2775 MW each located about 30km's north of Cape Town. These reactor units are in commercial operation since July 1984 and November 1985 respectively. In addition, South Africa has in operation for more than 50 years the SAFARI-1 research reactor that is currently primarily being used for isotope production.

No new nuclear power plants are being constructed. Eskom, the South Africa power utility, however applied in March 2016 for the licensing of the Thyspunt and Duynefontyn sites in terms of our siting regulations that were promulgated in 2011. The Thyspunt site is located in the Eastern Cape and is a greenfield site, while the Duynefontyn site is the site where the Koeberg Nuclear Power Station is located.

Needless to say, the focus and technical expertise of the National Nuclear Regulator, the NNR, up to that point has primarily been on regulatory oversight of the operating facilities and, where needed, making limited use of external technical support. The NNR is typically classified as a small regulator and had at up to recently no permanent technical support organisation.

In anticipation of new build and lessons with licensing of previous projects, the NNR embarked early on the development of its regulatory framework for the construction of new nuclear facilities. As such the NNR issued in 2011, regulations on the licensing of nuclear sites [1], and development subsequently regulatory guidance to support the implementation of the regulations [2]. These guidance, RG-011, Interim Guidance for the Siting of Nuclear Facilities, was issued in 2016.

In addition, the NNR also developed an internal assessment guidance [3], TAG-01, Technical Assessment Guide for the Siting of Nuclear Facilities that was issued in April 2016 just in time for the review of the two siting applications.

2. LESSONS LEARNT FROM PREVIOUS PROJECTS

Many lessons were learnt during the licensing of the Pebble Bed Modular Reactor (PBMR) project. The project was a first of a kind project that started in 2001. In view of the complexity of this project and acknowledging the developmental nature of the PBMR, a multi-staged licensing process has been adopted by the NNR. The major challenges faced by the NNR were mainly related to its internal human resources capacity to undertake the licensing review of the PBMR and the adjustment of the regulatory philosophy and processes to the licensing of a "first of a kind" reactor project.

The NNR therefore made extensive use of two external support organisations as part of the PBMR project and developed regulatory standards as the need arose or was identified. In a country with a small nuclear industry, human resources with relevant technical skill are at a premium and limited. Adding to the need for regulatory independence, the NNR was forced to make use of two international support organisations.

Lessons learnt from the PBMR project included amongst others that regulatory standards should ideally be in place in advance of a licence application and should inform the licensing process and the development of and subsequent review of the safety case by the Regulator. This is especially valid when making use of international support organisations as the tendency of these organisations are to interpret and review from their regulatory standards and practices perspective.

3. PROCESSING OF SITE LICENCE APPLICATIONS

Eskom applied in March 2016 for the licensing of the Thyspunt and Duynefontyn sites. The NNR reviewed and accepted the applications for further processing and technical review,and agreed with Eskom on a licensing schedule and submittal of documents.

3.1 Human resource needs

The Project Manager developed a human resources plan that has to be approved by the NNR Board in accordance with corporate governance processes.

The review of the safety case for a site licence will require amongst others the following skills: Geohydrology, Meteorology, Oceanography, Coastal Engineering, Geology, Seismology, Geotechnical Engineer, Marine biology, Ecology, Accident Analyses, Probabilistic Safety Assessments, and Radiological analyses.

A small regulator would not typically be resourced to process new applications. As siting is a multi-disciplinary area requiring specialized skills that are not typically required during other lifecycle stages of a nuclear facility, the human resource strategy includes both internal resources and external technical support.

The following options were evaluated to minimize the impact on existing programme activities as a result of the review of the siting documentations:

a) Make use of a TSO;
b) Appoint additional staff on a contract basis; or
c) Permanent appointment of additional staff.

It was accepted by the NNR Board considering the advantages and disadvantages of the above options that additional staff need to be appointed supported by external specialists. The team that will be responsible for the review of the siting applications will however primarily come from current NNR staff. To this end our current TSO, Mzesi, was requested to propose a team of experts that covers the identified technical areas. Due limited local skills available in the area and the need for regulatory independence, the TSO team comprised both local and international experts.

3.2 Review plan and approach

In parallel to mobilizing the team to perform the review, the NNR established the project organization and developed a detailed review and inspection plan.

3.1.1 Technical Areas

To facilitate team work, capacity building and assignment of responsibility and accountability the NNR review team comprising both internal and external specialists is grouped into the following eight technical areas:

a) External Events of Natural Origin;
b) External Events of Manmade Origin
c) Public Safety Assessment
d) Environmental Assessment
e) Emergency Planning
f) Risk Assessment
g) Nuclear Security
h) Quality and Safety Management

Team members were assigned to the various technical areas. Technical Area Leaders were appointed from the NNR team members. The NNR Technical Area Leaders are responsible for the control and execution of the assessment including quality assurance within a defined technical area. This includes the control, completion and fulfilment of the Consultants Work Requests and for the technical performance and quality of the review by the relevant NNR Technical Specialists.

3.2.2 Training

The review plan includes training and site familiarization of the team. The training comprised of generic training on the processing of site applications for internal NNR staff and some local external technical support specialists. A training workshop on the NNR licensing process and standards for the entire project team, including all external consultants, was conducted prior to the commencement of the review of the site safety report.

3.2.3. Production of review documents

In order to ensure quality of the review reports as well as to stimulate debate, discussions and skills transfer, the NNR defined a template for review reports and defined the process to categorize documents and review findings. All activities in the processing of review documents and experts' opinions must be traceable and documented in a clear manner to inform internal discussions and debate.

The Technical Area Leaders compiled self-contained review reports based on the contributions of the various specialists participating in the review / assessment of the appropriate documents / submissions. Additionally, Mzesi Project Manager ensured that the work produced by the consultants is of adequate quality and address the objectives of the Work Request.

Final approval and external release of the consolidated Review Reports is the responsibility of the NNR Project Manager.

3.3 Lessons with the implementation of the review plan

There was initially minimal interaction amongst the specialists due to primarily proximity and time zones. Some of the consultants are based in the USA.

To counter this a week workshop was organized at the end of the technical review process where the respective technical areas presented and defended their findings. This approached ensured that common themes of review issues were identified and debated. It also ensured that an integrated and consistent set of review comments that requires resolutions were agreed and transmitted to the applicant.

There is also a need to ensure that comments are consistent with the local regulatory standards and process. It is therefore important that the Technical Area Leaders are experienced reviewers and familiar with the NNR standards and processes and that external consultants are familiar with the local regulatory standards and process. This required is to ensure that NNR requirements and regulations form the basis for the review process.

4. CONCLUSIONS

In this paper, the experience of South Africa in developing and strengthening their regulatory function, in the area of siting, by using a TSO has been presented.

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TOPICAL SESSION 2.1

SAFETY ASSESSMENT

Chairperson
B. THOMAS
United States of America

Co-chairperson
K. TOMITA
Japan

Session 2.1 highlighted the importance of increasing awareness on TSOs contributions in support of the regulatory bodies to ensure safety assessment of nuclear regulation. The different elements of this support were illustrated and covered the following aspects: Tools aimed at systematic technical review of licensing documents; The increasing use of PSA as a supplement to deterministic analyses; The role of experiments to better understand physical and chemical phenomena; Development and validation of computer codes; Tests of high energy arcing fault events with potential of explosion and ensuing fires; Independent confirmatory calculations supporting technical reviews. It was also suggested that the IAEA continue promoting such cooperation through a forum.

IAEA INT'L CONFERENCE ON TOPICAL ISSUES IN NUCLEAR INSTALLATION SAFETY, JUNE 2017 – KEYINSIGHTS AND RECOMMENDATIONS

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Abstract

The sixth IAEA International Conference on Topical Issues in Nuclear Installation Safety: Safety Demonstration of Advanced Water Cooled Nuclear Power Plants took place in Vienna, Austria, 6 – 9 June 2017, see https://www-pub.iaea.org/books/IAEABooks/12286/Topical-Issues-in- Nuclear-Installation-Safety. Its purpose was to foster the exchange of information on the latest approaches, advances and challenges in the demonstration of the safety of nuclear power plants in particular those using water cooled reactors, including small and medium sized or modular reactors. The conference in the series was focused on the safety demonstration of the nuclear power plants that have been and will be licensed and constructed in the near future, which includes, among other aspects, the establishment of, and adherence to, comprehensive and rigorous requirements for siting, design and operation; the demonstration of adequate safety margins against external hazards; and a robust and reliable design to prevent early radioactive releases or radioactive releases large enough to require long term protective measures and actions.

This paper was not available for publication but the full presentation is included in the online supplementary files, for reference, and can be found on the publication's individual web page at https://www-pub.iaea.org/books/IAEABooks/12286/Topical-Issues-in- Nuclear-Installation-Safety

SYSTEMATIC APPROACH TO REGULATORY REVIEW AND ASSESSMENT OF SAFETY: DOCUMENTATION FOR IMPORTED NUCLEAR TECHNOLOGY

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Abstract

During the NPP licensing it is necessary to address requirements from relevant legislative and regulatory documents and technical standards of various sources. This process is determined mainly by the requirements applicable on NPP technology in the country of origin and by the requirements of the licensing country, but international safety standards also play a significant role. It is necessary to properly structure the requirements from various sources into the pyramid of requirements divided to several levels each representing different level of obligatoriness of requirements. In many cases the same or similar requirements from different sources may be found. Usually the total number of requirements comes over several thousand which makes orientation in the requirements very difficult and multi-layered. It is necessary to trace all the relations between requirements and NPP technology during the whole licensing process to prove that everything was satisfactorily addressed. Especially in countries with incomplete legislative and regulatory framework for new nuclear installations, the proper selection and structuring of requirements with consequent application on NPP is a very complex issue. This method shows one of the possible approaches based on author's experience how to handle the licensing process with use of the database tool specially developed by UJV Rez for the review and assessment of NPP licensing documentation. This approach provides the opportunity to accommodate thousands of requirements and relations in an effective manner. Practical illustration of the approach and the database tool with examples of issues important for the whole process will be presented.

1. INTRODUCTION

Many currently ongoing NPP projects are constructed in countries different than are the projects countries of origin. This fact brings up many challenges which may not be foreseen in the beginning of the project implementation. Very significant issue is a licensing of the project within the regulatory framework of another country. It is a complex task of adaption of original, or reference, design to the rules valid in a specific country. Implications of such process are hardly to be predicted during the design adaptation since they also tightly relate to close interaction of the licensee and licensing authorities during the consequent Licensing process. The volumes of licensing documents as well as requirements on project of a country where NPP is to be built are usually very extensive. Review and assessment of licensing documentation belongs to the main function of the regulatory body, as stated in the IAEA Safety Requirements GSR Part 1 [1]. The scope, methods and objectives of the review and assessment are described in the IAEA Safety Guide GS-G-1.2 [2]. In case of a need, in these activities the regulatory body can be assisted by external support organizations in accordance with the rules stated in the IAEA Safety Guide GSG-4 [3].The paper follows experience of the Author from the performance of the specific Technical Support Organization (TSO) services for the Turkish Nuclear Regulatory Authority TAEK within the Licensing process of Akkuyu NPP Unit 1 (works performed in years 2014-2018). Main task was to perform the review and assessment of the Licensing Documentation and preparation of the technical evaluation reports which supported the decision of the regulatory authority during the licensing process. Main tasks of the author's activities are described in following bullets:

- Preparation of Licensing Matrix. The Licensing Matrix is a set of requirements coming from licensing documents. Requirements are connected with the parts of the licensing documentation (i.e. chapters and subchapters of the PSAR);
- Performance of Review and Assessment of Licensing Documentation. This task was performed in more phases (starting with formal checks, through content checks and finalized with detailed checks of the Licensing Documentation compliance with the requirements including independent analysis of specific issues);
- Preparation of Technical Evaluation Reports for each review and assessment phase.

UJV company for performance of TSO activities, namely for above mentioned type of services, uses database systematic approach and its own software tool developed for these purposes. It is suitable to use this approach when thousands of licensing requirements must be sorted out and connected to the documentation structure such as PSAR. Such activity requires computerized method to allow effective work and traceability throughout whole licensing process. For the review and assessment of the Licensing Documentation of Akkuyu NPP a special software tool called LBAT developed originally for requirements managements purposes by UJV. This approach is not unique in the international context. The licensing process stakeholders seek for advanced measures to manage the process in planned schedule and in needed quality. From the UJV communication with the Finnish regulatory body STUK it is known that they use the similar approach however based only on Finnish legislative system using different computerized platform.

2. PROCESS DESCRIPTION

2.1 Licensing basis

The Licensing Basis is the set of documents containing licensing requirements relative to the licensed NPP. It is composed of documents of regulatory and legislative character (decrees, laws, guides and others). From the documents origin point of view in Akkuyu NPP case such set contained documents of Turkish, IAEA, Russian and International origin. Documents were structured into several levels as it is shown in following Fig. 1 when top levels of the pyramid represent most binding documents. Top Level I is represented by Turkish legislative documents followed by documents of IAEA and Russian nuclear regulations in Levels II and III. Lower Levels IV and V represent namely codes and standards of various origin applicable for Akkuyu NPP.

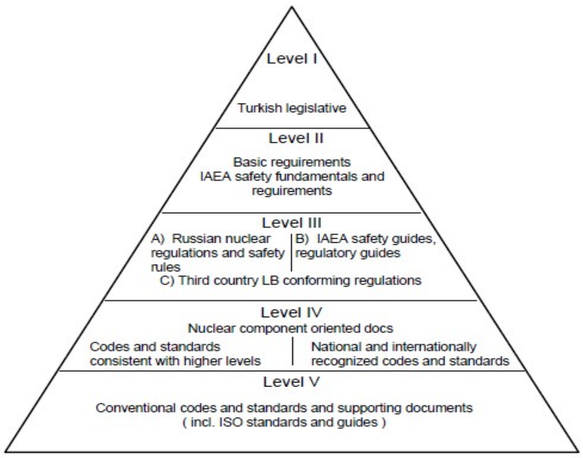

FIG. 1. Pyramid of licensing documents for the Akkuyu NPP.

The specification of each level of the Licensing Basis is provided in following bullets:

(a) Level I Turkish legally binding documents (laws and regulations).
(b) Level II IAEA Safety Fundamentals and Safety Requirements.
(c) Level III Level consisted of following subcategories:
    a. Nuclear safety regulations in force in the Russian Federation.
    b. IAEA Safety Guides and Turkish regulatory documents.
    c. Selected third country regulations.
(d) Level IVNuclear component-oriented documents: the codes and standards of the Turkish Republic, the Russian Federation and other internationally recognized codes and standards.
(e) Level V Conventional codes and standards and supporting.

All levels altogether contained approximately 900 documents from which about 16000 requirements were selected to be applied on Licensing Documentation during the review and assessment. It is obvious that nearly identical requirements of practically same meaning from different sources and even different levels of the pyramid were identified. Selected requirements were further connected to specific chapters and subchapters of the Licensing Documentation.

To utilize the advantages of the systematic database approach licensing requirements were accompanied with many information including:

(a) Source of the requirement within the Licensing Basis including all identifiers of the documents (title of document, its origin, year of issue, level within regulatory pyramid, etc.).
(b) Wording of the requirement.
(f) Links to the chapters and subchapters of the Licensing Documentation (in many cases more chapters and subchapters were linked).

2.2 Licensing Matrix

The structured requirements of the Licensing Basis form the pretext for preparation of the so-called Licensing Matrix. The Licensing Matrix is de facto a tool to be used during the review and assessment work. It is stored in the database and combines all information about individual requirements from the point of view of their origin, their position within the regulatory pyramid and their relevance (connection) to the Licensing Documentation. On this approach, the “requirement” is understood as an individual item taken from different safety rules, such as regulations, guides, international safety standards, third party regulations or guidance documents. Differences in mandatory level of various items are taken into account in formulation of needs for improvements.

The software tool allows grouping nearly identical requirements from various Licensing Basis documents, when they bear same or very similar information, to ease the review and assessment process by avoiding reviewing of each such requirement separately. When combined/grouped together the requirements form so called Criteria which are linked with their counterparts in the Licensing Documentation i.e. with its chapters and subchapters (one criteria may be linked to more chapters of the Licensing documentation).

Review and assessment of the Licensing Documentation is performed by evaluation of individual Criteria. The number of Criteria is significantly lower than the number of standalone requirements. Such approach of grouping requirements helps to decrease the number of operations, that would have to be repeated and separately documented by the evaluator during the review and assessment. Criteria are created as a simple sentence in a present tense including judgment or principle for evaluating implementation of requirements in design.

Nevertheless, the requirements from particular Licensing Basis documents were not omitted by this process, but the Criteria were underlaid in the database by relevant requirements for following review and assessment as it is shown in following bullets:

(a) N Requirements : 1 Criteria; Used for nearly identical requirements from various Licensing Basis documents, when they bear same or very similar information.
(b) 1 Requirement : 1 Criteria; Used usually for unique requirements with no other relative requirements or when the unambiguousness of the Criteria wording is needed.
(c) 1 Requirement : N Criteria; Used when the requirement has more possibilities of applications and/or levels of understanding.

2.3 Review and assessment and evaluations

The process of review and assessment is possible to be performed in more Review and Assessment Phases, as it was done during Akkuyu NPP Licensing are described in following bullets:

(c) Format and Content Check of the Licensing Documentation.
(g) Brief Review of the Licensing Documentation.
(h) Detailed Review of the Licensing Documentation.

These Review and Assessment Phases represent the review and assessment work firstly focused on formal side of the quality of the Licensing Documentation to more detailed review in consequent phases. Each level provided information corresponding to hold-points of the review and assessment process. Separate Criteria were prepared for each Review and Assessment Phase, or when one Criteria is used in different Review and Assessment Phases, the way of Criteria implementation differs for each phase. During the Criteria evaluation, the evaluator takes into account also underlaid requirements from particular Licensing Basis documents to ensure, that all of them are satisfactorily addressed.

To make the work with the Licensing Matrix maximally clear and to keep the intention of the Criteria creator how to use it, especially when the evaluator is a different person than the Criteria creator, most of the Criteria have its own Implementation Guidelines stored in the database to guide the evaluator how to correctly use the Criteria during the evaluation. This additional information was prepared typically for the Criteria in cases (a) and (c) mentioned in chapter 2.2 above with most complex nets of relations of the requirements with the Licensing Documentation or when the way of criteria evaluation differs for each of the Review and Assessment Phase.

Finally, each evaluation of the Criteria was made for its each relation to the structure of the Licensing Documentation i.e. one Criteria may result in multiple evaluations if it was linked to more chapters or subchapters of the Licensing Documentation. For example, requirement on safety classification may be evaluated in different technical disciplines and it is very appropriate to keep separate Criteria for each discipline.

3. LBAT TOOL FEATURES

LBAT system was developed in ÚJV Řež, ENERGOPROJEKT PRAHA division for the review and assessment of the NPPs safety and licensing documentation. LBAT includes whole review and assessment process described in chapters above. Main features and advantages are as follows:

(d) Addition of electronic copies of all documents such as application documents, licensing basis and other documents to database of the software.
(i) Development of requirements and Criteria set for a phase of licensing based on licensing basis and other documents including development of Criteria Implementation Guidelines.
(j) Performance of the Review and Assessment of the Licensing Documentation.
(k) System allows responsibilities management, data storage, work traceability, formats data exports etc.

4. CONCLUSION

Review and assessment of licensing documentation belongs to the most complex tasks of the regulatory body and often requires cooperation of the regulatory body with the specific TSO supporting its own review. Such task is often connected with high attention of a domestic as well as an international audience and the highest possible quality of the process is required. Since many currently ongoing NPP projects in the world are implemented in countries different than is the country of origin of the nuclear technology, the demands and the complexity of the licensing process significantly increase due to the necessity to apply thousands of licensing requirements of different origins on original NPP design.

It is rather difficult to manage such complex task without computerized systems supporting the review. The systematic computerized tool significantly facilitates performance of the review, monitoring of work progress, recording and storage the results, security of information and reporting the results. The approach ensures that in practice no licensing requirements are omitted during the review and assessment and provides systematically the results in needed detail and scope. The tool is not limited only for the purposes of the nuclear regulatory bodies and their TSOs during their review and assessment of the licensing documents but also for the Licensees to establish the perfect order in licensing requirements structure and their relations to the Licensing Documentation during its adaptation and modification. The effectiveness of such approach is much higher than the use of conventional instruments not based on the database methods. On the other hand, it is apparent that due to complexity of the issue the use of the method is quite demanding from the point of view of manpower and time necessary. In addition, the current version of the database reflects specific scope of licensing requirements and for the other applications the certain update would be needed, although comprehensive use of IAEA safety standards significantly reduces the scope of the modifications.

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PSA LESSONS LEARNED FROM VIEWPOINT OF THE ETSON TSOS

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Abstract

The ETSON PSA Expert Group has recently carried out investigations on the insights and lessons learned from probabilistic risk analyses (PRA) the Technical Safety Organizations (TSOs) have either conducted or reviewed. One observation of the ETSON PSA Expert Group is that even if the completeness of PSA increases progressively, some real events might not yet be adequately represented in PSA models, although these are regularly improved to incorporate operating experience. Quality and use of PSA have significantly increased over time. PSA is indispensable for present safety culture and some outstanding achievements of PSA have been identified. Nevertheless, the relevance of PSA in decision making varies between member countries and organizations. The paper provides some exemplary insights from PSA applications in ETSON member countries and reviews by member TSOs, not only in the frame of regular, full scope PSA but also by specific assessments required in case of findings or in supporting deterministic assessment for plant modifications. Benefits and limitations of PSA from TSO viewpoint are briefly summarized.

1. INTRODUCTION

ETSON, the European Technical Safety Organisations Network, is the European association of nuclear assessment bodies (Technical Safety Organisations - TSOs), which perform the technical evaluation of safety files in support of their national authorities. ETSON aims, among others, to develop and promote best practices in nuclear safety assessment. To facilitate the necessary technical exchanges, ETSON has created 14 Expert Groups[1] on different technical topics.

The present paper is a result of the exchanges undertaken within the ETSON PSA Expert Group EG8 on PSA. PSA plays an increasingly important role in nuclear power plant (NPP) safety analysis. The PSA specialists in the EG8 are also working on drafting a more detailed document for TSO use on lessons learned from PSA. The ETSON PSA Expert Group intends supplement existing PSA publications by capturing TSO experience in performing and reviewing PSA in the form of a set of technical issues and summary solutions/observations to assist understanding and improve PSA beyond formal guidelines, particularly for member TSOs.

[1] for more information, see the ETSON organisational structure on http://www.etson.eu/sites/default/files/information-center/information-materials/ETSON-organisational_chart.jpg).

2. BENEFITS OF PSA AS SUPPLEMENT TO DETERMINISTIC ASSESSMENT

The added value provided by PSA to deterministic safety analysis is that it allows considering all possible combinations of failures and human errors and determines the probability of hazardous events or sequences. This achievement makes it possible to identify important risk contributors that could not be identified within deterministic safety analysis:

PSAs play an important role within safety assessment today in:

- The assessment of the overall core and/or fuel damage frequency (CDF or FDF) and the dominant contributions to it,
- the assessment of the risk of radioactive releases in case of core or fuel element damage,
- the analysis of the relative risk contribution of different components, systems, or events, and
- the safety ranking based on quantitative risk indicators.

PSAs can be used to assess the advantages and drawbacks of the various design solutions and to determine the effects of/benefits gained from the design or operational changes. Such information, which cannot be obtained without PSA, may be generally used for:

- efficiently improving the plant safety,
- analysing the efficiency of the safety systems for reducing the risk,
- analysing the plant design balance (e.g., the independency between provisions for core or fuel element damage prevention and consequences mitigation),
- demonstrating compliance with quantitative safety objectives,
- improving plant or operational efficiency, and
- demonstrating continued safe operation is possible, e.g., during maintenance campaigns.

The use of PSA has gradually increased over time during the last several decades. It is now an integral part of the safety assessment process. Some historical outstanding achievements of PSA, sometimes resulting in significant plant modification, are:

- Identification of the risk relevance of small LOCAs (loss of coolant accidents) in a time when there was a common belief that the provisions against large LOCAs would envelope small LOCAs as well;
- Identification of the risk relevance of shutdown states;
- Significant improvements of plant safety by optimizing plant design and operation;
- Optimization of severe accident management provisions.

Today many PSA applications are in use and the methods are mature, especially to aid decision-making in terms of changes in design/operation, technical specifications for operation, incident analysis, inspections, preparation for accident management, etc.

3. EXAMPLES OF PSA USE AND APPLICATION FOR IMPROVING NUCLEAR SAFETY

This section provides a few examples from the TSOs´ experience to demonstrate that use of PSA in safety assessment can result in improved nuclear safety.

3.1. Operating experience from events in nuclear installations

In principle, operating experience from nuclear installations including real incidents has always informed PSA via data input (reliability data, initiating events frequencies, common cause failure (CCF) parameters, etc.). However, some PSA improvements can be more directly linked to such incidents:

- Loss of heat sink incidents: impact on total loss of heat sink initiator frequency;
- Loss of 6.6 kV safety busbars by a CCF incident: new initiator and 6.6 kV safety busbar CCF failure added to other initiators considered in all PSA;
- Reactor heat removal system break incident: impact on LOCA frequency during shutdown states.

The safety significance of site external hazards was highlighted by the Fukushima accident as well as by incidents in other countries, such as the first occurrence in France of a “beyond design basis situation” (Cruas, December 2009). Such events have highlighted the importance of extending the scope of PSA to, more fully, take into account external hazards. These events can have a high impact on safety as they are typically common cause events (inducing initiating events and affecting simultaneously plant mitigation systems).

One of the most important aspects to be considered is that internal as well as external hazards may affect all units of a given site. Activities for developing guidance, methods and approaches to model site events in PSA are ongoing in many ETSON member and international organisations (e.g., IAEA, OECD/NEA/WGRISK, EC).

3.2. Specific case studies of PSA applications

This section provides some focused examples of uses of PSA to address specific questions (e.g., for evaluation of different design options or to analyse risk connected with specific scenarios).

3.2.1 Safety demonstration for specific scenarios

This type of case studies relates to use of PSA to demonstrate that specific scenarios have negligible frequency (or probability). For example, the scenarios may arise from regulatory requirements, to verify the likelihood of a specific accident scenario or evaluate additional safety measures.

A challenging aspect for these analyses is that they involve very low probability events, possibly CCFs, for which probability estimates are very difficult to obtain. The solution typically involves the use of bounding and conservative values (as opposed to full-scale PSA applications within which conservatism is said to distort the assessed risk profile).

3.2.2. Informing safety-relevant decisions concerning design and operation

These case studies typically relate to PSA evaluation of different options for design and/or operation. An interesting decision case from [1] relates to the use of PSA for deciding on the position of a valve along the main piping of the fire extinguishing system of a NPP electrical building. PSA was used to assess the risk balance connected with two decisions, (i) regarding the normal position and type of the valve and (ii) regarding the pressure in the piping, supported by various assumptions and simulations of water flows in case of induced internal flood. The option chosen was 'motor-operated valve normally closed' which would entail a lower risk for internal floods, but with the need to open the valve to allow water in the piping in case of fire.

Other notable case studies relate to the use of PSA to evaluate or inform the evaluation of design options for new reactors, particularly in France concerning the EPR design. In addition, PSA has been extensively used for evaluation of safety-enhancing measures implemented in Europe following the Fukushima Dai-ichi accidents. Reference [1] reports on evaluations of provision of mobile equipment, improvement of procedural guidance, in support of preventive as well as mitigative measures.

3.2.3. Human performance in safety-relevant scenarios (improving procedural guidance and training)

Human Reliability Analysis (HRA) is the part of PSA that analyses the influences of human performance in accident scenarios. HRA can inform safety-enhancing measures related to human performance: typically concerning procedural guidance and training. Indeed, compared to other performance influencing factors typically considered in HRA (e.g., salience of the man-machine interface), modifications in the procedural guidance and training are more common results, because they are more flexible to implement.

For example, from [1], typical improvements of the procedural guidance concern better specification of the criteria for the operator to take actions or to change procedures. The PSA perspective allows the analysis of procedural guidance on the most risk-relevant accident scenarios, thus making the maximum benefit to safety.

A procedure for the PSA-informed review of the procedural guidance is presented in detail in [1]. A typical example of this review relates to the injection from alternate water reservoirs (external to the plant site) and/or fire water system sources. Generally, aligning these sources requires local actions (i.e., not carried out from the main control room) involving manual operation of valves, connection of hoses, alignment of movable pumps – depending on the cases. Based on the PSA-informed review, it was possible to identify scenarios for which early preparation of these options can further increase the margin for success of alternate injection.

4. LESSONS LEARNED

As a flexible tool, PSA has been continuously evolving, and currently is able to consider and incorporate plant modifications, new events or new knowledge. Depending on the type of the work performed by TSO, there are two kinds of lessons learned, as summarized below from [1]:

— Lessons learned from reviewing PSA:
    - For a better credibility of the PSA results, independent reviews are important. Moreover, the review accompanying the elaboration process of a PSA (on-line review) seems to be more efficient than a review performed after the PSA has been completed (off-line review).
    - The development of a PSA model by reviewers, independent from the PSA developers, is obviously an appealing approach. It may still require significant resources.

- Close interaction with knowledgeable non-PSA experts, e.g., plant inspectors, developers of procedures, training instructors, etc., provides essential information on technical systems, operational practices and procedures, including recent developments in the domain.
- Access to the whole PSA model is desirable at the latest when the PSA results are provided.
- Before performing a peer review against the requirements of the international standards, it is quite important to identify, as much as possible, the purpose and objectives of the PSA.
- Introduction of safety culture into PSA may yield significant benefits, because if the safety culture degrades during plant operation, the "real" CDF or FDF can become much higher.

— Lessons learned from case studies:
- The necessary PSA quality (level of detail, completeness, etc.) depends mainly on the application. Even a simple PSA can be sufficient to identify important safety improvements).
- The lack of a sufficiently broad range of supporting studies (e.g. thermal-hydraulic studies for various accident sequences) seems a recurrent issue within PSA Level 1 for HRA or for the validation of some success criteria.
- PSA based event analysis (PSAEA or precursor analysis) is helpful to the process of operational experience feedback (lessons learned from incidents, identification of corrective actions, etc.) and to further improve PSA models through identification of missing elements in these.
- Level 2 is not always developed at the same level of detail as Level 1 PSA. Level 1 PSA usually offers more opportunities for PSA applications (based on CDF/FDF, importance measures, using the same computer code) than Level 2 PSA (based on large and or early release frequencies (LRF/LERF), often using different computer codes with an in general not fully automatic Level 1/2 interface). The modelling of accident sequences, systems, and human actions is generally more elaborate in Level 1 PSA, whereas Level 2 PSA is often hampered by a less detailed modelling of possible mitigating strategies, measures, equipment, or manual actions., Nevertheless, Level 2 PSA shall provide indications on the dominant contributors to the risk of radioactive releases and thus help defining important risk reduction options.
- In Level 1 PSA, CDF and/or FDF are well-accepted figures of merit. In Level 2 PSA however, release categories or source terms are used. It seems that a universal risk metric (e.g., the sum of release frequencies times, the released activities [Bq/ry] of radionuclides) could promote the application of Level 2 PSA.
- PSA is an appropriate tool to enhance the plant procedural guidance, typically maintenance practices, Emergency Operating Procedures (EOPs) and Accident Management (AM) procedures.
- A dynamic risk assessment tool based on PSA such as a risk monitor can be used to support maintenance planning and determine the expected risk profile in advance of performing maintenance.

A wide range of PSA guidance is available aimed at covering all issues of safety significance. However, obvious challenges remain in creating effective PSA studies [1]. These include availability, quality and relevance of data but also real restraints of budget and resources (which can lead to issues being ignored or addressed in a manner which does not really represent the state-of-the-art).

5. CONCLUSIONS AND OUTLOOK

PSAs are meanwhile more and more complex in terms of scope and level of detail (internal and external hazards and event combinations, treatment of all dependencies including multi-unit aspects). This requires a continuous effort to improve and develop methodologies, specific software and to acquire suitable reliability data.

PSA experience improves the deterministic analyses of scenarios by more consideration of functional limitation, interdependency of the systems, unit configurations and operator actions; but there must be close cooperation between the deterministic and probabilistic team to ensure consistent interpretation of the analysis.

Different PSA purposes (e.g., safety assessment to demonstrate compliance with regulatory requirements, evaluation of proposed plant modifications, risk monitoring, etc.) may require substantially different level of details implemented in PSA model. Therefore, application of the model beyond its original intent requires careful examination of initial model scope, assumptions, simplifications and, in most of cases, a laborious effort on model update and extension to ensure that limitations of the original model do not compromise PSA results and conclusions for the extended usage area.

ACKNOWLEDGEMENTS

The authors want to thank all members of the ETSON Expert Group EG8 having provided valuable input and discussions with regard to lessons learned of PSA from their viewpoint as specialists working for a TSO.

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R&D PROJECT INVESTIGATING THE FILTERING SYSTEM IN THE SUMP OF A PWR NPP DURING LOSS OF COOLANT ACCIDENT: *Viktoria Experiments*

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Abstract

During Loss of Coolant Accident, water is injected in the core by the Emergency Core Cooling System (ECCS) to insure the long-term core coolability and spread into containment by the Containment Spray System (CSS) to remove residual heat and to maintain containment integrity. After the drainage of the RWST (Refueling Water Storage Tank), water is taken from the containment sump in the lower part of the nuclear reactor building. A filtering system is implemented at the bottom of the containment to collect debris produced by the pipe break as well as other latent materials, such as fiberglass, paint and concrete particles, and to minimize the amount of debris entering in the ECCS and CSS systems and therefore having the capability to be transferred to the reactor core (downstream effects). Consequently, one of the major issues to be assessed is the plugging of the filtering system due to mechanical or chemical conditions which can lead to an inadequate net positive suction head (NPSH) margin for the ECCS and CSS pumps. It can result in cavitation and the failure of the pumps of these systems. These phenomena might lead to a reduction of the water flow rate to the core and the long term coolability of the core might be impaired. From 2004, the "Institut de Radioprotection et de Sûreté Nucléaire" has launched an experimental R&D project investigating the plugging of the sump strainer and downstream effects. The most recent analyses of the experiments carried out on the VIKTORIA loop built up in 2011 which allows operation at high temperature give very useful results regarding sedimentation, transport of debris and physical plugging of the strainer, as well as the impact of chemical effects on the evolution of the head losses.
The observations realized during these campaigns of tests demonstrate the need to carry out tests at high temperature and with the real "chemistry" in the water to highlight potential phenomenon and to provide relevant assessments.

1. INTRODUCTION

The filtration of the water of the sump is one of the major issue to insure the long term core coolability after a Loss Of Coolant Accident. From 2004, the "Institut de Radioprotection et de Sûreté Nucléaire" has launched an experimental R&D project investigating the plugging (by physical and chemical effects) of the sump strainer and the downstream effects which was concluded by the design of VIKTORIA facility built up in 2011. The objectives of the recent experimental program performed in the VIKTORIA facility are:

- To collect data concerning the transport and settling of the debris in the reactor sump with an approved upstream debris source term;
- To investigate the head loss of the strainer (physical plugging) by studying the behaviour of the strainer for different kind of debris source term and relevant thermal hydraulic conditions (water temperature between 30 to 80°C) and flow velocity on the strainer surface (1 to 3 mm/s);

• To investigate the long-term evolution of the head losses (at least for 30 days) in compliance with the temperature profile (estimated by IRSN) and the chemistry of the water solution in the sump during a typical LOCA transient.

For this purpose, the VIKTORIA loop, co-funded by IRSN and VUEZ and operated by VUEZ at Levice in Slovakia, was equipped with one of the strainers equipping French NPP.

2. CONTEXT AND PHENOMENOLOGY

After the incident which occurred at Barsebäck (Sweden) nuclear power plant in 1992 [1] and pointed out the risk of strainers clogging by debris generated by a LOCA, various actions were launched by utilities, research organisations, regulators and TSOs in several countries to investigate this clogging issue. In particular for pressurized water reactors (PWRs), several research and development works [2] were carried out to assess the impacts of such debris on the safety systems used in LOCA accidents during the phase where these systems take suction through strainers from the sumps located at the bottom of the containment building.

After a Loss of Coolant Accident (LOCA), water is injected into the core by the emergency core cooling system (ECCS) to insure the long term core coolability. The containment spray system (CSS) is used to remove the residual heat from the containment and to maintain the containment integrity. At the beginning of the accident, ECCS and CSS pumps take suction from the RWST. As soon as a low water level is reached inside this tank, these pumps are switched to a “recirculation mode”, the water is then injected into the core and to the CSS spray nozzles sucking water in the sumps located on the lower part of the reactor building, fed by the water sinking from the break site and the CSS nozzles (*FIG. 2*).

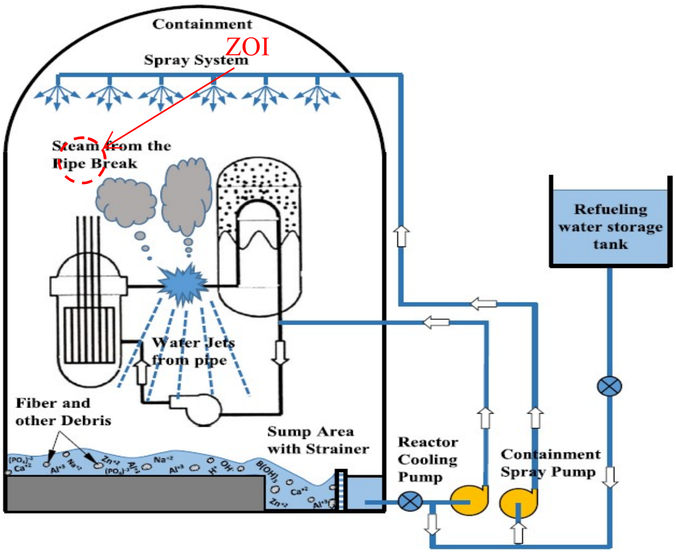

FIG. 2. Scheme of the recirculation loop in the NPP from [3]   *FIG. 3. The VIKTORIA facility*

The sumps are fitted with a strainer system in order to minimize the amount of LOCA-generated-debris entering the ECCS and CSS lines which could impede their safety functions. The primary break could generate shock waves and jets of coolant. Debris is then produced in the vicinity of the break. Debris could also result from the evolution of ambient conditions inside the reactor building due to the break and from the sprayed water.

Smaller and more transportable debris can be carried to the strainers and may create a fibrous bed. The way the particles are trapped in the strainer bed, or pass through it, depends on their size and properties, and also on the arrival delay from the break time. The fibrous bed also results from mechanical phenomena or chemical reactions under LOCA temperature and pressure conditions. The accumulated debris in the fibrous bed on the strainers may increase the differential pressure across them and thus decrease the net positive suction head (NPSH) margin available for the ECCS and CSS pumps. It can result in cavitation and failure of the recirculation function. Moreover, all the ECCS and CSS components located downstream the strainers must be qualified with water containing debris that could pass through the strainers. The availability of ECCS and CSS safety functions in case of post-LOCA-generated-debris is one of the major safety issues to be deeper investigated and verified. IRSN has carried out recent investigations to obtain reliable results to assess the demonstration of this operation mode.

IRSN expertise and its supporting research activities deal with the risk of strainers plugging as well as with the assessment of the impact of the debris on safety equipment located downstream the strainers, including fuel assemblies, and addresses both physical and chemical effects of the debris. Different key issues and parameters are identified: the transport and the settling of the injected debris, the characterisation of the upstream debris source term (amount of heat insulation, coating particles elements that could be released by water wash, size and distribution of debris), the maximum head loss and the net positive suction head margin for the ECCS and CSS pumps, the impact of the chemical phenomena (temperature profile, pH, consequences on the strainers clogging), the characterisation of the downstream debris source term, qualification of the ECCS and CSS components and core cooling capacity with debris-loaded water.

In case of a break on the primary coolant system, the volume of space affected by the jet of the primary break, or zone-of-influence (ZOI), is modelled to define and characterize the amount of generated debris.

The recommended conventional ZOI is a spherical boundary with its centre located near to the break site (*FIG. 2*). The ZOI is defined as the volume around the break in which the fluid escaping from the break has sufficient energy to generate debris from insulation, coatings, and other materials within the zone. The use of a spherical ZOI aims to encompass the effects of jet expansion resulting from impingement of structures and components, truncating the sphere wherever it intersects any structural boundary of large robust equipment. A ZOI is defined for fibers; another one for paint particles, based on the recommendations of USNRC to the Nuclear Energy Institute [4]. Latent debris (firewall products, and other dirt's) are also considered and correspond to the ones staying inside the reactor building after a standard process of cleaning before restarting the reactor and are submitted to the water washing. Among the generated debris at the break site, close to fifty percent of the heat insulator fibrous debris is carried downwards to the strainers. This transport coefficient is based on numerical analyses of the fluid flow generating by a primary break. Moreover, hundred percent of the coating particles due to their sizes are considered carried to the bottom of the reactor building. All the debris accumulated on the containment floor are carried to the strainers. The size distribution of the debris is established from destruction tests under a water jet and accidental conditions. During this project the Upstream Debris Source Term (TSD), including insulation materials as fiberglass and powder, painting chips and particles, concrete particles and specific products used as firewall protection, is representative of real materials that may be transported to the strainer during the recirculation process. Table 1 gives the main characteristic of the upstream TSD.

TABLE 1. TYPE OF DEBRIS FROM PWR NPP USED DURING THE VIKTORIA EXPERIMENTS

Fiberglass	Insulation powder	Painting debris	Concrete debris	Fire wall products
type A Length : 0,5 mm (ø ≈ 8 µm) Type B (ø ≈ 5 µm)	MICROTHERM® (ø < 20 µm)	As chips ($S < 10$ mm^2 Thickness = 100-200µm) As fine powder (20 < ø < 50 µm)	Class 1 (ø < 100 µm) Class 2 (100 <ø< 500 µm) Class 3 (500 <ø< 1000 µm)	MECATISS type Ca_2SiO_4 panel Silicon foam

Two types of fiberglass insulation were used depending on the test configuration: type A and type B that differ mainly by their chemical compositions (with SiO_2, Al_2O_3, Fe_2O_3 and alkalis Na_2O, K_2O, CaO, MgO at various wt %) and the diameter of the fiberglass. Real MICROTHERM® and concrete particles, MECATISS fire barrier material (mainly fiberglass and refractory glues) and firewall panel (made of calcium silicate

Ca_2SiO_4) were used, as they may have an impact on transport, plugging of the strainer and on chemical effects with regards to their specific chemical compositions. Preparation of fibrous debris follows the NEI guide [5]. Batches of fiberglass, manually removed from the conditioning rolls, are placed for 8 hours on a hot plate at 300°C +/- 40°C to simulate ageing. For these tests (*thick bed tests corresponding to a homogeneous injection of debris*), equal batches of debris mixture (non-fibrous debris+ fiberglass) are injected discontinuously at the beginning of the tests during 4 hours. We refer to the recommendations of the NEI Generic Guideline for Test Protocol [6] and the know-how of VUEZ to limit the concentration of debris upstream of the filter.

3. DESCRIPTION OF THE VIKTORIA FACILITY

The VIKTORIA (*FIG. 3*) thermal hydraulic test facility [7] consists of different interconnected segments:

a) Debris preparation and injection tanks where the debris, that would be transported to the strainer, is introduced and homogenously mixed;
b) Specific tank - a so-called "leaching tank" for placing coupons and samples of representative chemical reactive debris that would not be transferred to the strainer (total flow rate 8.5 m^3/h);
c) A tank for placing a scaled segment of a strainer. The injection tank is connected to the strainer tank by a flume to prototypically simulate the debris transport to the strainer (total volume of the loop 6.6 m^3);
d) Downstream modules - a series of parallel circuits that can be used to place fuel assemblies, valves, heat exchangers, absolute strainers or other components downstream of the main strainer.

Different types of strainer with new technologies are implemented in the French NPPs, with different designs and geometries: rectangular cartridges, planar and cylindrical grids. The strainer chosen for this study is that using rectangular cartridges (total surface = 2.1 m^2). Informations that have been used to define (with the scale of 1/250) the main thermal hydraulics parameters to perform the experiments are detailed in [8].

4. MAIN RESULTS OF THE EXPERIMENTAL PROGRAM AND PERSPECTVES

The preliminary analyses of the experiments on the VIKTORIA loop give very useful results regarding:

- The competition between sedimentation and transport to the strainer [9];
- The formation of the debris bed on the strainer and its stability;
- The impact of temperature and chemical effects on pressure drop evolutions [10];
- The downstream effects on "in-core" in a module representing the lower part of a classical NPP fuel assembly (including lower support plate, anti-debris grid, holding grid and one mixing grid).

The tests highlight the settlement of the largest particles (concrete and painted coatings) and part of the fiberglass, the transport of debris and the physical clogging of the strainer. The establishment of a correlation (strainer head loss versus debris mass at 30°C with tap water) allows an extrapolation of the maximum head losses (to roughly 10 kPa) without taking into account the amount of settling debris that may be linked to the test loop. The debris carried to the strainer (roughly 40 to 45% of the injected debris) generates at 80°C (*with chemistry - boric acid at boron mass concentration of 2500 ppm and NaOH at a concentration of 1800 ppm*) a very quick increase on the strainer head losses (up to 7 kPa). After 2-3 days, a pressure drop across the strainer was observed at a level that could be due to the chemical effects. An extrapolation, at low temperature (30°C), to the total mass of debris supposed to be transported to the strainer leads to head losses of about 20-25 kPa. This result has to be compared to the value of the maximal head loss allowing operation of the safety pumps. A part of the debris crossing the main strainer was collected on the fuel assembly module: even if it represents a small amount (<1%) of the upstream debris source term, it generates significant pressure drops on the grids.

Silicon and Aluminum concentrations in the water of the loop from measurements on samples using AES ICP spectroscopy for various elements (K, Al, Mg, Ca, Fe, Si, Mn, Ti) clearly indicate corrosion and dissolution of the fiberglass. The observations during these tests demonstrate the need to carry out tests at high temperature with the real "chemistry" in the water to highlight potential phenomenon and to provide relevant assessments.

Complementary experiments (with additional "chemical" tests and specific tests in order to investigate more in deep the fuel assembly blockage) are foreseen in 2018 in VIKTORIA, to complete our understanding and propose validated conclusions for the IRSN safety expertise. There will help IRSN to analyze the core coolability during the recirculation process and, in particular, the criteria on the fuel assembly proposed by the operators.

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CURRENT CHALLENGES IN NUCLEAR SAFETY R&D ESPECIALLY CODE DEVELOPMENT

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Abstract

The independent and non-profit organization Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH is the main Technical Support Organisation (TSO) in nuclear safety for the German federal government. One focus of research at GRS in reactor safety so far was and will be on the development and validation of simulation programs for the current reactor generation as well as the next ones. The code system of GRS today covers all relevant phenomena of reactor physics, thermal hydraulics and core meltdown as well as structure mechanics. The simulation codes are applied in connection with our work as authorized experts or as TSO, e. g. in our support of authorities in licensing and supervisory procedures.

For assessing and convincingly demonstrating the high safety level of advanced (Gen III, GEN III+) and innovative (GEN IV) reactors and small modular reactors (SMRs), there is a need to continuously improve the codes used for analysing reactor safety, e. g. by considering important new features of those plants, other working fluids or core components. This is a cornerstone of GRS strategy to build up competences, know-how and validated simulation tools for safety assessments also for advanced and innovative reactors and SMRs. The paper discusses selected challenges in nuclear safety R&D, especially related to the code improvements that will be needed; some examples of code applications will be provided, too.

1. INTRODUCTION

The European civil nuclear sector is an established industry, generating 27% of all electricity consumed in the European Union (EU). It contributes significantly to the EU economy's energy supply, competitiveness, security, limitation of CO_2 emissions and reaching the EU's 2020/2030/2050 energy and climate policy objectives. All scenarios of the Energy roadmap 2050 of the European Commission (EC) include the reliance on nuclear power. Therefore, EC stated in its Energy Union Communication that putting the EU at the forefront of the world's safest nuclear power generation is central and that EU should also ensure that it maintains technological leadership in the nuclear domain. New builds are seen as a motor for growth, jobs and competitiveness. This concerns all nuclear stakeholders such as vendors, operators, regulators, Technical Safety Organisations (TSO), expert organisations, research institutes and universities [1] [2] [3]. From the present perspective, the EU targets can only be achieved with advanced light-water cooled reactors incl. small modular ones now under construction or development. The deployment of these reactors could build the bridge throughout the 21st century between the ageing nuclear reactors currently in operation, and the Gen IV reactors proposed by the Gen IV International Forum and promoted by the Sustainable Nuclear Energy Technology Platform (SNE-TP) and the European Sustainable Nuclear Industrial Initiative (ESNII).

In contrast to these expectations for the European Union, the German government decided to phase out the energy production by Nuclear Power Plants (NPP) until the end of 2022. At the same time, the German government clearly emphasized the need to maintain the knowledge and know-how on the various disciplines within the nuclear sector. GRS as the main German TSO will retain its function in supporting the German government in all nuclear safety and radioactive waste management relevant issues. Research at GRS in reactor safety so far was and will focused on code development and validation for all reactor generations. The scientific basis for the code development and validation activities as well as current challenges in nuclear safety R&D are given by new insights on physical phenomena, reliable plant data for next generation plants as well as SMRs, or information gained from operational occurrences or accidents. For assessing and convincingly demonstrating the high safety level of next generation reactors, there is a need to continuously improve the codes, e. g. by considering important new features of those plants, other primary fluids or core components. Gen III, III+ and IV NPP incorporate passive safety systems, which do not require any active controls or operator intervention to manage accidents. By combining these passive safety features with proven active safety features, the next generation reactors can be considered to be amongst the safest equipment ever made; SMR may pose additional requirements.

2. NUCLEAR SIMULATION CHAIN OF GRS

Over 60 technical experts are developing and validating a nuclear simulation chain, which allows the simulation and assessment of all relevant phenomena for the analysis of operational states, anticipated operational transients, accidents and severe accidents in NPP and in other nuclear facilities. With the help of these computer codes, it is possible to analyse the behaviour of these reactors or individual components over a range of conditions, from normal operation up to severe accidents. In general, GRS develops, as far as possible, its own codes, because this approach leads to an improved understanding of the relevant physical phenomena. Additionally, this approach allows GRS to be independent of the interests of commercial software developers and therefore – if necessary – to improve selected codes to respond faster and more flexibly to current events [4].

Today, a comprehensive, historically grown scientific code system is available at GRS (see Figure in APPENDIX). The codes are assigned to main research fields: reactor physics, thermal hydraulics/severe core damage and structural mechanics. The central element of the nuclear simulation code chain in the thermal-hydraulics/severe core damage domain is the coupled lumped parameter (LP) code system AC^2 which consists of: ATHLET (simulation of leaks and transients in the reactor coolant circuit of NPPs), ATHLET-CD (extension of ATHLET for severe accidents in the reactor coolant circuit of NPPs), and COCOSYS (simulation of conditions within the containment/buildings of NPPs in case of accidents and severe accidents). Other elements consist of codes used for reactor physics, as e.g.: DORT-TD/TORT-TD (time-dependent neutron transport equations for 2D/3D transient analyses), QUABOX/CUBBOX (3-D neutron kinetics core model), KMacs (3-D core simulator), KENOREST and MOTIVE/VENTINA (prediction of the nuclide inventory and radiological characteristics of irradiated LWR fuels), and TESPA-ROD (fuel behaviour code for reactor operation, accident conditions and long-term storage). In the structural mechanics domain, one should mention e.g.: PROST (probabilistic code for the determination of structural reliability of piping and vessels), and WinLeck (calculation of leak areas and discharge flow rates based on geometry, material and medium). Finally, for sensitivity and uncertainty analyses together with some of the above-mentioned codes, the following tools are provided: XSUSA (influence of nuclear cross section uncertainties on reactivity, power distribution, etc), and SUSA/SUnCISTT (influence of parameter uncertainties on reactivity, power distribution, core degradation, etc).

The advantage of the nuclear simulation chain is that selected modules and/or codes can be coupled if necessary. The selection of the appropriate approach and code for the respective issue is based on the necessary spatial resolution. With these options, it is possible to determine the overall reactor circuit behaviour by the LP code while relevant parts being of special interest can be calculated in a detailed 3D resolution. All applied codes are systematically validated, e. g. the thermal-hydraulic codes based on a well-balanced set of integral and separate effect tests e. g. derived from CSNI code validation matrices. Because GRS operates no test rigs, monitoring and evaluation of the results of national and international reactor safety research network projects and especially the participation in experimental programs are an essential part of the work. Through its national and international research and expert activities, GRS can consider, in this context, the current state of science and technology.

3. EXAMPLES OF CURRENT CHALLENGES IN CODE DEVELOPMENT AND APPLICATION

3.1 Reactor physics

The current challenge in code development is the application of models respectively its improvement for Gen III, III+ and IV NPPs as well as for SMRs. Coupled neutron kinetic / thermal-hydraulic codes systems allow for the analysis of respective feedback mechanisms and their influence on safety-related operation parameters under normal and accident conditions, for both current LWR and innovative reactor designs. A relatively new tool is the core simulator KMacs, to be applied for detailed operation cycle calculations, currently being validated for western-type PWR and now to be extended to hexagonal assembly structures like VVER. In the field of neutron kinetics, the application of modern, sophisticated deterministic and stochastic neutron transport codes and their coupling into a multi-physics, multi-scale code environment is of high interest, with a dedicated focus on the generation and qualification of problem-dependent, high-fidelity neutron cross section libraries e.g. for fast neutron spectra. Where experimental data lack or are sparse up to now, a strong emphasis is given to comparative numerical benchmark calculations as well as to the application of extensive sensitivity and uncertainty studies e.g. by the application of the GRS tools XSUSA and SUnCISTT..

3.2 Fuel behaviour during long term storage

In Germany, spent fuel dry cask storage facilities were originally intended to be used for ~40 years only. However, today it becomes obvious that this period will not be sufficient on the way towards final disposal. Regarding an extended long-term operation of such dry storage facilities, it must be shown that the safety functions – safe enclosure of the radioactive inventory, subcriticality, radiation shielding, and decay heat removal – will be fulfilled during the envisaged timeframe beyond 40 years. Further, important aspects for the strategy of long-term storage prior to final disposal are transportability of the casks and manageability of the fuel assemblies. Safe enclosure and manageability of fuel assemblies require that systematic failure of the fuel rods does not occur, and fuel assemblies maintain their geometric arrangements. Evidence of conformity has been verified for the initial 40 years of storage by the licensees. To realise a long-term storage concept beyond that, additional knowledge and data about material and component performance in conjunction with predominant conditions are necessary for sufficient safety assessments, as additional long-term physico-chemical phenomena during cooling become relevant which need to be taken into account in an appropriate manner.

Of special interest are the inaccessible interior structures of the dry storage casks, in particular the long-term behaviour and integrity of fuel rods including the evolution of pressure, radiation and temperature. Further, the characteristics of the materials like deformations, ductility or creep are investigated in greater detail. Effects like the oxidation, radiolysis, the formation of hydrides and the resulting strains are investigated for possible boundary conditions including burn-up, fission gas and its release, and the influences of different material characteristics [5, 6]. Within ongoing research programs [7, 8], GRS follows the strategy to identify and analyse relevant phenomena and time scales, to assess fuel rods and fuel assemblies sensitive to long-term effects as well as different loading schemes of casks which might amplify relevant degenerative mechanisms, and to develop new tools to predict long-term behaviour. The investigations consider the entire phenomenology of the cladding behaviour during its lifetime: fabrication, radiation in the reactor core, the wet storage and forced cooling, the subsequent drying process, and the slow cooling during the dry storage phase. One key parameter to describe degradation effects of the cladding is the temperature. GRS investigated results for the three-dimensional temperature field of a loaded cask using the code COBRA-SFS. Large variations of the cladding temperatures can be observed in both horizontal and vertical directions. The temperature results are used to predict the thermo-mechanical cladding behaviour with the GRS code TESPA-ROD. New models for effects relevant to describe the long-term behaviour, e.g. the evolution of hydride re-orientation by dissolution and reprecipitation in the cladding during storage, are under development and implementation. To ensure the safety of long-term-term dry storage, further reliable experimental data are needed in combination with models and codes for validated theoretical predictions.

3.3 Component behaviour under severe accident loading

In the aftermath of the events in Fukushima Dai-ichi 2011 a better understanding of the depressurization process of the reactor(s) during the severe accident sequence(s) was requested. As best-estimate methods for the assessment of the integrity of components during severe accidents are an essential part of the GRS code chain, such are applied together with the thermal hydraulic codes to correctly represent the period prior and after component failure. In case of such a high-pressure core melt accident scenario, partial melting of the fuel and oxidation of the zirconium cladding leads to gas temperatures up to 1800 °C and the gases heat up the components along their flow path between core and relief valve into the containment to more than 800 °C, so that a combined high stress high temperature loading arises. Gravitational loads and secondary loads from starting (visco-) plastic and thermomechanical deformations additionally act on these components. Metallic components may fail due to plastic instability, ductile fracture or creep rupture. In case of high-pressure scenarios without constraint of thermal strains plastic instability plays an important role. The failure mechanisms can appear independently or in combination. The first failing component as well as the exact location, time and mode of failure can have a large influence on the further progress of the accident. Any component failure under high pressure can be connected with immense energy release and secondary damage to the containment and can open a path for radionuclides to be released either into the secondary circuit or directly into the atmosphere. Otherwise, a (local) failure of the RPV is linked to high pressure melt ejection, spreading of hot material and reducing the endurance of the containment by direct containment heating.

The analysis methodology has been validated on large scale experiments and in the framework of international benchmark activities. The behaviour of the components of a generic PWR cooling loop due to postulated high-pressure core melt scenarios has been investigated [9]. Future work is concentrated on local failure and geometrically complex components as well as asymmetric loads in combination with the determination of the finite leak size. CFD codes or well resolved system code models allow a better local resolution of loads which can be and will be used in refined calculations on integrity assessment of components.

3.4 System behaviour of SMR – modelling gaps

SMRs are one interesting option for new builds in almost all countries worldwide. For asserting of legitimate nuclear safety and/or security interest’s German authorities require in this context own and independent expertise for the safety assessments. The GRS has among others performed a study on Safety and International development of Small Modular Reactors [10] to identify essential issues of SMR safety as well as needs for adaption, improvement and validation of nuclear evidence tools developed and applied by GRS. It was concluded that light-water-cooled SMR have the best prospects for realization. At least short and medium-term safety demonstrations will be assessed by independent confirmatory calculations with the existing simulation tools, first – neutron kinetics code QUABOX/CUBBOX and the thermal-hydraulic code system AC^2 [11]. Consequently, we evaluated these tools and identified several modelling gaps for the simulation of light water cooled SMRs [12, 13]. However, the following list does not claim to be complete. QUABOX/CUBBOX requires further model improvements and validation, e.g. for: long fuel cycle length (> 24 month), cores with higher burn-up (> 50 MWd/kg) and/or higher fuel enrichment, advanced loading pattern, boron free cores under consideration of burnable absorbers at the beginning of new cycles, and moveable reflectors for long-term compensation of excess reactivity.

AC^2 requires further model improvements and validation for selected phenomena, e.g. for: single and two-phase flow natural convection, flow instabilities and transition range between both; 2D/3D models for water pools with regard to temperature and velocity fields, thermal stratifications; heat transfer models: at bundle surfaces at free convection, subcooled or saturated boiling conditions, horizontally arranged containments in large water pools / the ocean at RA-numbers of approx. 10^{15}; enhancement of the parameter ranges of correlations towards low pressures; improvement and validation of the semi-empirical closure correlations for interphase friction, heat and mass transfer and if necessary implementation of properties for new (heat pipe) working fluids. As well as new components/containment designs needs special attention, e.g. for: steam condensation effects at walls, structures and internals of small SMR containments in case of small break LOCAs, or in case of inertised containments or containments operated at near vacuum conditions; infinite passive containment cooling to an ultimate heat sink in ocean environment (influence of seawater, mussel growth, etc.); passive safety systems (start-up behaviour, mutual interactions), innovative and high-performance heat exchangers (helical coiled, plate and bayonet heat exchanger, SCOR design), special check-valves, in which the opening cross section and the associated form loss is calculated dependent on the pressure difference up- and downstream the valve.

4. FUTURE MISSION AND OUTLOOK

The focus of reactor safety research at GRS so far was on the development and validation of simulation programs for the current reactor generation and will be in future extended to the next reactor generation including SMRs. Newly added are issues such as spent fuel rod behaviour during long-term interim storage as well the aging of the storages beyond the planned and approved periods. Germany also intends to continue its reactor safety research in an international context, which requires necessarily an appropriate knowledge and a preservation of nuclear know-how. That's why the German government funds the further development and validation of the GRS nuclear simulation chain for the safety assessment, introduced in this presentation. The simulation chain covers all relevant phenomena of reactor physics, thermal hydraulics and core meltdown as well as structure mechanics. GRS is also faced with challenges that stem from the fact that many of the codes are legacy codes. They retain code segments and structures that follow the good practices of the 1970s and 1980s and are not always suitable for the current programming approaches and tools and extension towards application for next generation reactors. GRS therefore needs to pursue the re-factoring of these codes to migrate them to recent programming standards and make use of up-to-date methods. Finally, GRS is also challenged in finding new staff with prior experience in programming languages that are less common nowadays and a solid understanding of the underlying physical phenomena. With its on-going development and validation programme and on-going recruitment and internal development of new staff, GRS is successfully addressing these challenges.

ACKNOWLEDGEMENTS

The development and the validation of simulation codes at GRS are funded by the German Federal Ministry of Economic Affairs and Energy (BMWi) on the basis of several resolutions of the German Bundestag.

FIRE SAFETY REGULATION ON HIGH ENERGY ARCING FAULTS (HEAF)

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Abstract

Large-scale electric discharges event called high energy arcing faults (HEAF) has been reported in non-negligible number at nuclear power stations (NPS) worldwide. If a HEAF occurs in electrical equipment, the pressure and temperature rise rapidly, causing an explosive phenomenon that results in serious damage to the equipment. Furthermore, a HEAF may cause a fire which would have a serious impact on cables and components in and around the equipment. On the Great East Japan Earthquake of March 11, 2011, a fire occurred in 6.9kV metal-clad switchgears (M/C) at Onagawa Unit 1 which was presumably caused by a HEAF. In order to investigate the HEAF event and understand well the phenomena involved, S/NRA/R conducted a series of HEAF tests. The test results indicated that the conditions for occurrence of ensuing fires are different between 480V distribution panels (DP) and M/C. The arc energy value which can cause ensuing fires was between 26.3 and 28.6 MJ for the DP and between 42.6 and 57.2 MJ for the M/C. These energy thresholds are considered to be dependent on the characteristics of individual electrical cabinets. If the arc discharge duration is reduced, the arc energy can be decreased and consequently the occurrence of ensuing fires would be prevented. According to the knowledge obtained by the present test, regulatory requirements to take measures for prevention of ensuing fire and mitigation of explosion were issued on August 8, 2017 and enforced on the same day. The use of safety research for developing new HEAF regulation was described.

1. INTRODUCTION

The Committee on the Safety of Nuclear Installations (CSNI) of the Organization for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) set up a working group on high energy arcing faults (HEAF) events in 2009 and has been advocating the importance of discussing HEAF events to ensure the safety of nuclear facilities. The OECD/NEA FIRE Database (1979-2012) has indicated that such HEAF events occurred in 48 cases out of the total 415 fire events [1].

FIG 1. Damage to metal-clad switchgears caused by the Onagawa HEAF event *[1]*

A HEAF event occurred in the medium-voltage (6.9kV) metal-clad switchgears (M/C) at unit 1 of Onagawa Nuclear Power Station (NPS) of the Tohoku Electric Power Company Co., Inc. due to the Great East Japan Earthquake of March 11, 2011. Figure 1 shows the damage to M/Cs of the Onagawa HEAF event [2]. Not only the affected M/C but also connected cables and other components were damaged due to the arc thermo-mechanical energies and an ensuing fire that subsequently spread to 10 other M/Cs via cable duct. As a result, two residual heat removal pumps were stopped for a short period and consequently influenced the safety function of the unit. Similar HEAF events, although their impacts are different from each other, have occurred in the electrical equipment and components at NPSs worldwide [1-2]. Therefore, from the point of view of the safety regulation, it is necessary to evaluate the influences of HEAF events on the safety functions of NPSs.
This paper summarizes the information on the S/NRA/R test results such as knowledge about how HEAF events develop, how much arc discharge energy generates, and under what conditions a fire occurs, which are important factors to prevent ensuing fires and were used as the basis of the new HEAF requirements.

2. EXPERIMENTAL

S/NRA/R HEAF tests used three types of electrical cabinets such as M/C (around 7,000 V), distribution panel (DP (480 V)) and motor control center (MCC (480 V)). There is a need to set a short-circuit current as the target current value by which arc discharge is generated in electrical cabinet in a HEAF test. The short-circuit value of each electrical cabinet is set when the electric system of the nuclear power plant is designed, and it is calculated based on the impedance of the upstream trans-former and the rated current of the secondary-side transformer. The HEAF tests were conducted under the following test condition on the electrical cabinets such as M/C (around 7kV, 22.3kA), DP (480V, 52.3kA) and MCC (480V, 63.5kA).

3.RESULTS AND DISCUSSION

3.1 M/C HEAF test results

Figure 2 is a group of photos illustrating the HEAF test of the M/C. Photo (1) shows the M/C before the test. Photo (2) shows the moment when arc discharge occurred (after 0.2 seconds). Part of the arc discharge and metallic fumes came out of the switchgear from the opening on the top. Photo (3) shows the continuous arcing and generation of large quantities of metallic fumes, etc. (after 2 seconds). Photo (4) shows the ensuing fire (after 10 minutes). The ensuing fires occurred several minutes after the arc discharge, which caused spreading fires to the adjacent M/C and cables in the vertical tray. As seen in these photos, HEAF consists of two phases: the first phase is an explosive fast energy release (photo (2), (3)), and the second phase is ensuing fire resulting in the damages to the neighboring cabinets and cables (photo (4)).

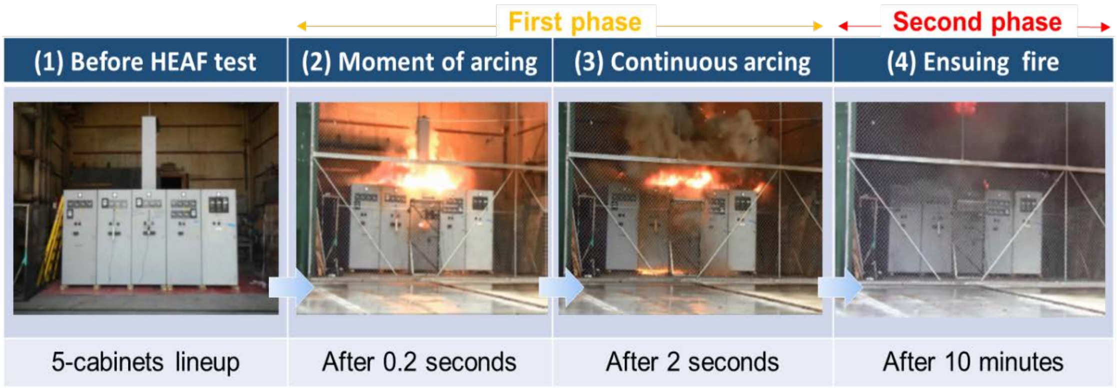

FIG. 2. HEAF test of M/C [3].

3.2 Relationship between Occurrence of Fire and Arc Energy

Thirteen HEAF tests were conducted: six tests with M/C, three tests with DP, and four tests with MCC. An ensuing fire occurred in six of the thirteen tests: four with M/C and two with a DP. Figure 3 shows the relationship between the arc energy and arc discharge duration required for causing ensuing fire. The arc energy increases with the arc duration. The tests where an ensuing fire occurred are marked with red. Ensuing fires occurred at conditions with higher arc energy and longer arc discharge duration.

The values of arc energy which can cause ensuing fires were between 26.3 and 28.6 MJ for the DP and between 42.6 and 57.2 MJ for the M/C. From these test results, it is said that an ensuing fire can be prevented by decreasing the arc discharge duration and the arc energy. The ensuing fires caused by HEAF events did not occur immediately after an arc discharge was generated but were observed several minutes after an arc discharge was generated. An ensuing fire occurs presumably because the generated arc energy heats up the cables and other components in the electrical cabinet, thereby causing flammable materials to catch on fire. The arc energy necessary for causing an ensuing fire differs between the DP and the M/C. As mentioned regarding the relationship between the occurrence of a fire and the arc energy, M/C and DP have different chassis sizes (internal volumes) and different levels of containment such as tightness and chassis strength, etc. Therefore, the arc energy necessary to cause an ensuing fire is thought to depend on the internal volume and openings (containment level) of each electrical cabinet. For example, an electrical cabinet with a smaller internal volume will accumulate the arc energy shortly, resulting a higher internal temperature and is more likely to cause the cables and other flammable materials in the cabinet to burn at a lower arc energy than electrical cabinets with a larger internal volume. An electrical cabinet with a higher containment level releases less energy and is more likely to cause the cables and other flammable materials in the electrical cabinet to burn at a lower arc energy than electrical cabinets with a lower containment level. These facts are clearly shown in the test results for the M/C and DP in Fig. 3. That is to say, because the M/C have a larger internal volume than the DP and have a lower containment level with vents in their tops, more energy is needed in the M/C to cause an ensuing fire than the DP by at least 20 MJ. Therefore, in evaluating the generation of an ensuing fire, it is required to properly take the internal volume and containment level of each electrical cabinet into consideration.

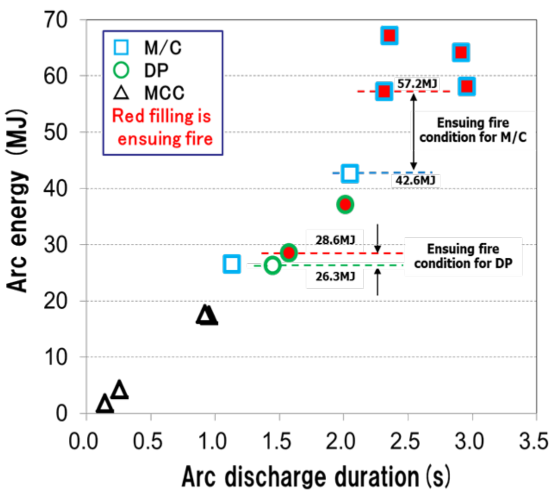

FIG. 3. Arc energy required for causing fire [3].

Accordingly, the results of the HEAF tests show that an ensuing fire can be prevented by decreasing the duration of arc discharge or decreasing the arc energy.

4. HEAF PROTECTION MEASURES (MEASURES FOR PREVENTING ENSUING FIRE)

HEAF is a phenomenon where a large current arcing occurs, resulting a rapid release of energy (explosion) accompanying heat, light, metal vaporization, and a pressure increase in the first phase, and a fire may break out due to the accumulation of heat in the second phase.

Although the detailed understanding of the phenomena and evaluation methods of explosion in the first phase are still under study in safety research, the knowledge about fire occurrence in the second phase has been accumulated by the HEAF tests, and as a result, for example, it is becoming clear that if arc duration can be shortened by operating the protective relay of a power supply board in a short time or by other ways, as a measure for preventing fire, it is possible to prevent fire and to decrease the impact of explosions. One of the possible counter measures is replacement of analog type over-current relays (OCR) to digital type OCR. The response of the digital type OCR is much faster than that of old analogy ones.

5. HEAF REGULATORY REQUIREMENTS

The concept by which regulatory requirements for strengthening protection for damages of electrical cabinets due to a HEAF according to the abovementioned background is as follows [4].

1) Objectives
   To prevent fire and to decrease the impact of explosions due to a high energy arcing of concerned electrical cabinets.
2) Concerned facilities and equipment
   Electrical cabinets of commercial nuclear power reactor facilities, research reactor facilities, and reprocessing facilities (hereinafter referred to as "commercial power reactors and other facilities")
3) Requirements
   Regarding the concerned electrical cabinets, it is required to decrease the consequences of an explosion and to set the cut-off time of upstream breakers appropriately so that an ensuing fire does not break out.

6. SUMMARY

The HEAF tests were conducted in order to obtain technical knowledge about the development of high energy arcing fault (HEAF) events, the arc energy level at which an ensuing fire occurs, and the impact of arc discharge. The technical knowledges were utilized for developing new HEAF regulation.

The approximate arc energy necessary for causing an ensuing fire was confirmed. The values of arc energy which can cause ensuing fires were between 26.3 and 28.6 MJ for the DP and between 42.6 and 57.2 MJ for the M/C. The energy necessary for causing an ensuing fire is thought to depend on the internal volume of each electrical cabinet and containment level.

The knowledge about ensuing fire occurrence in the second phase of HEAF has been accumulated, and as a result, for example, it is becoming clear that if arcing time can be shortened by operating the protective relay of a power supply board in a short time or by other ways, it is possible to prevent fire and to decrease the impact of explosions. This assessment results gave a significant contribution to prepare new regulatory requirements for the HEAF.

In the new Japanese HEAF regulatory requirements, prevention of ensuing fire and mitigation of explosion are required. Amendment of the regulatory requirements were issued on August 8, 2017 and enforced on the same day. One of the possible counter measures is replacement of analog type OCR to digital type OCR. The response of the digital type OCR is much faster than that of old analogy ones.

In addition, concerning the degree of HEAF impact and other factors, safety research and investigations are to be continued, and when new knowledge is obtained, the results will be further reflected in the regulatory standards, as necessary.

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SUPPORT OF UKRAINIAN REGULATORY AUTHORITY IN LICENSING PROCESS OF NUCLEAR FUEL SUPPLIER DIVERSIFICATION

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Abstract

At present, the diversification of nuclear fuel is ongoing at operating Ukrainian NPPs in accordance with European Energy Security Strategy. Nuclear power supplies almost half of Ukraine's electricity production, therefore, the diversification of fuel supplies is a strategic direction for ensuring the uninterrupted operation of nuclear facilities and one of the main aspects of energy security in Ukraine. A significant effort has been made to license alternative fuel designs for the VVER plants in Ukraine. As a technical support organization of the Ukrainian regulatory authority, SSTC NRS takes part in the licensing process for introduction of new FA types. The main approaches and experience of new fuel licensing in Ukraine are presented in this report. It covers such aspects as mixed cores licensing and operation, fuel management issues and regulatory authority's approaches for carrying out of independent confirmatory calculations.

1. WESTINGHOUSE FUEL ASSEMBLIES QUALIFICATION FOR UKRAINIAN NPPS

The need to search alternative nuclear fuel supplier for the Ukrainian nuclear power plants is rigidly connected with the economic and energy independence. Diversification of fresh nuclear fuel supply is one of the highest priorities for the most complete and optimal use of installed power of Ukrainian nuclear power plants. On the one hand, it positively affects the growth of fuel efficiency, as providing customer requirements on the compatibility of nuclear fuel, the competing suppliers (manufacturers) are interested in improving the quality and performance of its fuel. On the other hand, competition between suppliers (manufacturers) promotes the establishment of a market (grounded) price for the supply of fuel.

Implementation of diversification of nuclear fuel supply to Ukrainian NPPs started soon after the signing of the Agreement between the Government of the United States of America and the Government of Ukraine concerning the Ukraine Nuclear Fuel Qualification Project [1] at June 6, 1998. The company Westinghouse won the tender for nuclear fuel supply and technology of its design in Ukraine. An important role in the results of the tender was the fact that the company Westinghouse had already designed the fuel for WWER-1000 reactor at the NPP "Temelin" (Czech Republic) before tender. Choice of Westinghouse as a potential alternative supplier of nuclear fuel to Ukrainian NPPs best meets the objectives of diversification.

The Ukraine Nuclear Fuel Qualification Project provided development and introduction of alternative nuclear fuel, which would be compatible with the TVEL design fuel under operation of mixed cores. The South Ukraine Nuclear Power Plant (SUNPP) Unit №3 was chosen for test operation of Westinghouse nuclear fuel [2].

The project was implemented in two phases [3]:

— six Lead Test Assemblies (LTA) were manufactured, supplied and operated at the SUNPP Unit №3;
— pursuant to the second phase a reload batch of 42 Westinghouse fuel assemblies (hereinafter WFAs) was produced and loaded for WFAs test operation on the SUNPP Unit №3.

During the project implementation also:

— the Russian JSC "TVEL" and Westinghouse design fuel assemblies (FA) compatibility substantiation was performed;
— trial operation of LTAs was permitted by Ukrainian Regulator Authority;
— six LTAs have been successfully operated during four fuel cycles provided by the SUNPP Unit No3 project (the 17th to 20th fuel cycles from 2005 to 2010). Moreover, as part of the mixed core loading of the last 20th cycle in addition to TVEL' FAs of TVS-M design and Westinghouse LTAs the 42 other TVEL' FAs of TVSA design were in operation. These latter FAs are characterized by high lateral stiffness due to the inclusion of rail corners in the frame design. Average burnup of unloaded LTAs was ~43.56GW*d/tU, while the maximum values reached 46.00 GW*d/tU;
— based on the positive results of the six LTAs trial operation, for the 21st SUNPP Unit No3 fuel cycle the first 42 Westinghouse fuel assembles (WFAs) reload batch, and WFAs were operated in surrounding of 79 TVS-M and 42 TVSA type FAs during 21th fuel cycle.

The design of the first reload batch of 42 WFAs is similar to LTA. However, the FA project improvement and transfer of FA produce from Columbia factory (South Carolina, USA) to Vesteras factory (Sweden) have led to some changes in the design. Main differences are [4]:

— the improved frame stiffness by mounting of intermediate and upper spacer grids to guide channels;
— application of gadolinium oxide (Gd_2O_3) as an integrated burnable absorber, rather than zirconium diboride (ZrB_2) thin fuel tablet cover layer, used earlier in the LTAs design;
— application of zirconium alloy (zirconium with one per cent niobium) for all intermediate spacer grids instead of alloy 718 due to a low neutron capture cross-section and high corrosion resistance.

Based on the positive results of the six LTAs trial operation and of the first 42 WFAs reload batch of the unit №3 of SUNPP operator NNEGC Energoatom had expanded the use WFAs at the unit №2 of SUNPP. The second 42 WFAs reload batch was refueled for 22th fuel cycle at the unit №3 of SUNPP and total number of WFAs amounted 84 in the core of this unit. Moreover, the first 42 WFAs reload batch of was refueled for 24th fuel cycle at the unit №2 of SUNPP. Next operation of the WFAs in these companies at SUNPP unit №2 and unit №3 was held without any problems.

Some outer spacer grid deformation were identified in 2012 during core refueling SUNPP unit №3 after operation of 22th fuel cycle [5]. The systematic character of the detected deformations was confirmed by the results of the inspection of reload batch of 42 WFAs during scheduled core refueling at SUNPP unit №2 in June 2012. An investigation of the WFA grid deformation causes concluded the necessity of strengthening WFA frame. Expansion and operation of delivered in 2012 and 2013 WFAs were temporary suspended.

Next WFA modification (RWFA) is developed by Westinghouse to avoid the outer straps of WFA spacer grids deformation. Westinghouse used spacer grids with modified outer strap and increased thickness. In the intermediate spacer grids the additional inner straps were added. Material of spacer grids changed from zirconium alloy to stainless. Additionally, design of top and bottom nozzles was changed [5]. First reload batch of improved 42 RWFA was loaded for 25th fuel cycle of unit №3 in August 2014.

Therefore, three various FA types (WFA and RWFA of Westinghouse design and TVSA of TVEL design) were installed simultaneously in the core of the SUNPP unit №3 during the 25th fuel cycle.

At present time distribution of loaded diversified FAs on Ukrainian NPPs looks as follows:

— SUNPP unit №3 during 27th fuel cycle was loaded simultaneously with two different FA types (3/4 core - RWFA of Westinghouse design). At the second half of the 2018 there are plans to load full reactor core of unit №3 with FA types of Westinghouse design;
— SUNPP unit №2 during 29th fuel cycle was loaded simultaneously with two different FA types (2/4 core - RWFA of Westinghouse design);
— ZNPP unit №1 during 29th fuel cycle was loaded simultaneously with two different FA types (1/4 core - RWFA of Westinghouse design);
— ZNPP unit №3 during 30th fuel cycle was loaded simultaneously with two different FA types (1/4 core - RWFA of Westinghouse design);
— ZNPP unit №4 during 30th fuel cycle was loaded simultaneously with two different FA types (1/4 core - RWFA of Westinghouse design);
— ZNPP unit №5 during 29th fuel cycle was loaded simultaneously with two different FA types (3/4 core - RWFA of Westinghouse design);

Moreover, operator of Ukrainian NPPs has plans to extend Westinghouse FA supplies also on 3rd unit of Rivne NPP.

2. ASPECTS OF SAFETY AND LICENSING REGARDING MIXED CORES OPERATION

2.1 Compatibility

The design and licensing of a fuel load in a reactor core is a complex undertaking, even without the additional complication of differing fuel performance. The issues that need to be considered include the basic geometrical compatibility of the various types of fuel, their differing thermal-hydraulic characteristics and nuclear behavior [6]. For safety justification of the transition cycles, and mixed cores where several types of fuel are operated simultaneously, the initial core limits and safe operation conditions are implemented. The unit 3 SUNPP core with WFAs is refueled according to the current practice developed to Ukraine's NPPs. The WFAs enrichment and profiling for transition cores consider the following factors:

— assurance of core power requirements;
— nuclear interchangeability and compatibility with the inventories of current FA design;
— meet all specification constraints for all types of jointly operated fuel;
— power reduction in the hot WFA channel due to the hydraulic irregularity of the core.

The transition and the equilibrium cycles with an annual fee of 42 WFAs were also developed. As follows from the comparative analysis of cycles from justification materials, the main nuclear parameters used by the Russian design FA and WFA in the safety evaluation for the equilibrium cycle are very close.

The program of the post-irradiation evaluations (PIE) was developed to examine the Westinghouse fuel performance and to demonstrate the capability of WFA operation in the WWER-1000 core. The based on the standard NPP methods program contains a FA structural component on each face visual inspection as well as a FA length measurements in the core; dropping time of Rod Cluster Control Assembly (RCCA) and drag force at the start and end of cycle; assembly drag forces during core loading and off-loading and insertion in the condensed spent fuel pool racks. In addition, measurements of FA elongation, FR growth and bow, and FA distortion were conducted using the Westinghouse fuel inspection / repair equipment (FIRE) during the 2012 outage at SU3. Evaluation of the experimental data demonstrated that elongation of the FA, growth and bow of FR due to irradiation, and corrosion of spacer grid and fuel pin cladding met the design limits. The deformation of assembly (bow and twist) have not influence on the dropping time of the RCCA. During the fresh WFA loading into the mixed core with the co-resident TVSA fuel, the deformation of zirconium alloy outer strap was found. The fundamental investigations carried out, it allowed the root cause of the grid outer strap deformation to be identified and to suggest modifications to the WFA design to avoid deformation to grids at a maximum of 225 kg of handling trip.

2.2 In-core monitoring system

Historically, Ukraine has the following situation. The whole core assembly-wise power distribution reconstruction software was developed by the Russian institutions as a fuel supply country presentative. This software originally dealt with design and the physical characteristics of Russian assemblies. For example, a accounting of axial profiling of uranium-235 enrichment in fuel pin was not carried out by the fuel supplier, and therefore the reconstruction software could not deal with axially profiled fuel. This problem had been already faced by the South Ukrainian NPP with the organization of the trial operation of 6 LTE produced by Westinghouse which had an axially profiled enrichment [7].

Two different approaches to the in-core monitoring systems (ICMS) modification for controlling kinetic and thermophysical parameters of reactor core with WFA were introduced and put into commercial operation at the units 2 and 3 of SUNPP:

- the ICMS is used at the 3rd Unit of SUNPP, where the Westinghouse BEACON system was used as the top-level software;
- the previously installed program "Voyage" is modified for reactor core control with WFA at the 2nd Unit of SUNPP. ICMS software developer implemented the calculation mode with few group cross section libraries prepared by the Russian SVL program, which is the property of the Russian company SNIIP-Atom.

With the further extension of Westinghouse fuel assemblies on the Zaporizhzhya NPP units, the operator identified the next two main ways of problem decision:

- replacement of the integrated "Voyage" software with the software for physical calculation BEACON – a case of dissemination of the 3rd Unit of SUNPP experience;
- new few groups cross section library preparation for Westinghouse fuel and its application in the format "Voyage" with following testing without replacing the ICMS software and hardware.

The ICMS program BEACON has been built for today on Units № 3 and 4 of Zaporizhzhya NPP's. But the second option is also implementing by the operator – the first stage of the trial operation of renewed few group cross section library was carried out at the 5th unit during a 27th fuel cycle, in this case measured data was not output to operator for the reactor controlling and worked with BEACON software parallely. The successful results of the first stage of the trial operation provided reasons for decision to continue the trial operation at the second stage. It was done during a 30th fuel cycle at unit 4, but for this once operational data was output for reactor control to operator.

3. FUEL MANEGMENT

3.1 Fuel transportation

To obtain permission for the first Westinghouse assemblies transportation in the U.S. fuel shipping package MCC-5 through the territory of Ukraine, operator provided Regulatory Authority the U.S. certificate with substantiation documents for its multilateral approval. The safety substantiation documents were a subject of multifaceted state technical review in such areas as safe handling of nuclear materials, nuclear and radiation safety, strength and structural reliability. According to the existing practice of Ukrainian Regulatory Authority, the primary certificate was approved on the ground of a comprehensive analysis of justifying materials.

In 2016, due to the expiration of the certificate on the MCC-5 container, operator provided to the Regulatory Authority documents in the framework of the multilateral approval of certificate for a new type of shipping package "Traveller-VVER" based on the US NRS certificate that will be valid until March 2020. A permanent neutron flux trap and single fuel assembly confinement system distinguish the Traveller package design from the MCC package that was previously being used to transport fuel assemblies. It should be noted that both packages are much safer than transport container TK-C5, in which Russian design fuel is supplied. So the critical safety index of "Traveler-VVER" amounts 0.7, as TK-C5 has a value of 4.17. This means that 150 packages "Traveler VVER" provide fulfillment of the nuclear safety criterion under emergency conditions of transportation and 375 - under normal conditions. For TK-C5 packages, the minimum relevant values are 18 and 45 ones.

3.2 Equipment for fuel inspection and repair

The regular monitoring of the condition of the Westinghouse fuel assembly during four fuel cycles was defined as one of the Regulatory Authority's requirements for its implementation. Westinghouse has designed and produced a Fuel Inspection and Repair Equipment (FIRE) for this purpose. Using this equipment allows studying fuel assemblies and fuel rods, as well as obtaining additional information about conditions of fuel assemblies during the refueling operation time.

Firstly, nuclear fuel inspection was carried out by staff from Westinghouse Electric Sweden AB. Starting from 2017 utility staff self-sufficient performs the entire inspection complex: assembling and setting up of FIRE and all its measuring systems, control of fuel and subsequent dismantling of the equipment. Westinghouse specialists attended the inspection at SUNPP and ZNPP as observers. In particular, in June 2017, utility staff conducted fuel inspection in the amount of 8 Westinghouse assemblies at the unit 5 of Zaporizhzhya NPP.

The nearest objectives of the utility on using equipment are: adapting the FIRE to the capability of the Russian design fuel assembly inspection; improving the design of the equipment for removing foreign objects from fuel assemblies; performing scheduled fuel inspections during the long repair operation period without affecting the refueling operation terms and conditions of NPP power units, etc.

3.3 Interim storages

The on-site interim spent fuel storage facility (ISFSF) is used for storage of spent fuel assemblies from units of Zaporizhzhya NPP. Its design based on a ventilated storage cask (VSC-24) system, which was developed by US Sierra Nuclear Corporation (SNC) and licensed by US NRC. The analysis of temperature, deformation and strength characteristics of Westinghouse fuel assembly’s fuel elements and the most important design components of storage cask for transport-lifting operations was carried out in justification of the safety of ISFSF operation with the spent fuel assemblies of Westinghouse design.

For storage of spent fuel assemblies from units of South Ukraine NPP using of Central Spent Fuel Storage Facility is provided. Technology and equipment for the project are provided by the US company Holtec International. Safety analysis report was developed in the framework of facility licensing providing for the storage of spent fuel assemblies of Westinghouse design.

4. APPROACHES OF UKRAINIAN REGULATORY REVIEW FOR CARRYING OUT INDEPENDENT CONFIRMATORY CALCULATION

Being a technical support organization of Ukrainian Regulatory Authority's, State Scientific and Technical Center for Nuclear and Radiation Safety "(SSTC NRS) is engaged in the licensing process for new type of fuel implementation at units of Ukrainian NPPs. One of the main SSTC NRS approach during state technical review of substantiation materials includes performing independent confirmatory calculations for new fuel type implementation nuclear safety issues as much as possible. SSTC NRS intends to confirm its decision by quantitative assessment of neutron kinetic and thermohydraulic, operational, radiation safety analysis issues, strength and structural reliability questions etc. For given purpose SSTC NRS is provided by powerful calculating capabilities by way of complex of codes and models [8].

Established licensing process practice of new fuel type implementation at units of Ukrainian NPPs supposes the next independent verification calculations to be carried out:

— fuel assembly multiplication capabilities and preparation of few group cross-section library;
— neutron kinetic characteristics of stationary as well as transitional fuel cycles;
— fuel pin thermal hydraulic reliability in normal operation modes as well as in accidents;
— fuel storage, transportation and handling system criticality;
— estimation thermo-mechanical fuel pin characteristics in normal operation modes and in accidents;
— evaluation of new fuel type implementation effect on radiation load at reactor vessel.

Under development of calculation models, almost all mixed core features were considered on each mentioned issue.

In the context of provision of few group neutron cross section library the such differences between all used fuel assembly types are considered as differences in geometry of fuel pin (dimensions or absence of central gas hole, outer diameter, etc.) and related to it issues such as choice of fuel temperature for depletion calculation, differences in geometry and material of constructional elements (central and guide tubes, spacer grids, presence of stiffness corners in fuel assembly design), fuel enrichment radial profiling, using of burnable absorber, type of burnable absorber application (covered/integrated, etc). Taking into account additional heterogeneity of mixed cores from point of view neutron kinetic aspects such advanced features were included into few group neutron cross section library as assembly discontinuity factors and sub-library for accounting spectral history effect. In frame of few group neutron cross section library preparations, the effect of corner at neighbored FA on peripheral row pin power was studied also. Results of given studies were used for assessment of margin sufficiency in pin power distributions during burnup of mixed cores [9].

Regard to core modelling attention was paid to the design differences of spacer grids, top and bottom nozzles that caused a different hydraulic resistance coefficient of each type of FAs. Difference between total hydraulic resistance coefficient of RWFA and TVSA type fuel assemblies amounts ≈36%. It caused redistribution of coolant flow rate in mixed core that it's necessary to take into account during analysis of core kinetic characteristics and fuel pin cooling.

Thanks to flexible capabilities the composed calculation model for WWER-1000 mixed core allows to account next features:

- use individual coefficients of hydraulic resistance for each type of fuel assembly;
- for each type of fuel assembly, using separate thermal physical properties (such as thermal capacity and conductivity) of pin materials (fuel and cladding) in the heat transfer model;
- separate masses of uranium per different type of fuel assembly;
- irregular core model axial meshing due to axial profiling (accounting WFA and RWFA concept of blankets);
- features of fuel pin configuration – fuel and cladding inner / outer diameters, gap width between fuel and cladding filled by gas for different type of fuel assembly.

In the context of analyzing mixed core characteristics, greater emphasis was placed on compliance with next parameters:

- assembly- and pin-wise peaking factors, linear powers of fuel pin in core volume;
- assembly- and pin-wise burnup distribution;
- reactivity coefficients;
- individual CR, group-wise and whole scram efficiency, etc.

Considering the hydraulic resistance coefficients differences of each assembly type, certain limits have been set more stringently than regulation [10] namely pin-wise power peaking factor. Additionally, these limits are modified as a function of the amount of loaded fuel assemblies of each type in mixed core for each next fuel cycle. For example, different peaking power limits Fq for three different FA types were established for the first transitional (25th) fuel loading of SUNPP unit 3. For further transitional fuel loadings a difference between power peaking power Fq limits for different FA types is decreased.

Presently, in the context of the safety analysis study in Ukraine, the best estimate computer codes combined with conservative initial and boundary conditions (combined analysis) are used for design basis accident (DBA) analysis. With regard to reactivity induced accidents (RIA) for a given purpose, the technique is evolved to incorporate all significant conservative initial and boundary conditions into realistic reactor core model. Introducing of conservative values of all key parameters are provided in developed models for purpose of DBA analysis. Taking into account given approach for independent verifying calculation such conservative initial and boundary conditions were chosen that covered all FA type limit requirements. Consequently, it caused more conservative results than presented ones in safety justification materials. Thus for most representative initial event of RIA group, control rod ejection, the maximal values of fuel and cladding temperature by the verifying calculation are significant greater than ones by justification material. However, the acceptance criteria are met even under such conservative initial and boundary conditions.

The confirmation calculations under RWFA implementation for the study of the thermomechanical fuel behavior were carried out for both normal operating modes and accidents. Individual fuel pins linear power histories for all transitional and stationary fuel cycles was taken into consideration. Additional margin factor 1.2 was applied to linear pin power. Main attention was focused to the pins with maximum linear power value and maximum burnup value. Verifying calculation results gave only slight divergences from justification material results – for example, ≈0.5MPa in gas pressure into the pin or ≈100ºC in fuel pellet temperature or normal operation modes. These divergences caused by the difference in both models and library of independent thermomechanical codes and in linear powers that are used as initial data for this kind of calculations. Accordingly, a fulfilment of acceptance criteria was confirmed for normal operation modes. Besides normal operation modes a fulfilment of acceptance criteria was confirmed also for an initial event "control rod ejection" as the most representative of RIA group by verifying calculation.

Another important issue of carrying out of verifying calculation is an estimation of effect on reactor vessel neutron fluence. The submitted safety substantiation of RWFA implementation materials had a drawback that is the lack of direct assessment of this impact. Alternatively, a comparison of peripheral FA power distribution (that gives maximum contribution to vessel radiation load) has been given. A reduction in power of the peripherial fuel assemblies was shown as evidence of reduced rates of reactor vessel radiation load. The confirmation calculations of WFA to RWFA transition impact regarding vessel radiation load were performed with state technical review. The full 3D-scale model with pin-wise distributed neutron sources was used under carrying out of calculations in accordance with recommendations [11]. The results of the confirmatory calculation indicated a decrease in the growth rates of vessel radiation load of 5-7 per cent. However, taking into account the length of the transitional fuel cycle, the calculation of the average vessel flux for the cycle is more relevant in this case. With regard to the averaged over fuel cycle flux at the pressure vessel, its reduction in most presentative axial layer amount almost 3 per cent.

Among wide range of the verifying calculations under RWFA introduction, the next aspects should be pointed also:

- performed as usually verifying calculations of fuel management criticality system were avoided due to new fuel (RWFA) smaller enrichment and neutron-multiplying properties;
- verifying calculations of isotopic composition with accounting a conservative engineering margin that allows to apply «burnup credit» approach for analysis of criticality safety in the transportation, storage and treatment of spent fuel;
- verifying calculations of residual heat of spent fuel that aimed to assessment of residual heat increase due to transition to RWFA fuel. However, concerning RWFA introducing, verifying calculation pointed to insignificant residual heat increase in range of 0.3%.

Thus the calculating models developed by SSTC NRS take into account most issues of the new fuel type implementation and mixed core features. Performing confirmatory calculations as an important part of the licensing process significantly increases the quality assurance of the state technical review. It gives reasonable assurance to the Regulatory Authority that the safety substantiation materials are being properly developed and assessed.

5. CONCLUSIONS

Nuclear fuel suppliers' diversification is a strategic task to ensure continuous operation of Ukrainian nuclear power plants and one of the key energy security issue. A consequential activity have been realized on this issue by operator and vendor on one side, and regulatory authority together with technical support organization on other. Ukraine today takes the position of leadership in East Europe's nuclear fuel supply diversification process.

Alternative supplier nuclear fuel usage challenge at half of all units of Ukrainian NPPs in fully meet the European Energy Security Strategy statement regarding need of diversified overall fuel supply portfolio for plant operators.

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TOPICAL SESSION 2.2

RADIATION AND WASTE MANAGEMENT SAFETY

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Session 2.2 presented a wide range of topics linked to radiation and waste management safety. The presentations focused on how to formalize the practical elimination of large releases, the development of an expert network on waste management safety and the modernization of a remote monitoring network. The TSOs can play a significant role in enhancing safety by developing new ideas and techniques and their guidance on safety principles should be part of the development of IAEA Safety Standards in these fields. The value in wider networks that include TSOs, regulatory bodies and civil society, especially in the area of waste management, was highlighted. Participants pointed out the necessity to balance the diverse needs of the regulatory body and the public, especially in areas such as radiation monitoring.

NUCLEAR SAFETY SHOULD BE AS HIGH AS REASONABLY ACHIEVABLE

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Abstract

After Fukushima nuclear accident, some new safety concepts and new safety requirements are proposed and discussed among the nuclear industry and nuclear safety regulatory authorities all over the world. Nowadays, "Design Extension Condition" and "practically elimination of large radioactive release" have been widely accepted and adopted by design requirement of NPP latest published by IAEA and P. R. China. In the paper, "nuclear safety as high as reasonably achievable" are discussed, in order to identify the safety vulnerabilities in the design of NPPs, and reasonable practicable measures should be taken to minimize the probability and/or the consequence of residual risk, and to achieve the safety goal of practically elimination of large radioactive release.

1. NUCLEAR SAFETY: AN IMPORTANT PART OF NATIONAL SECURITY

The development and utilization of nuclear energy has brought new impetus to human development. Meanwhile, development of nuclear energy is also accompanied by risks and challenges of nuclear safety. Although the international community has come to an agreement that the nuclear safety shall be strengthened, potential nuclear terrorism has become "The Sword of Damocles" in the international community with the rise of the threat of international terrorism. Nuclear materials and nuclear facilities throughout the world are at risk of nuclear pollution, nuclear releases and even nuclear attacks due to nuclear accidents and nuclear crimes. All these unsafe factors can cause major disasters to human society. Therefore, nuclear safety is not only a national but also a global issue.

Nuclear safety concerns people's health, social stability and economic development. It even affects fate, prospect and future of a country. Nuclear safety is an important part of national strategic security. China promulgated the "National Security Law of the People's Republic of China" on July 1, 2015, incorporating nuclear safety into the national security system along with political security, homeland security, military security, economic security, cultural security, social security, science& technology security, information security, ecological security, resource security etc., which demonstrates a clearer and more explicit definition of nuclear safety. Nuclear safety is not only a technical issue but also a political issue. Certain nuclear safety issues cannot be considered only from a technical point of view but need to be planned in an integrated manner and comprehensive measures must be taken to achieve effective solution.

2. NEW SAFETY GOAL: TO PRACTICALLY ELIMINATE POSSIBILITY OF LARGE RADIOACTIVE RELEASE

After the Fukushima Daiichi NPP was hit by the twin disasters of strong earthquake and tsunami, a severe nuclear accident occurred, which resulted large amount of radioactive substances were released to the environment. However, the fact that the Fukushima nuclear accident has so far caused no direct death of person and is expected to witness no significant increase of cancer risks and furthermore compared with earthquakes and tsunamis directly causing death or disappearance of nearly 20,000 people, which fully demonstrated that the safety level of the Fukushima Daiichi NPP can meet the safety goal of two "one-thousandths" (as proposed by NRC). In terms of this perspective, the Fukushima nuclear accident proves the robustness of the safety of NPPs.

However, on the other hand, as the Fukushima nuclear accident still caused serious environmental pollution and enormous economic losses, the consequences of the accident were severe, the Fukushima nuclear accident was considered unacceptable. Therefore, in addition to meeting the safety goal of the two “one-thousandths,” NPP designers must also take into consideration new factors such as environmental damage, public panic, and social stability as the result of nuclear accidents. NPP designs should shift to a new safety goal “practically elimination of large radioactive release”.

The Chinese government has required clearly in “The 12th Five-Year Plan for Nuclear Safety and Radioactive Pollution Prevention & Control and Vision for 2020” [17] to be issued in 2012 that: new nuclear power units are being or to be constructed during the period of 13th Five-Year Plan and beyond strive to achieve the goal in design to practically eliminate the possibility of large radioactive release. In the “13th Five-Year Plan for Nuclear Safety and Radioactive Pollution Prevention & Control and the Vision for 2025” released in 2017, it is clearly stated that newly built nuclear units will maintain international advanced level and achieve in design the goal to practically eliminate large radioactive release.

The new safety goal of “practically elimination of large radioactive release” not only considers political factors such as to restore public confidence in NPP safety after the Fukushima nuclear accident, but also brings forward higher safety requirements of NPP designs from technological and engineering perspectives: under the condition of design basis accident (DBA) and design extension condition (DEC), accidents in nuclear power plant will not result in significant release of radioactive substances; under extreme conditions, there will be no large-scale release of radioactive substances, so as to protect people, society, and the environment from hazards, and in particular, from accident scenarios similar to the Fukushima accident which caused lasting serious pollution on the surrounding environment. The new safety goal of “practically elimination of large radioactive release” is not intended to abolish off-site emergency plan & response because the Fukushima nuclear accident has proved importance of the off-site emergency plan & response. The term hereof "large release", refers to radioactive release scenario similar to that of the Fukushima nuclear accident.

China National Nuclear Safety Administration released a new version of “Safety Regulations for Nuclear Power Plant Design (HAF102-2016)” in October 2016. HAF102-2016, as one of the important documents in China's nuclear safety regulation/law system, specifies binding requirements for design, specification and arrangement of structures, systems, and components important for safety of NPPs, as well as requirements for conducting comprehensive safety assessment. HAF102-2016, with reference to the IAEA Nuclear Power Plant Safety: Design (SSR2/1, Rev.1), also incorporates relevant requirements published by regulatory bodies and organizations such as the United States Nuclear Regulatory Commission (NRC) and the Western European Nuclear Regulators’ Association (WENRA), such as protection against malicious impact by commercial aircrafts.

HAF102-2016 lays equal stress on the following three issues: (1) equal emphasis on prevention of both internal events and external events; (2) equal emphasis on both prevention and mitigation of severe accidents; and (3) equal emphasis of both deterministic and probabilistic approach. Major upgrades introduced in HAF102-2016 include: (1) to strengthen prevention of radiological consequences unacceptable to the public and the environment; (2) to avoid early release and long-term pollution on the surrounding environment by taking measures for severe accident mitigation; (3) to prevent severe accidents through NPP design, including strengthening the fourth level of defence in depth, considering consequences of external events and maintaining sufficient safety margin; (4) to strengthen reliability of ultimate heat removal; (5) to consolidate emergency power supply; (6)) to enhance safety of fuel storage to avoid exposure of fuel; (7) to provide interfaces to facilitate uses of mobile devices where necessary; (8) to strengthen performance of emergency response facilities.

In general, as long as new NPPs meet the requirements of HAF102-2016, it would be reasonable to say that NPPs achieve the goal in design to practically eliminate the possibility of large radioactive release.

3. RESIDUAL RISKS SHOULD NOT BE NEGLECTED

NPPs which practically eliminate large radioactive release in design can be considered to be "absolutely safe" in a common sense. However, there are still residual risks from a technological point of view. Residual risks refer to risks related to beyond design basis conditions which NPP designers fail to clearly identify (or recognize) or believe to be with very low probability of occurrence and currently there are no reasonable and effective measures in place to guard against. There are two scenarios of residual risks: (1) events that are beyond current human cognition; and (2) events that have a very low probability of occurrence and currently there are no reasonable and practical measures to deal with.

Residual risks are generally considered to be very small in the past NPP designs so there is no need to take corresponding measures. The Fukushima accident shows that residual risk is still an important risk that cannot be ignored. It is generally believed that residual risk is mainly caused by extreme external events and human malicious damage will induce events that are beyond design considerations. These are new areas and new issues in nuclear safety research. It is advisable to minimize consequences of residual risks by such measures as increasing safety margins, adopting supplementary safety measures, and strengthening defence-in-depth. Design and setup of supplementary safety measures should be based on the principle that nuclear safety should be as higher as reasonably achievable and ensue there being no negative effects. To this end, various factors that may cause residual risks and accompanying consequences should be comprehensively taken into consideration to avoid adverse effects on response functions dedicated to normal operation, anticipated operation occurrence (AOO), design basis accident (DBA) and design extension condition (DEC).

Extreme external events and human malicious damage can led to extensive damage of structure, system and component of NPP, so the utility of NPP should prepare extensive damage management guideline (EDMG) and Emergency response procedure to mitigate the consequence of such accident should they occur.

4. NEW AREAS AND ISSUES IN NUCLEAR SAFETY

Nuclear safety is an area of continuing learning, updating, and improvement with good experience feedback systems. Safety of nuclear facilities can be effectively improved through in-depth analysis of all types of incidents, internal and external, domestic and foreign, and even of other industries, to find direct and root causes and then to take appropriate and effective measures toward eliminating potential safety risks.

Accidents or disasters can be considered in nuclear safety include: Three-mile Island nuclear accident (human factor), Chernobyl nuclear accident (nuclear safety culture), Fukushima nuclear accident (extreme natural disaster, nuclear safety culture), 911 Terrorist Attack (malicious impact by large commercial aircraft) in New York, US, “8•12” fire and explosion accident in Tianjin Port, China, and the aviation accidents of German wing Airline 4U9529 (psychological problems of personnel in special positions such as operators of nuclear facilities).

The new areas of nuclear safety that have received attention include: (1) impact of extreme natural disasters; (2) impact by large commercial aircraft; (3) cyber security of nuclear facilities; (4) mental health of nuclear facility operators; (5) prevention of and strike at terrorism targeting nuclear facilities.

5. A NEW CONCEPT OF NUCLEAR SAFETY: AS HIGH AS REASONABLY ACHIEVABLE (AHARA)

The lessons learned from the Fukushima nuclear accident show that due to limitations of human cognition, NPPs are faced by potential uncertainty in safety, namely, residual risks. In the light of extreme importance of NPP safety, NPP designs should adopt a nuclear safety concept of As High As Reasonably Achievable (AHARA), that is, all reasonably achievable and practically effective measures should be taken to ensure NPPs achieve a higher safety level than what is required by nuclear safety regulations and laws. It means that both deterministic and probabilistic methodologies should be used to identify the safety vulnerabilities in the design of NPPs, and reasonable practicable measures should be taken to minimize the probability and/or consequence of residual risk, and to achieve the safety goal of practically elimination of large release of radioactive materials.

AHARA principle of nuclear safety is very similar to ALARA principle of radiation protection, and AHARA principle is consistence with the spirit of nuclear safety culture and highest safety standard.

The principle of AHARA is the driving force and basis for continuous improvement of nuclear safety in the future. Promotion of AHARA concept will help continuously improve nuclear safety through latest technologies and research results and will encourage nuclear safety regulatory body and its technical support organization to take more active efforts to improve nuclear safety and to update nuclear safety requirements through reviewing practices and experiences in improving nuclear safety.

In the paper entitled “Discussion of some new safety concepts and new safety requirements in light of the Fukushima nuclear accident”[1] presented during the third TSO international conference in China, some of these new safety concepts have been widely accepted and have been adopted in HAF102-2016, but there are different opinions regarding AHARA in nuclear safety regulatory body and in the nuclear industry despite that AHARA had been adopted in the design of CAP1400.

The main reasons of disagreement include: (1) Some leaders and experts in the nuclear safety regulatory body think that nuclear supervision and its related safety review should be based on clear and definite acceptance criteria. If AHARA is adopted, there will be no clear and definite acceptance criteria, and there will be some uncertainty for the project being reviewed, and meanwhile the reviewer can have chance of power rent-seeking. (2) Some leaders and experts in the nuclear industry think that the cost of NPP will increase and nuclear power will lose its competition if AHARA is adopted.

AHARA not only reaches higher safety level, but also emphasizes reasonably achievable. For example, Diversity actuation system (DAS) is required to be safety class in some countries, however DAS is not necessary to be safety class as it is not reasonable and inconsistent with the safety classification principle. The digital protection system for DBA is safety class, the DAS system is used to mitigate DBA coincident with failure of digital protection system which has lower probability than DBA, so DAS may not safety class. Promotion of AHARA can be a driving force to use best achievable technology (BAT), to reach a higher safety level without increase the cost. There are some cases where the designers don't want to use more advance and cheaper technology because they consider that their design can meet the safety requirement.

6. CONCLUSION

Due to limitations of human cognition, NPPs are faced by potential uncertainty in safety, and the residual risks should not be neglected. In the light of extreme importance of NPP safety, NPP designs should adopt principle AHARA, so as to identify the safety vulnerabilities in the design of NPPs, and to take reasonable practicable measures to minimize the probability and/or the consequence of residual risk, and to achieve the safety goal of practically elimination of large radioactive release.

AHARA not only reaches higher safety level, but also emphasizes reasonably achievable.

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SITEX_NETWORK FOR THE DEVELOPMENT OF SUSTAINABLE AND INDEPENDENT TECHNICAL EXPERTISE ON RADIOACTIVE WASTE MANAGEMENT: *General overview of the Network and its interactions with Civil Society*

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Abstract

SITEX_Network is an association with a purpose to enhance and foster cooperation at the international level in order to achieve a high-quality Expertise Function, independent from organizations responsible for the implementation of waste management programmes, aiming at supporting the Nuclear Regulatory Authorities (NRAs), as well as the Civil Society (CS), in the field of safety of radioactive waste management including disposal. The network is currently composed by 14 organizations (Bel V, EIMV, GI-BAS, ENERGIAKLUB, FANC, MKG, Mutadis, NTW, IRSN, PSI, SURO, SYMLOG, VTT, TS Enercon). The added value to other existing TSOs and regulator's networks is seen in bringing together different categories of contributors to /end-users of the expertise, such as TSOs, Research Entities (REs), NRAs and CS organizations. SITEX_Network entails activities related to R&D and Safety Case Review methodology and practices, as well as training and work on how to promote efficient interactions with CS and institutional experts. Moreover, SITEX_Network intends to maintain and further develop the position of the Expertise Function within the international R&D scene, and for instance within the future European Joint Programming on Radioactive Waste Management (which includes disposal). The paper will give an overview of the SITEX_Network objectives, current programme of activities and interactions with CS.

1. GENERAL OVERVIEW OF SITEX_NETWORK

1.1 Context

In the context of Geological Disposal (GD), the mission of the Expertise Function is to support the regulatory function as illustrated in Fig. 1 [1] by ensuring that the disposal facility is developed, constructed, operated and closed in a safe manner, without imposing undue burdens on future generations i.e. people and the environment are protected against the hazards of ionising radiations emitted by the disposed radioactive waste. This mission involves several types of activities, such as participating in the establishment of regulatory requirements, developing guidance for meeting these requirements at the different stages of the licensing process, as well as evaluating the Safety Case (SC) developed by the Waste Management Organization. As stated by article 6-2 of the EC Directive 2011/70/Euratom of 19 July 2011 [2], the regulatory function has to be independent of the implementing function fulfilled by WMOs. Accordingly, the independence of the regulatory function calls for the support of an independent Expertise Function that develops and maintains the necessary know-how and skills in the field of safety of radioactive waste management. For complex issues such as those associated with the operational and long-term safety of waste disposal facilities, this can be notably achieved by performing and/or overseeing R&D activities in support of safety analyses and activities such as exchanging on practices, establishing states of the art and transferring knowledge. These activities are important for developing the technical expertise of organizations with an Expertise Function and are necessary to build the credibility of their technical competences (e.g. vis-a-vis the civil society), integrity and judgement. Moreover, the need in such activities is clearly identified in international recommendations and requirements For instance, Article 8 of the 2011/70/EURATOM directive requires all parties, i.e. Expertise Function included, to carry out education, training and R&D activities. It is also stressed in IAEA safety guides that the Regulatory Body (RB), and thus its supporting organisations (see Fig. 1), may need to conduct or commission R&D in support of regulatory decisions (see IAEA GS-G-1.1 [3] (see §3.33) and IAEA GS-G-1.2 [4] (see §3.68)). The European Commission (EC) has considerably supported collaborative R&D projects involving TSOs, notably through the EURATOM programme on radioactive waste management. Today, the EC supports the implementation of a Joint Programming (JP) on radioactive waste management including disposal between the European Member States, considering the stage and the priorities of their national programmes. The objective for the EC is to promote and co-fund ambitious joint programmes rather than individual projects, bringing together entities from EU Member-States and associated countries.

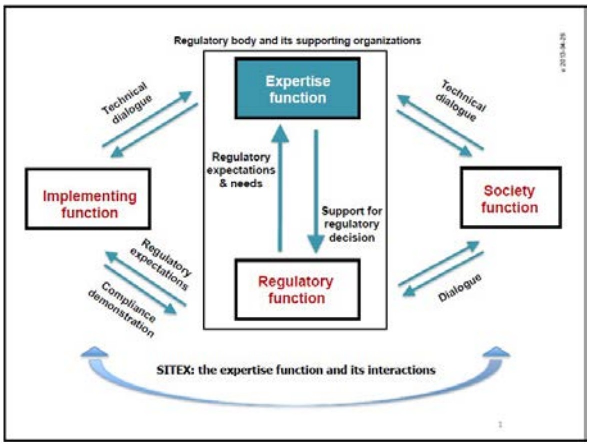

FIG. 1. The Expertise Function and its interactions [1].

1.2 From SITEX projects to SITEX_Network

The EC FP7 SITEX and H2020 SITEX-II [5] projects (SITEX stands for "Sustainable network for Independent Technical EXpertise of radioactive waste disposal", and II for "Interactions and Implementation") gathered NRAs, TSOs and REs fulfilling an Expertise Function, as well as civil society (CS) experts, interacting with a wider group of European CS organisations involved in the field of radioactive waste management. The overall objective of these projects was to prepare the foundation of the SITEX_Network aiming at consolidating at the international level the knowledge base and expertise upon which organisations fulfilling an Expertise Function in the context of radioactive waste management can rely on, and to stimulate its sharing amongst all stakeholders, including CS. The possible activities and interaction modes of this network were respectively identified and tested in the SITEX and SITEX-II projects. In particular, the following tasks were carried out in the SITEX-II project:

- The definition of a Strategic Research Agenda (SRA) of the Expertise Function, taking into consideration the concerns and proposals of the CS. This SRA [6, 7] has been an important input for identifying the TSOs priorities [8] to be considered in the establishment of the future JP.
- Terms of references for the implementation of future R&D activities [9];
- The production of guidance on the technical review of the safety case [10, 11];
- The development of a training module for generalist experts involved in the SC review process [12];
- The development of interactions between institutional experts and CS [13];
- The preparation of the administrative framework for the SITEX_Network [14].

1.3 The SITEX_Network

Based on the results from SITEX and SITEX-II projects, the SITEX_Network was set up in 2018 in the form of a French non-profit Association by the following organizations: Bel V, EIMV, ENERGIAKLUB, FANC, GI-BAS, IRSN, MKG, Mutadis, NTW, PSI, SURO, SYMLOG, TS Enercon and VTT. The purpose of the network is to enhance and foster cooperation at the international level in order to achieve a high quality Expertise Function, independent from organizations responsible for the implementation of waste management programmes, aiming at supporting the Nuclear Regulatory Authorities (NRAs), as well as the CS, in the field of safety of radioactive waste management and disposal. SITEX_Network objective is achieved through close cooperation between its Members with a plurality of views and competencies, involved or willing to be involved in different waste management programmes at different stages of development: NRAs, TSOs, REs with an Expertise Function and non-institutional CS experts. Though the CS does not have any formal regulatory or Expertise Function, its views and concerns shall nevertheless be considered while developing a disposal facility, in respect of the Aarhus Convention that recognizes that *"improved access to information and public participation in decision-making enhance the quality and the implementation of decisions"* [15]. The Societal Function (carried out by non-institutional experts, CS groups and the public) therefore exerts vigilance and gives inputs that constitute a complementary contribution to safety case reviews. The added value to other existing TSOs and regulator's networks is seen in bringing together different categories of contributors to /end-users of the expertise, such as TSOs, REs, NRAs and CS. In addition to bringing to its members the benefits from its activities, SITEX_Network intends to maintain and further develop the position of the Expertise Function within the international R&D scene. Specifically concerning the R&D and other activities that will be performed within the first JP (if approved by the EC), being a SITEX_Network Member will allow to exchange and to develop common views on [16]:

- the joint activities implemented at EU level on radioactive waste management (including disposal);
- the development of high quality and balanced proposals having more chance to be selected for funding through the JP.

The management bodies of SITEX_Network are:

- the General Assembly (GA) organized in 3 colleges,
- the Management Board (MB) elected by the colleges and its Bureau.

Both are composed of Members of SITEX_Network. Each Member belongs to one of the 3 following colleges:

- College 1: Technical Expertise Function (comprises Technical Safety Organisations (TSOs) or other entities fulfilling this function for the Regulators, such as Research Entities (REs));
- College 2: Regulatory Function (comprises Nuclear Regulatory Authorities (NRA));
- College 3: Civil Society Function (comprises CS stakeholders who may either be individuals or groups, such as non-institutional experts, NGO's …) .

Members elect their college representatives in the MB, adopt a Roadmap and an annual plan of activities, bring forward proposals for activities, and assess the work to be performed by the network. The paramount activities of SITEX_Network may entail:

- R&D related activities, programmed via the SITEX_Network SRA and Deployment Plan: development of, or contribution to, high quality R&D project proposals, coordination or facilitation of participation in international projects (e.g. European Joint Programming), or of joint research within the network, guidance and advice to organizations fulfilling an Expertise Function in initiating R&D activities related to waste management safety;
- Activities related to Safety Case Review methodology and practices: exchanging on guidance and requirements, when appropriate formulating position papers or harmonizing approaches and practices (e.g., development of safety case reviewing procedures, development of safety case reviewing tools);
- Training activities: development of professional capabilities, preparation and delivery of training programmes at European level for generalist experts and about specific technical domains, that may include training courses, seminars, visits to disposal facilities sites and underground research facilities, safety case review exercises;
- Work on how to promote efficient interaction with CS and its experts: establishing principles and ways for the dialogue and transparent information between the Expertise Function and the CS, strengthening knowledge and skills, adapting culture and practices of the Expertise Function to accommodate the active contributions of CS and its experts, acting in complement to WMOs where public expects an independent view on its scientific and safety concerns and expectations.

Further, SITEX_Network carries out dissemination and planning activities, such as:

— Knowledge exchange: providing a forum for information exchange and sharing data among Members; supporting Less Advanced RWM Programmes (LAPs);
— Interaction with international entities: organize interactions with other entities involved in regulatory and Expertise Function activities (e.g. WENRA, ETSON, ENSREG, ENEN, IAEA, OECD/NEA) or in implementing activities (e.g. IGD-TP): possible interactions could be dissemination, consulting for harmonization of the existing regulations and guidance, regular informing of the progress and outcomes of activities, establishing cooperation with specific projects (e.g. IAEA GEOSAF), etc.;
— Presenting its activities and results of joint effort at different international events.

2. SITEX_Network INTERACTIONS WITH CIVIL SOCIETY

Towards the end of the SITEX project there was an effort to have an outreach to a few selected civil society (CS) organisations to explore the possibility of including an effort of interaction between TSOs and CS in the SITEX-II project. This endeavour was successful and in the SITEX-II project there was a special work package on CS interaction involving three tasks; formulating key technical and socio-technical issues that from a CS perspective could be interesting to be included in European R&D on RWM, investigating how safety culture for RWM can be shared through different interested parties and what the concrete conditions and means necessary for efficient public engagement are, and issues involving intergenerational governance in RWM [17]. The CS experts involved as research partners in the task were from Mutadis and Symlog in France, REC in Slovenia, Energiaklub in Hungary and MKG in Sweden. The small group of research partners interacted all along the project with a larger group of CS organisations representatives co-ordinated by the Brussels-based organisation Nuclear Transparency Watch (NTW). In all there were 35 environmental non-governmental organisations (NGOs) from 18 countries in Europe making an input into the work done, reflecting a variety of partly very specific situations at national level. Much of the work done and the results achieved in the SITEX-II project can be expected to be the basis of the work on CS interaction in the SITEX_Network and is therefore described in a little more detail.

The first task formulated R&D key technical and socio-technical issues that CS expects to be developed in R&D programmes and contributed actively to review the SITEX SRA by trying to place the CS interests into the research matrix developed by the experts community of the SITEX-II project, by discussing with them the possibility to include citizen and social science in the SRA and by developing a concept of “Knowledge Sharing and Interpretation” for allowing CS interactions in future EU research projects on RWM. This concept is now first tested in the Euratom Horizon EU project Beacon [18]. The task also started thinking about new R&D topics, including the incorporation of citizen and social science, that would allow European discussions on potential crosscutting areas, i.e. the discussion of uncertainties. These were to possibly be included in future European Joint Programming R&D in RWM. The second task investigated how safety culture can be shared through different interested parties and what the concrete conditions and means necessary for efficient public engagement are. Through a questionnaire and a set of 27 personal interviews of various representatives of non-institutional CSOs and institutional actors in Europe (regulators, TSOs, researchers), the task identified commonalities and differences in the vision on safety culture in RWM and investigated the expectations of non-institutional as well as institutional actors regarding the engagement of CS in the safety case review of GD facilities. Based on the performed analyses, conclusions on the conditions and means to involve CS along the safety case review process of GD facilities were drawn.The third task was dedicated to intergenerational governance and performed desk review and analyses of the literature of the past and existing research and on-going reflections of international projects related to the intergenerational aspect of RWM (EU projects MoDeRn, Insotec, SITEX, …), as well as perception and ideas from CS organisations (national, international). The task also developed a new approach, entitled Pathway Evaluation Process (PEP), conceptualized as an exercise of participative and comparative assessment of different parallel alternative scenarios on long-term management of radioactive waste. The method is presented as a board game that can be used by different stakeholders to support discussion and identification of possible strategies for RWM. In addition, the task moderated discussions to reflect on and challenge the provisions and requirements related to intergenerational aspects of RWM and spent nuclear fuel (SF) management, as set out in different international treaties/conventions and other EU binding legislation.

As a result of the work done in the SITEX-II project it was decided that CS interaction could also be part of the work carried out within the SITEX_Network and a separate college that allows the membership of CS organisations was organised. There is therefore also representation from the CS in the Management Board. As described above the expectations are to be able to do work on how to promote efficient interaction with CS and its experts: establishing principles and ways for the dialogue and transparent information between the Expertise Function and the CS, strengthening knowledge and skills, adapting culture and practices of the

Expertise Function to accommodate the active contributions of CS and its experts, acting in complement to WMOs where public expects an independent view on its scientific and safety concerns and expectations.

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ACKNOWLEDGEMENTS

SITEX and SITEX-II projects received funding from the EURATOM research and training programmes 2012-2013 and 2014-2018 under grant agreements No 295889 and 662152.

MODERNIZATION OF THE IRSN'S REMOTE SENSING NETWORK

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Abstract

In the absence of strict regulatory requirements, the design, deployment, maintenance and upgrade of an environment monitoring network can always be viewed as a compromise trade-off. This trade-off is itself the result of an analysis process taking into account among other considerations, the legal context of a country (which defines the respective responsibilities of the parties involved), the precise purpose of the network, its role within the global protection system and with regard to other monitoring systems, the available techniques, the economic cost (absolute or proportionate to the issue), its importance with regard to the perceived risk ... and, in a way, the history and culture of the country. The variety of responses that can be made to each step of this analysis leads to the fact that monitoring networks are rarely the same from one country to another. In the early 2010's, IRSN began to modernize its remote sensing network measuring the ambient gamma dose rate by examining these different parameters. The results of this analysis and its implementation are presented. The main challenges for its further development are identified and should lead to some upgrade in the relatively short term.

1. INTRODUCTION

1.1 The French early warning network Téléray

Following the Chernobyl accident, European states realized the value of having reliable, accurate and responsive radiological early warning networks in the event of a nuclear accident. France, through SCPRI and then OPRI, set up in 1991, across the national territory and near nuclear facilities, a network of probes for measuring the ambient dose equivalent rate (ADER), called Téléray. Since 2002, this national network has been placed under the responsibility of IRSN, which operates and maintains it under operational conditions.

The Téléray network is now part of a radiological environmental monitoring system implemented by the radiological intervention and environmental monitoring service (SIRSé) through remote sensing or sampling activities on the whole national territory, overseas territories included.

The aim of the Téléray network is to detect, as quickly as possible, any increase in the level of ambient radioactivity. The main purpose of this network is to monitor the environment vis-à-vis nuclear facilities that may release radioactive substances into the air (aerosols and gases) that could result in significant effective doses to the population, in France or abroad.

1.2 Situation in 2009

The objectives assigned to environmental monitoring by early warning network are:

- To determine the reference radiological background over the territory, in order to assess its potential variability to characterize the abnormality;
- To ensure the early detection of any abnormal elevation of radioactivity above the previously stated reference levels;
- To ensure the health protection of populations and the environment by determining the potentially artificial nature of an elevation and by assessing the dose to which the population has been or could be exposed;
- To ensure regulatory compliance, by collecting real-time measurements from operators to verify their reliability. IRSN can also carry out measurements independent of those of the operators in places allowing to measure possible chronic discharges;
- To inform the public by publishing the results of the measurement on different web sites and by ensuring the diffusion to the international partners (bilateral exchanges, European Commission, IRMIS, etc.).

As shown in the map below, the network was initially composed of about 160 tags at its creation to reach 170 probes in 2009.

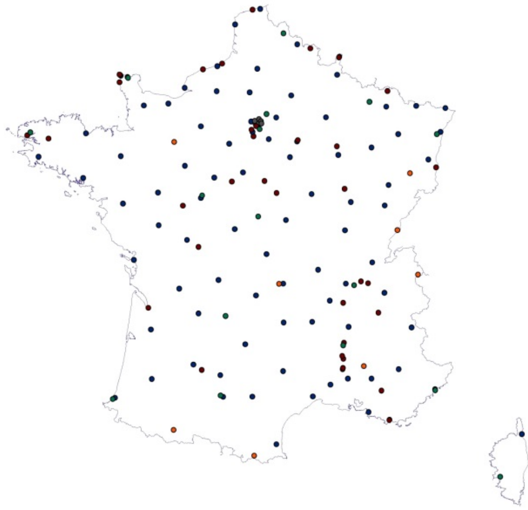

FIG. 4. Map of the initial setup of Téléray probes until 2009.

1.2.1 Strategy (beyond 2009)

Starting in 2007, IRSN, in charge of the Téléray network, found it was essential to organize the revival of such a tool. Two main reasons led to this observation: on the one hand, the proven obsolescence of certain IT components (supervising software, database), on the other hand, the foreseeable obsolescence of certain equipment (probes, modems, connectors, etc.), this modernization, started in 2010. This led to the replacement of the supervision software allowing to include within a same information system, a switched network and a connected network (ADSL network). This modularity has also made possible to introduce new measuring devices, with much higher metrological performance (proportional counters instead of Geiger Müller counters).

This technical modernization was logically accompanied by a strategic review of the geographical deployment of the probes over the territory. The logic adopted was to cover all French administrative units, in order to guarantee the coverage of the main population centers in France, including overseas territories. In parallel, IRSN has increased the density of its monitoring system around nuclear facilities, beyond the 10 km zone, in addition to the monitoring carried out by the operators, in particular EDF. This French operator has the largest number of nuclear installations on the territory and transmits the measurements from 500 probes in real time to the IRSN. The measuring devices were thus positioned on the population centers present in the 10 to 30 km zone around EDF's nuclear facilities. An agreement signed in 2012 between the Gendarmerie Nationale and IRSN allowed the hosting of IRSN equipment and data transmission via the resilient and secured network of the Gendarmerie brigades located near the NPPs. This possibility resulted from a desire of the Gendarmerie Nationale to pool its technical resources with those of other public entities.

1.2.2 Assessment (between 2009 and 2018)

The figure below (Fig. 2) shows on the left the probes deployed over the years between 2010 and 2015 and, on the right, the inventory of metropolitan probes early 2018 according to the type of network on which they are connected.

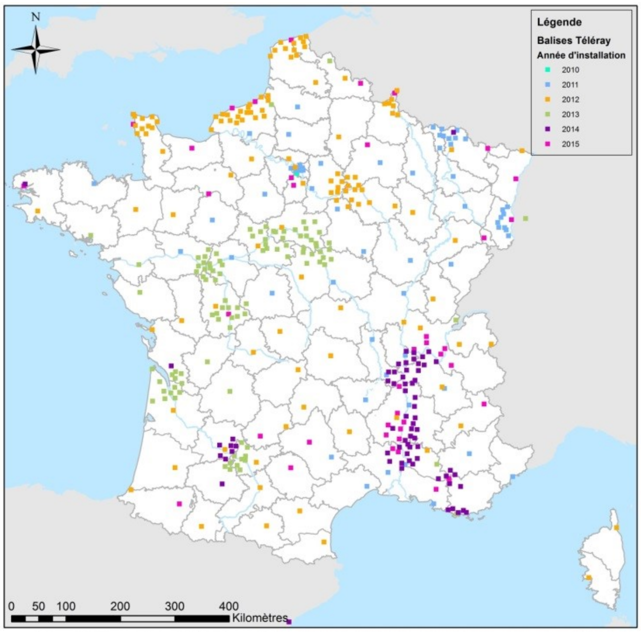

FIG. 5. Map of the setup of Téléray monitoring network after 2016.

As of 2018, 413 probes are already installed, according to the following distribution:

- 315 probes located on Gendarmerie Nationale brigades whose data are transmitted via the MPLS (Multi Protocol Label Switching) network
- 89 probes on public buildings (mainly prefectures or sub-prefectures) interconnected on the dedicated MPLS network at IRSN,
- 9 probes located in specific locations via standard routers on the internet.

2. FEEDBACK AND PERSPECTIVES

The main advantages of the Téléray network are as follows:

- An ambitious modernization program that completely renewed the monitoring probes, telemetry network and supervising system for a budget lower than initially planned;
- High performance probes with excellent sensitivity to detect very low levels of radioactivity. In practice, it is possible to detect dose rate increase with an alarm threshold of 40 nSv/h and less than 10 nSv/h with post-processing techniques.
- A deployment evaluated through atmospheric dispersion simulations which demonstrated the good adequacy of the position of the beacons with regard to accidental releases of INES type 5 to 7;
- A resilient system thanks to a redundancy of the IT infrastructure;
- Multiple robust data telemetry networks;
- A supervising system, developed in the frame of a collaborative work including end-users, that allow online and fast data management;
- Strong skills to better understand, explain and analyze measures.

IRSN has now has a plurality of real-time in situ monitoring tools, which can be used to answer the needs of permanent monitoring, public information, site studies and which would be among the most first to be mobilized in a crisis situation.
The probes are able to detect a radioactive plume conveyed by the air masses and then very quickly, to make it possible to quantify the dose equivalent rate due to the particulate deposits on the ground.

A complementary deployment of gamma spectroscopic probes in the near field of nuclear installations will be carried out from 2019, which will allow redundancy of monitoring devices and a real metrological added value to fulfill IRSN's missions. The contribution of the gamma spectroscopic probes will allow to identify the radionuclides present in the plume (including noble gases) in order to compare with modelling prediction.

3. CONCLUSION

It is impossible to easily setup probes at any point of the territory, at any time (costs, technical constraints, maintenance, etc.), which means that a monitoring program is always a compromise. Each country has its own policy, depending of the existence of nuclear installation, the size of the country, etc.

The recent improvements in IT technologies allow TSO to have tools that are able to perform mobile measurements in order to achieve a very large quantity of measurements even where no probe exists.

After Fukushima accident, the citizen network for radiological monitoring has developed and increased a lot, it is a challenge for TSO to be able to analyse its own data but also to analyse the ones for civil society.
Challenges for the future are:

- To improve the quality of the fixed probes measurements with new spectroscopic probes,
- to obtain in real time the measurements of all nuclear operators in order to allow IRSN to have an expanded view of automatic radioactivity measurements in France,
- to be able to analyse measurements that could emerge from systems different from those in the nuclear sphere, such as citizen monitoring systems (Safecast, OpenRadiation, etc.).
- to develop and improve new signal processing techniques able to deal with large variety of data which could be relevant of interest.

TOPICAL SESSION 2.3

INTERNATIONAL COOPERATION

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Session 2.3 highlighted the importance of international cooperation, whether bilateral or within international frameworks and networks, to satisfy the targets of the regulatory bodies and to enhance the expertise and capabilities of TSOs. Participants made presentations that demonstrated the significance and value of continuous international collaboration to optimize efforts and to make the best use of the available resources and expertise. Multilateral cooperation among TSOs, in areas such as international R&D activities involving TSOs or support to MDEP, helps ensure a high level of global nuclear safety. It was highlighted that the IAEA should consider continuing to promote awareness on TSO contributions in support of the regulatory bodies and encouraging embarking countries to participate in networks involving TSOs. These activities are necessary to build up and maintain a high level of competence and expertise in a challenging scientific context to support the respective national regulatory needs.

EC DG DEVCO ACTIVITIES PROMOTING NUCLEAR AND RADIATION SAFETY WORLDWIDE: Regulatory Support Activities Involving Major Contributions from The European TSOs

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Abstract

The European Commission, DG DEVCO, manages cooperation projects with eligible nuclear regulators all over the world to enhance their regulatory effectiveness, by improving safety assessment and other regulatory capabilities. The framework for this cooperation is a financial instrument called Instrument for Nuclear Safety Cooperation or INSC. Several European TSOs play an important role in delivering support to partner nuclear regulators as members of the consortia carrying out the work in the regulatory cooperation projects. In addition to the participating EU nuclear regulatory bodies, the contribution of the EU technical support organizations is indispensable when transferring EU best practice and experience to the partners. This is also true for the training & tutoring (T&T) projects, because the EU TSO experts contribute with their experience and skills in various training activities and they are able to provide relevant knowledge and skill transfer.

The paper provides a brief overview of INSC activities, focusing on regulatory support projects in the areas of nuclear and radiation safety, radioactive waste management and remediation of contaminated legacy sites, as well as T&T activities. Project planning, specification, tendering and implementation phases are discussed, explaining the role of DG DEVCO and the assistance provided by the Joint Research Centre (JRC). An overview of selected on-going projects where EU TSOs provide valuable contributions shows the diversity and scope of the cooperation activities.

1. INSTRUMENT FOR NUCLEAR SAFETY COOPERATION

The Instrument for Nuclear Safety Cooperation ([1], [2]) of the European Union (EU) aims at promoting nuclear and radiation safety worldwide. In principle, the EU Instrument for Nuclear Safety Cooperation is open – with certain conditions – to any country outside the EU, but the Instrument focuses on the EU candidate and neighbourhood countries. The Instrument finances projects supporting the promotion of a high level of nuclear safety, radiation protection and the application of efficient and effective safeguards of nuclear material in third countries. One of the main methods of the INSC is cooperation with national nuclear regulatory authorities (NRAs) and their technical support organisations (TSOs, in this article used in its broadest sense) to enhance their regulatory effectiveness, e.g. by improving licensing capabilities and safety assessment skills. The level and technical areas of the regulatory cooperation with a specific country depends on the maturity and needs of the NRA, but the reinforcement of the nuclear safety infrastructure – including the establishment of an appropriate legal framework – is always number one priority.

The INSC was preceded by the TACIS programme (Technical Assistance to the Commonwealth of Independent States) launched in 1991 by the EC. The Nuclear Safety component of TACIS provided assistance to improve the safety of civil nuclear facilities in the Commonwealth of Independent States (CIS) countries and Mongolia. The first 7 year INSC programme (INSC-I) was launched in 2007 to provide a global coverage outside the EU [1], while at that time the nuclear cooperation with EU candidate countries was covered by the Instrument for Pre-Accession, IPA [3]. The INSC-I programme was continued by the current INSC-II programme [2] covering the period 2014 – 2020. The INSC has no geographical limits outside the EU: it is a global Instrument accessible to countries at their request, subject to a formal proposal by the European Commission and approval by the EU member states.

The INSC is one of the smallest EU instruments for external cooperation and focused on world-wide cooperation to enhance nuclear safety, but because of the combined effort of the 28 EU member states it can support significant projects. The cumulative TACIS budget in the 1991-2006 period amounted to EUR 1.260 billion, while the EU allocated a budget of 534 million euro for INSC-1 between 2007 and 2013 (see e.g. [4] and [5] for details). Note, that between 2007 and 2013, 50% of the INSC budget was allocated to support Ukraine, including large contributions to the Chernobyl Shelter Fund for financing the construction of the New Safe Confinement over Unit 4 of the Chernobyl NPP, which was destroyed in the 1986 accident. With the current completion of this large, urgent project [6], the available budget for the ongoing INSC-II programme is EUR 225 million for the budgetary period of 2014-2020. With INSC-II, the priority areas of support were significantly changed. The on-site assistance to nuclear power plant operators (a dominant activity earlier) was gradually phased out and the division of the budget is as follows: 50% to projects improving nuclear safety culture; 35% to the safe management of spent nuclear fuel and radioactive waste and 10% to nuclear safeguards activities (the remaining 5% of the budget is to cover the support measures, see [8]).

2. THE OPERATION OF INSC

2.1 The programme operator

The instrument is operated by the Directorate-General for International Cooperation and Development (DG DEVCO) of the European Commission. The Joint Research Centre (JRC) of the European Commission provides scientific and technical support to DG DEVCO at all stages of project implementation, e.g. definition and specification of projects, tendering and evaluation, follow-up of project implementation, reviewing deliverables, dissemination of project results, etc. Programming, adoption of the projects, contractual and financial issues are handled by DEVCO.

2.2 Multiannual and annual programming

The programme implementation is based on a general strategy paper for INSC, constituting the general basis for the international cooperation for a period up to 7 years. The strategy paper defines the EU strategy for cooperation, taking into account the needs of the countries concerned, the priorities of the EU, the international situation and the activities of the respective third countries (see [7] for more details).

In the next step – on the basis of the strategy paper – multiannual indicative programmes (MIPs) are prepared, covering 2 to 4 years of planned activities [8]. MIPs define priority areas, specific objectives and expected results, together with key performance indicators (KPIs) and preliminary allocation of funds. Member States of the European Union actively participate in the preparation of these MIPs which reflect also the permanent dialogue with the Beneficiary countries benefiting from the cooperation.

The above-mentioned priorities are then outlined in Annual Action Programmes proposing the corresponding projects to be financed by the Instrument. These AAPs describe objectives, fields of intervention, related activities and expected results in more detail, together with the funds allocated. An AAP may correspond to a single Beneficiary country or to several countries in a region, depending on the optimal implementation scheme determined by DEVCO. The AAPs are then scrutinized by several internal committees and the final opinion is issued by the INSC Committee consisting of representatives of the EU Member States. Based on the favourable opinion of the INSC Committee, the Commission's decision is published by the European Commission for the implementation of the programme.

During the whole programming process the duplication with other EU initiatives or similar international programmes is avoided. Transparency is duly ensured thorough the whole programming process and during the implementation of individual projects.

2.3 Contracting and implementation

Currently, almost all INSC projects are awarded through the standard EU open tendering procedure. The INSC basically uses two different tender types: the service contract and the (equipment) supply contract. The technical contents of a service contract is usually specified in detail in a Terms of Reference (ToR) document, while the equipment to be purchased in a supply contract is specified in a detailed Technical Specification (TS) document. The quality of these ToR and TS documents is one of the key factors to ensure the successful completion of a project; therefore, DEVCO pays great attention to them. ToRs are often prepared by JRC experts having ample experience in writing adequate specifications for various INSC projects. In certain cases, requiring special expertise the preparation of the ToR is outsourced to an appropriate consultant company, which is then excluded from participating in the tendering procedure. Technical Specifications are frequently prepared as part of a service contract, because often very special equipment is to be procured (e.g. environmental radiation monitoring or radioactive waste processing industrial equipment). The financial regulation for external actions of the European Union applies to the INSC and the tendering and contracting procedure is controlled by strict rules, documented in the Practical Guide to Contract Procedures for EU External Actions (PRAG, [9]). Bidding is usually a two-step procedure: first eligible candidates are selected by a short-listing committee; then the short-listed candidates are requested to submit detailed technical and financial offers which are assessed by an evaluation committee. The contract is awarded to the contractor/consortium offering the best price/quality ratio.

Regulatory support INSC projects usually span over 2 to 3 years and the allocated funds per project are in the EUR 0.5 million – 5.0 million range per project and are mostly service contracts. After a service contract is signed with the winning consortium the so-called inception phase commences. First an inception meeting is organised, where project partners fine-tune the technical contents and schedule of the work in a more detailed manner. Also, all project bodies (e.g. working groups, steering committee) are established; communication and quality assurance rules are agreed upon. During project implementation the Contractor regularly reports the work progress to the DEVCO project manager. Regular project meetings (in 6 or 9 month period) must be organised and a 6 month progress report must be submitted. A project is closed by a final meeting and by the issuance of the final report. Individual tasks are closed by issuing the corresponding technical reports and the final task report summarizing the work carried out within the task. The exact project structure depends on the activities carried out. The DEVCO project manager is assisted by JRC in these project supervision activities, e.g. JRC reviews deliverables and takes part at selected project meetings. In certain beneficiary countries, the local TSO is a member of the consortium and actively takes part in the technical implementation work (see e.g. [4] for details on the role of the Ukrainian TSO).

3. CURRENT PROJECTS WITH SUBSTANTIAL TSO INVOLVEMENT

TABLE 1. OVERVIEW OF CURRENT REGULATORY COOPERATION INSC PROJECTS (JULY 2018)

Beneficiary	Project ID	Project title / description	Consortium leader + [NRAs] + (TSOs) + others	Status
Assistance projects to enhance regulatory capabilities				
Armenia	A3.01/15A A3.01/15B	Enhancing the capabilities of the Armenian NRA in preparedness for and response to a nuclear or radiological emergency	**TBD**	Under contracting
	A3.01/16A	Enhancing the capabilities of the Armenian NRA and its TSO in reviewing documents demonstrating the long-term safety of Unit 2 of the Metsamor NPP	**RISKAUDIT** + [SÚJB] + (IRSN, GRS, SSTC) + TECNATOM	On-going
Belarus	BY3.01/13	Support and assistance to strengthen the capabilities of the Belarusian NRA in the field of licensing and supervision of construction of the Belarusian NPP	**RISKAUDIT** + [STUK, ISPRA, SNRIU, VATESI] + (IRSN, GRS, LEI, SSTC) + ITER	On-going
	BY3.01/16	Support and assistance to strengthen the capabilities of the Belarusian NRA	**RISKAUDIT** + [BNRA, SSM, SNRIU, VATESI] + (IRSN, GRS, LEI, SSTC)	On-going
China	CN3.01/15	Enhancing the capacity & regulatory capabilities of the Chinese National Nuclear Safety Administration in the areas of waste management	**RISKAUDIT** + [ASN, CSN] + (IRSN, GRS) + TECNATOM, ANDRA	On-going

		and decommissioning, emergency preparedness & response, transport, reprocessing plant safety, seismic safety and the national R&D base		
Indonesia	ID3.01/13	Enhancing the capacity and effectiveness of the regulatory body and developing a national waste management strategy	**RISKAUDIT** + [STUK] + (IRSN, GRS)	On-going
Iran	IRN3.01/16	Enhancing the capabilities of the Iranian Nuclear Regulatory Authority (INRA)	**ENCO** + [HAEA, SNSA, SÚJB, ÚJD]	On-going
	IRN3.01/17	Support to the Iranian Nuclear Regulatory Authority (INRA)	**TBD**	Under contracting
Jordan	JO3.01/13	Provision of assistance related to developing & strengthening the capabilities of the Energy and Minerals Regulatory Commission and related to radioactive waste management in Jordan	**ENCO** + [HAEA] + (NRG, TÜV NORD)	On-going
Morocco	MO3.01/15	Support to the regulatory body of Morocco for capacity building and for enhancing the regulatory framework for nuclear and radiation safety;	**RISKAUDIT** + [CSN] + (IRSN, GRS, BEL V, SSTC) + TECNATOM + ANDRA	On-going
Turkey	TR3.01/16	Support to the Regulatory Authority of Turkey	**RISKAUDIT** + [ASN] + (IRSN, GRS) + BUREAU VERITAS	On-going
Ukraine	U3.01/12	Support to the Ukrainian regulatory authority	**RISKAUDIT** + [STUK] + (IRSN, GRS, BEL V, SSTC)	On-going
	U3.01/14-15	Support to the Ukrainian regulatory authorities	**RISKAUDIT** + [BNRA, NRPA] + (IRSN, GRS, BEL V, LEI, SSTC, VÚJE) + ITER	On-going
Vietnam	VN3.01/13	Enhancing the capacity and effectiveness of the Vietnam Agency for Radiation and Nuclear Safety and its TSOs	**RISKAUDIT** + [ASN, STUK] + (IRSN, GRS, BEL V)	On-going
Assistance projects supporting the regulator in the safe management of radioactive waste and remediation of contaminated sites				

Armenia	A3.01/13	Enhancement of ANRA and NRSC capabilities for safety review and assessment of radioactive waste management facilities and activities	**ITER** + [ISPRA] + (VTT) + SOGIN	Completed
Iraq	IQ3.01/14	Support to the regulatory body of Iraq on radioactive waste management, decommissioning of nuclear facilities and remediation of contaminated sites	**ANDRA**	On-going
Mongolia	MN3.01/11	Establishment of a regulatory framework for uranium mines and milling operations in Mongolia	**AMEC EARTH** + WISUTEC, AMEC NUCLEAR	On-going

3.1. Regulatory capacity building

Assistance projects supporting the capacity building of the national nuclear regulator are currently under implementation in the following countries: Armenia, Belarus, Iran, Jordan, Morocco, Turkey and Ukraine. In China, Indonesia and Vietnam the currently on-going regulatory support projects are nearing completion.

3.2. Safe radioactive waste management

Assistance projects supporting the establishment of an appropriate framework for safe radioactive waste management are currently performed in the following countries: Iraq, Jordan, Mongolia and Ukraine. These projects either support the NRA to create an appropriate regulatory framework or provide direct assistance to the national operator responsible for the safe management of radioactive waste.

3.3. Remediation of contaminated legacy sites

Projects aimed to remediate contaminated legacy sites are currently performed in the following countries: Iraq, Kyrgyzstan, Mongolia, Tajikistan, Uzbekistan and Ukraine. These projects are either supporting the NRA to create an appropriate regulatory framework or providing direct assistance to the region involved (see [10] for details).

3.4. Involvement of the European TSOs in the various INSC projects

Naturally, the involvement of European TSOs is the largest in the regulatory assistance projects, because this is the area closest to their institutional knowledge and experience.

The following TSOs contribute to several INSC projects all over the world: IRSN (France), GRS (Germany), Bel V (Belgium); ENCO (Austria); LEI (Lithuania) and SSTC (Ukraine). Their experts are involved in regulatory assistance projects e.g. in Armenia, Belarus, China, Indonesia, Turkey, Ukraine and Vietnam. Recently SSTC, the Ukrainian TSO also takes part in the implementation of the worldwide training and tutoring project [11]. In addition to the above institutes, e.g. ÚJV Řež (Czech Republic); VÚJE (Slovakia) and VTT (Finland) are also active in the implementation of INSC regulatory support projects.

Knowledge transfer performed by the TSOs is focused on the following regulatory areas: safety assessment and licensing of nuclear facilities (including radioactive waste management); severe accident modelling and analysis; feedback of operating experience; risk based regulation approaches; neutron physics and thermal-hydraulic analyses (including containment calculations); inspection methods.

As a general rule, consortiums contracted by DEVCO to provide regulatory support to a partner NRA must include at least one EU nuclear regulator. The most active EU NRAs in the INSC are ASN (France), STUK (Finland), SÚJB (Czech Republic), CSN (Spain), BNRA (Bulgaria), ÚJD (Slovakia), SNSA (Slovenia), ISPRA (Italy) and VATESI (Lithuania), but also e.g. SSM (Sweden), NRPA (Norway) and HAEA (Hungary) participate in INSC consortiums. Very often the EU regulator works in close cooperation with its national TSO to provide the contracted services in an INSC project.

It must be noted that INSC regulatory cooperation projects are also targeted to improve the capabilities of the national TSOs working for the partner NRA. An illustrative example for the success of this activity is SSTC NRS, the Ukrainian TSO, established 26 years ago. SSTC received TACIS and INSC assistance during many years to build up its organisation and to improve its technical and scientific capabilities. This support certainly contributed to the current status of SSTC, when the Ukrainian TSO is already able to work as a member of an INSC consortium and participate in other international – often commercial – nuclear projects (see [4] for more details on the nuclear cooperation between SSTC NRS and the EU). Another characteristic example is Belarus, where the INSC on-site assistance team provided efficient and valuable help to define and create a so-called TSO coordination unit embedded into the organisation of the Belarusian nuclear regulator. This unit will be responsible for the coordination of the safety assessment and other regulatory support activities to be carried out in several scientific and engineering institutes constituting the national TSO network in Belarus.

4. ACTIVITES RELATED TO TRAINING AND TUTORING

National nuclear safety regulators have the obligation to establish, maintain and develop their professional expertise in the areas related to their characteristic licensing and licensee supervision practice. This obligation is clearly defined in Article 7 of the Nuclear Safety Directive [12], outlining responsibilities of the EU Member States to maintain expertise and skills in nuclear safety at high level: "Member States shall ensure that the national framework requires all parties to make arrangements for the education and training for their staff having responsibilities related to the nuclear safety of nuclear installations so as to obtain, maintain and to further develop expertise and skills in nuclear safety and on-site emergency preparedness."

When a country decides to embark on the utilization of nuclear technology for electricity generation for the first time, the national regulator faces a demanding task to build-up and maintain the regulatory capacity required for the proper execution of the forthcoming regulatory tasks, such as licensing, assessment and inspection, but also planning and prioritisation. The required expertise is manifold: it includes site licensing, reactor design evaluation, reviews of preliminary and final safety analysis reports, on-site inspections and reviews of commissioning tests, assessment of normal and emergency operating procedures, severe accident management guidelines, emergency response measures, etc. The IAEA supports the nuclear development of its member states with various review missions [13], but neither these reviews, nor any other external support can take over the responsibilities of the national regulator (or the duties of the operator). It is therefore essential that the national NRAs (as well as operators) are committed to the continuous training and development of their employees in order to enhance efficiency and effectiveness of their organisation in the area of nuclear safety, that they achieve the objectives of their missions and that they facilitate the development of a competent, motivated and safety-conscious workforce. The need to provide high quality training to the staff members of the NRAs and their TSOs is continuously maintained by several factors, e.g. recruitment campaigns to increase staff number, acquiring contemporary nuclear safety R&D results including novel safety assessment techniques and staff competence development in general.

Up to 2010, all trainings provided through INSC were included in the country specific, bilateral projects, but this approach was not cost effective and could not ensure the desired training quality in all projects. In order to ensure consistent quality, as well as to increase training effectiveness and efficiency, trainings intended for regulators – and being relevant for more than one country – were combined into dedicated training projects. These dedicated training projects are managed under the T&T initiative (capacity building in nuclear safety, nuclear security and radiation protection) [11], representing an important element in the regulatory capacity building efforts of INSC.

Several general T&T projects – available for all regulators of INSC partner countries and other interested partner countries if justified – are allocated to provide training and tutoring in applied nuclear safety principles and concepts which are relevant for regulatory activities. These projects offer general applied training in topical areas which are common to more than one partner country. These multi-country T&T projects are very successful initiatives attracting a large number (up to now almost 2000) of trainees worldwide from more than 40 countries. In these projects the experts of the nuclear regulators and their TSOs, as well as specialists of radiation protection, safeguards and radioactive waste management facilities may receive training.

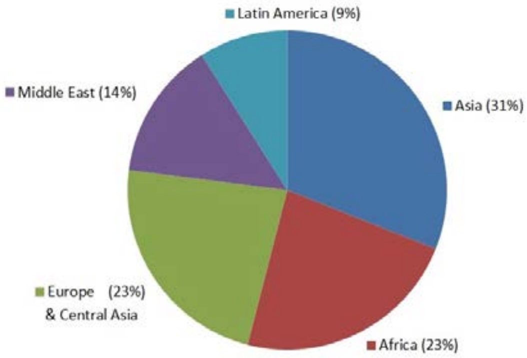
4.1. Involvement of the European TSOs in the T&T projects

In practice the T&T initiative is implemented through contracts with service providers [11]. These consortia provide state-of-the-art knowledge and know-how transfer services using the expertise of several EU regulators and TSO's, including TSOs from the ETSON community (as e.g. IRSN/France, GRS/Germany, ÚJV/Czech Republic and LEI/Lithuania). Therefore the consultants have access to a large pool of experts with expertise covering practically all areas of nuclear, radiological and radioactive waste safety to provide initial and recurring training courses. On behalf of EC DEVCO, they provide training and tutoring outside the European Union, under the INSC T&T initiative [14].

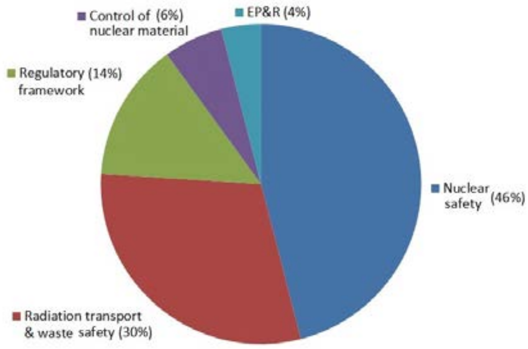
The T&T initiative is being implemented since January 2012 and so far EUR 15 million was devoted to the programme. Currently two projects MC3.01/13 and MC3.01/14 are ongoing with planned activities until 2019 [14].

Between January 2012 and July 2018 altogether 1872 trainees and tutees participated in the T&T trainings; the gender distribution was 71% men and 29% women. The total T&T amounted to 13 400 days of training and 3 200 days of tutoring (on the average, this is equivalent to about 9 T&T days provided to each trainee). Altogether 730 senior expert trainers and tutors provided the above T&T services, representing 36 organisations located in 14 European countries. The majority of trainers and tutors came from France (32%), Germany (14%), Italy (11%), Slovenia (8%), Spain (7%), Lithuania (6%) and Belgium (5%). The remaining 17% included trainers from Croatia, Czech Republic, Finland, Hungary, Netherlands, Poland, Romania, Sweden, Ukraine and the United Kingdom. The vast majority of the experts came from technical support organisations (73%) and about 25% was the employee of an EU NRA.

The training and tutoring project includes also regional training activities, with participation of local experts, including from Armenia, Belarus, Jordan, Libya, Mongolia, Morocco, Philippines, Singapore, South Africa, Thailand, Tunisia, Turkey and Vietnam.



Distribution of T&T participants by region



Most important T&T topical areas

FIG. 6. T&T participation by regions and the most important T&T topical areas [15]

The numbers given above are impressive and the T&T is a successful initiative, but there is always room for further improvements, which are based on feedback by the stakeholders. Broadening the number of training organisations participating in the T&T training activities will be possible if they take part in future tendering procedures or join the work as subcontractor.

5. LESSONS LEARNED AND CONCLUSIONS

DG DEVCO manages a large diversity of cooperation projects to improve nuclear and radiation safety in eligible countries all over the world. The motivation, structure and operation of the Instrument for Nuclear Safety Cooperation are in line with the main goals and mechanism of the EU nuclear safety cooperation projects. The EU TSOs – in cooperation with EU nuclear regulators – play a valuable and indispensable role in transferring EU nuclear and radiation safety know-how, experience and best practice to the partner countries. During the 25 years of the EU nuclear safety projects, the number of TSOs contributing to the knowledge transfer gradually increased to include the majority of the EU Member States. In the first 15 years the focus was on Ukraine and Russia. Later INSC "opened up" to deliver nuclear and radiation safety assistance all over the world and this change attracted additional EU nuclear regulators and TSOs to participate. During the past 10 years this "widened resource pool" significantly contributed to the successful completion of many INSC projects, because it channelled additional expertise and workforce into the INSC implementation and represented considerable added value. Further widening the resource pool could also be observed in the participation in the training and tutoring activities.

Recently the European Commission proposed to continue these activities under a new Instrument after 2020, when the current 7-year period expires ([16]). Further enlargement of the TSO pool is expected in the future, because of the expressed interest by many EU TSOs in the INSC activities.

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LIST OF ABBREVIATIONS

AAP - Annual Action Programme
AMEC - British consultancy, engineering and project management company
ANDRA - Agence Nationale pour la Gestion Des Déchets Radioactifs (Radioactive Waste Mgmt. Operator, France)
ASN - Autorité de Sûreté Nucléaire (Nuclear Safety Authority, France)
BNRA - Bulgarian Nuclear Regulatory Agency (Bulgaria)
BEL V - the Belgian TSO, subsidiary of the Belgian NRA (FANC = Federal Agency for Nuclear Control)
CIS - Commonwealth of Independent States
CSN - Consejo de Seguridad Nuclear (Nuclear Safety Council, Spain)
DG DEVCO - Directorate-General for International Cooperation and Development (European Commission)
EC - European Commission
ENCO - Austrian expert company providing consultancy services in areas related to nuclear safety
EP&R - Emergency Preparedness and Response
ETSON - European Technical Safety Organizations Network
EU - European Union

GRS	- Gesellschaft für Anlagen- und Reaktorsicherheit, the German TSO
HAEA	- Hungarian Atomic Energy Authority (Hungary)
INSC	- Instrument for Nuclear Safety Cooperation
IPA	- Instrument for Pre-Accession
IRSN	- Institut de Radioprotection et de Sûreté Nucléaire, the French TSO (established in 2002)
ISPRA	- Istituto Superiore per la Protezione e la Ricerca Ambientale (Italian NRA)
ITER	- Independent Technical Evaluation and Review (Italian expert company)
JRC	- Joint Research Centre (EC)
KPI	- Key Performance Indicators
LEI	- Lithuanian Energy Institute (Vilnius, Lithuania)
MIP	- Multiannual Indicative Programme
NPP	- Nuclear Power Plant
NRA	- Nuclear Regulatory Authority
NRG	- Nuclear Research and Consultancy Group (Nederlands)
NRPA	- Norwegian Radiation Protection Authority (Norway)
NRSC	- Nuclear and Radiation Safety Center (Armenian TSO)
PRAG	- Practical Guide to Contract Procedures for EU External Actions
SNRIU	- State Nuclear Regulatory Inspectorate of Ukraine
SNSA	- Slovenian Nuclear Safety Administration (Slovenia)
SOGIN	- State owned company responsible for the decommissioning of nuclear facilities (Italy)
SSM	- Strål Säkerhets Myndigheten (Swedish Radiation Safety Authority, Sweden)
STUK	- Säteilyturvakeskus (Radiation and Nuclear Safety Authority, Finland)
SSTC NRS	- State Scientific and Technical Center for Nuclear and Radiation Safety (Ukraine)
SÚJB	- Státní Úřad pro Jadernou Bezpečnost (State Office for Nuclear Safety, Czech Republic)
TACIS	- Technical Assistance to the Commonwealth of Independent States
T&T	- Training and Tutoring
ToR	- Terms of Reference
TS	- Technical Specification
TSO	- Technical Support Organisation (in this article used in its broadest sense)
ÚJD	- Úrad Jadrového Dozoru (Nuclear Regulatory Authority, Slovak Republic)
ÚJV	- Ústav Jaderná Výzkumu (Nuclear Research Centre), Řež, Chech Republic
VATESI	- State Nuclear Power Safety Inspectorate (Lithuania)
VTT	- Teknologian Tutkimuskeskus (Technical Research Centre), Espoo, Finland
VÚJE	- Výzkumu Ústav Jaderná Elektrárna (Nuclear Power Plant Research Institute), Trnava, Slovakia
WISUTEC	- German company dealing with mine closures, environmental monitoring, and geoinformatics

CO-ORDINATED RESEARCH ACTIVITIES IN THE FIELD OF THE OECD/NUCLEAR ENERGY AGENY COMMITTEE ON THE SAFETY OF NUCLEAR INSTALLATIONS

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Abstract

The OECD/Nuclear Energy Agency (NEA) is an intergovernmental organization that supports the co-ordination and harmonization of activities in the field of the peaceful and safe generation of nuclear energy. Currently 33 Member countries work together with the main target of preserving and continuously improving the level of nuclear safety. The NEA has 8 different thematic areas that are managed and guided by dedicated committees composed of representatives from the different member states. This paper focusses on the activities under the Committee on the Safety of Nuclear Installations (CSNI) which cover various safety-related topics. In addition to the co-operation in specific CSNI working groups, the member states also co-ordinate their research efforts in jointly funded Safety Research Projects under the auspices of the CSNI.

1. INTRODUCTION

Founded in 1958, the OECD/Nuclear Energy Agency has a long and successful history as an intergovernmental organization providing a platform to facilitate the efficient co-operation of member states on various aspects of nuclear energy generation with a special focus on nuclear safety and sustainability. According to its Mission Statement [1], the role of the NEA is:

"To assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes. It strives to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies."

The work under the auspices of the NEA covers a wide range of nuclear energy related topics from regulatory and research related issues of nuclear safety to environmental and legal aspects as well as technology development and nuclear science including the provision of nuclear data and dedicated computer programs. Under the governing body of the NEA, the "Steering Committee for Nuclear Energy", the member states have established 8 topic-related committees which manage the work within their thematic area, including the recently established Committee on Decommissioning of Nuclear Installations and Legacy Management. The committee structure is depicted in Fig.1.

The membership of the NEA currently comprises 33 industrialised member states that together represent most of the world-wide experience gained from the development, generation and regulation of nuclear energy. Beyond its membership, the NEA has also established working relationships with key partner countries, notably the People's Republic of China, India, Brazil, Indonesia and South Africa. The co-operation between the countries creates significant synergetic effects and allows the maximum possible mutual benefit from their collective individual experience. These benefits are reinforced by the close co-operation of the NEA with other bodies of the OECD, especially the International Energy Agency, with the IAEA and the European Commission as well as with other international organisations.

FIG. 1. Structure of Nuclear Energy Agency Committees and Subsidiary Bodies

2. ACTIVITIES UNDER THE UMBRELLA OF THE CSNI

2.1 Working Groups and Task Groups

The Committee on the Safety of Nuclear Installations (CSNI) was one of the first committees established under the NEA. Currently the CSNI oversees the activities of 8 different working groups, several subgroups and task groups. A broad range of topics is covered by these working groups including, for example, the analysis, management and mitigation of accidents or the performance of components, systems and structures under various boundary conditions. The mainly research-related work is performed via the co-operation between the delegations of the member states which include representatives from regulatory bodies, government ministries, TSOs (technical support organizations), research organisations, universities and industry. Based on this collaboration, the various participants develop a common understanding and shared knowledge of different challenges, mechanisms and phenomena that builds on their individual background and experience. The groups organise workshops and conferences, write technical opinion papers and develop common state of the art reports or technical reports on specific topics, taking into account the most recent experimental results or modern approaches. As a result, the members of the CSNI work together at the forefront of science and technology and actively contribute to a continuously increasing world-wide level of nuclear safety. Recognizing the overarching importance of nuclear safety, the CSNI has agreed that approved reports should be made freely and publically available. The following describes in more detail the main activities of the 8 CSNI working groups.

The application of Probabilistic Safety Assessment (PSA) methods is the focus of the work within the Working Group on Risk Assessment (WGRISK). The target is to expand the utilisation of PSA methods in the different phases of the life-cycle of a nuclear installation. With an improved understanding of the main contributors to risk, additional information can be obtained for the design and operation of nuclear installations as well as for prevention strategies and the management of incidents and accidents.

The assessment of potential accidental scenarios in nuclear power plants and the development of mitigation and management activities are conducted by the Working Group on Analysis and Management of Accidents (WGAMA). In fulfilling its task, the WGAMA covers a wide range of topics such as thermal-hydraulics, in-vessel and ex-vessel phenomena including the status of the core and the reactivity of the related material during an accident, combustion phenomena as well as fission-product behaviour. A main part of the activities is also the application of simulation tools with the assessment of uncertainties and the development of guidelines and best practises for the application. WGAMA also promotes common research efforts and benchmarks in order to close research gaps or to improve the understanding of certain phenomena.

Aspects related to the behaviour of components, systems and structures for the design as well as for the life management of nuclear power plants are dealt with by the Working Group on Integrity and Ageing of Components and Structures (WGIAGE). This working group is composed of one main group and three sub groups which focus on metal structures and components, concrete structures as well as the seismic behaviour of components and structures.

The Working Group on Human and Organisational Factors (WGHOF) is focussed on improving the understanding of the effects of human and organisational factors on the safety of nuclear installations. This is mainly done by an exchange of experience and the comparison of different approaches methodologies in the member countries and the development of technical review papers on important aspects in the field.

The Working Group on Fuel Safety (WGFS) focuses on the behaviour of traditional and advanced fuel during operation, transients and accidents in order to analyse the implications on the integrity and safety behaviour of nuclear fuel. The working group assesses the current safety criteria and investigates the applicability new fuel types taking into account changing operational conditions and new developments in fuel design and materials. Other tasks are the identification of research needs to improve the understanding as well as the review of core safety assessment methodologies.

Excluding reactor operation and the long-term management of radioactive waste, the Working Group on Fuel Cycle Safety (WGFCS) considers safety related issues of the entire fuel cycle starting from uranium mining and fuel fabrication to processing and storing radioactive waste on a short-term basis. In addition, the working group includes the reprocessing of spent fuel and the related facilities as well as the decommissioning of nuclear facilities in its work portfolio. To conduct the work in an efficient way, the WGFCS co-operates closely with the IAEA and the two organizations jointly manage the Fuel Incident Notification and Analysis System (FINAS) database.

The main task of the Working Group on External Events (WGEV) is to investigate the effects of external hazards on the safety on nuclear installations. This is done with a special focus on natural hazards and the related response of components and structures. In order to avoid any duplication of work, the working group co-ordinates parts of its work with the seismic subgroup of the WGIAGE who will assess purely seismic events but the combination of events e.g. a seismic event with a flooding in handled by WGEV.

Safety issues related to the electrical systems of nuclear installations are analysed by the Working Group on Electrical Power Systems (WGELEC). The work of the group concentrates on all of the related equipment necessary for the electricity supply to maintain the safety functions of a nuclear power plant including, for example, instrumentation and control equipment.

Besides the individual working groups the CSNI also establishes dedicated Task Groups for a limited time to investigate specific topics of common interest. In this regard, the CSNI established in 2017 a Senior Expert Group on Safety Research / Support Facilities for Existing and Advanced Reactors 2 (SESAR/SFEAR2) to conduct a thorough review of the current status of research facilities required to support the safety of nuclear installations with a primary focus on light water reactors. With the creation of this group, CSNI is responding to the specific challenges of research facilities and supporting the development of strategies to ensure the sustainability and better use of essential facilities for the benefit the entire nuclear community. Subject to the availability of sufficient information the task group also considers research facilities outside the NEA member states. The task group will develop a final report on its activities which is meant to provide the basis for well-informed policy-level decisions on maintaining key resources and on international co-operation on research infrastructure. A similar activity has been conducted several years ago which led to the publication of a final report in 2007[2]. This report will be updated and provides the basis for the work of the follow-up activity.

2.2 Joint Safety Research Projects

Besides the regular activities organized under the supervision of the Committees, a sub-group of NEA member countries can also launch joint undertakings in order to address questions of more limited but still common interest. These activities will then be financed by those member states and organised as well as managed by the states in collaboration with the NEA. Under the auspices of the CSNI, the NEA supports the establishment and management of Joint Safety Research Projects on various topics. These Research Projects demonstrate the benefit of international co-operation and complement or partially replace research activities on a domestic level. They are regarded as valuable component of the work within the NEA since they provide invaluable insights for the understanding of specific processes and promote the development and enhancement of nuclear safety including regulatory aspects. The Joint Safety Research Projects can look back on a very successful history with the first projects launched in 1958 during the first days of the NEA. A summary report of the main benefits from 30 years of Joint Projects in nuclear safety was published by the NEA in 2012[3].

Currently there are 13 experimental Joint Projects ongoing and several are in their launching phase. Usually these projects are established for the performance of experiments in specific research facilities or for investigations to be made be dedicated research labs. A broad range of topics are investigated in those projects and whereas various projects may focus on the same main topic, their content is complementary and not overlapping. For example, the Halden Reactor Project (HRP), the CABRI International Project (CIP) as well as the Studsvik Cladding Integrity Project (SCIP) investigate safety relevant issues concerning the behaviour of nuclear fuel and cladding materials in operational, transient and accidental conditions. The thermal hydraulics of nuclear facilities is analysed in the ATLAS project, the PKL project as well as the Loss of Forced Cooling experiments for gas-cooled reactor safety project (LOFC). Projects assessing the behaviour of fission products or hydrogen in nuclear reactor containments are the Behaviour of Iodine Project (BIP), the Source Term

Evaluation and Mitigation (STEM) project, the Thermal-hydraulics, Hydrogen, Aerosols & Iodine (THAI) project as well as the Hydrogen Mitigation Experiments for Reactor Safety (HYMERES) project. Safety aspects related to fires in multi-compartments are investigated in the PRISME project. After the events in Fukushima Daiichi in March 2011, the CSNI started several tasks to address the specific challenges and open questions arising from the accident. A group of member countries also decided to set up a specific project to close some knowledge gaps and to support the Japanese authorities in their efforts to collect all necessary information for the decommissioning activities. As a result, the Benchmark Study of the Accident at the Fukushima Daiichi NPP (BSAF) was started and is now complemented with the Preparatory Study on Fuel-Debris Analysis (PreADES) project. An overview of the experimental Joint Safety Research Projects can be found in Fig 2.

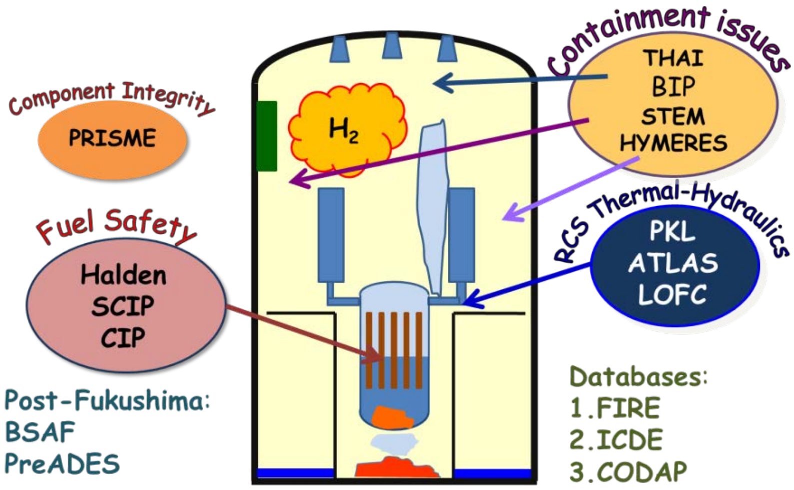

FIG. 2. Overview of ongoing Joint Safety Research Projects

Usually these projects have a project period of 3-5 years, but follow-up project phases can be initiated to address the remaining open questions. During a project period and a subsequent confidentiality period, only the project member countries have access to the project results. After this phase, all NEA member countries can be granted access to the results subject to acceptance of certain constraints (e.g. regarding publication). In this way, the projects contribute to the benefit of the entire research community.

In addition to the experimental projects, different groups of the NEA Member States have decided to combine their efforts in collecting information for different purposes. Therefore, database projects were also established under the auspices of the CSNI. Currently there are 3 database projects ongoing for the collection of data related to component degradation (Component Operational Experience, Degradation and Ageing Programme event database (CODAP)), for information of fires in nuclear installations (Fire Incidents Records Exchange project (FIRE)) and for information on common-cause failures (International Common-cause Failure Data Exchange (ICDE)). In order to stimulate an exchange of experiences in the use of NEA database projects and to identify new data needs for probabilistic safety assessment, a common workshop of the database projects was organised by the Working Group on Risk Assessment (WGRISK) in April 2018.

3. CONCLUSION

The work performed under the CSNI is a good example to illustrate that international organisations like the OECD/NEA can provide an effective and successful platform for the collaboration among member states on specific topics. With the application of the appropriate instruments the specific needs of the countries can be addressed in a very flexible way. With a strong co-operation of the international organisations it is possible to avoid the duplication of efforts and to make the best use out of the available resources.

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OVERVIEW OF ETSON MODELLING AND EXPERIMENTAL CAPABILITIES FOR R&D ON NUCLEAR SAFETY: *ETSON Research Group activity*

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Abstract

The European Technical Safety Organizations Network (ETSON) is an association of Technical Safety Organizations (TSO), whose main goal and duty is to provide technical expert support to national Authorities in Nuclear Safety and Radiation Protection. Research is fundamental not only to develop and maintain a high level of technical expertise necessary for TSO expert safety assessment, but also to support the whole international research community to achieve safety objectives, in the context of IAEA, OECD or European platforms such as NUGENIA. Moreover, the TSOs' needs for advanced R&D contribute to orienting research in this field and establishing priorities. This helps to concentrate the resources available for research, with focus on topics which are relevant for most countries and avoiding duplication of efforts.

The ETSON Research Group (ERG) aims to identify the needs for nuclear reactor safety research for Gen.II-III Nuclear Power Plants (NPP), ranking their priorities, sharing information on R&D projects/activities in which ETSON members are involved, and launching initiatives for new R&D projects. The ETSON members address most technical domains relevant for safety by national and international R&D projects and collaborations. In these domains, they have set up experienced experimental and modelling teams, built experimental research facilities, developed simulation codes and performed their verification and validation. These domains are principally: thermal hydraulics; material testing reactors and fuel behaviour; reactor physics and criticality; materials, mechanics, chemistry and corrosion; severe accidents, emergency preparedness and response; uncertainty methods and probabilistic safety assessment; hot laboratories with irradiated materials and research reactors; and fires and explosion. They also work on waste disposal, but these activities are not described in this paper.

For each of the above domains, a few illustrations of ETSON experimental facilities and simulation codes, with their scope of applicability, will be briefly described. For modelling, the focus will be on the code developers' teams, mainly for large or unique codes, and a list of most widely used codes will be given. On facilities, the focus will be made on the large or unique facilities. The possibility of the modelling and experimental teams receiving students and/or researchers through mobility within ETSON is highlighted.

This emphasizes that, as a whole, ETSON covers all safety issues with experienced teams and capabilities and can address further R&D challenges such as new materials, fuels, and safety systems.

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1. INTRODUCTION

TSOs have a primary role in assessing the status of nuclear safety and radiation protection by reviewing safety assessments submitted by the licensees to regulatory authorities and in performing their independent nuclear safety assessments. For these tasks, developing and maintaining expertise in different areas is an utmost prerequisite and must be based, among other factors, on relevant safety research. It is also noted that R&D activities are driven by specific regulatory needs. In the performance of their R&D activities, TSOs conduct activities in both national and international collaborative framework, develop and apply computational codes and run experimental facilities. The ETSON Research Group (ERG) aims at identifying the needs for nuclear reactor safety research for Gen.II-III NPPs, ranking their priorities, sharing information on R&D projects/activities in which ETSON members are involved, and launching initiatives for new R&D projects

In 2016 ETSON listed the R&D priorities necessary for implementation of the 2014 Euratom Directive on the safety of nuclear installations [1], and in 2017 established a ranking of priorities on research activities for the next few years [2]. The capability to perform R&D activities to support the regulatory body or other public authorities is also highlighted in many publications (e.g. [3][4]), amongst others the recent IAEA TECDOC on TSO [5].

The ETSON members address most technical domains relevant for safety by national and international R&D projects and collaborations: thermal-hydraulics; material testing reactors (MTR) and fuel behaviour; reactor physics and criticality; materials, mechanics and chemistry; severe accidents, emergency preparedness and response; uncertainty methods and probabilistic safety assessments (PSA); hot laboratories with irradiated materials and research reactors; and fires and explosion. They also work on waste disposal, but these activities are not described in this paper.

For each of the above domains, a few illustrations of ETSON experimental facilities and simulation codes, with their scope of applicability, are briefly described. For modelling, the focus will be on the code developers' teams, mainly for large or unique codes, and a list of most widely used codes will be given. On facilities, the focus will be made on the large or unique facilities. The possibility of the modelling and experimental teams receiving students and/or researchers through mobility within ETSON is highlighted.

2. The MAIN ETSON EXPERIMENTAL FACILITIES AND SIMULATION CODES

2.1 Thermal hydraulics

Many system codes are used by the ETSON partners. A majority apply TRACE and RELAP5 that are distributed by the United States Nuclear Regulatory Commission. A few apply CATHARE (developed by CEA and jointly owned by EDF, Framatome and IRSN) [6] or the AC^2 code system (developed by GRS) consisting of the system codes ATHLET, ATHLET-CD and COCOSYS [7].

Several examples of application of these codes are summarized below:

- Bel V uses CATHARE for verification of safety thermal-hydraulic calculations performed by the NPP Licensee in order to get better understanding of the course of a given transient; and for safety analysis using advanced approaches (3D modelling, steam generator with multi-U tubes) to gain insights in potential improvements of the current accident procedures. Bel V also uses the code in support to analytical activities in the framework of experimental projects such as IRSN's DENOPI, as well as OECD/NEA PKL and ATLAS.
- GRS supported the Office for Nuclear Regulation (United Kingdom) by developing input files for different reactor designs and performing independent confirmatory calculations in support of the generic design assessment with AC^2. AC^2 was also coupled to the GRS diffusion code QUABOX/CUBBOX for investigation of Anticipated Transients Without Scram (ATWS) scenarios. AC^2 is continuously validated against a well-balanced set of integral and separate effect tests e.g. derived from CSNI code validation matrices. Examples of experimental facilities used for this purpose are PKL, ATLAS and THAI.
- JSI developed the first RELAP5 input model of the Krško (Slovenia) NPP more than 20 years ago and regularly updates it. The code is being used to simulate transients in the plant if detailed calculations are necessary for expert opinions or other projects related to plant operation and safety.
- NRA uses the TRACE code to evaluate the peak clad temperatures with uncertainties in large break Loss Of Coolant Accidents (LOCA).

- SEC-NRS uses the internally developed computer code Rainbow-TPP, which is implemented to perform calculations of neutron kinetics, thermal-hydraulics and other processes in the reactors and NPP systems influencing safety functions.

CFD (Computational Fluid Dynamics) codes are also used by ENEA, GRS, JSI, PSI, SSTC-NRS, VTT and Wood in order to provide more detailed calculation of specific phenomena. Interest in the further development of CFD tools has increased: GRS, e.g., is actively developing OpenFOAM solvers for nuclear safety applications.

Some trainees can be accepted on case by case basis in Bel V, ENEA, GRS, IRSN, PSI and SSTC-NRS.

Regarding experimental facilities, ENEA runs the SPES large-scale facility, and IRSN runs the THEMA platform [8] on thermal-hydraulics for mitigation of reactor accidents (LOCA, spent fuel pools) that is used for the DENOPI project on spent fuel pool accidents. All other members rely on the few facilities that still exist in Europe like PKL (in Germany) and PSB-WWER (in Russia) or in Asia like LSTF/ROSA (in Japan) and ATLAS (in Korea).

The challenges for the future will be to be able to maintain knowledge and experts in the field, further develop the codes, establish couplings between codes to improve multi-scale and multi-physics capabilities, and continue to operate the large integral facilities which are difficult to maintain.

2.2 MTR and Fuel behaviour

CABRI is an important research reactor devoted to the study of fuel behaviour in accident conditions, and in particular Reactivity Insertion Accidents (RIA) [8]. It is located at Cadarache (France), and is owned and operated by CEA mainly for IRSN and EDF customers, in particular for OECD R&D projects.

Two ETSON members are developing simulation tools for fuel safety: SCANAIR (RIA) and DRACCAR (LOCA) by IRSN, and TESPA-ROD by GRS.

The code most used by the ETSON members is the TRANSURANUS code (European Commission, Joint Research Centre), used by ENEA, RATEN ICN, SSTC-NRS and VUJE. Three members use FEMAXI (developed by JAEA): NRA for analysing the fuel behaviour under conditions of both normal operation and anticipated operational occurrences, RATEN ICN and LEI. In addition, NRA and ENEA use FRAPTRAN to evaluate fuel behaviour considering the fuel fragmentation, relocation and dispersal phenomena.

With the changes in fuel design and operation (e.g. new materials, higher burnup levels, power uprate, load following, etc.), guaranteeing an acceptable level of safety will require testing and analysis for the most challenging conditions such as LOCA and RIA.

2.3 Reactor physics and criticality

Three ETSON members are developing simulation tools in this field:

- GRS [7]: DORT-TD/TORT-TD for solution of time-dependent neutron transport equations for 2D/3D transient analyses; QUABOX/CUBBOX, a 3D neutron kinetics core model; KENOREST for prediction of the characteristics of irradiated LWR fuel; and KMACS, a core simulator.
- IRSN: MORET, a 3D Monte-Carlo code for simulating neutron transport using multigroup and pointwise cross-sections and the “formulaire” CRISTAL, both available through OECD/NEA, and, for evaluation of material neutron activation, the VESTA generic depletion interface code that aims to support any Monte Carlo transport code (such as MCNP), any depletion code (such as ORIGEN 2.2 or PHOENIX) and any standard nuclear formatted data.
- Wood: MONK for nuclear criticality, WIMS for reactor physics (also used by SEC NRS), and MCBEND and RANKERN for radiation shielding and dosimetry.

Each of the development teams draw on many years’ experience of nuclear code development, with continuous improvement based on validation programs and feedback from customers. Underlying the codes is detailed understanding of Monte-Carlo and deterministic methods, and of processing of nuclear data, as well as software engineering, customer support, training and quality assurance.

The Monte Carlo neutron transport MCNP code is used by a majority of ETSON members. NRA uses the following codes: MVP-II (with JENDL-4.0 nuclear data library) for criticality, CASMO5/SIMULATE5 for reactor calculations for PWRs and BWRs, TRACE5.0/PARCS for kinetic calculations of accident scenarios with thermal-hydraulics and neutronic coupling.

Concerning reactor physics, the core power distribution governs the plant behaviour and determines the operating safety margins. Indeed, the linear heat rate dependency on burnup (which is a 3-dimensional vector of spectral histories, burnable poison history, control rod history, etc.) is a key parameter for safety analyses such as in the case of large break LOCA and control rod ejection studies. No single code is capable of covering all phenomena involved in the nuclear safety field, therefore coupling reactor physics codes with tools of other disciplines is needed to carry out reliable safety analyses.

For TSO activities supporting their national safety authorities, assessments of criticality are needed for fuel storage, waste disposal, new reactor systems and transport of nuclear material.

2.4 Materials, mechanics, chemistry and corrosion

At Warrington, Wood has unique facilities for materials testing in support of nuclear power plant operation, including facilities for handling irradiated materials. The mechanical laboratories allow tensile, fracture, fatigue, hardness and creep testing of materials, at temperatures up to 1000°C, including testing of large components. The corrosion laboratory incorporates high temperature, pressurized water rigs to study effects of material, environment (temperature, water chemistry, gas) and loading (active or passive) on activation and progression of corrosion processes. On-line monitoring enables accurate measurement of crack initiation and growth.

IRSN currently runs two experimental platforms [8]: ODE, composed up to 60 large-scale concrete blocks with a detailed instrumentation, to study concrete pathologies linked to ageing of NPP containment; MAESTRO for characterization of materials, thermomechanical behaviour of metallic components (fuel claddings in particular), high temperature ovens…

GRS is developing the following codes [7]: PROST for the assessment of structural reliability of piping and vessels, WinLeck for calculation of leak areas and discharge flow rates on the basis of geometry, material and medium. With these tools leak-before-break assessments are performed. Furthermore, ASTOR is being developed as a simplified tool for the determination of failure times of reactor pressure vessels and piping loaded under internal pressure and high temperatures due to severe accident scenarios.

One important aspect to consider is the ageing of the operating NPPs. There are several degradation mechanisms affecting nuclear components. TSOs give a very high importance to maintaining the capabilities mentioned above and to progress in R&D, since there are still gaps regarding e.g. modelling of irradiation embrittlement, thermal fatigue, Stress Corrosion Cracking (SCC) and mechanical wear as well as joint action of degradation mechanisms [2].

2.5 Severe accidents, emergency preparedness and response

Two ETSON members are developing simulation tools in this field:

- GRS [7] with the AC² code system consisting of ATHLET, ATHLET-CD, COCOSYS and ATLAS (ATHLET-CD: extension of ATHLET for severe accidents, COCOSYS: lumped parameter code for determination of containment conditions during (severe) accidents).
- IRSN first with the ASTEC integral code [9], developed today by IRSN and considered as a reference code in Europe due to the continuous capitalization of knowledge acquired in Europe, and secondly with the MC3D multiphase multi-dimensional code for fuel coolant interaction.

A large majority of ETSON members (10 over 15) apply the IRSN ASTEC code, and several use AC². All ETSON members except IRSN use MELCOR for performing safety studies. JSI developed a MELCOR model of the Krško (Slovenia) NPP and uses it to assess the influence of the plant safety upgrade on meeting Severe Accident Management Guidelines (SAMG). Further development of the model and its use for simulations of different severe accident scenarios in the plant are foreseen. In Bel V (see [10] §4.4), MELCOR is used to strengthen the Bel V capability for independent severe accident safety assessments for the Belgian nuclear installations. Bel V also uses the code in support to analytical and experimental activities in international projects such as H2020 FASTNET, IRSN's DENOPI and OECD/NEA THAI-3. ENEA performs best-estimate MELCOR or ASTEC calculations of severe accident sequences or of Design Extension Conditions (DEC), as well as to assess existing SAMGs or to propose and evaluate new and improved ones. NRA uses MELCOR for analysing accident progression for representative reactor types of the current Japanese LWR fleet. The results are applied in reviewing the licensing safety analysis, planning of the emergency response, improving Level-2 and level-3 probabilistic risk assessment (PRA) methodologies and the source term for the consequence analysis by Win-MACCS.

The main experimental facilities are located in:

- IRSN [8]: the CHROMIA platform on chemistry and radiochemistry of fission products (in particular iodine and ruthenium) in severe accidents conditions, including an irradiator; within the THEMA platform, the PEARL facility devoted to the reflooding of debris beds, at a relatively large scale; and the ENACEFF facility on explosion of combustible gases such as hydrogen.
- MTA-EK: the CERES facility, representing a 1:40 slice of the WWER-440 type Paks NPP vessel outer cooling channel to test the heat transfer capabilities in case of molten corium in the vessel bottom.

For Emergency Preparedness and Response, ENEA uses the RASCAL 4.3 fast-running code, capable of evaluating LWR source terms within about 1 minute of computation time given a minimum set of information on the reactor status provided by the user. This code also performs simplified atmospheric transport and consequence calculations within about 180 km from the source. ENEA uses RASCAL to prepare quick estimates of severe accident Source Terms for the NPPs near the Italian national borders. For longer-range atmospheric transport calculations, ENEA uses the Lagrangian code FLEXPART with ECMWF weather data, as well as the Eulerian code ldX (developed by IRSN). For Preparedness and PSA level 3 studies pertaining to the neighbouring NPPs, ENEA has recently acquired the simplified code Win-MACCS for near-range atmospheric transport.

IRSN is developing the code system SESAME for evaluation of source term released to the environment and the C3X platform for evaluation of transfers in the environment and the doses received by the population as a function of meteorological conditions.

For fast source term predictions, GRS is developing the FaSTPro tool which collates information on source term predictions for severe accidents from deterministic analysis codes like AC² or MELCOR and on accident progression from PSA Level 2 models. Specific information on the accident can be fed in and is treated in a Bayesian belief network to update the predicted source terms. The output of FaSTPro then serves as input data for the RODOS transport and consequence calculation tool used by the German Office for Radiation Protection.

On a case-by-case basis, trainees can be accepted in the modelling teams in Bel V, GRS, IRSN, and SSTC-NRS.

Despite progress in research, and effort to capitalize knowledge into integral codes such ASTEC or MELCOR, modelling phenomena for conditions expected in the SA domain are still subject to great uncertainties. Thus, it is extremely important that the simulation codes and methods are validated for their intended purposes and key research infrastructures still support the reduction of the uncertainties in the phenomena.

2.6 Uncertainty methods and PSA

Two ETSON members develop PSA tools:

- GRS: SUSA for uncertainty and sensitivity analyses; XSUSA for nuclear cross section uncertainty and sensitivity analysis; and MCDET for Monte Carlo event tree analysis for probabilistic assessment of consequences of (severe) accident scenarios.
- IRSN: SUNSET for uncertainty and sensitivity analyses; and KANT, a probabilistic code for level 2 PSA.

RATEN ICN uses the WinBUGS Microsoft Windows version of BUGS (Bayesian Analysis Using Gibbs Sampling) that performs Markov chain Monte Carlo (MCMC) computations for a wide variety of Bayesian models. The code was used in identification of trends in components failure data, assuming that ageing effects are inducing these trends by degradation of components safety performances. The output of the analysis is the identification of the best distribution for the evolution in time of the failure data, and, by using this assumption in a PSA model, the evolution of the risk profile of the plant was obtained.

NRA uses WinNUPRA for internal event PRA (including fire and flooding) and external event PRA (including seismic and tsunami). Seismic PRA is quantified with an NRA internal code and Minimal Cut Sets (MCS) are generated using WinNUPRA.

For performing and assessing PSA, several European TSOs use the RiskSpectrum code by Lloyds Register.

An overview of the main challenge for the future application of PSA has been presented in [12] and although a ranking of the findings is needed (e.g. possible subjects of future activities), these are mainly related to:

- improved probabilistic software tools;
- methodologies extending the scope of existing PSA;
- the status of geosciences for assessing natural hazards and quantitatively addressing severity and frequency of both single and correlated natural initiated events;
- solutions to develop fragility analysis and to develop plant response analysis generally, including severe accident progression.

2.7 Hot laboratories with irradiated materials and research reactors

Several hot laboratories and facilities for irradiated materials are available: 2 at Wood, 1 at JSI, 3 at PSI, and 1 at VTT.

Concerning research and training reactors, TRIGA reactors are run at RATEN ICN, JSI and ENEA. In RATEN ICN, the TRIGA SSR - 14 MW and TRIGA ACPR research reactors are unique facilities at national level, providing irradiation of nuclear fuel and structural materials, radioisotopes production, analysis services for neutron activation, prompt gamma spectrometry, neutron dosimetry, determination of irradiated fuel burn-up. In addition, transient tests in the ACPR reactor support the homologation documentations for Gen.IV fuels, etc. The post-irradiation examination laboratory is equipped with facilities and equipment that allow the following activities: testing, handling and examination of nuclear fuel and structural materials used for nuclear reactor; manufacturing sealed nuclear radiation sources and radioisotopes used in industry, agriculture and medicine; characterization of radioactive waste.

While fundamental because of their unique multidisciplinary capabilities, operation and maintenance can be challenging especially for research and training reactors. The main issues are connected to lack of full utilization, ageing, staff requirements and funding. IAEA has several programs on those subjects.

2.8 Fires and explosion

Two ETSON members are developing fire and explosion simulation tools:

- IRSN with SYLVIA [12], a system code for a simplified simulation of fire scenario in a nuclear facility with a mechanical ventilation; ISIS CFD for detailed simulation of a fire in a room of a nuclear facility [13]; and PR^{2}MICS CFD for detailed simulation of a gas explosion in a compartment of a nuclear facility.
- GRS with COCOSYS containment response code that includes a pyrolysis model.

NRA uses SYLVIA, ISIS and FLUENT for fire phenomena analysis, mainly glove box fire. NRA uses FLACS and AUTODYN for hydrogen explosion analysis during a severe accident. Wood uses ABAQUS & CFAST for fire modelling, while Bel V and VTT use FDS CFD code (with LES turbulence model) for simulation of fires.

The only experimental facility, owned by IRSN, is the GALAXIE platform [8] for well ventilated and under-ventilated fires, in confined or open atmosphere, including malfunction of electrical equipment.

In 2017, the majority of ETSON members took part in a joint benchmark exercise using simulation tools to model experiments on hydrogen explosion in NPP containment [12].

Fires pose a significant risk to the safety of NPPs and other nuclear installations. The risk management strategy relies on the defence-in-depth concept, which in fire safety means the use of consecutive safety systems or barriers. Therefore, fires are taken into account as an initiator in PSA studies. Such studies demonstrate that fires can be an important contributor to core damage frequency and other plant damage states of NPPs (e.g. see results of PRISME OECD project), thus confirming the interest in further research on the subject.

3. CONCLUSION

This paper focuses on a few illustrative examples only, but the full list of ETSON members' modelling and experimental capabilities includes a dozen major large-scale facilities, often unique in the world, plus more than one hundred smaller-scale facilities. For modelling codes, some being developed by ETSON members (GRS and IRSN mainly) constitute international reference codes, while the other members use a large number of codes of diverse types. Finally, it is emphasized that, as a whole, ETSON covers all Gen.II-III safety issues with experienced teams and capabilities and can address further R&D challenges such as new materials, fuels, safety systems etc.

Thanks to R&D activities performed in support of regulatory needs, ETSON is able to keep a high level of competences and expertise in a challenging scientific context in continuous evolution. This allows ETSON members to concentrate the resources available for research on topics which are relevant for most countries, thus avoiding duplication of efforts, while keeping the highest standard necessary in this field. A good example is a common use by a large majority of ETSON members of two reference integral codes for simulation of severe accidents, ASTEC and MELCOR.

ACKNOWLEDGEMENTS

Special thanks go to J.P. Van Dorsselaere who led the ETSON Research Group from 2011 to mid-2018. The paper has been prepared thanks to the information provided by the ERG member organizations. The effort of Steve Powers for the complete review is also to be acknowledged.

ABBREVIATIONS/GLOSSARY

ABAQUS	Software suite for finite element analysis and computer-aided engineering
ACPR	Annular Core Pulsed Reactor (TRIGA)
AC²	ATHLET, ATHLET-CD, COCOSYS
ASTEC	Accident Source Term Evaluation Code
ASTOR	Approximated Structural Time Of Rupture code
ATHLET	Analyses of the Thermal Hydraulic Leaks and Transients code
ATHLET-CD	Analyses of the Thermal Hydraulic Leaks and Transients - Core Degradation code
ATLAS	*in §2.5*: Analysis simulator for interactive plant simulation *elsewhere:* Advanced Thermal-hydraulic test Loop for Accident Simulation
ATWS	Anticipated Transient Without Scram
AUTODYN	Computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions
BUGS	Bayesian analysis Using Gibbs Sampling software
BWR	Boiling Water Reactor
CABRI	French research reactor
CASMO	Lattice physics code
CATHARE	Code for Analysis of THermalhydraulics during an Accident of Reactor and safety Evaluation
CERES	Cooling Effectiveness on Reactor External Surface facility
CFAST	Consolidated Fire and Smoke Transport code
CFD	Computational Fluid Dynamics
CHROMIA	Experimental chemistry and radiochemistry platform
COCOSYS	COntainment COde SYstem
CRISTAL	Criticality calculation package
C3X	Atmospheric dispersion and radiological consequences software platform
DEC	Design Extension Conditions
DENOPI	Spent fuel pool loss-of-cooling and loss-of-coolant accident project

DORT-TD/TORT-TD	Two/Three-dimensional neutron/photon transport computer programs
DRACCAR	Deformation and reflood of a fuel rod assembly during a loss-of-coolant accident code
ECMWF	European Centre for Medium-Range Weather Forecasts
ENACEFF	Containment flame acceleration test facility
ERG	ETSON Research Group
ETSON	European Technical Safety Organizations Network
FASTNET	FAST Nuclear Emergency Tools project
FaSTPro	Fast Source Term Prognosis tool
FDS	Fire Dynamics Simulator
FEMAXI	Thermal and mechanical behaviour of light water reactor fuel rods code
FLACS	FLame ACceleration Simulator
FLEXPART	FLEXible PARTicle dispersion model
FLUENT	Commercial CFD software
FRAPTRAN	Fuel Rod Analysis Program TRANsient
GALAXIE	Experimental platform for fire analysis
IAEA	International Atomic Energy Agency
ISIS	Computer tool for 3D fire simulation in industrial enclosures
JENDL	Japanese Evaluated Nuclear Data Library
KANT	Quantification software for level 2 PSA
KENOREST	Coupled code system for criticality and burnup inventory calculations
KMACS	Kernsimulator – Modular Adaptable Core Simulator
ldX	Eulerian model for atmospheric transport of radioactive products
LES	Large Eddy Simulation
LOCA	Loss Of Coolant Accident
LSTF/ROSA	Large Scale Test Facility / Rig-Of-Safety Assessment
LWR	Light Water Reactor
MACCS	MELCOR Accident Consequence Code System
MAESTRO	Experimental platform for mechanics and materials
MCBEND	Monte-Carlo code for General Radiation Transport analysis for shielding and dosimetry analysis
MCDET	Monte Carlo Dynamic Event Tree
MCMC	Markov Chain Monte Carlo computation
MCNP	Monte Carlo N-Particle code
MCS	Minimal Cut Sets
MC3D	3-dimensional thermo-hydraulic multiphase flow code mainly used for fuel-coolant interaction (or steam explosion)
MELCOR	Methods for Estimation of Leakages and Consequences of Releases code
MONK	Monte-Carlo code for nuclear criticality safety and reactor physics analyses
MORET	Monte-Carlo code for the evaluation of criticality risk in nuclear installations
MTR	Material Testing Reactors
MVP-II	General purpose Monte Carlo code for neutron and photon transport calculations (continuous-energy method)
NPP	Nuclear Power Plant
ODE	Experimental platform devoted to research on concrete ageing for containment buildings of NPP or waste repository facilities
OECD	Organization for Economic Cooperation and Development
OpenFOAM	Open Source CFD toolbox
ORIGEN	Oak Ridge Isotope GENeration code
PARCS	Purdue Advanced Reactor Core Simulator
PEARL	Experimental facility concerning debris bed reflooding
PHOENIX	Depletion module
PKL	Primary coolant loop test facility
PRA	Probabilistic Risk Assessment
PRISME	Project on fire propagation in elementary, multi-room scenarios
PROST	Probabilistic Structure Calculation code
PR^2MICS	CFD code for gas explosion in a compartment
PSA	Probabilistic Safety Assessment
PSB-WWER	Integral-type test facility
QUABOX/CUBBOX	Code for 3D neutron kinetics core model analysis

Rainbow-TPP	Neutron kinetics, thermal-hydraulics and other processes code
RANKERN	Point-Kernel program for gamma ray transport solutions
RASCAL	Radiological Assessment System for Consequence AnaLysis
RELAP	Reactor Excursion and Leak Analysis Program
RIA	Reactivity Insertion Accident
RiskSpectrum	Risk and reliability analysis software
RODOS	Real-time On-line DecisiOn Support system
R&D	Research & Development
SAMG	Severe Accident Management Guidelines
SCANAIR	Code for analysing reactivity-initiated accidents
SCC	Stress Corrosion Cracking
SESAME	Software for emergency management (diagnosis and prognosis of the status of a damaged reactor and estimates of actual or potential releases)
SIMULATE	Nodal simulator analysis code
SPES	Simulator Pressurized Experiments on Safety
SSR	Steady State Reactor (TRIGA)
SUNSET	Sensitivity and UNcertainty Statistical Evaluation Tool
SUSA	Software for Uncertainty and Sensitivity Analyses
SYLVIA	Computer code system to study fire ventilation and airborne contamination
TECDOC	Technical Document (IAEA)
TESPA-ROD	Temperature, Strain and Pressure Analysis of a fuel ROD code
THAI	Thermal-hydraulics, Hydrogen, Aerosols and Iodine facility
THEMA	Experimental platform for thermal hydraulics
TRACE	TRAC/RELAP Advanced Computational Engine
TRANSURANUS	Fuel performance code
TRIGA	Training, Research, Isotope production, General Atomic
TSO	Technical Safety Organization
VESTA	Monte Carlo depletion interface code
WIMS	General purpose reactor physics program for core physics calculations
Win-	Microsoft Windows operating system version
WinLeck	Analysis methods for leakage rates in pressurized components
WinNUPRA	Probabilistic safety/risk assessment software package for Level 1 PSA and reliability analyses
WWER	Water-Water Energetic Reactor
XSUSA	Cross (X) Section Uncertainty and Sensitivity Analysis

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SCIENTIFIC AND TECHNICAL SUPPORT TO THE REGULATORY BODY WITHIN THE FRAMEWORK OF MDEP VVERWG ACTIVITY

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Abstract

The Working Group on new VVER designs (VVERWG) within the Multinational Design Evaluation Programme (MDEP) comprises the members from the nuclear regulatory authorities of China, Finland, Hungary, India, Russia and Turkey.

VVERWG as well as the other five MDEP design specific working groups (EPR, AP1000, APR1400, ABWR and HPR1000) is successful in sharing information and experience on the regulatory safety reviews of new reactor designs with the purposes of enhancing the safety and enabling regulators to make timely licensing decisions.

Since 2013 up to mid-2018 VVERWG had been chaired and managed by SEC NRS (TSO of the Russian Regulatory Authority) in arrangement of the group activity providing support to the regulators and reporting to the MDEP Steering Technical Committee and Policy Group on the benefits. Since mid-2018 VVERWG has been chaired by STUK (Finnish Regulatory Authority).

VVERWG includes four technical expert subgroups: Severe Accidents Management, Fukushima Lessons Learned Covered by Design Solutions, Reactor Pressure Vessel & Primary Circuit Components and Accident and Transient Analysis. The group activities include exchange of information on national legal framework related to new designs, regulatory safety requirements, safety assessment approaches, safety review results and experience.

SEC NRS supports the interactions between the VVERWG members and the Russian design, vendor and operating organizations to get additional information about new VVERs design solutions related to safety during joint meetings and technical visits to new VVER units under construction and commissioning in the Russian Federation and abroad.

1. INTRODUCTION

The working group on new VVERs (VVERWG) is one among other design-specific working groups (EPR, AP1000, APR1400, ABWR and HPR1000) within the framework of Multinational Design Evaluation Programme (MDEP).

VVERWG comprises the members from regulators of China, Finland, Hungary, India, Russia and Turkey. The VVERWG (as well as the other five MDEP design specific working groups) is a good platform for sharing information and experience on the regulatory safety reviews of new designs, and on construction and commissioning of new reactors.

Since 2013 up to mid-2018 VVERWG had been, on behalf of Rostechnadzor (Russian Regulatory Authority), chaired and managed by the Scientific and Engineering Centre for Nuclear and Radiation Safety (SEC NRS), being the TSO of Rostechnadzor (according to the [1]) in arrangement of VVERWG activities providing support to the VVERWG regulators and reporting to the MDEP Steering Technical Committee and Policy Group on the benefits. There is a common understanding of regulators [2] to use the efforts of technical support organisations (as additional resource with experts of special high-level skills) for regulatory review and assessment during the process on new reactors commissioning. Since mid-2018, VVERWG has been chaired by STUK (Finnish Regulatory Authority).

2. VVER TECHNOLOGY EVOLUTION

Peculiar design features of water-water reactors (VVER), as compared with the pressurized water reactors (PWR), are the following:

— increased coolant volume above the reactor core level;

— increased coolant volume in the primary circuit, as compared with the nuclear fuel mass and the reactor core thermal output;

— increased volume of pressurizer vessel;

— significant volume of coolant inventory in steam generators of horizontal type;

— absence of tie-ins and holes beneath main coolant nozzles at reactor vessel and, accordingly, below the top elevation mark of the core.

Due to large coolant inventory in the primary and secondary circuits, the behaviour of VVER unit during transients and emergency situations is characterized by higher thermal inertia of the processes. This provides longer retention of safe operation conditions, keeping the reactor core drained, and absence of the operator intervention. Besides, another particular feature of VVER is the compactness of the reactor core that is actually void of xenon density oscillations and provides smooth distribution of neutron flux.

Of course, new VVER-1200 designs [3] took into account both the experience of VVERs operation during the long-term history and the lessons learned from accident at Fukushima NPP (2011). Certainly, new technical solutions are subjects for regulatory safety review and assessment.

3. GOALS AND DIRECTIONS OF VVERWG ACTIVITIES

One of the main goals of VVERWG is to leverage national regulatory resources by sharing information and experience on the regulatory safety design reviews of new VVERs, including exchange of experience on licensing process and design safety reviews, lessons learned, and design-related construction, as well on commissioning of a new VVER unit operation during the initial two years and understanding the differences in regulatory safety review approaches in each country to support potential use of other regulators while design safety evaluations.

Another goal of VVERWG is to provide inputs to other MDEP working groups on potential topics of regulators' significant interest regarding the safety.

The next goal of VVERWG is to enhance the safety of new designs through regulators' cooperation and by harmonization of regulatory practices including elaboration of regulators' technical reports and common positions on design safety review on common assessments results; sharing the regulators' common positions to vendor and operators regarding the safety; usage of the experience gained in learning similarities and differences in regulatory approaches and requirements to identify potential paths forward to a safety benefit for new VVER designs.

Additionally, the VVERWG activity covers the experience and information exchange on regulators' approaches and safety review related to new VVER designs in member-countries. VVERWG holds regular meetings of the main group and technical experts' sub-groups on common assessment of safety issues related to new VVER designs. The comparison table of differences in new VVER designs has been developed and updated by VVERWG members.

4. VVER WORKING GROUP STRUCTURE AND ACTIVITIES RESULTS

VVERWG includes four technical expert sub-groups: Fukushima Lessons Learned Covered by Design Solutions, Severe Accidents Management, Reactor Pressure Vessel and Primary Circuit Components, and Transient and Accident Analysis.

VVERWG ensures the effective cooperation among members on evaluation of new VVER designs, convergence (harmonisation) of safety requirements and regulatory practices, information exchange on national legal framework related to new designs, regulatory safety requirements, safety assessment approaches, safety review results and experience in construction and commissioning of new VVERs.

SEC NRS supports the interactions between the VVERWG members and the Russian design, vendor and operating organizations to get additional information on the design solutions related to safety during joint meetings. Technical visits of VVERWG members to new VVER units being under construction and commissioning in the Russian Federation and abroad are arranged.

4.1 Technical expert subgroup on Fukushima-related issues

Technical expert subgroup 'Fukushima Lessons Learned Covered by Design Solutions' (lead by TAEK, Turkey) had the initial task to develop the Common Position [4] addressing Fukushima-related issues. The developed Common Position covers 4 topics: accounting for external events in the design; reliability of safety functions implementation; design solutions to cover specific BDBA's (SBO and loss of UHS); emergency preparedness and response.

The Common Position [4] was approved by MDEP Steering Technical Committee (STC) in 2017. But, there is a new assignment given by MDEP STC to elaborate an additional section addressing the Vienna Declaration on Nuclear Safety (dated 09.02.2015) in order to pay attention on Principle 1 mentioned in the declaration on avoiding early radioactive releases or large radioactive releases.

SEC NRS was requested to address the Russian design organisations with respect to provide some presentations on how new reactor designs touch upon these issues.

4.2 Technical expert subgroup on severe accidents management

Technical expert subgroup ‘Severe Accidents Management’ (lead by SEC NRS, Russia) has objectives to identify commonalities and differences in regulators’ approaches used in VVERWG member countries and develop technical reports and common positions on regulatory approaches and criteria related to severe accident assessment and management.

One Technical Report [5] (covering regulators’ requirements to general and legal issues, procedures, guidelines, equipment and severe accidents analyses) was developed by the group, approved by the MDEP STC and published in 2017.

It is planned to develop a technical report (fall 2019) that will reflect the ex-vessel melt retention and assessment criteria of core catcher efficiency for melt stabilization (technical report will be a basis for further development of the common position).

SEC NRS was requested to address the Russian design organisations with respect to provide the presentations on how new reactor designs touch upon the issue of ex-vessel melt retention in core catcher.

4.3 Technical expert subgroup on reactor pressure vessel and primary circuit components

Technical expert subgroup ‘Reactor Pressure Vessel and Primary Circuit Components’ (lead by HAEA, Hungary) has objectives to identify commonalities and differences in regulatory approaches used in VVERWG member countries, and develop technical reports and elaborate Common Positions related to

- application of leak-before-break concept,
- manufacturing of primary circuit components,
- radiation embrittlement of reactor pressure vessel regarding use of new base metal,
- pre- and in-service inspection of primary circuit components,
- design basis loadings and their combinations for primary circuit components,
- cladding of primary circuit,
- protection against overpressure of primary circuit,
- qualification of a ‘first-only-a-kind’ components (FOAK components), etc.

One Technical Report [6] (covering seven first topics mentioned above) was developed by the group, approved by the MDEP STC and published in 2017. It is planned to develop next Technical Report (fall 2018) and a Common Position (beginning of 2019) on reactor pressure vessel and primary components reliability and submit to MDEP STC for review and approval.

4.4 Technical expert subgroup on transient and accident analysis

Technical expert subgroup ‘Transient and Accident Analysis’ (lead by STUK, Finland) has objectives to identify commonalities and differences in regulators’ approaches used in VVERWG member countries and develop technical reports and common positions on regulatory approaches and criteria related to regulatory requirements and criteria for transients and accidents assessment that could be applied for new reactor designs.

The subgroup started its activity in 2017 on the following topics agreed for joint considerations:

- regulatory requirements for accident and transient analyses, including acceptance criteria, expectation for analyses documentation (lead by STUK, Finland),
- regulatory assessment of tools (computer programs) used for transients and accidents analysis (lead by SEC NRS, Russia),
- performance and analysis of passive systems (lead by STUK, Finland),
- cooling in spent fuel pool with internal and external hazards (lead by TAEK, Turkey),
- regulatory procedures for safety review and licensing (lead by HAEA, Hungary).

It is planned to develop a technical report (mid 2019) on regulators practices for the review and assessment of accidents and transients analysis and send to MDEP STC for review and approval.

4.5 Activities in construction and commissioning experience

VVERWG (as other MDEP design-specific working groups) is an effective platform to share the significant lessons related to construction and commissioning of new reactors. VVERWG members from China, India and Russia provide information both on construction experience as well as on commissioning and operation experience during the first period related to new VVERs.

SEC NRS in close cooperation with Rosenergoatom (the Operator of Russian NNPs) provides actual information on commissioning and trial operation of Novovoronezh NPP-II Unit 1, including operational events, root causes of the events as well as the technical solutions and regulatory decisions to solve the events. Moreover, SEC NRS provides actual information on construction experience at Novovoronezh NPP-II Unit 2, and Lenigrad NPP-II Units 1&2 (all of VVER-1200 design).

On the regular basis SEC NRS organizes the meetings with designs organizations to get additional information and data on technical solutions, which are significant to safety of new VVERs.

VVERWG members arrange the technical visits to NPP sites with new VVERs being under construction or at commissioning stage (Leningrad NPP-2 and Novovoronezh NPP-2 in Russia, Tianwan NPP in China).

5. CONCLUSIONS

MDEP is a good regulators' forum for information exchange on approaches to safety issues and systematic evaluations of new reactor designs.

The achieved results of MDEP activities show its high effectiveness at the practically past phase on common regulators' design review. Now, the focus of MDEP activity is more and more on the experiences of commissioning and initial operation of new reactors during first years after commissioning.

It is necessary to find some mechanisms to transfer the knowledge of the MDEP regulators (accumulated in many technical reports and common positions at the MDEP library) to regulators of newcomer countries in order to support their activities.

Experience of Rostechnazor shows that it is effective to involve a technical and scientific support organisation for regulatory review and assessment during the process on new reactors commissioning. Moreover, Rostechnazor used and will continue to use the MDEP technical materials to be applied to the national regulatory practice in Russia.

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TOPICAL SESSION 3

ROLE OF THE TSOs IN EMERGENCY PREPAREDNESS AND RESPONSE

Chairperson
J.-L. LACHAUME
France

Co-chairperson
A. KURYNDIN
Russian Federation

This third session discussed the roles of, and challenges faced by TSOs in terms of providing support to government authorities competent in emergency preparedness and response. The TSOs play a wide range of roles in emergency preparedness and response at the national level, it often goes beyond support to the regulatory body. The support of the TSOs is related to assessment, prognosis and monitoring, including managing or supporting the emergency centres in some Member States during an emergency response or related drills and exercises. It was suggested that embarking countries define the role of TSOs in the context of national emergency preparedness and response approaches, taking into account the roles of all involved stakeholders as appropriate. It was noted that the IAEA should consider facilitating the sharing of experience at regional and international levels, as well as on a bilateral basis. In particular, experience gained through involvement in emergency drills and exercises could be shared at the level of the TSO Forum in a dedicated working group. It was also highlighted that the IAEA should consider developing guidance on the role of TSOs in emergency preparedness and response.

EMERGENCY, PREPAREDNESS AND RESPONSE: AN IMPORTANT STAKE FOR IRSN

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Abstract

Providing the public authorities with a rapid, high-quality, and operational technical support of the Safety Authorities in emergency situations is one of the major IRSN's missions. As the National public expert in nuclear and radiation risks, IRSN has a clearly defined role in the French National Response Plan for Major Nuclear or Radiological Accidents, where it is tasked with assessing risks and predicting how an accident will unfold.

1. INTRODUCTION

IRSN provides support to public authorities in case of incident or accident and puts forward recommendations to the safety authorities on technical, health and medical actions to protect population and environment in the area concerned, and to bring the facility under control. For IRSN's teams, preparedness is tested mainly through participation in national and international exercises. IRSN is involved in preparing French policy on managing the post-accident phase of a possible nuclear accident. IRSN is also involved in international activities to strengthen its knowledge and to foster a uniform approach to risk management in Europe and throughout the world.

2. IRSN ROLE IN CASE OF AN EMERGENCY

A nuclear or radiological alert can be triggered by different ways. A nuclear operator can declare an emergency on its facility; the Civil protection can send an alert in case of a radioactive material transport; the Public authorities can pass an abroad emergency situation. Moreover, the IRSN Teleray network can detect any increase of the level of environmental radioactivity in France. Whatever the situation, a specific organization is implemented, according to the French National Nuclear Accident Response Plan. The nuclear operator is responsible for the safety of the affected facility and implements the necessary procedures and its emergency plan for preventing radioactive releases and for returning the facility to a controlled state. The Public Authorities are in charge of the protection of the population and the environment according to specific emergency plans: ORSEC at a national level and PPI at a local level. The Safety Authorities supported by IRSN are in charge of providing technical expertise on radiological and nuclear risks. As such, the IRSN participates in managing emergencies. It proposes to the Safety Authorities technical, health and medical measures to protect people and the environment and return facilities to safe conditions. It assists the Safety Authorities and the ministries. These tasks are set out in special agreements and protocols. The IRSN centralises the results of environmental measurements and cooperates with Météo-France. The IRSN's mobile units enable it to go directly in the field to organize measurements and provide local authorities with information.

So, in case of an emergency in France, IRSN is able to implement quickly an emergency assessment system in order to support the Authorities. The assessment consists in analysing a continuous flow of technical data coming from the damaged facility and the available environmental measurements in order to establish in real time:

- The diagnosis of the situation since the beginning of the accident: evaluation of the level of the damages at the facility involved and of the potential radioactive releases with the view of evaluating the consequences on people and the environment.

- The forecast of the evolution of the situation, at least for the 24 upcoming hours. It consists of an evaluation of the predictable evolution of the accident and of the radioactive releases, as well as the possible doses to the population. In addition to that, IRSN considers some potential incidents that could make the consequences worse.

The results of these evaluations aim to allow the anticipation of consequences on the potentially exposed people in order to decide, in timely manner, some countermeasures to avoid or reduce the doses (sheltering, evacuation…).

In case of an accident happened abroad, a similar emergency assessment system is implemented, depending, of course, on the possibility to have access to technical information and environmental data, in order to advise the French authorities on possible consequences on the French territory, on French people living in the concerned country and on commercial activities (importations).

3. IRSN ORGANIZATION

A dedicated emergency organization (see Fig.1) has been set up at IRSN in order to fulfil its commitments in case of an emergency. Every week, an IRSN servant is on duty 24/7 to answer any emergency phone call. Depending on the situation, in agreement with the Director General, he can decide to activate the Technical Crisis Center (CTC) located at IRSN headquarters in Fontenay-aux-Roses. A 27-staff team is on duty 24/7 and reaches the CTC within one hour. Their first mission is to evaluate the situation as soon as possible with the available data (automatic data from the Nuclear Power Plant, Teleray network, operator's messages…). A partnership with Meteo France gives IRSN access to very accurate meteorological forecasts. A first appraisal of the situation is established about one hour after the CTC activation. According to the type of accident and its severity, other experts can reinforce the CTC. A pool of more than 300 IRSN specially trained experts can be part of the CTC team and allow the CTC activation for a long period.
If needed, IRSN can send a mobile unit in the area near the facility to coordinate samplings and environmental radioactive measurements. IRSN can also send a mobile health unit to monitor the internal contamination of people.

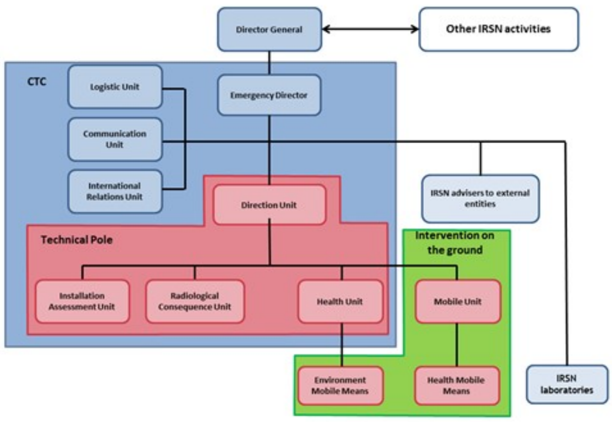

FIG. 1. The IRSN emergency organization

The CTC is composed of several cells. The "facility evaluation" cell is in charge to establish in real time the diagnosis of the situation (state of the facility and of the radioactive releases) and a forecast of the evolution at least for the upcoming 24 hours. The "radiological consequences" cell evaluates the possible consequences of the radioactive releases on people (doses) and on the environment. These assessments are crucial because they are the foundation for the countermeasures taken by the Public Authorities to protect the population (sheltering, evacuation, iodine pills intake…). A "health" cell, working in close connection with the "radiological consequences" cell, evaluates the individual doses (population, workers), gives advice for the health management of the exposed population and can calculate the doses for people carrying out specific operations. A "communication" cell is in charge to provide a technical, quick, reliable and credible communication. Finally, an "international cell" has been recently created to coordinate the international relationships with relevant organizations and to get information in case of an abroad accident.

The specific expertise and calculation at the CTC are based on a homemade methodology called "3D/3P". The aim of 3D/3P is to give structure to the evaluation process of the Reactor Assessment Unit, to allow focusing on key parameters for a pertinent and a global assessment, to facilitate dialog and information sharing with other Emergency Teams (safety authorities, operators), to allow anticipating the potential evolutions of the situation and to answer the main question: What about release in the past and in the future? The 3D/3P methodology provides a diagnosis and a forecast of the status of the 3 barriers. For a NPP, these 3 barriers are the fuel and cladding, the primary system envelope and the reactor building containment. This methodology is very powerful and successfully used in France during emergency drills. It is applicable for every kind of NPP but also for every nuclear facility.

4. EMERGENCY DEVELOPMENTS AT IRSN

IRSN is very committed to enhance its capabilities in Emergency, Preparedness and Response. This commitment is based on the feedback of past accidents like Chernobyl and Fukushima, of real incidents that occurred in France and on several emergency drills. Each year, there are about twelve emergency drills in France on civil and defence nuclear installations.

One of the top priority activity at IRSN is related to the post-accident phase. In the event of an accident occurring at a nuclear facility and leading to the release of radionuclides into the environment, the distinction is commonly made between: the emergency phase, during which management efforts focus on the accident and its immediate consequences and the post-accident phase, during which management efforts are aimed at managing the later consequences of the accident (population exposure due to radioactive deposition having contaminated the territories). Indeed, in France an important work has been realized, in the framework of the so-called "CODIRPA" under the responsibility of the French regulatory body ASN with the strong support of IRSN. In 2012, the first elements for a national policy on post-accident management were drawn up with respect to nuclear accidents triggering short-term (less than 24 hours) radioactive release of medium scale, with a chance of occurring at French nuclear facilities. These policy elements outline a range of actions applicable over successive periods of time, designed in order to attain the fundamental gains achieved and in line with the principles set out.

Currently, IRSN is working on possible evolutions of the French doctrine and on a methodology to perform radioactive measurements in the environment to quickly establish a map of the ground contamination (see Fig.2) that will allow the Public authorities to determine areas where protecting the population is required (relocation, remediation…). So far, IRSN recommends mainly a better consistency between the countermeasures in the emergency phase and the post-accident phase, and to use more efficiently the results of the radioactive measurements to assess the long term countermeasures. That's why IRSN works on a methodology combining airborne and ground measurements using airplanes, helicopters, drones, cars, motorcycles, pedestrians to establish as fast as possible a map of the ground contamination.

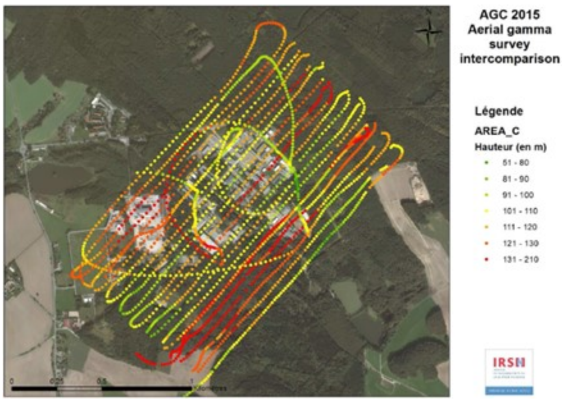

FIG.2. Example of airborne measurement

5. INTERNATIONAL ACTIVITIES AT IRSN

IRSN plays a driving role in advancing nuclear safety, radiation protection and emergency, preparedness and response in an international context. As a Technical and Scientific Support Organization (TSO), IRSN sets up a number of multinational scientific partnerships and participates in international projects/programs under the auspices of the EU (ETSON network of TSOs), the IAEA or the OECD/NEA. These international activities contribute to strengthen the IRSN's knowledge and its high level of expertise while facing different technologies and safety practices. They also enable the development of shared knowledge among partners and foster a uniform approach to risk management in Europe and throughout the world.

In this context, IRSN has 2 main priorities for its international activities. The first is related to Europe and the necessity to harmonise the countermeasures, since an accident occurring in Europe would also have consequences in every European country indeed. So, considering that an important step has been reached through by the European regulatory bodies with the so-called HENRA/WENRA approach, IRSN supports the strengthening of the European TSOs and their network ETSON, in the field of EP&R. Also, IRSN will take some initiative in this regard consistently with HERCA and WENRA.

The second priority is related to the IAEA. IRSN intends to enhance its capability to support the agency in case of a nuclear accident occurring in any country around the world in order to strengthen the coordination of international emergency preparedness and response. In this regard, IRSN will reinforce its collaboration with the IAEA Incident Emergency Center, thanks to stronger involvement in international emergency drills and by providing the IEC with one staff and with a cost free expert working on emergency tools and doctrine.

6. CONCLUSION

In some respects, preventing or managing a radiological or nuclear emergency may be thought of as the ultimate purpose of IRSN. That's why a lot of effort is dedicated to the continuous improvement of Emergency, Preparedness and Response. A high priority is given to enhance the IRSN's emergency strategy specifically regarding the post-accident management and the development of international activities.

ENHANCING EMERGENCY PREPAREDNESS AND RESPONSE IN GERMANY
GRS' role and contribution

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Abstract

Technical Safety Organisations (TSOs) play a major role in nuclear emergency preparedness and response (EP&R) in many European countries. This is no different in Germany, where the German TSO, the *Gesellschaft für Anlagen- und Reaktorsicherheit (GRS)* provides support to the Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The BMU leads the newly founded Federal Radiological Situation Centre (RLZ) which combines the personnel and technical capacities of several authorities and organisations at the federal level, including those of the GRS. The RLZ is responsible for the prognosis and evaluation of the radiological situation in the event of supra-regional emergencies. In addition, the RLZ coordinates the necessary protective measures between the federal government, the *Länder*, other countries and the EU. The paper will address three aspects of GRS' role and contribution to Germany's EP&R arrangements: Emergency planning, the GRS Emergency Centre and international cooperation. As regards emergency planning, GRS supports the BMU and its advisory boards. This task comprises of the drafting of regulatory documents as well as the development of realistic exercise scenarios. Based on such scenarios, GRS assists in planning, conducting and evaluating exercises for the federal authorities. Moreover, GRS continuously enhances the scientific base in order to understand nuclear incidents and accidents, e.g. by the development of accident analysis tools. In case of an emergency in a nuclear power plant, the GRS Emergency Centre is prepared to assess the technical condition, provide prognoses concerning the future accident progression and evaluate information on the release of radioactive material. Finally, the Fukushima accident has shown the importance of international cooperation between both authorities and TSOs. GRS supports European and international cooperation in EP&R and has been a driving force in this area through its participation in and contribution to several international and bilateral working groups dedicated to EP&R.

1. INTRODUCTION

In Germany, emergency preparedness in the nuclear and radiological fields is designed to prevent or mitigate the radiological effects on the environment in the event of incidents and accidents. This task is fulfilled on the one hand by the preventive planning of the operators of nuclear facilities or other facilities with larger inventories of radioactive substances *via* the on-site emergency management. On the other hand, the competent authorities at regional, state and federal levels plan measures to protect the population outside of facilities, i.e. off-site EP&R.

The transposition of Directive 2013/59/Euratom (EU BSS) [1] into German law by the Radiation Protection Act (StrlSchG) [2] led to innovations in the emergency management system of both the federal government and the *Länder*. Up to now, the regulatory framework for emergency preparedness consisted primarily of recommendations and related mainly to emergencies in nuclear facilities. The new provisions of the StrlSchG provide for the development of coherent emergency plans covering the entire spectrum of nuclear and radiological emergencies. In addition to the requirements for early protective measures, particularly regarding disaster control, large parts of medium- and long-term emergency management are now to be mapped and adopted as general administrative regulations.

GRS' role and capacities as the independent and non-profit TSO in nuclear safety for the German federal government shall briefly be outlined in the following.

2. EMERGENCY PLANNING

As regards emergency planning, GRS supports the BMU and its technical advisory boards, such as the Reactor Safety Commission (RSK) and the Commission on Radiological Protection (SSK), in particular the committee on "Emergency Management in the Environment of Nuclear Installations" and its working groups. The Fukushima accident required a thorough reassessment of the regulatory framework for the off-site EP&R to cope with potential accidents in German nuclear facilities implying potentially significant radiological consequences. GRS supported the dedicated working group "Lessons Learned from the Fukushima Accident" of the SSK in reviewing the relevant German regulations and clarifying whether or not, and, if necessary, how the requirements for emergency management should be changed or supplemented. The findings compiled and elaborated contributed to the updating and thus improvement of the concepts for the protection of the public based on an in-depth analysis of the Fukushima accident. As a result of these findings, the SSK issued a central recommendation [3] which serves as a technical foundation for the renewal of the German regulatory framework in EP&R in the aftermath of the Fukushima accident.

The current concept of the EU BSS [1] with regard to emergency management differs significantly from the previous principles that had been included in the relevant European and German regulations. Examples are the system of requirements for the protection of emergency workers, the reference value concept and the establishment of optimised protection strategies which combine short and long-term measures. In addition, new terminology has been introduced by the EU BSS which necessitated compatibility checks with existing national regulations and corresponding amendments. In this context, GRS checked the existing regulations for compatibility, identified the need for amendments and supplements and drafted proposals for amendments and supplements to the emergency management regulations, including the parts addressing EP&R in the new StrlSchG.

The StrlSchG foresees a coherent system of emergency plans which are related to a set of reference scenarios covering all types of nuclear and radiological accidents. This set is not confined to accidents at nuclear facilities. Radiological emergencies in the area of transport and handling of radioactive materials and events with a terrorist background are also considered. The development of the corresponding scenarios has been the task of the German Federal Office for Radiation Protection (BfS). GRS provided support to this task with its interdisciplinary competence in the plant-specific and radiological areas as well as with its experience gained through the planning of measures. In particular, GRS provided a set of source terms for most of the reference scenarios selected by BfS and BMU. Based on hazard analyses for the individual reference scenarios, GRS also contributed to the development of optimised protection strategies. These consist of combined measures for the protection of the population and emergency services that are adapted to the respective reference scenario and the actual situation. The optimised protection strategies are the core of the related emergency plans which have to be developed for different governmental levels and technical areas. General planning and information on responsibilities are the subject of the federal government's general emergency plan. For certain areas, special contingency plans are also drawn up by the relevant federal authorities. The plans of the federal government are to be specified in future through the plans of the *Länder*. As support to BMU, GRS has already drafted a prototype for the federal general emergency plan which is currently being discussed and aligned between the different competent authorities at the federal and *Lände*r levels involved.

GRS' interdisciplinary experience in the definition of realistic scenarios facilitates detailed and realistic simulations of processes ranging from events in the plant to potential radiological consequences and reactions from the population and the public. To optimise efficiency in emergency organisation for official practice in Germany, exercise scenarios with specific event sequences have been developed for domestic as well as foreign nuclear power plants. For the emergency response organisations at the federal level, a scenario catalogue has been developed and the so-called "CORE" exercise series have been set up. As a recent example, exercise "CORE 2017", mainly prepared and evaluated by GRS, provided the first comprehensive test for the newly established RLZ. "CORE 2017" was linked to a French national exercise addressing an accident scenario at the French nuclear power plant Cattenom. Members of the GRS Emergency Centre participated in the exercise and acted as observers. As part of the preparation, employees of the BfS and the BMU were trained.

GRS continuously enhances the scientific base in order to understand nuclear incidents and accidents through the development of accident analysis tools. The code system of GRS covers all relevant phenomena of reactor physics, thermal hydraulics and core meltdown as well as structure mechanics. It allows for the simulation of all essential safety-relevant processes, from the behaviour of the reactor core to the effects of mechanical impacts on plant components and building structures. In particular, the following codes are designed for the analysis of severe accidents and the prediction of radioactive releases:

— The ASTEC code, which was developed jointly with the French TSO, *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN), allows for the modelling of severe accident scenarios from the initiating event to core meltdown and a possible release of radioactive materials into the environment. The simulation of a severe accident propagation in containments of nuclear power plants is required for the analysis of the potential consequences of severe accidents and possible counter measures under conditions as realistic as possible. Therefore, at GRS the Containment Code System (COCOSYS) [4] has been developed. The main objective is to provide a code system based on models for the comprehensive simulation of all relevant phenomena processes and plant states during severe accidents in the containment of light water reactors, also covering the design basis accidents.

— The thermal-hydraulic computer code ATHLET (Analysis of Thermal-Hydraulics of LEaks and Transients) is being developed for the analysis of operational conditions, abnormal transients and all kinds of leaks and breaks in nuclear power plants. [5] The aim of the code development is to cover the whole spectrum of design basis and beyond design basis accidents (without core degradation) for PWRs, BWRs, SMRs and future Gen IV reactors with one single code. For accidents with core damage, ATHLET-CD (Core Degradation) provides extensions for the simulation of the mechanical fuel behaviour, core melting and relocation, debris bed formation as well as fission product release and transport.
— The fast source term prognosis tool (FaSTPro) [6] is applied for core melt accidents. The tool is based on deterministic analyses, probabilistic estimates and observations of characteristic plant data during an accident and has been modified in order to predict source terms in case of an accident in a spent fuel pool. The predicted source terms serve as data base for RODOS (Realtime Online Decision Support System) used at the BfS to improve forecast assessments and emergency preparedness.

For a successful application of predictive computer codes and tools, the relevant parameters characterizing the respective plant and environmental conditions must be available. Regarding domestic nuclear power plants, the comprehensive TECDO ("Technical Documentation") knowledge base, which has been established by GRS, is available for this purpose. Recently, GRS developed the emergency knowledge base for foreign facilities (WINO) to complement such knowledge for facilities abroad. WINO contains emergency-relevant plant information on nuclear reactors and nuclear facilities in Europe and elsewhere, which can serve as an information basis for GRS staff in their Emergency Centre in the event of an emergency in a foreign nuclear installation. The data sets are intended to provide the user with a brief introduction to the operation, safety systems and emergency measures of the respective system. Moreover, the most relevant static input data for simplified calculations of the plant state and possible releases are available in WINO together with a toolbox for such calculations.

3. GRS EMERGENCY CENTRE

After the Fukushima accident on 11 March 2011, the BMU, the media and the public were continuously informed by the GRS emergency response team, on the situation in the Japanese nuclear power plant and the radiological impacts. Between March and June 2011, GRS issued more than 200 status reports and published them initially on the GRS homepage and subsequently on a dedicated Fukushima website.

The experiences with the Fukushima accident encouraged GRS to optimise their emergency organisation and to create a completely new infrastructure for their Emergency Centre at the company headquarters in Cologne. The new Emergency Centre started its activities in May 2013. The Radiological Protection Act acknowledges GRS' role in support of the BMU and included the GRS Emergency Centre in the newly founded RLZ.

In case of a nuclear incident or accident in Germany or abroad, the GRS Emergency Centre is activated. A team of up to 60 experts comes together to inform the federal government about the situation in the installation concerned. In case of an emergency in a nuclear power plant, the GRS Emergency Centre is prepared to assess the technical condition, provide prognoses concerning the future accident progression and evaluate information on the release of radioactive material. Moreover, GRS is always prepared to provide answers to *ad hoc* questions and special situations, such as transport accidents or malevolent acts. The GRS emergency staff is available and ready to work 24/7. The Emergency Centre uses all available comprehensive information and programme systems in the nuclear field. The experts gather information on the accident depending on the individual situation, evaluate the information and make forecasts on other possible developments.

The heart of the Emergency Centre is an emergency response team made up of experts from various disciplines. The emergency response team is composed of three teams: the system engineering team, the analysis team, and the radiation protection team.

In case of an incident or accident, the system engineering team analyses the current state of the installation determining thereby the failed and remaining safety systems and accident management measures. Based on this information, the analysis team investigates further behaviour of the installation based on a wide range of simulation results of conceivable accident scenarios. The radiation protection team analyses the radiological situation on-site and in buildings, assesses the resulting limitations of operator actions and, if necessary, the release of radioactive substances into the environment. The analysis team's estimations of the source term provide an important reference for this. The information produced by the above teams is reviewed, compiled into reports and released by the coordination team.

Among others, the source term indicates the quantity and composition of the radioactive substances released. In order to improve the assessment of the situation in the installation and further developments, available measurement data in the vicinity of the plant is used and coordinated with plant-specific information in close cooperation with the system engineering and the analysis teams. The available information about current plant condition and off-site radiological measurements are used to assess the plausibility of available source term data and provide supplementary information on demand. The results of each expert team are contiguous and complement one another. They are coordinated regularly and transmitted to the BMU in the form of status reports.

4. INTERNATIONAL COOPERATION

GRS supports international cooperation at all levels. Since early on GRS has been a driving force of European and international cooperation through its participation in and contribution to several international and bilateral working groups dedicated to EP&R.

In 2006, GRS, IRSN and the Belgian TSO Bel V founded the European Technical Safety Organisations Network (ETSON). Regarding technical exchange, the objective of ETSON is above all the harmonisation of safety assessment methods. Furthermore, the network promotes the cooperation of its members in dedicated international projects.

GRS also participates in the European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS) to establish a forum for dialogue and methodological development between all European organisations and associations taking part in the decision-making of protective actions in nuclear and radiological emergencies and recovery in Europe. A common working group of HERCA, the Heads of the European Radiation Control Authorities, and WENRA, the Western European Nuclear Regulator Association, developed the HERCA-WENRA approach for better cross-border coordination of protective actions during the early phase of a nuclear accident. GRS has been continuously supporting BMU in its efforts to contribute to the EP&R related activities in HERCA.

GRS contributes to emergency preparedness also by evaluations of international developments and tools used abroad. Technical assistance and support is provided to the BMU in the deliberations on special emergency preparedness concepts in the SSK and the International Atomic Energy Agency (IAEA). GRS maintains the information on external emergency preparedness provided by Germany in the IAEA Emergency Preparedness and Response Information Management System (EPRIMS), reviews, and as appropriate comments on IAEA Document Preparation Profiles. In addition, this information is incorporated into the development of rules, guidelines or instructions for action for the respective competent authorities at federal and state levels. The BMU is additionally supported by technical and organisational assistance to and participation in working groups on EP&R of bilateral commissions and expert groups in the field of nuclear safety (e.g. FR-DE, CH-DE, NL-DE).

5. CONCLUSIONS AND OUTLOOK

GRS supports the BMU and its advisory boards in the preparation of relevant regulatory documents concerning emergency planning, protective measures and the further development of realistic exercise scenarios, taking into account the experience gained following the Fukushima accident and international developments in recent years. The competence of the GRS Emergency Centre in the event of nuclear or radiological emergencies is used to continuously enhance its expertise and develop methods that can be used quickly and efficiently. GRS proceeds with code development, validation, application, transfer and user support and training. This will strengthen the operational capability of the Emergency Centre, especially against the background of possible extensions of the range of tasks at federal level and the corresponding advisory requirements of the emergency organisations of the BMU and the BfS. By expanding the scientific basis for the work of the Emergency Centre, GRS' competences in merging and analysing technical and radiological information for optimum use in assessing the condition of the plant and qualifying or complementing information on the source term will be systematically expanded. The knowledge gained from this can be made available to experts at national and international level in all aspects that are not subject to privacy protection or confidentiality in the form of scientific publications and conference contributions.

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THE ROLE AND RESPONSIBILITIES OF RATEN ICN AS TSO FOR THE ROMANIAN NUCLEAR REGULATORY AUTHORITY IN EMERGENCY PREPAREDNESS AND RESPONSE ACTIVITIES

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Abstract

The Institute for Nuclear Research (RATEN ICN) is the only research entity in Romania operating a research reactor, having a unique infrastructure and great experience in the areas of reactor safe operation and operational radiation protection, including emergency preparedness. Due to its experience and proven capabilities, RATEN ICN acts as TSO for the National Commission for Nuclear Activities Control (CNCAN) and other authorities providing expertise in the area of nuclear safety and security. The main responsibilities of RATEN ICN in this regard are to provide training and technical assistance to CNCAN staff and first responders concerning preparedness for response in case of nuclear accidents and radiological emergencies. Also, RATEN ICN has declared capabilities to support CNCAN in the emergency response, mainly in gathering monitoring data and evaluation of radiological consequences as part of the process of decision support. The paper presents arrangements and actions performed by RATEN ICN to ensure and improve its capabilities as TSO and its involvements in some national and international events related to the emergency preparedness and response.

1. INTRODUCTION

In the 1960s, Romania decided to develop a full nuclear program targeting the entire nuclear fuel cycle. Inorder to provide the scientific and technical support for the National Nuclear Program, in 1971, upon the recommendation of an IAEA expert mission, the Institute of Nuclear Technologies was established on the Mioveni platform. Within the institute, it was developed a complex infrastructure to support research and development activities such as: a CANDU nuclear fuel manufacturing pilot plant, the TRIGA (dual core, SSR14MW and ACPR) material and fuel testing reactor, the post-irradiation examination laboratory with hot-cells, the radioactive waste treatment plant, etc. Currently, the institute is called the Institute of Nuclear Research (RATEN ICN) and it is a branch of the State-Owned Company Technologies for Nuclear Energy (RATEN). Among the strategic objectives of RATEN there is:

- maintaining and developing the technical-scientific support capacity for the safe operation of the Cernavoda NPP CANDU units and the extension of their lifetime;
- operating and developing nuclear installations as the essential infrastructure of the scientific research, technological development and testing of RATEN under nuclear safety conditions;
- managing radioactive waste and spent fuel under nuclear safety conditions;
- increasing the environmental protection efficiency and improving the radiation protection measures.

At the same time, Romania has also developed the regulatory, licensing and control framework for nuclear activities. Today, the regulatory and control body in Romania is the National Commission for Nuclear Activities Control (CNCAN), whose attributions and responsibilities are established by Law no. 111/1996 on the safe conduct, regulation, authorization and control of nuclear activities with subsequent modifications and completions.

The relationship between CNCAN and RATEN ICN is developed in two directions: one in which the institute, as the holder of nuclear and radiological installations, is authorized and controlled by CNCAN, and another in which the institute cooperates with CNCAN as a technical support organization (TSO). The second situation is regulated by the provisions of Law no. 111/1996, modified and completed by the provisions of Law no. 63/2018 as follows:

Article 4, paragraph (6) it is provided: "(6) In the exercise of its duties, CNCAN uses territorial departments without legal personality, established by order of CNCAN president, as well as technical-support institutes, established by Government decision, for carrying out specialized studies."

In Appendix no. 2, point 11, it can be found the definition of the technical support institution/organization:

"11. Technical support institute – unit having attributions for expertise, studies on the nuclear facilities siting, non-destructive examinations, nuclear safety analyses and assessments, nuclear facilities decommissioning, implementing and assessing management systems in the nuclear field, assessments of radioactive waste facilities, as well as research and development studies in the field of nuclear safety, protection against ionizing radiation, radioactive waste management, natural and environmentally-induced radioactivity, radiochemistry and radiobiology, radiological emergencies in case of nuclear accident, in accordance with national and international requirements;"

In this context, CNCAN has to promote a government decision to designate RATEN ICN, among other institutions, as a technical support organization and through which establishes the funding mechanisms for support activities. Although the legal framework has so far not supported the funding of support activities, RATEN ICN has acted as TSO at its own expense in the following areas:

- Mitigating the illicit trafficking of radioactive and nuclear materials;
- Planning and preparing the response in case of radiological emergency or nuclear accident.

RATEN ICN became ETSON member in 2017 and organizes in September 2018 the junior staff program.

2. RATEN ICN CAPABILITIES

The success in operating a nuclear facility depends on several factors. An important factor is the establishment and maintenance of a set of effective radiation protection measures. In this respect, there are two main objectives for the Institute:

- Ensuring the radiation protection and environmental protection measures for its own nuclear installations; and
- Supporting a research and development program for increasing the efficiency of human and environmental protection against radiation-related risks.

In order to reach these 2 goals, within RATEN ICN there is a department with the appropriate capabilities. This department is the Radiation Protection, Environmental Protection and Civil Protection Laboratory (LRPMPC).

The term "radiation protection" covers the range of activities to protect human beings against the harmful effects of ionizing radiations, a field at the border between physics, engineering, metrology, biology and medicine. To achieve the first goal, the laboratory staff performs the following tasks:

2.1 Radiation protection

- operational radiological protection of professionally exposed personnel;
- monitoring workplaces and employees (dose and dose rate measurements);
- evaluating air radioactive contamination (sampling, alpha-beta-gamma measurements, evaluation);
- evaluating surfaces radioactive contamination (sampling, alpha-beta-gamma measurements, evaluation);
- assessing the concentration of tritium and carbon-14 in water, air, etc.;
- assessing the uranium concentration in the urine.
- developing procedures for employees monitoring.
- monitoring methodologies:
- developing procedures for the assessment of radioactive contamination (internal and external).
- dose calculations and model development:
    - calculation of doses of internal exposure due to ingestion and inhalation of radioactive substances.

2.2 Environment protection

- Environment radioactivity:
    - Direct measurement of nuclear radiation fields
    - Assessment of radioactive contamination
    - Identification and quantitative determination of gamma emitting radionuclides
    - Determination of strontium-90 content in milk, dairy products and fish

- Determination of atmospheric air radioactivity
- Determination of natural uranium content in soil, vegetation and water
- Determination of gross beta activity
- Measurement of radioactive samples by liquid scintillation beta spectrometry
- Determination of radioactive strontium concentration in aqueous samples
- Determination by alpha spectrometry of the content of actinides in aqueous samples, soil, aerosol filters and biological samples
- Radiological characterization of materials by IN SITU gamma spectrometry
- Determination of tritium concentration in atmospheric air
- Determination of Ra-226 and Ra-228 content in drinking water by liquid scintillation counting
- Determination of Po-210 content from aqueous samples, environmental samples and biological samples
- Determination of concentration of radon in atmospheric air by measuring the activity of its alpha emitting daughter products
- Determination of C-14 concentration in aqueous samples

- management of discharges into the environment:
  - procedures for monitoring radioactive effluent discharges;
- monitoring:
  - Programs for the monitoring of effluent radioactivity and the environment around the site.

2.3 Emergency Planning and Civil Protection

- exercises:
  - developing scenarios for exercises;
  - annual exercises for interventions in nuclear accidents or radiological emergencies at the TRIGA reactor or other nuclear installations;
  - quarterly exercises with shift teams.
- emergency planning and preparation:
  - developing the on-site and off-site emergency response plans;
  - technical support for local and national authorities in emergency planning.
- radioactivity monitoring in emergency situations:
  - dose monitoring and sampling on-site and off-site.
- development of specific databases (meteorological, agricultural, demographic, etc.) for use in assessing the radiological consequences of a nuclear accident;

The Radiation Protection, Environmental Protection and Civil Protection Laboratory within RATEN ICN is member of IAEA's networks ALMERA (Analytical Laboratories for the Measurement of Environmental Radioactivity) and RANET (Response and Assistance Network).

3. PROTOCOLS OF COLLABORATION WITH AUTHORITIES

As mentioned in the first chapter, RATEN ICN has continuously developed a collaboration relationship with CNCAN to provide technical and scientific support to the regulatory body. In 2015, for the first time, a written collaboration protocol between the two organizations was signed to increase the efficiency of emergency response preparedness, through prevention, identification, monitoring, analysis and management of nuclear accident or radiological emergency and operative information and assurance of specialized technical assistance in accordance with the legal provisions and obligations assumed by Romania under international treaties.
The objectives of the collaboration are:

1. Ensuring by RATEN ICN Pitesti the technical support required for CNCAN in order to: perform the radioactivity monitoring function around the nuclear installations, improve the assessments and analyses regarding the evolution of the emergency situations in the event of nuclear events and accidents and the training of the CNCAN personnel participating to the response in the event of a nuclear accident or a radiological emergency.
2. Increasing the effectiveness of the measures proposed by CNCAN and RATEN ICN within the National Management System for Emergency Situations in order to limit the consequences of nuclear emergency situations.
3. Ensuring the conditions for implementing the decisions adopted by the National Committee for Emergency Situations, by mutual information, development and optimization of the support granted to the National Management System for Emergency Situations for the prevention and management of nuclear accident or radiological emergency situations

4. Facilitating the exchange of information for the training of CNCAN and RATEN ICN personnel for the management of emergency situations
5. Personnel training and joint exercises to improve the response to nuclear accident or radiological emergencies

Subsequently, at the request of CNCAN, RATEN ICN declared its technical support to CNCAN, by RATEN ICN Pitesti, based on the LRPMPC capabilities:

- Radiological monitoring during a nuclear accident or radiological emergency situations:
  - Ground-based radiological Survey
  - Radiological mapping of areas, buildings and structures contaminated radioactively
  - In situ gamma spectrometry
- Environmental sampling and laboratory analysis to assess radioactive contamination
- Radiological characterization of Nuclear Materials and Radioactive Materials in response to incident or illicit trafficking:
  - Determination of the content of gamma emitting radionuclides and gross alpha / beta activity
  - Determination of tritium and C-14 content from combustible materials
  - Determination of the content of Sr-90, Po-210, Ra-226, Ra-228 and actinides from various types of materials
  - Determination of the isotopic composition of uranium-containing materials, by gamma spectrometry
- Participation with specialists and equipment within CNCAN's coordinated mobile team for technical and scientific support for ensuring the response to incident and illicit trafficking of nuclear and radioactive materials
- Technical-scientific support for developing radiological monitoring strategies to support decision-making in nuclear accident or radiological emergencies
- Participation with experts within the working groups coordinated by CNCAN, in support to the national structures with responsibilities in risk assessment in the event of nuclear accident or radiological emergency
- Planning and implementation of radioactivity monitoring programs in the proximity of installations from the nuclear fuel cycle
- Radiological characterization of materials from authorized nuclear practices
- Monitoring the radon concentration in indoor air by short and medium-term active measurements (up to one week)
- Determination of radon content in drinking water or underground waters, by liquid scintillation counting
- Radiological characterization of contaminated sites NORM

Subsequently, in 2017, RATEN ICN signed a similar protocol with Arges County Inspectorate (ISU Arges). As part of this collaboration, RATEN ICN has declared its support in the following activities

- RATEN ICN Pitesti will organize, within the limits of the possibilities and pending to CNCAN approvals, a training course in radioprotection required for licensing the personnel of ISU Arges - CBRN crew.
- RATEN ICN Pitesti will participate with specialized lecturers to train the personnel responsible for the management of nuclear and / or radiological emergencies within ISU Arges. The request of participation will be made through the written request of ISU Arges, and the topic will be agreed upon.
- RATEN ICN Pitesti will provide specialized personnel and sources of ionizing radiation for the practical training of CBRN team within ISU Arges. The training will take place at RATEN ICN site.
- RATEN ICN will, as far as possible, provide radio-analytical services at the request of ISU Arges under the terms of the authorization of Radiation Protection, Environmental Protection and Civil Protection Laboratory.
- RATEN ICN will ensure, as far as possible, specialized personnel at the site of an event involving ionizing radiation on the territory of Arges County. The travelling of the RATEN ICN and ISU Arges personnel at the event venue will be carried out with vehicles belonging to ISU Arges..

4. ACTIVITIES

4.1 Collaboration activities with CNCAN

During 2017, RATEN ICN Pitesti carried out a series of activities under the collaboration protocol with CNCAN regarding the increase of efficiency of activities for management and prevention of emergency situations, identification, monitoring, analysis and management of nuclear accident or radiological emergency situations and of radiological and operative information and assurance of specialized technical assistance in accordance with the legal provisions and obligations assumed by Romania under international treaties. These activities covered a wide range of topics in the field of nuclear safety and security, materializing through the active participation of RATEN ICN specialists in CNCAN actions.

At CNCAN's request, within ICN it was conducted an independent analysis of a draft standard project on basic radiological safety requirements, developed for the purpose of implementing the provisions of Directive 2013/59 / EURATOM. This analysis was carried out by a group of RATEN ICN specialists as radiological protection experts, appointed by the commission. During the debate, CNCAN organized a series of sessions for the standard project analysis, RATEN ICN assuring the participation of its representatives in all these actions.

Between 20 and 22 June, the international exercise ConvEx-3 was organized and RATEN ICN took part by evaluating the content of gamma radiation radionuclides in a simulated contamination water sample and reporting the results in a predefined format to CNCAN (the national point of contact of RANET network). This activity represented on one hand a verification exercise of the national communication channel and on the other hand a check-up of the radio-analytical performances of RATEN ICN's Radiation Protection Laboratory.

RATEN ICN Pitesti participated in RANET activities organized in 2017 through the participation of a specialist at the „*Workshop on Implementation of Recommendations on Response Harmonization and Assistance Capabilities*", which took place from 16 to 20 October 2017, at the IAEA headquarters, in Vienna. Throughout the workshop, the organizers stressed the need to implement, within each Member State, at national level, the recommendations on the compatibility of the methods used and the results provided during response to nuclear or radiological emergencies.

This can be achieved by defining monitoring and reporting procedures that comply with the compatibility requirements presented in the relevant IAEA documents and their implementation within the national emergency response system. This will create the premises for a proper integration of the assistance that Romania can offer to other IAEA Member States within the RANET actions, and also for enhancing the absorption capacity of foreign assistance in the situation where our country would have to resort to this. RATEN ICN, as a technical support organization, is to provide support to CNCAN to implement these recommendations at national response capabilities in nuclear accident or radiological emergency situations.

At the beginning of 2018, the Nuclear and Radiological Emergency Risk Assessment Working Group (GLERUNR) was established, organized and coordinated by CNCAN, based on a decision of the Romanian Government regarding the organization and functioning of the National Disaster Risk Reduction Platform. The activities of this working group consist of providing expertise with the purpose of:

- Improving the regulatory framework for nuclear safety and security;
- Conducting studies, analyses and evaluations in the field;
- Increasing the inter-institutional collaboration and the civil society involvement;
- Contributing to the development of strategies, policies and plans for reducing disaster risk and increasing resilience;
- Contributing to increasing the response capability of the national emergency management system.

RATEN ICN Pitesti is represented in GLERUNR by a group of specialists from LRPMPC, appointed as experts in fields related to the group's activity. A first activity of the group consists of the elaboration of a technical study on the detection of Ru-106 on the territory of Romania during October-November 2017.

Also, at the request of CNCAN, during 2018, RATEN ICN Pitesti specialists participated in working sessions for discussing the way of granting international assistance through the RANET mechanism and for analysing the *National Response Plan in case of Incidents /Events or Illicit Trafficking with Nuclear or Radioactive Materials*.

4.2 Collaboration activities with AN&DR

In the first part of 2017, at the request of AN & DR, the support documentation for the review of the National Medium and Long-Term Strategy on the Management of Spent Fuel and Radioactive Waste Including the Disposal and Decommissioning of Nuclear and Radiological Facilities was analysed. The evaluation group of RATEN ICN Pitesti was made up of specialists from the following departments: Department 2 – TRIGA Reactor, Department 10 – Radioactive Waste Treatment Plant (STDR) and Laboratory 5 – Radiation Protection, Environmental Protection and Civil Protection. They submitted comments on the inclusion in the strategy of an objective related to the creation of a medium and intermediate low-level intermediate repository on ICN site, for the storage of long-lived waste and waste for which there is no conditioning technology available so far.

4.3 Collaboration activities with ISU Arges

According to the provisions of the above-mentioned cooperation protocol, in the period immediately after its signing, the liaison officers were nominated by the two institutions and the channels of communication were established. Discussions were held to initiate joint training of first responders by organizing theoretical and practical training sessions. It was established, together with ISU Arges representatives, that an initial course of first responders should be organized in the next period, presenting the properties of ionizing radiation and the basic principles of their detection.

The course took place at RATEN ICN Pitesti in the first half of November and consisted of: theoretical training (Radiological Emergency Monitoring and Use of Personal Protective Equipment) and practical activities (equipment of intervention staff, workshops with real sources of radiation for equipment testing and improving radiation detection techniques). The training was attended by seven members of the CBRN crew of ISU Arges as trainees and two specialists from RATEN ICN Pitesti, as lecturers.

5. CONCLUSIONS

RATEN ICN Pitesti has taken actions, in the last period, to define and strengthen its role as technical support organization for the national entities responsible for implementation of the governmental responsibilities related to safety and security of nuclear and radiological activities. In this respect, written agreements have been signed with CNCAN and local authority for management of emergency situations which laid down the framework for collaboration in the field of enhancing capabilities for response to nuclear accidents or radiological emergencies. Several activities conducted by RATEN ICN as TSO, in the last two years, have been presented, as follows:

- Supporting CNCAN in developing regulations concerning safety and security of nuclear activities
- Participation to development of national framework for response to events/incidents and trafficking to nuclear situations
- Supporting CNCAN to improve the national capabilities for response in case of nuclear accident or radiological emergency
- Supporting the national authority for management of radioactive waste for development of the relevant national strategy
- Supporting the local authority for the management of emergency situations to improve preparedness for response in case of nuclear accidents or radiological emergencies
- Providing qualified support to national and local authorities in response to incidents concerning materials out of regulatory control.

Through the above-mentioned activities, RATEN ICN proved its commitment to support governmental authorities in maintaining an adequate level of safety and security for nuclear activities in Romania.

REFERENCE

[1] Romanian Parliament, Law no. 111/1996 on the safe conduct, regulation, authorization and control of nuclear activities with subsequent modifications and completions.

SEC NRS ACTIVITIES IN SUPPORT TO ROSTECHNADZOR'S INFORMATION AND ANALYTICAL CENTRE

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Abstract

In accordance with requirement 8 "emergency preparedness and response" of IAEA safety requirements "governmental, legal and regulatory framework for safety" GSR part 1 (rev. 1) [1] in preparing an emergency plan and in the event of an emergency, the regulatory body shall advise the government and response organizations, and shall provide expert services (e.g. Services for radiation monitoring and risk assessment for actual and expected future radiation risks) in accordance with the responsibilities assigned to it. It should be noted that in requirement 2 of GSR part 1 (rev. 1) [1] the provision for preparedness for, and response to, a nuclear or radiological emergency as a task within state framework for safety has the same importance level as traditional (in particular in Russian Federation) regulatory tasks like provision for the inspection of facilities and activities, and for the enforcement of regulations, in accordance with a graded approach; promulgating (or preparing for the enactment of) regulations and preparing guidance for their implementation; granting the permissions for activities on facilities.

1. Introduction…….

Competence of regulatory body for nuclear and radiation safety are established in IAEA safety requirements "Preparedness and Response for a Nuclear or Radiological Emergency" [2]. In accordance with points 4.13 and 4.14 GSR part 7 [2] in executing the task for regulating emergency preparedness and response the regulatory body:

- Shall require that arrangements for preparedness and response for a nuclear or radiological emergency be in place for the on-site area for any regulated facility or activity that could necessitate emergency response actions and shall verify compliance with the requirements for such arrangements.
- Before commencement of operation of the facility or commencement of the activity shall ensure, for all facilities and activities under regulatory control that could necessitate emergency response actions, that the on-site emergency arrangements:
  - integrated with those of other response organizations, as appropriate;
  - provide, to the extent practicable, assurance of an effective response to a nuclear or radiological emergency.

In accordance with requirement 20 of GSR part 1 (rev. 1) [1] the regulatory body may decide to establish a dedicated support organization (further - TSO), in which case clear limits shall be set for the degree of control and direction by the regulatory body over the work of the support organization.

Spectrum of TSO tasks within framework of support of regulatory functions, which established in 4.13 and 4.14 GSR part 7 [2], are delineated in IAEA-TECDOC-1835 on Technical and scientific support organizations providing support to regulatory functions [3]. In accordance with [3] TSO tasks can range from performing a technical action requested by the regulatory body to the TSO's full involvement in the national EPR plans. In [3] also mentioned that the TSO typically supports the regulatory body and/or government and public authorities, notably by participation within the response organizations including development and support of its own capacity in the assessment of the potential consequences of an emergency and prognosis of its possible progression (to support the regulatory body). It's established in tecdoc [3] that adequate and effective support tools such as computer codes, data collection and display systems, training, drill and exercise programmes may also be incorporated in the infrastructure to support of the regulatory body and government authorities in carrying out their emergency preparedness and response functions. Based on [3] information the

TSO is able to support the periodic evaluation of authorized parties' emergency preparedness and response programmes and capabilities against designated objective. Typically, this is done by performance evaluation of programmes and processes, via training, exercises, self-assessments, audits and inspections.

It's notable that in accordance with point 6.30 of GSR part 7 **Error! Reference source not found.**] exercises, conducted based on the programmes, shall be evaluated by the regulatory body.

The IAEA requirements and guidelines, which are mentioned above, are implemented in Russian regulatory infrastructure by following way.

In accordance with government decrees [4]and [5] Rostechnadzor under Russian Unified state system for prevention of and response on emergencies) manages its functional subsystem for control of radiologically hazardous facilities (further - FSCRHF). The named Russian Unified system is similar to all hazard emergency management system in terms of GSR part 7. FSCRHF tasks are [6]:

Control on preparedness of facilities management and personnel for response to nuclear and radiological emergencies.

Provision of Rostechnadzor preparedness for response actions to nuclear and radiological emergencies.

It's notable that the first tasks are carried out by Rostechnadzor under government decree dated 15.10.2012 № 1044 "On federal state oversight in the field of atomic energy use" by inspections on facilities. Within the framework of these inspections the main EPR aspects, which are inspected are availability on facilities' necessary plans and procedures for emergency response (e.g. personnel protection plan, accident (including severe ones) management procedures) and availability of resources for the plans' and procedures' practical use.

SECNRS are recognized by Rostechnadzor as a TSO according to Provision on attribution of parties to technical scientific support organization of regulatory body on safety in the field of atomic energy use [8].
There is stated in [3] that TSOs are participate in the development of safety documents for legislation, regulations and guides. Of course, this relates to EPR regulations. SEC NRS activities follows this best practice as far as it develops federal rules and regulations for safety in the field of atomic energy use. Under this activity SECNRS developed amount of regulation which enacted by Rostechnadzor [9], [10], [11], [12], [13], [14], [15], [16], [17]. EPR aspects which falls under these regulations are illustrated on figure 1.

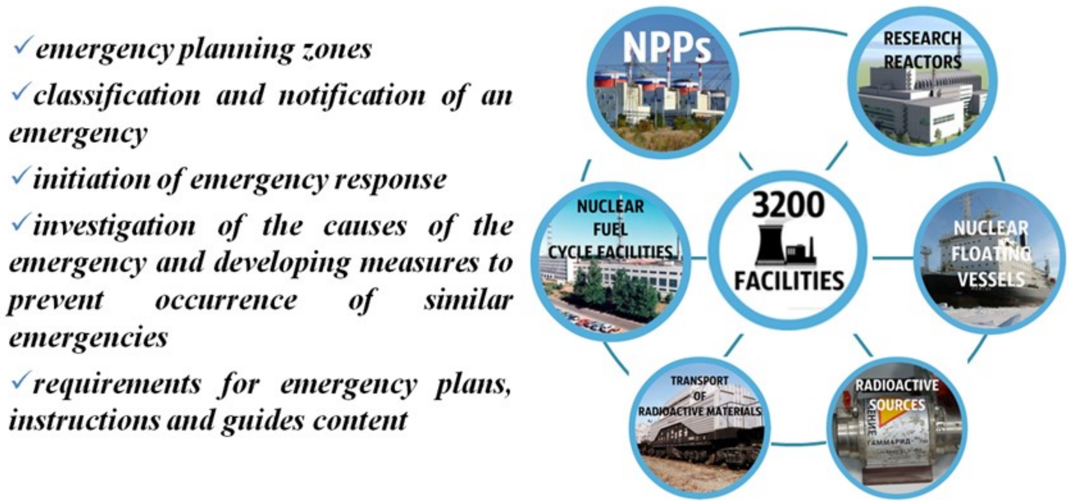

FIG. 1. EPR aspects which falls under regulations developed by SEC NRS.

Evaluation of emergency drills and exercises are carried out within organization structure of Information and analytical centre of Rostechnadzor (further – Rostechnadzor IAC) and by using of its means for communication, notification and information support of FSCRHF. Tasks of Rostechnadzor IAC given in figure 2.

SECNRS experts under Rostechnadzor IAC activities carry out analysis, assessment and prognosis radiological exposures and consequences, integrity of physical barriers and performance of safety functions, evaluation of compliance with emergency plans and procedures. Outcomes from carrying out of mentioned tasks are used for evaluation of operators' actions during emergency drills and exercises. This evaluation up to significant extent are fulfilled by SECNRS experts.

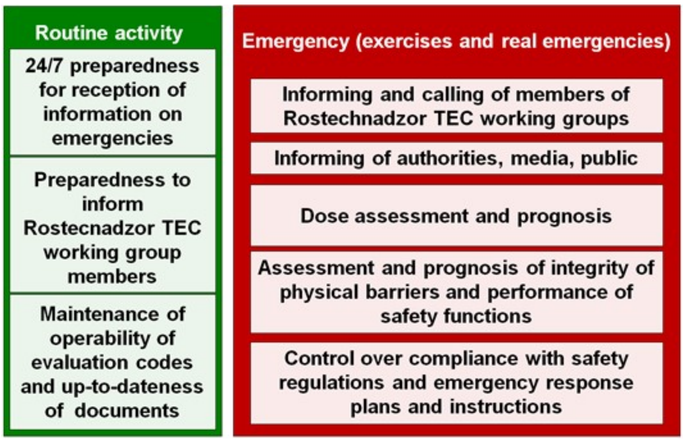

FIG. 2. Tasks of Rostechnadzor IAC.

As it was mentioned above point 6.30 of GSR part 7 sets that emergency exercises shall be evaluated by the regulatory body. Nevertheless, even those regulatory bodies which fulfill emergency exercise evaluation on a regular basis are face challenge to formalize their approach for the evaluation and to put evaluation methodology in single document or system of documents. The relevant evidence is contained for example in reports on results of IAEA IRRS missions [18], [19], [20]. At the same time US NRC have enacted document on holistic methodology for emergency drills and exercises evaluation [21].

In accordance with OECD NEA document "Strategy for Developing and Conducting Nuclear Emergency Exercises" [22] and IAEA document "Preparation, Conduct and Evaluation of Exercises to Test Preparedness for a Nuclear or Radiological Emergency" [23] there are two approaches for evaluation of emergency drills and exercises. The first one is prescriptive, i.e. directed on evaluation of compliance of response organizations' actions with formal criteria, which aren't clearly provide accomplishment of the goals of emergency response (e.g. the ones which established in point 3.2 of GSR part 7 [2]). The second one is performance-based approach, which directed on evaluation of compliance with clear and verifiable (during the emergency drills and exercises or as a result of them) criteria, which provide accomplishment of the goals of emergency response. Main feature of the performance-based approach based on [22] is that such approach takes into account that every system (in particular the emergency response system) is more than the sum of its parts, and that the different response elements can function together to achieve the overall objectives.

The challenges of implementation of performance-based approach for emergency exercise evaluation into regulatory activities are used to be pressing for Russian Federation as well. Recently in order to evaluate emergency drills and exercises SECNRS and Rostechnadzor experts used to utilize methodology which was present a list of EPR-related requirements of federal rules and regulations in the field of atomic energy use and of few requirements of IAEA safety standards. That's why within the framework of IAEA IRRS follow up mission conducted in November 2013 in Russian Federation IAEA experts suggested to review and enhance current exercise evaluation methodology and include a performance-based approach in it with account of [23].

To cope with this suggestion SEC NRS developed Recommendations on evaluation of NPP operators' emergency response actions during emergency drills and exercises (further - Recommendations) which enacted by Rostechnadzor. The Recommendations are based on federal rules and regulations in the field of atomic energy use and contain methodology for assessment how of NPP operators' actions comply with these requirements. Unlike the previous methodology, evaluation by which considered to be completed when compliance with all relevant EPR requirements was evaluated, [24] allows to carry out aggregate evaluation resulting in single numerical value, which reflects preparedness level of NPP operator. The new approach complies with main features of performance-based approach which established in [22[12] and [23].
Overall flowchart of process for emergency exercise evaluation of NPP operators' emergency response actions, which established in Recommendations, presented in figure 3.

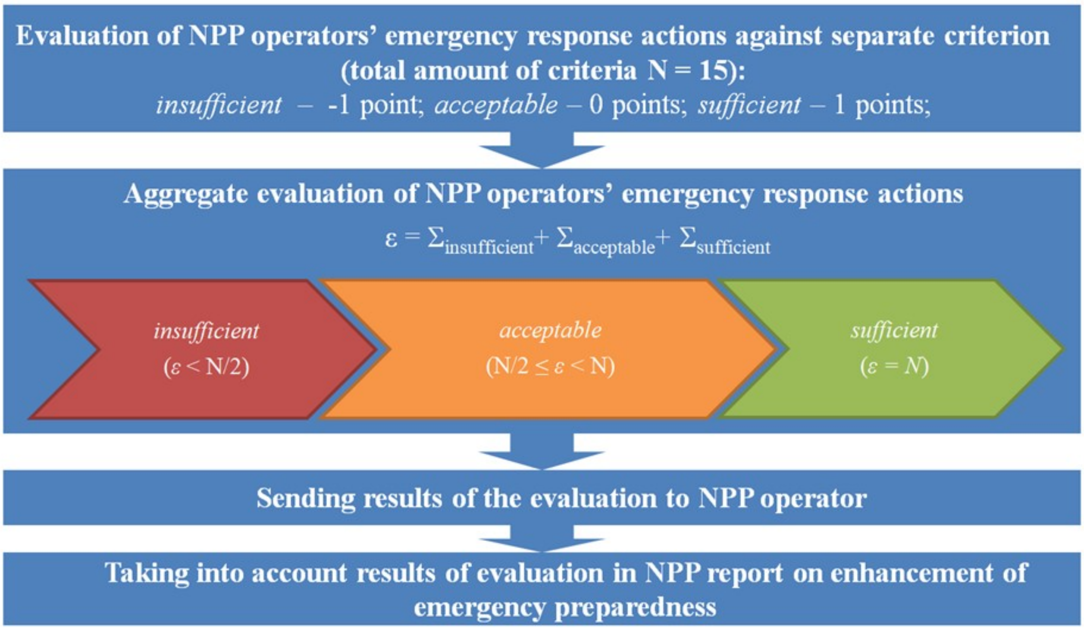

FIG. 3. Flowchart of process for emergency exercise evaluation of NPP operators' emergency response actions, established in [24].

Using tools for assessment of current safety parameters (including conditional ones claimed during emergency drill or exercise) of facility, which characterize integrity of physical barriers and performance of safety functions, and for calculation of radiological impact of the facility, is a crucial part of exercise evaluation in Rostechnadzor IAC. For these purposes SEC NRS experts use following tools in Rostechnadzor IAC:

— NOSTRADAMUS – atmospheric dispersion modeling based on puff model in fixed meteorological conditions due to accidental airborne releases and dose assessment.
— RECASS NT – atmospheric dispersion modeling in variable time-dependent prognostic meteorological conditions, as well as modeling of radionuclides in surface water bodies (due to direct liquid releases into water body as well as due to deposition from atmosphere onto its watershed) and dose assessment.
— CASSANDRA – modeling of radionuclides' transfer in surface water bodies and dose assessment.
— SCALE – core inventory calculations.
— RAINBOW TPP – modeling of NPP physical barriers integrity and its safety functions performance in emergency conditions based on coupled neutronic – thermo-hydraulic calculations.
— TPP – modeling of 2nd circuit, safety systems and containment.

FIG. 4. Group for radiological impact assessment of Rostechnadzor IAC during its work and results of calculations by its tools.

It's notable that one of criteria for evaluation of emergency drills and exercises in [24] is correctness of nuclear or radiological emergencies' INES level estimated by operator. Operators' obligation to carry out this estimate established in federal rules and regulations document "Provision on the procedure of investigation and accounting of operational occurrences at nuclear power plants" (NP-004-08) [25]. At the same time, it should be noted that INES level estimates are required under requirement 10 "Providing instructions, warnings and relevant information to the public for emergency preparedness and response" of GSR part 7 [2]. Efficiency of any actions as in real emergency conditions and within emergency drills and exercises is a crucial factor for EPR control. INES level estimation isn't exception from this rule. It can be concluded from the practice of SEC NRS participation in emergency drills and exercises that INES level estimation via The International Nuclear and Radiological Event Scale User's Manual [26] is rather complex and time-consuming task and despite the fact that it exists more than 20 years currently there isn't widely available tool implementing its methodology. To cope with this challenge SEC NRS experts - members of Rostechnadzor IAC working groups are developed computer application "INES classifier 1.00", which fully inplement the methodology of [26] and covers as NPPs and other facilities. The application intended for use in Rostechnadzor IAC as in real and in simulates emergency conditions. An example of interface of "INES classifier 1.00" is presented in figure 5.

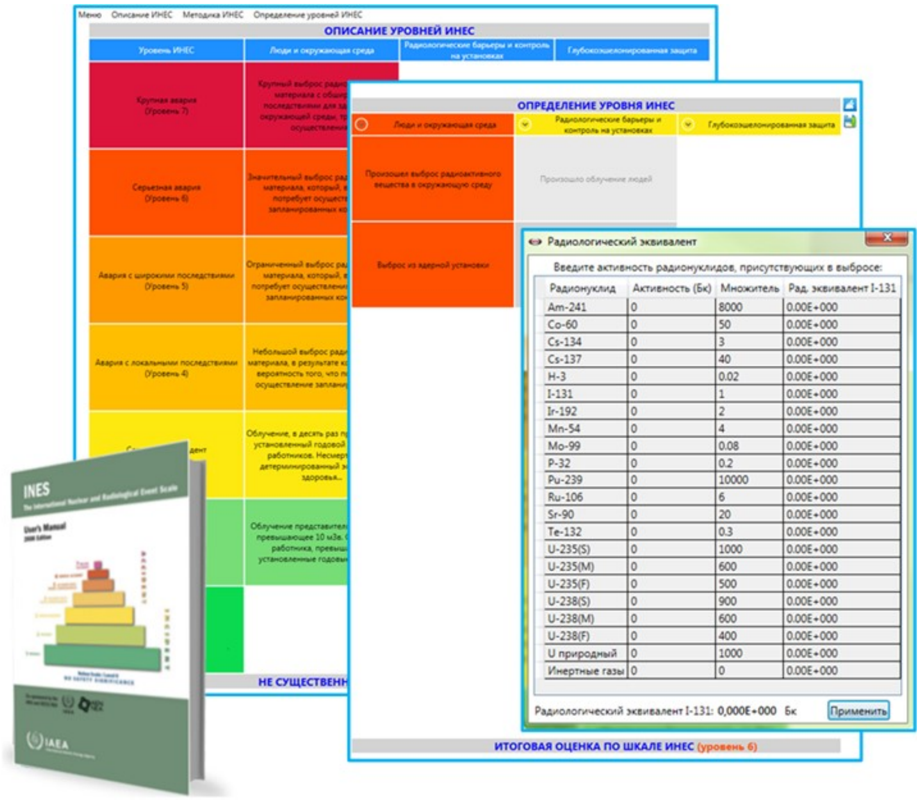

FIG.5. Example of interface of "INES classifier 1.00".

Based on aforesaid it can be concluded that level of involvement of SEC NRS in Rostechnadzor activity on operators' EPR control generally follows to that of established in [3], and that TSO participation in regulatory activities is a crucial factor to overcome the challenges faced as by regulatory body and TSO.

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R&D ACTIVITIES TO BE CONDUCTED BY TSO IN EMBARKING COUNTRIES
R&D to Support Understanding of Severe Accident and Planning of Emergency Response

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Abstract

IAEA advises embarking countries to become a knowledgeable customer when entering nuclear power programme. In the pre-project phase, the future TSO can play an important role in providing scientific information and advice to the government, the NEPIO, the operator and the regulator to ensure a knowledgeable decision. Two issues to be focused at this phase are accident prevention and mitigation, and emergency preparedness and response. Thailand Institute of Nuclear Technology (TINT) which positions itself as a TSO for the future nuclear power programme is now focusing on R&D to support understanding of severe accident and planning of emergency response. R&D activities are divided into four groups following the typical progression of a severe accident: (1) accident progression in reactor pressure vessel; (2) behaviour of radionuclides in containment vessel; (3) atmospheric dispersion, transport and deposition of released radioactive release; (4) accident consequence assessment. Not only Thailand but also other ASEAN countries express interest in R&D on severe accident. The 2017 Benchmark Problem of the ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) is on atmospheric dispersion assessment of a radioactive release from a hypothetical severe accident, and many participating countries suggest moving forward to upstream assessments, e.g. source term assessment and reactor thermal hydraulic assessment. Through these assessments, the country can familiarize itself with the assessment, while assessing the extent of impacts of a severe accident in neighbouring countries to their citizens. This R&D programme can be a good model for an embarking country planning for a nuclear power programme in the future.

1. INTRODUCTION

A nuclear power programme is a major undertaking of a country. It requires large investment in terms of time and resources. Before a decision to launch a nuclear power programme is taken by a newcomer country, a sustainable national infrastructure that provide governmental, legal, regulatory, managerial, technological, human resource, industrial and stakeholder support for the programme is needed, so that the country is ready to make a knowledgeable commitment to a nuclear power programme [1]. With respect to nuclear safety, the Nuclear Energy Programme Implementing Organization (NEPIO), which is a mechanism to coordinate the work during the pre-project phase, will need to focus on several important issues including:

— The IAEA safety standards;
— The prime responsibility of the licensee for safety;
— An effective legal and regulatory framework for safety;
— The establishment of effective leadership and management for safety;
— Decommissioning and long-term management of spent fuel and radioactive waste;
— Siting;
— Efforts to prevent and mitigate accidents;
— Arrangements for emergency preparedness and response.

In this pre-project phase, the NEPIO, the future operating organization, the future regulatory body and the future Technical Support Organization (TSO) may not be adequately equipped with human resources since the government may hesitate to invest large amount of resources when the decision to go nuclear has not been made. Aforementioned safety-related tasks have to be wisely distributed to respective organizations. To pursue its role in technical assistance, the TSO can take responsibility in providing scientific information and advice on accident prevention and mitigation, and emergency preparedness and response.

Thailand is now at the pre-project phase of the nuclear power programme [2]. Thailand Institute of Nuclear Technology (TINT) which positions itself as a TSO for the future nuclear power programme is now focusing on research and development (R&D) to support understanding of severe accident and planning of emergency response. This paper will present the way that TINT structures and performs its R&D activities to support the pre-project phase of the nuclear power programme with limited human resources. The paper will also introduce the ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) which is established by nuclear research institutes in the region to strengthen R&D, human resource development and regional cooperation in the field of nuclear power safety in ASEAN, and

TINT's attempt to disseminate its practice in severe accident R&D through ASEAN NPSR.

2. TINT R&D PROGRAMME ON SEVERE ACCIDENT

The overall picture of the R&D activities at TINT is shown in Fig. 1. The activities focus on severe accident due to two reasons. One is that the accident at the Fukushima Daiichi Nuclear Power Station (1F Accident) in March 2011 can be categorized as a severe accident. The other is that the study on severe accident will not only help understand the accident prevention and mitigation, but it will also provide good inputs for the consideration of emergency preparedness and response strategy. R&D activities are divided into four groups following the typical progression of a severe accident: (1) accident progression in reactor pressure vessel; (2) behaviour of radionuclides in containment vessel; (3) atmospheric dispersion, transport and deposition of released radioactive release; (4) accident consequence assessment, each of which will be explained in detail below.

2.1 Accident progression in reactor pressure vessel

An accident becomes a severe accident when the reactor core loses its intactness. One way to understand the reactor core response to an accident and the progression afterward until the core melts is to use a system code, e.g. RELAP, TRACE, CATHARE, MELCOR, to evaluate selected accident scenarios. They are calculation codes which output time dependent thermal hydraulic parameters, e.g. flow rates, pressures, and temperatures at positions or components of interest. The analyst can realize the relationship among these thermal hydraulic parameters along the progression of the accident. In the case of a severe accident in which the reactor core melts, the code will demonstrate deformation of fuel cladding and fuel elements, core melting, core relocation, hydrogen generation, and other typical phenomena observed in a severe accident [3]. The effectiveness of accident management strategies, e.g. water injection from fire engine, can also be tested in these codes.

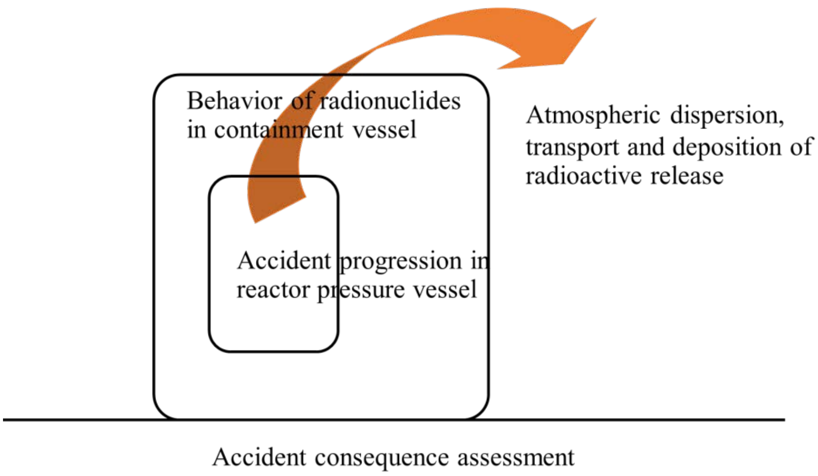

FIG. 1. TINT R&D activities on severe accident

In order to understand both experimental and computational aspects of the evaluation of accident progression in reactor pressure vessel (RPV), TINT uses RELAP/SCDAPSIM Mod 3.4 [4] to evaluate the Power Burst Facility (PBF) Severe Fuel Damage (SFD) tests. Results calculated by RELAP/SCDAPSIM Mod 3.4 were compared with experimental results of PBF SFD Scoping Test (SFD-ST) and 1-4 Test (SFD 1-4). The former provides information of fresh fuel behaviour during a severe accident when reflooding is available [5] while the latter assists understanding of the response of irradiated fuel and control rods to severe accident conditions when reflooding is not available [6]. It was found that RELAP/SCDAPSIM Mod 3.4 can predict the parameters relatively well when compared with previous versions. The study was done in cooperation with Innovative System Software (ISS), the code developer, and helped validated the code toward these PBF SFD tests.

2.2 Behavior of radionuclides in containment vessel

After the core melts, the fission products escape from the fuel to the RPV and the reactor cooling system. The released radionuclides can leak into the containment vessel (CV) when there is a break in a pipe or a breach in the RPV. Therefore, the second group of the R&D activities focus on the behaviour of radionuclides in the CV. Behaviour of radionuclides depends on several factors, e.g. forms (gas or aerosol), physical properties (density, melting point, boiling point, particle diameter, etc.), chemical properties (solubility, polarity, chemical stability, enthalpy of formation, etc.). These factors affect the transportation of radionuclides within the CV and the deposition of radionuclides toward the CV surface. Thorough understanding of CV behaviour can help determine strategy to reduce the source term being released to the environment.

As is the case of the study of accident progression in the RPV, the usage of a calculation code to simulate the experiments can help grasp both experimental and computational aspects. ART Mod 2 [7] is used to study the behaviour of iodine and caesium compounds in the CV of the Phébus FPT3 experiment [8]. The aerosol deposition model was modified to better capture the deposition toward the CV wall due to Brownian diffusion, and the model for cesium molybdate compound was added to the code to better represent the caesium compounds during a typical severe accident [9]. Correct understanding of radionuclide behaviour, especially iodine and caesium, is essential for the obtainment of accurate results in downstream assessments.

2.3 Atmospheric dispersion, transport and deposition of radioactive release

When the radioactive material is released from the CV, it passes through the reactor building (RB) to the environment. It can disperse in the atmosphere and be transported to other places by wind. The radionuclides slowly settle by the gravity and can be washed out from the atmosphere when it rains. Apart from the understanding in behaviour of the released material, the information on meteorological and geological characteristics along with the comprehension of how they affect the dispersion, transport and deposition of the released material is needed. If the mechanism of atmospheric dispersion, transport and deposition of radioactive release is correctly understood, the area that may be affected by the release can be predicted with high confidence.

TINT started the work on atmospheric dispersion calculation with OSCAAR (Off-Site Consequence Analysis code for Atmospheric Releases in reactor accidents) of the Japan Atomic Energy Agency (JAEA) [10]. It was used to compare the influence of weather conditions in Thailand and in Japan when the same accident scenario is applied [11]. TINT made further effort to evaluate the atmospheric dispersion of a release from a hypothetical accident in proposed nuclear power plants in neighbouring countries [12] using HotSpot 3.0 [13]. The results indicated that the dose at the boundary of Thailand may be negligible, though the uncertainty remains large since the change in meteorological conditions is not systematically taken into account. An in-house code is being developed based on OSCAAR to address the issue.

2.4 Accident consequence assessment

A traditional chain of assessment of a severe accident stops at atmospheric dispersion, transport and deposition calculation which outputs the individual/collective dose to public and level of land contamination. However, 1F Accident demonstrated various types of accident consequences covering health, economic, social and environmental aspects. This implies that the existing methodology which concentrates only on health impacts is insufficient. The last group of R&D activities focuses on the development of accident consequence assessment scheme which can cover the whole, or at least the major part, of the consequences of a severe accident. The findings from the study can be applied to the design of emergency preparedness and response strategy.

The R&D in this group started from the development of consequence assessment methodology [14]. Different types of consequences were monetized and added up to form the cost per severe accident. (Later, the name of the index was change to nuclear accident consequence index (NACI) [15] to avoid confusion with actual cost of accident.) It covers health, economic, social and environmental impacts of the accident. The NACI was modified to cover time-dependent properties of the accident consequences and applied to the evaluation of a hypothetical accident in a virtual nuclear power plant in Thailand [16]. If the site for the future nuclear power plant is selected, the methodology can be used to consider an appropriate emergency preparedness and response scheme for it.

3. ASEAN NETWORK ON NUCLEAR POWER SAFETY RESEARCH

ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) acts as a platform for information/ knowledge sharing and research cooperation for researchers in the field of nuclear power safety in South East

Asia. Its scope covers the R&D activities discussed in this paper, and one of its pilot activities has a strong link to the aforementioned TINT R&D programme on severe accident. ASEAN NPSR can serve as a platform for dissemination of good practice to other countries in the region and has a great potential to support the R&D activities in future TSOs in ASEAN. This section introduces the background of ASEAN NPSR, as well as its goal, objective and scope. The 2017 Benchmark Problem which deals with the atmospheric dispersion, transport and deposition of radioactive release is also briefly described.

3.1 Background

ASEAN NPSR was formulated to help facilitate information and knowledge sharing throughout the region and enable research cooperation among ASEAN countries. The Joint Communique on the establishment ASEAN NPSR [17] was agreed upon by seven member states, including Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam in March 2017 in Bangkok, Thailand. The Joint Communique of ASEAN NPSR was endorsed by the Sub-Committee of Sustainable Energy Research (SCSER) and approved by the ASEAN Committee of Science and Technology (ASEAN-COST) in October 2017.

3.2 Goal and objectives [17]

The goal of the ASEAN NPSR is to *strengthen R&D, human resource development and regional cooperation in the field of nuclear power safety in ASEAN in order to support the formulation of the regional strategy for accident management and to be consistent with the IAEA Safety Standards*.
There are four objectives of ASEAN NPSR, namely:

- *To be the regional platform in the field of nuclear power safety research to promote the data and information sharing and cooperation among the Member States;*
- *To fulfil the needs and address the gaps of countries in the ASEAN region in R&D;*
- *To strengthen the capability in R&D of the Member States in order to be able to provide the technical support for decision making;*
- *To establish and enhance the cooperation between the ASEAN network and the IAEA and other relevant international organizations.*

3.3 Scope [17]

ASEAN NPSR will *support R&D activities of the Member States in the field of nuclear power safety, including but not limited to:*

- *Design basis accident analysis;*
- *Severe accident analysis;*
- *Probabilistic risk assessment;*
- *Fission product transport;*
- *Accident consequence assessment;*
- *Linkage between reactor assessments and environment impact assessment;*
- *Other topics agreed upon by the Member States.*
-

It can be observed that several topics here overlap with the TINT R&D programme on severe accident introduced above, e.g. severe accident analysis, fission product transport, and accident consequence assessment. As the delegates from many countries are from a national research institute which has potential to turn to a TSO when the nuclear power programme is launched, it can somehow be claimed that R&D in the field of severe accident is included in the plan of the future TSOs in ASEAN countries to develop their competencies to technically support the future nuclear power programmes in the region.

3.4 2017 Benchmark Problem

ASEAN NPSR plans to conduct four following activities to cover the aforementioned scope [17]:

- *Creation of information and knowledge sharing platform;*
- *Assessment of benchmark problems;*
- *Research collaborations;*
- *Annual meeting.*

After an active discussion, the members concluded that the first benchmark problem (the 2017 Benchmark Problem) will be on the assessment of atmospheric dispersion of a radioactive release from a hypothetical severe accident in existing or planned power plants around the region. Through this activity, the participating members will be able to familiarize themselves with the assessment of atmospheric dispersion, transport and deposition of radioactive release. At the same time, they can also assess the extent of impacts of a severe accident in neighbouring countries to their citizens. Some members expressed interest to move forward to upstream assessments, e.g. source term assessment and reactor thermal hydraulic assessment. These assessments match perfectly with the first three groups within the R&D programme on severe accident described in Section 2. It can thus be said that many countries in ASEAN, all of which possess no nuclear power plant, plan to conduct research on severe accident to evaluate the impacts of neighbouring power plants and to prepare human resources in order to become a future TSO. The aforementioned R&D programme can be a good model for an embarking country planning for a nuclear power programme in the future, especially those locating near countries with nuclear power plants.

4. CONCLUSIONS

The R&D program on severe accident of Thailand Institute of Nuclear Technology (TINT) which positions itself as a TSO for the future nuclear power programme is introduced. The programme aims to support understanding of severe accident and planning of emergency response. R&D activities are divided into four groups following the typical progression of a severe accident: (1) accident progression in reactor pressure vessel; (2) behaviour of radionuclides in containment vessel; (3) atmospheric dispersion, transport and deposition of released radioactive release; (4) accident consequence assessment.

Background, goal, objectives and scope of ASEAN Network on Nuclear Power Safety Research (ASEAN NPSR) are introduced. Overlap between the scope of ASEAN NPSR and TINT R&D programme on severe accident is observed. It can somehow be claimed that R&D in the field of severe accident is included in the plan of the future TSOs in ASEAN countries to develop their competencies to technically support the future nuclear power programmes in the region.

The 2017 Benchmark Problem of the ASEAN NPSR is on atmospheric dispersion assessment of a radioactive release from a hypothetical severe accident. Many participating countries suggest moving forward to upstream assessments, e.g. source term assessment and reactor thermal hydraulic assessment. These assessments match perfectly with the TINT R&D programme. Through these assessments, the country can familiarize itself with the assessment, while assessing the extent of impacts of a severe accident in neighbouring countries to their citizens. This R&D programme can be a good model for an embarking country planning for a nuclear power programme in the future.

Though the TINT R&D Programme seems good as a start for an embarking country, TINT recognizes rooms for further improvement in all aformentioned R&D activities. These gaps can be fulfilled by collaboration with well-established TSOs. Likewise, ASEAN NPSR is also aware of lack in competencies and resources for members to perform a comprehensive assessment of the 2017 Benchmark Problem. Therefore, ASEAN NPSR, represented by TINT, is requesting technical assistance and funding for this activity from the IAEA through a Technical Cooperation (TC) project. ASEAN NPSR also welcomes cooperation with other networks of TSOs to enhance the scope of activities in order to achieve its goal and objectives.

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SPECIAL MONITORING CAPABILITIES DEVELOPED AT THE INTERNAL DOSIMETRY LABORATORY OF THE ARGENTINE NUCLEAR REGULATORY AUTHORITY

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Abstract

The Internal Dosimetry Laboratory (LDI, acronym in Spanish) of the Argentine Nuclear Regulatory Authority has established itself as a reference laboratory at National level, where bioassays and dose assessments are implemented following the highest standards of quality and the internationally accepted criteria in routine and special monitoring. Particularly, the special monitoring program may be necessary as a result of a known or suspected exposure, an incident or an accident; and the degree of accuracy required for the exposure assessment should increase with the level of exposure likely to have been received by the person. In case that a special monitoring is necessary, the LDI has three suitable measurement techniques: lung counting, whole body counting and thyroid counting; these two last techniques are carried out with portable equipment to measure outside the laboratory. In this paper the characterization of the systems and the calibration process for special monitoring are presented, using different physical and simulated phantoms. Furthermore, within the framework of the IAEA Project identified as RLA 9075, and in order to create a technical support for dosimetry assessment of overexposure persons in Latin America, the LDI has improved the ability to develop specific accidental scenarios and models for persons, using Monte Carlo simulations methods (MCNP). The experience and the progress of the laboratory in computational dosimetry to support a rapid response to a possible situation of overexposure are presented.

1. INTRODUCTION

The LDI is a laboratory for the *in vivo* measurement of people for the determination of the activity of photon-emitting radionuclides retained throughout the body or in specific organ. Special monitoring response capacities developed at the LDI are described in this paper.

2. MATERIALS AND METHODS

The LDI has three suitable *in vivo* measurement techniques available for special monitoring: lung counting, whole body (WB) counting and thyroid counting; these two last techniques with portable equipment to measure outside the laboratory, if necessary. In Table 1, the features of the systems are presented.

TABLE 1. IN VIVO MEASUREMENTS SYSTEMS

N°	Detector	Shielding	Measurement Geometry
1	Four Canberra LEGe detectors ACTII (GL3820RT/S). Active area= 3800 mm^2, diameter =70 mm and thickness = 20 mm per detector	A chamber of 200×150×200 cm and 40 t weight. The walls are made of 5 mm iron laminates joined together in order to reach 15 cm thickness. It is also supplied with a graded Z-liner inside (0.5 cm lead and 0.05 cm cadmium) to provide an extra background reduction in the low energy region. The access is a pneumatically driven sliding door.	

N°	Detector	Shielding	Measurement Geometry
2	GeHp 100% for WB model GC10021, 82.6 mm × 68.7 mm	Located in the same chamber where is the lung counter system described previously, it can be removed to be used as portable equipment.	
3	NaI(Tl) 3×3 in for Whole Body	A chamber of 200×93×130 cm. The walls are made of lead bricks of 8 cm thick. With measurement geometry of chair type.	
4	NaI(Tl) 1.5×1in for Thyroid	Lead cylindrical shell with outer diameter of 12.7 cm, inner diameter 6.9 cm, length 39.5 cm. It can be used as portable equipment.	
5	NaI(Tl) 3×3 in for Thyroid	Lead cylindrical shell with outer diameter of 13.3 cm, diameter of 8.29 cm, length 34.5 cm. It can be used as portable equipment.	

2.1 Phantoms

The phantoms used to calibrate the systems are shown in Fig.1-3.There are two neck phantoms, the first one is an ANSI phantom [1] of 12.7 cm in diameter and height, made of PMMA, developed by Lawrence Livermore National Laboratory (LLNL), with a hole that allows the localization of a vial with a liquid source. The second neck phantom is a cylinder of 11.4 cm in diameter and 11.3 cm height which is made of resin and was developed by IRD [2], with a slot to position a flat sealed source with a thyroid shape. Three different sizes of thyroid sources were constructed to represent child and adult thyroid [3, 4]. The second phantom is the Sliced BOMAB Phantom that performs equivalently to a BOMAB Phantom, which is the internationally accepted standard for calibration of whole-body counters (WBC) [5]. This phantom is made with polyethylene slices adapted to be used with solid and sealed sources and allows the calibration of WBC with linear and chair geometry. The third phantom is the LLNL realistic torso phantom, which is composed by a torso, lungs, different chest plates to represent different muscle thoracic thickness (MTT) and other organs [6]. By last, for validating computational simulations a torso phantom made of PMMA was constructed. It consists of two cylindrical blocks of 30 cm in diameter and 15 cm in height each. The interior of the lower block contains holes where personal dosimeters and blood samples can be located (Fig.4).

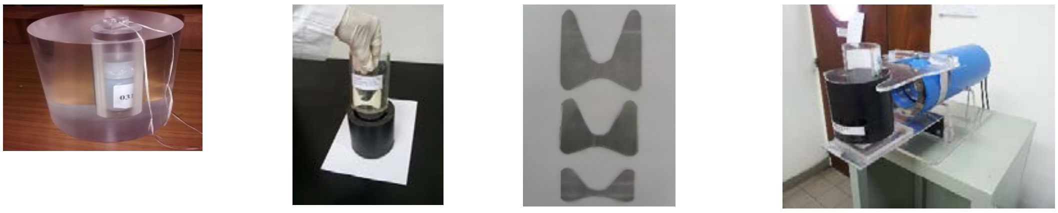

FIG. 1. ANSI and IRD neck phantoms, three sizes of thyroid sources and measurement geometry

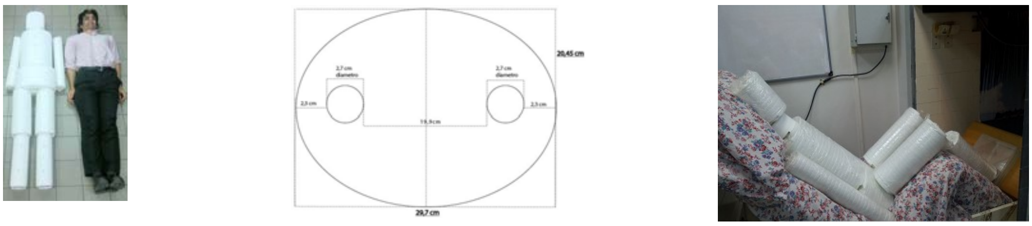

FIG. 2. Sliced BOMAB Phantom, schematic drawing for one flat source and chair type measurement geometry

FIG. 3. LLNL realistic torso phantom, different chest plates and measurement geometry

FIG. 4. Torso phantom with holes where TLDs and blood samples can be located for computational validation

2.1 Calibration and Activity Determination

The calibration of the *in vivo* measurement systems consists of three consecutive stages: energy calibration, efficiency calibration and determination of the Detection Limit (DL) associated with the calibration. All LDI systems were calibrated following internal procedures based in international recommendations [7], within the framework of a quality assurance programme. Efficiency calibration is the most important, since it allows relating the response of the detector to the activity retained in the body or in a specific organ; and it was made using the phantoms, previously described, and sources traceable to a national or international standard. For the ACTII system, efficiency calibration was also obtained as function of chest-wall thickness for men [8], and to be appropriate for the measurement of women, a special efficiency procedure was performed [9]. In this method proposed by J. Farah *et al*., involving a library of 24 realistic female computational phantoms, the value of the efficiency obtained for the man, with the LLNL torso phantom, was corrected by a factor that takes into account the different breast sizes. For efficiency calibration, chest-wall thickness for men and DL determination, expressions 1 to 4 were used:

$$Ef = \frac{A_N}{A_{mm} \times \varepsilon \times T} \tag{1}$$

$$DL = \frac{3 + 4{,}65\sqrt{B}}{Ef \times \varepsilon \times T} \tag{2}$$

$$CWT\,(cm) = 11{,}5\left(\frac{W}{H}\right) - 2{,}0038 \tag{3}$$

$$Ef_{ACTII\_Woman} = \frac{Ef_{LLNL\ torso\ phantom}}{Correction\ Factor} \tag{4}$$

Where **Ef** is the efficiency in counts per second per Bq (cps Bq^{-1}), $\mathbf{A_N}$ is the net area at determinate energy of the interest peak (corresponding to the radionuclide used in the calibration expressed in counts), $\mathbf{A_{mm}}$ is the activity contained in the phantom at the date of measurement, $\boldsymbol{\varepsilon}$ is the photon yield corresponding to the interest peak, **T** is the measurement time, **B** is the number of total counts corresponding to the area of interest peak (measured with an appropriate blank), **CWT** is the chest-wall thickness for men, **W** is the weight in kg, **H** is the height in cm and the **Correction Factor** is a value that can be obtained for specific woman using the size of the torso and breast [9].

The measurement of the person is carried out with the system properly calibrated, positioning the person in the same geometry established during the efficiency calibration process. The measured activity is determined according to expression 5 as:

$$M(Bq) = \frac{V_P - V_F}{\varepsilon \times Ef \times T} \tag{5}$$

Where **M** is the activity retained in the body or in a specific organ or tissue, $\mathbf{V_P}$ is the net count rate of the person at the interest peak and $\mathbf{V_F}$ is the net count rate of the blank corresponding to non-contaminated person.

2.3 Dose Assessment

The LDI implemented the IDEAS methodology [10] for internal dose assessment in both: routine and special situations. Nevertheless, many times in special monitoring it is necessary to perform a quick test of the potential dose, therefore the TIARA method [11] is implemented, previous to IDEAS methodology. In case of high level of internal exposures, the LDI implemented the Clinical Decision Guide (CDG) that can be used as operational quantity for considering the need for medical treatment for internally deposited radionuclides [12, 13].

In order to create a technical support for dosimetry assessment of overexposure persons in Latin America, within the framework of the IAEA Project RLA 9075, the LDI has improved the ability to develop specific accidental scenarios and models for victims, using Monte Carlo simulations methods (MCNP). The first task achieved was to develop the computational phantom of the acrylic torso (Fig.4), using MCNP code vs 6.1 with TLDs dosimeters and blood samples inside it, to simulate an overexposure situation with a gammagraphy source located near to the torso surface.

3. RESULTS

In Table 2 are presented the calibration results of each *in vivo* system for selected radionuclides and different groups, and the activity that should be measured in the different tissues corresponding to the intake of one CDG. These retention activities were calculated assuming the measurement of the corresponding tissue, 24 hours and 30 days after intake (a.i.) of one CDG.

TABLE 2. CALIBRATION RESULTS FOR LDI *IN VIVO* MEASUREMENTS SYSTEMS

							Retention Levels Indicative of Intake of 1 CDG (Bq) at	
Group	Nuclide	Type Absorption	N° System-Tissue	T (s)	Ef	DL (Bq)	24 h a.i.	30 d a.i.
Man	Am-241	M	1- Lung	3600	1.1E-2 - 5E-3	3E+0 - 7E+0	5.33E+02	3.56E+02
Woman	Am-241	M	1- Lung	3600	1.1E-2 - 5E-4	9E+0 - 1.8E+1		
Ref. Adult	Co-60	S	2-WB	300	2.78E-04	7.0E+01	7.17E+06	7.88E+05
			3-WB	300	2.78E-04	6.2E+02		
	Cs-137	F	2-WB	300	5.81E-04	6.0E+01	2.24E+07	1.34E+07
			3-WB	300	5.81E-04	4.6E+02		
Child (7-12 y)	I-131	V	4-Thy	300	8.00E-04	3.3E+02	1.28E+04	9.09E+02
			5-Thy	300	7.20E-03	1.0E+02		
Adult 18-40 y	I-131	V	4-Thy	300	8.70E-04	3.0E+02	6.25E+04	4.43E+03
			5-Thy	300	8.00E-03	9.0E+01		
Adult >40 y	I-131	V	4-Thy	300	8.70E-04	3.0E+02	3.13E+06	2.21E+05
			5-Thy	300	8.00E-03	9.0E+01		
Preg. or lact. woman	I-131	V	4-Thy	300	8.70E-04	3.0E+02	3.13E+04	2.21E+03
			5-Thy	300	8.00E-03	9.0E+01		

For radionuclides other than radioiodine, the CDGs for children (age 0 to 18 y) and pregnant women are defined as one fifth the adult value [12]. For intake or expected intake of radioiodine, KI should be administered to adults >40 y if the projected dose to thyroid (AD_{Thy}) is ≥5 Gy, to adults 18 to 40 y of age if the AD_{Thy} is ≥0.1 Gy, and to pregnant or lactating women or persons <18 y of age if the AD_{Thy} is ≥0.05 Gy [12, 13].

Related to the simulation of the gammagraphy accident, the dose assessment results were satisfactory, since they were validated through an intercomparison performed with regional experts, where the simulations were compared with the experimental doses in blood and TLDs, by biodosimetric and physical methods [14].

4. CONCLUSIONS

The characterization of the LDI *in vivo* systems and the calibration process for special monitoring were presented, using different physical and simulated phantoms to improve monitoring of different groups of persons. The DLs obtained, for selected radionuclides were very low, which allows not only to assess doses well below the action levels, but to use smaller measurement times if it is important to measure rapidly a large number of people. Depending on the time after the intake, the CDGs can be analysed in terms of the measurement of the retained activity, which facilitates the interpretation of the measurement and communication with stakeholders. Finally, it was shown the LDI experience in the development of an overexposure scenario with an industrial radiography source using MCNP method; in that way it was developed an appropriate and validated source of gammagraphy for calculation of absorbed doses and its distribution into the body of overexposure persons.

ACKNOWLEDGEMENTS

The authors would like to thank to IAEA Technical Cooperation Department and Nuclear Safety and Security Department, IAEA projects: RLA 9085 and TC ARG0015 for the support and assistance in improving and strengthening the capacities of the LDI.

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TOPICAL SESSION 4

OTHER CHALLENGES OF TSOS

CHAIRPERSON
Y. Lee
Republic of Korea

CO-CHAIRPERSON
M. Skrzypek
Poland

The fourth session addressed other areas, such as: public engagement, openness and transparency, communication with stakeholders, interfaces between safety and security, safety and security culture, physical protection and capacity building. It was noted that the openness and transparency of the TSO safety expertise may enhance regulatory effectiveness. The participants recognized the need for clarification of the role of TSOs in these other areas: transparency versus security, and safety and security interfaces. It was added that the IAEA international cooperation mechanisms (e.g. TSO Forum, Regulatory Cooperation Forum, Global Safety and Security Network) have proven to be very effective platforms and should be continued to address those challenges.

SCIENTIFIC AND TECHNICAL SUPPORT IN ENHANCEMENT NUCLEAR SECURITY: ROLES, CAPABILITIES AND CHALLENGES

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Abstract

Although the legal responsibility rests with the regulatory body, Regulators always need support in many areas in nuclear security from external technical and scientific organization (TSO). Paper will discuss the importance of TSO in enhancement nuclear security in nuclear embarking countries. The roles and responsibilities of both TSO and regulator should be defined to integrate each other for excellent enhancement of nuclear security. The important of establishing an independent TSO from any external interests will help in carrying out their roles and responsibilities. An efficiency technical support staff as a number of researchers, engineers and technologists should be developed their capabilities by excellent education and professional training courses to form a technical staff that had broad backgrounds, high levels of performance and follow special standards. Also, it should be taking into consideration the scientific collaboration between the international communities to support the TSO in nuclear embarking countries to facilitate the exchange of experience and good practices in capacity building activities, and they should make arrangements for identifying areas in which they require assistance to fulfil their responsibilities. These can be achieved by organizing conferences and scientific projects with international organization for sharing experience. There are also many challenges facing the establishment and implementation of TSO roles in embarking countries especially in management the interface between the TSO and regulatory functions, independency and security financial support which were discussed in the study.

1. INTRODUCTION

Technical and scientific support organizations (TSO) provide supports in a full range of nuclear science such as: environmental sciences, waste management, radiation protection, nuclear safeguards, and nuclear security. This support function is provided across the full range of nuclear and radiological facilities and activities including uranium mines and mills, fuel fabrication pilot plant, research reactors, power reactors, and radiation sources facilities…etc. In addition to its purely scientific role in nuclear security, TSO staff also provides support to the regulatory body in establishing guidelines to arrange and carry out the inspection process, review of licensee submissions, and in the development of regulatory policy. Collaboration frequently includes contributions from several disciplines within the TSO, thus requiring an integrated approach to issue resolution with regulatory authority. This study describes structure and roles of TSO organization and benefits associated with implementing TSO, also mentioned the challenges may face embarking countries in establishing an independent technical and scientific support organization. Management of the interface between the TSO and regulatory authorities was also discussed.

2. STRUCTURE OF TSO ORGANIZATION

TSO can be built by combining several working units from research centers and/or scientist from universities who are specialized in a nuclear and radiological related science to form strong and independent TSO. The legal status of the TSO should be strong enough to enable it to keep its independence. The legal status of the TSO's organization should be established either as a part of the governmental structure or put in higher position in the government hierarchy based upon the national need and legal infrastructure, but it should be independent from the regulator or licensee. The TSO should be funded from the national budget and be separated from the budget of the licensee and the regulatory body. Also, TSO must be able to develop and express its technical assessment independently of any external interests, such as political or economic [1].

3. ROLE OF TSO ORGANIZATION IN ENHANCING NUCLEAR SECURITY

Establishing TSO has necessary roles in enhancing nuclear security aspects by allowing the exchange of views on security research needs as following:

- TSO should be able to provide technical and scientific support for the regulatory functions of the regulatory body and inspectors, especially in conducting review and assessment of licensing documents submitted by applicants and developing guidelines to implement the physical protection inspection [2].
- Providing efficient nuclear security training courses; and carrying out expert assessment.
- On the other hand, TSO are also expected to assume a public outreach role, providing a bridge between the Government and the public, particularly in education and information dissemination.

4. SCIENTIFIC AND TECHNICAL SUPPORT CAPABILITIES

An efficiency technical support staff as a number of researchers, engineers and technologists should be developed their capabilities. Thus, there are many factors assist in developing the capabilities of the technical support staff in embarking countries were discussed below:

4.1 International Scientific collaboration

The scientific collaboration between the international communities to support the TSO in nuclear embarking countries should be carried out to facilitate the exchange of experience and good practices in capacity building activities, and they should make arrangements for identifying areas in which they require assistance to fulfill their responsibilities. These can be achieved by organizing conferences and scientific projects with international organization for sharing experience [3].

4.2 Research and Development

It is important to point out that TSOs may conduct research activities in basic science but can also conduct more focused research on the needs of the regulatory process. The rapid development of new concepts for physical protection, nuclear forensics and all other nuclear security issues with increasing complexity clearly demonstrates the need for the involvement of TSOs in conducting research activities to evaluate the nuclear security applications and to propose the necessary actions to the regulator or inspector, in order to protect nuclear and radioactive materials and facilities which will reflect into protect public and environment.

4.3 Education and Training

An efficiency technical support staff should be developed their capabilities by excellent education and professional training courses to form a technical staff that had broad backgrounds, high levels of performance and follow special standards. TSO may also provide education and training to inspectors, reviewers and staff members engaged in regulatory activities. An intensive training program for inspectors must be in place, including technical aspects, quality system training and behavioral aspects. Through the knowledge existing in them and by providing laboratories and installations for the conduct of education and training activities, TSOs contribute to the development of programs at different training levels, such as short duration extension courses, formal education and the post-graduate educational Course. Also, TSO may organize a Master, Diploma or high education courses of Science program in different nuclear security issues, formally recognized by the high education and research Ministry, in a related scientific university. And also provide scientific Regional or basic training courses to the nuclear and radioactive materials handling in a scientific view [4].

5. SCIENTIFIC AND TECHNICAL SUPPORT CHALLENGES

There are many challenges arise in embarking country could obstruct the scientific and technical support organizations establishment or prevent to carry out its responsibilities. These challenges are mainly regarding the interface between regulator and TSO, which could be overcome by providing a clear understanding of roles and responsibilities of both of them and specific rules of conduct, as discussed below.

The regulatory staff is responsible and accountable for: Requesting the technical assessments and recommendations from the TSO; Requesting the cooperation with TSO stuff to develop many nuclear security issues such as: establishing DBT, nuclear security regulations, review and assessment the licensee documents…etc. The important of establishing an independent TSO from any external interests will help in carrying out their roles and responsibilities. Also, the shortage of the financial support in the embarking countries cause delay in establishing an efficient TSOs [5].

6. CONCLUSION

The technical and scientific support should be established to support the regulator in nuclear security issues. Establishment of an independent TSO and involving it in public education and dissemination of information on the nuclear power program is considered to be a good practice. Establishment of the TSO itself will improve the national nuclear security infrastructure, which in turn could increase public confidence. The challenges of a changing world can only be addressed if technological advancements are accompanied by effective organization of available resources. In this study, the importance of International Scientific collaboration, Research and Development, Education and Training in developing the capabilities of the technical support staff were discussed. There are some common challenges arise regarding the interface between regulator and TSO. These challenges are manageable by providing a clear understanding of roles and responsibilities for each of them. Above all, clear and respectful communication is required.

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THE CHALLENGES FACED BY TSOs IN THE FIELD OF NUCLEAR FACILITY PHYSICAL PROTECTION

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Abstract

First, this paper discusses Physical Protection System of nuclear facilities as the first line of defense, which plays an important role in the national nuclear security architecture. Then, I introduce the following main fields of the regulation and supervision implemented by competent authority on nuclear facilities' PPS: a) The Approval of Design Basic Threat; b) The Review of PPS design document; c) The site acceptance test of PPS after construction is completed; d) The Inspection of facilities during the operation period. Then, I point out that to assist with the competent authority, the TSOs need to establish the following core technologies and abilities: a) Threat evaluation technology based on multisource and isomerism big data analyze technology for DBT, which requires TSO to establish the ability to collect data with credibility and abundance; b) Effectiveness assessment technology based on software compliance check, which requires TSO to establish the technology to simulate the reality using an assessment software; c) Site acceptance test technology, which requires TSO to enhance the ability of a wider coverage of both system and equipment tests; d) Online inspection technology based on facility's operation and maintenance situation, which need TSO to collect and analyze the facilities PPS's operation and maintenance data online without disturbance.

1. THE STATUS OF PHYSICAL PROTECTION OF NUCLEAR FACILITY

Nuclear energy with its unique advantages of cleanness and efficiency will become an important energy source in the 21st century. However, the development of nuclear energy is also accompanied by risks and challenges. Among the terrorist activities seriously endangering the security and stability of the international community, nuclear terrorist attacks cause the most concern. Nuclear security summit came into being in 2010 and has been successfully held for four times. The summit focused on strengthening nuclear security to prevent terrorists from acquiring nuclear and radioactive materials and against the sabotage of nuclear facilities.

Nuclear security has lots of contents, such as physical protection, nuclear material control and accounting, response force, cyber security, international cooperation, security culture. However, we can divide nuclear security work into four defenses from the position of government or competence authority:

1.1 The First line of defense: MPC&A of nuclear facility and material's transportation

The very first mission of competence authority against terrorist is to prevent them from acquiring nuclear materials and radioactive substance of any type from nuclear facility. There are two major measures in nuclear facilities supporting this mission: Physical Protection and Nuclear Material Account & Control.
Physical Protection System (PPS) always has the function of Delay, Detect, and Respond following the principle of "Defend in depth and Balance protection". a) Delay: The function of delay system is to increase the total time that an adversary needs to complete sabotage or theft. Generally, there are two types of delay facility. One is passive delay equipment, which has always been put into use, such as double-fences, security doors and windows, enhanced walls and tie-downs; The other one is active delay equipment, which will only been put into use when the alarm is triggered and confirmed by operator, such as fog generator in bunker, road block in access control point, foam generator on material. b) Detect: The function of detection system is to detect any one who is approaching facility without authorization. Usually there are at least two types of detection equipment protecting one area, such as mirco-wave, buried cables, vibration sensors, tension detector, passive/active infrared. Detection system has to work with CCTV system together to achieve the best efficiency because of the principle "No valid alarm without confirmation". c) Respond: The police officer or military guard on site will call out in nuclear security events and hold back or capture the adversary before they can do harm to the facility.

Nuclear Material Account & Control in a facility is extremely similar to nuclear safeguard in a nation. The operator has to divide the whole facility into several *Material Balance Areas (Each Material Balance Areas* *has a coordinator and relevant procedures responsible for the security and safeguard within the Material Balance Area)* and select several Key Measurement Points. The operator has to make sure that the material unaccounted-for(which describes the difference between concerned isotopic content in input-raw-material and isotopic content of output-product) in each *Material Balance Areas* is non-significant and less than the requirement, that is to say there is no obvious material loss in the facility.

In addition, the requirement of material during transportation is the same as the requirement in fixed nuclear facility.

1.2. The Second line of defense: Control of border and custom

According to IAEA Incident and Trafficking Database (ITDB), incidents involving attempts to sell nuclear or other radioactive material indicate that there is a perceived demand for such material. In many imaginary situations, terrorists acquire nuclear material from one nation but use the material in another nation, which means the target nation couldn't guarantee security even they guarantee security of their own facility and material. Therefore, the second line of defense is needed to be deployed in border and custom to prevent the nuclear material and radioactive substance from export or import without authorization. In ideal circumstances, every cargo, vehicle, carriage, container, person, package should be examined by radioactivity monitoring devices to avoid illicit smuggling of nuclear material and nuclear substance.

1.3. The Third line of defence: Protection of public events and important targets against nuclear terrorism

Apart from the scenario that a terrorist directly sabotages nuclear facility to realize their political purpose, the terrorist more likely chooses large public events or important targets (such as waterworks or landmark building) as his target with simple nuclear/radioactive device to spread horror and damage. The competence authority is encouraged to deploy many mobile and temporary measures, equipment and response force to protect potential targets as well as to deter potential adversary. In the worst scenario that the terrorist has successfully carried out nuclear/radioactive attack, the competence authority must have the capacity to mitigate consequence and recover the contaminate area. This is the third line of defense.

1.4. The Fourth line of defense: Nuclear forensics

The fourth and the last line of defense is nuclear forensics, which gives the regulatory body strong evidence to estimate where the unidentified material came from, thus help the investigation. Nuclear forensics usually analyzes the trace impurity, age, stable isotope and other nuclear features of the unidentified material seized in customs and border or left in the contaminated (target) area after the terrorist nuclear assault.

As we can see above, there is much security-related work requiring cross-department cooperation, which makes it more complex and difficult. Though lots of work need to be done, however, the nuclear facility, which is the first line of security defense, has gradually improved its ability to reduce the possibility of terrorist acquiring nuclear material. The first line of defense has significant deterrent and protection effect. The survey shows that investment directly to the facility, whether it's for physical protection or material account&control, has better cost performance.

2. MAIN FIELDS OF REGULATION AND SUPERVISION

In order to effectively promote and direct the nuclear security work at facilities' level, the competent authority has always two different section: One section is in charge of nuclear material account&control, the other one is responsible for nuclear facility physical protection system (PPS). The later section has four main fields of regulation and supervision listed below:

2.1. The approval of Design Basic Threat

Design Basic Threat (DBT) is the foundation of physical protection system. Design Basic Threat clarified the boundary of responsibility that facility should bear by describing the capability that imaginary adversary may have. Adversary whose capability is beyond DBT is the responsibility of a nation instead of a facility's operator. It is observed that DBT, which determines the investment scale, construction content, technology level, and other system features, is the first input condition when a construction of PPS is implemented. Furthermore, the approval of DBT is the first and most serious step for regulatory bodies. Also, this step always needs technical support from TSO ensuring that the approved DBT is suitable for a nuclear facility.

2.2. The Review of PPS design document

After the Design Basic Threat is approved, the designing institute will compile the design document of PPS which has the content of general drawing, PPS element drawing, PPS equipment requirement, preliminary security plan, compile illustration and so on, according to DBT. Competent authority has to review all the stuff in the document to see whether they meet the relevant regulation and standard. This comprehensive review sets higher requirement for TSO to find out inadequacy, inappropriateness and irregularities. Because once design document is approved and commercial procedures of PPS construction is carried out, any tiny change of system or equipment would be rather difficult and even impractical.

2.3. The site acceptance test of PPS

Finally, the construction unit complete the establishment and commissioning of PPS, waiting for site acceptance. Before the regulatory body issues the license, a comprehensive acceptance test for PPS by an independent third party such as TSO is necessary. Site acceptance is the last opportunity to compensate for the lack of design, last chance to check equipment defects, final chance to clarify the responsibilities of each unit as well as the last stage of program management. In order to accomplish those meaningful tasks, a highly professional, independent, stable group of PPS background is prerequisite.

2.4. The Inspection of facilities during operation

Acceptation test is a one-by-one compliance check regarding the direct content of construction project of physical protection system. However, those factors closely related to the operation's effect including personnel maintenance and relevant procedures still lack assessment. What's more, as time goes on while both technology and threat changes, the well-done PPS can't support the proper capability against adversary forever. That's the reason why license has a time limit of 3-10 years. To ensure that facility has the capability to handle the adversary describing in approved DBT all the time, competent authority takes actions like routine inspection, spot check, special inspection, etc. In most cases, most inspection group members come from relevant TSO, which means the TSO needs to have the ability to figure out more problems in limited time.

3. CORE TECHNOLOGY TSO'S NEED TO ENHANCE

Corresponding to the abovementioned regulation fields of regulatory bodies who are responsible for nuclear facility physical protection system, TSO needs to enhance these four-core technologies listed below.

3.1. Threat evaluation technology

TSO shall assist competent authority to review the DBT that facility submitted and updated in a certain frequency. TSO should take both facility inherent risk and regional/national threat into consideration to review a submitted DBT. Except analyzing the basic character like type, motivation, scale, tools, weapons and capability of potential adversary, TSO also needs to analyze the character of material, the type of facility, the security situation of location and nearby high-risk industry, to complete the final DBT. This calls for advanced threat evaluation technology based on multisource and isomerism big data analyze technology, because TSO usually needs to process an enormous amount of data from different department (such as public security, intelligence, foreign affairs, national security, etc) and different type. That is to say, TSO should develop an algorithm of giving each relevant element a weighting factor to work out the proper DBT. What's more, before integrating all the information, TSO lacks the ability to collect or even examine data with credibility and abundance from regional to regional in most cases.

3.2. Effectiveness assessment technology

It's often very hard to predict the efficiency of a PPS in design-review period. However, this is exactly what regulatory body asks TSO to do. There are two ways to do the effectiveness assessment of the PPS, one is based on specific criterion while the other one is based on PPS performance. In the period of design-review, TSO often calls up a group of subject matter experts to manually check the compliance of design document. As a result, negligence occurs inevitably. TSO should establish a credible technology based on software compliance check, which can compare relevant physical protection system element with criterion with least human intervention. For example, the software could take the CAD graphic and its symbol as input, meanwhile output is the result of compliance check, showing where the design fails to meet the criterion

On the other hand, sometimes the assessment based on performance is recommended because of the diversity of location, DBT, budget and type of facilities. TSO could assess the performance via simple principle software like *Estimate of Adversary Sequence Interruption* (EASI) or *System Analysis of Vulnerability to Intrusion* (SAVI), which can calculate the defeat probability based on weak paths analysis, detect probability, delay time and response effectiveness. However, this kind of software has limitation when multi-path intrusion, insider assistance and other complex situations are considered, which are more likely to happen. To develop an assessment software, TSO needs the ability to simulate the complex reality, taking weather influence, lanchester damage theory, insider assistance, mutli-path intrusion and PPS operation into consideration.

3.3. Site acceptance test technology

Acceptance test mainly focuses on the on-site compliance testing subjecting to the physical protection system equipment conducted by the third party, which does not involve the overall acceptance of the project funds audit, data archiving, business review, construction content, equipment sets, project progress and other content. It only concerns about the function of physical protection system itself.

Site acceptance is key premise of issuance the nuclear material license. Prior to the site acceptance test, the physical protection project shall meet the following conditions: a) Preliminary design shall pass the examination, and construction must be based on the formal design document; b) After the joint-commissioning of the system, the PPS shall run for at least one month and the trail report shall be submitted; c) During the commissioning period, the designer and the construction units shall cooperate with the owner together to establish the management system of operation and maintenance; d) The completion material of concealed work; e) Designer, the construction unit and the owner should jointly set up a special acceptance testing committee, which shall hold responsible for acceptance testing of the implementation of specific work; f) The construction unit and vendors must carry on the operational technical training to the personnel concerned so as to enable the main users of the system to operate independently.

In particular, many of the physical protection systems of nuclear facilities often work with other construction elements of the facility, such as surrounding environmental governance, information security rectification, facility expansion, and upgrading of the process system—all of them are bundled together to form a major project for advancement. According to the "three simultaneous" principle, which requires that the design, construction and operation shall be conducted simultaneously, the project should be completed at the same time.

Site acceptance test should concern sufficient test items rather than just count the PPS equipment to see if it is in right location. This requires a wider coverage of systems, equipment categories of test items, like tamper alarm of remote devices, definition of camera, illuminance of lighting, mis-identification of reader at access control point, usability of integrated platform , during project examination.

However, physical protection system contains three important basic functions: detection, delay, and response. It is difficult to use other formats except practical rehearsal to assess the delay and response systems for nuclear facilities. In addition, considering that the access control, intrusion detection, CCTV and other functional subsystems interconnect with each other and the subsystems share the same data exchange and processing platform, it's also necessary for physical protection system to conduct stress test under specific circumstances including extreme weather condition or nuclear emergency.

3.4. Online inspection technology

In some cases, the inspection of PPS is just like an acceptance SPOT test, which contains almost the same test item and procedure like acceptance test. This kind of inspection is inefficient and costly. In my point of view, the inspection should pay more attention to the implementation of approved security plan and operation procedure. TSO should establish an online inspection technology based on facility’s operation and maintenance situation. That is to say, in ideal cases, facility should update their operation and maintenance data in a standard format via a confidential system. The operation and maintenance data include false alarm report including frequency and reason of false alarm, system failure report, equipment repair report, self-assessment report, drill report and so on. TSO shall develop the ability to collect and analyze the facilities PPS’s operation and maintenance credible data online without disturbance.

4. CONCLUSION

As we can see above, there is a huge difference between nuclear security with other issues. Technology development introduces enhancement of both operator’s and adversary’s capacity. As the old Chinese saying goes, “He who doesn’t advance loses ground”, TSO must to catch up with the most leading-edge technology. Also, big-data analysis is very important in most cases. However, TSO don’t have many experts major in computer science and data analysis. In China, regulatory body concerns these four main fields, there should be more concerned aspects connected with nuclear security. And there is more to do to make a more security nuclear industry.

OPENNESS TO CIVIL SOCIETY: WHICH CHALLENGES FOR A TSO?
Examples of interactions to enhance safety through civil society vigilance

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Abstract

Annual surveys carried out by the Institute for Radiation Protection and Nuclear Safety (IRSN) in France on public opinion about risks and safety shows that French people strongly support pluralism in risk assessment and interaction with experts. The European framework (under the Aarhus Convention) and French acts enhance legal requirements for transparency in the nuclear field and access to information on nuclear safety. Within this framework, IRSN has developed an openness strategy which is implemented through a Charter that includes commitments to improve risk assessment through a better interaction with society. Therefore, the National Federation of Local Information Committees (ANCCLI) and IRSN set up joint actions in order to establish a continuous technical dialogue on sensitive issues dealing with nuclear safety. Benefits can be gained for both civil society and technical support organizations (TSO). This paper presents different examples of interactions to illustrate that civil society vigilance may contribute to enhance safety. For a TSO, this constitutes a new way to enlarge its expertise rather than just another way to pass on its expertise and share its views.

1. INTRODUCTION

The French annual Barometer of the perception of risks and safety, created by IRSN in 1988, shows that French people strongly support transparency and pluralism in risk assessment and interaction with experts.

These expectations are recognized legally through international and national frameworks. In this context, IRSN has conducted a long-standing initiative of openness to society formalised in a dedicated Charter. Within this strategy, the National Federation of Local Information Committees (ANCCLI) and IRSN set up joint actions in order to establish a continuous technical dialogue on sensitive nuclear safety issues.

2. RISK GOVERNANCE AND OPENNESS TO SOCIETY

The governance of risks has changed for the last 20 years. As shown by the French Barometer of the perception of risks and safety[11], the public expects more transparency and is worried about the health impact of activities. This annual public perception survey is carried out to follow developments in public opinion on risks and safety, most notably in areas of health, industry, food and the environment.

In 2017, this Barometer clearly showed that:

— 88 % of the French people polled approve structures bringing together scientific experts, political decision-makers, industrialists, associations and citizens in order to deal with risk situations; for 42% the advantage of such structures is to better identify risks and for 35% is to contribute to reduce risks;

— 69 % of the French people polled consider that IRSN must share its technical advice with non-governmental organizations (NGOs) and citizens.

IRSN has practised an initiative of openness to society for more than 15 years. The aim is both to help stakeholders to build their technical skills and to give an opportunity to enhance its own expertise through the prism of the complementary point of view of social stakeholders.

[11] http://barometre.irsn.fr/

In 2008, IRSN shared a charter on openness to society with other French expertise and research institutes. This Charter states:

- Three commitments to improve risk assessment through a better interaction with society:
  - Enhance transparency in presenting its work;
  - Share its knowledge;
  - Help stakeholders acquiring the skills necessary to actively participate.
- Three commitments to implement openness to society:
  - Enhance the ability of its staff to interact with stakeholders;
  - Identify and mobilize resources to further stakeholders' involvement;
  - Carry out an internal policy on openness to society and publicly report progress achieved as well as problems encountered.

At the same time, it is important to keep in mind that the law gives citizens more rights. At the international level, the "Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters" – or the Aarhus Convention – was adopted on 25 June 1998 at the Fourth Ministerial Conference in the Danish city of Aarhus (Århus).

In France, transparency in the nuclear field and public involvement are legally binding under the 2006 Act on Transparency and Security in the Nuclear Field (TSN-Act) and the 2015 Act on energy transition for green growth (TECV-Act).

Under the TSN-Act, it is now mandatory to create a local information commission (CLI) for each nuclear facility or site. The missions of these CLIs are monitoring, public information and consultation on any matter concerning nuclear safety and radiological protection. The CLI members are all volunteers and consist of local elected officials, members of environment protection associations, representatives from the nuclear operator labour union and qualified persons. ANCCLI is their national federation. The TECV-Act also reinforced the involvement of CLIs in decisions on issues like decommissioning or emergency preparedness and response.

Since 2008, ANCCLI has worked with the European Commission to organize a process called the "Aarhus Convention & Nuclear" (ACN) approach. The aim of this approach is to reinforce public participation in decision-making in the nuclear field. With the help of the French Nuclear Safety Authority (ASN) and IRSN, ANCCLI and the European Commission organized feedback workshops that were attended by representatives from civil society and institutions in several European countries involved. These workshops showed the importance of giving the public access to the existing operator documentation and expert assessments as early as possible, to enable people to become involved in the decision-making process. ACN determined that a key prerequisite is to give people enough time to build their skills. Moreover, it is necessary to develop participation in decision-making on key strategic guidelines, plans and programs, while all options are still open.

Within the framework of this ACN approach, the French High Committee for Transparency and Information on Nuclear Security (HCTISN)[12] and the ANCCLI teamed up to conduct three working groups leading to 13 recommendations. The main conclusions are that:

- Society stakeholders must be informed of the existing expertise and have access to it and to the resources needed to build citizen instruction on technical files;
- Any consultation may be carried out only over the long term: time is not an enemy; used in an optimum way, consultation improves the chances of success, because it teaches the various actors how to dialogue, obtain information, build competence, etc;
- The consultation must be able to influence decisions: the way that it is taken into account throughout the decision-making process and in final decisions must be explained.

Since 2003, ANCCLI and IRSN have had a cooperation agreement and carried out joint actions to implement access to expertise and competence building of CLI members. These actions cover environmental, health, waste and safety issues.

[12] Created under the French TSN-Act, the HCTISN is a body for information, consultation and debate on the risks related to nuclear activities and the impact of these activities on the health of people, on the environment and on nuclear security.

3. TECHNICAL DIALOGUE ON SENSITIVE NUCLEAR SAFETY ISSUES

After the Fukushima accident, the civil society raised a lot of questions, especially on the implementation of stress tests. The CLIs and associations wanted to have access to a complete and detailed review of the risk of accident in French nuclear facilities, so as to be able to understand and analyse the nuclear operators' reports that were made available on internet. Thus, ANCCLI decided to organize exchange seminars.

A first seminar was organized by ANCCLI and IRSN, in September 2011, just before the deadline for operators to deliver their report, which were to be public. The seminar gave the participants technical and methodological information to help them study the operators' reports, in the best possible conditions. After this seminar, CLIs and association proceeded to study the reports. A second meeting was organized in November 2011, after IRSN published its report shortly after its completion, and the main points of this analysis were discussed. The CLIs also presented their own analysis. After the ASN published its report, a third seminar was organized in January 2012. This provided a new opportunity to share different analysis made by ASN, CLI, ANCCLI, HCTISN and IRSN.

These opportunities expanded the discussion on safety issues, beyond the scope of stress test to enlarge to other safety issues. Early access to reports was a key factor in the public involvement process. And it also enabled expertise to benefit from this interaction with the civil society.

After this experience, ANCCLI and IRSN wanted to pursue interactions on safety issues, along with the expertise process. They decided to create places of exchange and dialogue on the subjects of safety:

- Firstly, by organizing several workshops on safety (two new ones on post-Fukushima stress-tests in 2013, one on organizational and human factors in 2013, one on nuclear facilities decommissioning in 2014);
- Secondly by establishing continuous technical dialogue on issues requiring long-term follow-up.

A continuous technical dialogue was established in 2014 concerning the 4th periodic safety review and the long-term operation of the operating nuclear power plants.

In 2014 ANCCLI and IRSN decided to create a working group on this topic to exchange about the main orientations of this particular safety review. Five meetings were organized with some 30 CLI members or associations to exchange about the main safety issues for this review - specific items such as the ageing of the reactor vessel or the reactor containment building. ASN also organized a meeting during its public consultation about arrangements for the orientation of this safety review. As the meetings progressed, ANCCLI developed its own view on important issues and shared it with ASN and IRSN.

In 2016, ANCCLI, the CLI of Tricastin (CLIGEET), ASN and IRSN organized a dissemination seminar in order to involve more CLI members in this safety review. This provided the opportunity not only for the operator (EDF), IRSN and ASN to present their analysis of the subject, but also for the CLI and ANCCLI to expose their view and the way they could be involved in the process.

Since 2017, ANCCLI, ASN and IRSN have decided to continue the technical dialogue during the expertise process for specific issues: conformity and ageing, protection against internal and external hazards, the prevention and mitigation of core meltdown accidents. Three meetings were organized to gather questions on these subjects from civil-society representatives.

Since 2015, ANCCLI, CLI Flamanville, ASN and IRSN have established a continuous technical dialogue on the analysis of the consequences of the anomaly in the Flamanville EPR reactor pressure vessel head domes on their service ability. The main objective of this dialogue is to help civil society to obtain accessible information on safety related issues with highly technical aspects.

Several meetings were organized with the participation of various types of stakeholders: CLIs, NGOs, non-institutional experts, the nuclear authority, experts and operators. At each step of the assessment, ASN and IRSN presented the expertise methodology and results. These meetings provided the occasion to discuss civil-society concerns such as how representative the tests are, defence-in-depth issues, margins, manufacturing inspections among others.

This dialogue allowed civil society to participate in and better understand the decisions taken by ASN. Even if this involved presenting highly technical issues to non-specialists, it enabled the experts to offer an overview of all the components that contribute to the safety margins.

4. CONCLUSION

The first challenge facing TSOs is how to enhance transparency. The issue of publishing the conclusions of expertise has been pondered for ten years now, and IRSN advices have been published on its web site since 2016. But as the ACN approach has shown, transparency is not enough. Civil society needs more time to grasp the issues.

For that reason, the second challenge facing TSOs is how to develop dialogue and exchange throughout their expertise and assessment processes. Therefore, ANCCLI and IRSN have developed continuous technical dialogue on specific topics.

There are benefits for civil society: developing their own technical skills, gradually building a reciprocal understanding of expectations and constraints, and facilitate the emergence of news ideas or hypotheses. These all contribute to enhance safety through citizen vigilance.

The benefits for a TSO are to improve the confidence in its actions and to take benefit of the interaction with stakeholders in its expertise.

The vigilance exercised by the public contributes to safety. It goes through transparency and, moreover, through pluralistic exchanges.

IMPACT OF EXTERNAL INFLUENCES TO THE DEVELOPMENT OF CULTURE FOR SAFETY IN NUCLEAR ORGANIZATIONS OF BANGLADESH

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Abstract

Bangladesh is embarking on NPP. It is evident that Bangladesh Atomic Energy Commission (BAEC), the largest promoter of peaceful usage of atomic energy in Bangladesh, becomes the owner-operator organization of the country's first NPP. Bangladesh Atomic Energy Regulatory Authority (BAERA), a newly established organization, stands as the sole regulatory body to regulate radiation/nuclear activities in the country. Decision making processes, which is very crucial in the nuclear organizations, can be enhanced through developing culture for safety and security. It is essential for BAEC as a TSO to maintain and enhance values towards development of culture for safety within the organization as well as support the regulatory body (RB). Safety performances have to be recognized and grown from within the existing culture of a country or an organization and inherent safety values of human beings must be aligned to grow culture for safety in a society or group. However, prior to engaging efforts for developing and shaping existing culture for safety to an intended extent, it is very important to identify the factors of national culture and sub-cultures that can impact the organization's culture and culture for safety. Moreover, dynamics of organizational culture are constantly created by mutual interactions and shaped by leadership behavior, and a set of structures, routines, rules, and norms that guide and constrain behavior. With the help of surveys, literature review and knowledge gained through observation, dialogue and discussions, the present study is focused on development of a conceptual framework to identify and assess the impact of external influences and challenges primarily faced by BAEC as a TSO, mainly manifested by the political, social, and contextual human factors and perceive if the influential factors are beneficial or detrimental to the development of a 'good' culture for safety. The study findings shed new lights on developing culture for safety and pathways for TSOs and the RB to synchronize their activities toward enhancing

1. INTRODUCTION

Since its inception in 1973, Bangladesh Atomic Energy Commission (BAEC), the promoter of peaceful usage of atomic energy in Bangladesh, is committed to ensuring nuclear and radiation safety in conformity with the international standards through protecting the workers, the public and the environment from the undue radiation hazards. It is evident that the uses of nuclear energy and technology for rendering research activities and services in the fields of human health, food, agriculture, education, industry etc., in Bangladesh have been increasing and Bangladesh will soon embark on NPP through ongoing implementation of Rooppur Nuclear Power Project (RNPP) by the BAEC. Moreover, following the directives of the Bangladesh government, BAEC is carrying out preliminary surveys to find suitable sites for another nuclear power plant to the south of the country. Besides, the BAEC has been operating a 3 MW TRIGA MARK II research reactor and a radioactive waste management facility. BAEC also continues to provide technical support to the newly established Atomic Energy Regulatory Authority (BAERA) of Bangladesh. Hence, the BAEC will have multiple roles to play as owner/operator ~~and~~ as well as an internal TSO for the regulatory body in Bangladesh toward ensuring safety and security to the nuclear installations in the country.

It is convincing that improved technology, a primary means to ensure safety, however, cannot guaranty overall safety to a nuclear power plant or a nuclear facility. Technology and human go hand in hand in a sophisticated technology like nuclear. A huge number of people are usually involved during the pre-operational (pre-project, design, construction and commissioning phases), operational and decommissioning phases of an NPP project. And it's obvious that man makes mistakes, which may not be eliminated but can be minimized through improved human performances that can continuously and sustainably be enhanced if a strong culture for safety remains in place. As culture grows from within it and culture sustains by itself, continuous cultivation, inculcation and nursing as well as aligning of safety values within an existing culture is needed to have a healthy culture for safety to support the desired nuclear safety. Unceasing intensive efforts are essential for a culture for safety to grow and sustain. National culture and sub-cultures have great impact on people's beliefs, understanding, interpretations, perceptions and common expectations regarding safety in their day-today activities [1–3]. Strengths and weaknesses of the national culture, organizational culture and sub-cultures in Bangladesh are needed to be clearly understood and properly treated toward developing a strong culture for safety in the country. Prior to engaging efforts for improving and shaping existing culture to any intended extent, it is very important to identify the factors of national culture and sub-cultures that can impact the organization's culture and culture for safety [4].

Culture for safety does not mean to create a new culture instead, focuses on alignment of the various components and values lying at different layers of a culture toward continuously improving safety performances at nuclear and other facilities. Safety performances have to be recognized and grown from within the existing culture of a country or an organization and inherent safety values of human beings must be aligned to grow culture for safety in a society or group [5–6]. Therefore, real challenges are comprehended toward developing and maintaining a strong safety culture, which is a continuous process and requires a systematic, sustainable, long term commitment to continuously improve safety culture in all organizations working with nuclear technology in Bangladesh. Moreover, dynamics of organizational culture are constantly created by mutual interactions and shaped by leadership behaviour, and a set of structures, routines, rules, and norms that guide and constrain behaviour [7–8].

It is believed that the decision-making processes, crucial for ensuring nuclear safety and security can be enhanced through developing culture for safety and security within the organizations. It is, therefore, essential for BAEC as a TSO to maintain and enhance values through development of culture for safety and security within the organization and capacity building to support the regulatory body. For Bangladesh Atomic Energy Commission, as the pioneer and largest nuclear organization and technical and scientific support provider; and for Bangladesh as a new-comer country, the scientific and research basis for understanding organizational culture, culture for safety and security, how organizational culture influences culture for safety and security, how both organizational culture and culture for safety and security impact performance in nuclear facilities in Bangladesh are, therefore, extremely needed. Furthermore, understanding of external and internal influences on organizational culture and factors that can influence culture for safety and security are crucial toward growing and sustaining a healthy culture for nuclear safety and security in nuclear organizations of Bangladesh.

2. METHODOLOGY

The study deploys survey method, document reviews, and focused group interview to collect data and validate the proposed conceptual model. An anonymous survey is being carried out among the employees of BAEC. Management commitment, safety standards efficacy, work environment, continuous learning, safety accountability, safety communication, knowledge opportunism frame, knowledge integration frame, policy knowledge frame and safety assimilation are the organizational and human measurement factors.

The outcomes of surveys, designed to be carried among the workforce of nuclear organizations, including TSO and the regulator in Bangladesh, will be analysed using the proposed model, which will be detailed in the future studies. Validation and confirmation of the model will be carried out after processing of data. Firstly, the organizational factors and human factors will be evaluated through processing the survey information. Other factors, including external factors that can influence culture and organizational culture will be determined and analysed using the model. In addition, organizational absorptive frames will also be introduced in the model that will help enhance the understanding of parameters related to and needed for improvement of organizational factors and human factors in the organization's culture for safety and security in Bangladesh.

3. CONCLUSION

The study is being carried out within the scope of the research contract, entitled 'Factors that can influence culture for safety, organizational culture and human performance at nuclear and other facilities in Bangladesh' under the IAEA CRP-I22004, Coordinated Research Project on Organizational Culture Basis for Successful Performance in Nuclear Power Plants. The study bears a great deal of academic interest and significant managerial implications. A comprehensive study is, therefore, needed to be carried out. The outcomes of the study, as it progresses, will be continued to publish in journals in the near future. It is strongly believed that the study findings reveal ways to address challenges faced by TSO in developing culture for safety that impacts on the decision-making processes of both organizations and create pathways for working together toward enhancing nuclear safety and security capabilities.

ACKNOWLEDGEMENTS

The contributions of the esteemed experts Ms Monika Haage, Dr. Sonja Haber and Prof. Frank W. Guldenmund towards enhancing knowledge and understanding through interactions and communications at professional and personal levels are gratefully acknowledged. The study is being carried out within the scope of the research contract under the IAEA CRP-I22004, Coordinated Research Project on Organizational Culture Basis for Successful Performance in Nuclear Power Plants.

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ROLE OF A TECHNICAL SUPPORT ORGANIZATION IN DECOMMISSIONING OF A NUCLEAR POWER PLANT

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Abstract

A Technical Support Organization (TSO) assisting Regulatory bodies may be involved from early stages of a project in regulations preparations, reviewing and assessing of Site Evaluation Report (SER), Environmental Impact Assessment (EIA) report, Preliminary Safety Analysis Reports (PSAR), Final Safety Analysis Reports (FSAR), Commissioning plans, implementation and test reports, Operation activities, Re-fueling Outages (RFOs), Maintenance activities, Design Modifications, Initial Decommissioning Plan etc. Maintaining a multidisciplinary technical expertise by a Regulatory body is difficult, therefore it may seek assistance of a TSO for different services specially for decommissioning activities. During the operational phase of a NPP, the preparation for the decommissioning phase must start at some optimum point. During this phase, work must start beyond Initial Decommissioning Plan by moving in to the detailed plan involving recording plant radiological dose mapping, safety assessment, hazard identification, hazard frequency and consequence analysis, accident sequence determination, engineered and administrative control requirements determination, skilled manpower requirements, phase wise planning and financing. This transitional phase requires an early and full engagement of a TSO and full involvement and priority of the plant management, regulatory bodies and collaborative efforts of International Agencies for advice and expert opinion.

1. INTRODUCTION

Decommissioning is based on technical and non-technical factors. The decision to consider going towards Decommissioning of a NPP may be based on economic considerations, where it is no longer feasible to operate the plant in a safe and cost effective manner. Once the decision has been made to commence with the Decommissioning, a strategy has to be devised which is consistent with the National Policies and Regulations regarding Radioactive Waste Management and Radiation Protection. Preparations to start transition from Operation to Decommissioning may start during the end stage of the operations. Decommissioning needs to be considered as a separate project for all the practical purposes and requires a dedicated team working on it. The decision whether to use immediate dismantling, delayed dismantling or some mixed strategy depends on various factors such as economical, technical, political and hazards involved. National Regulatory framework for Decommissioning activities has to be in place. Technical and Scientific expertise become important in order to assist the National Regulations in making regulations and rules, technical reviews of safety related submissions, deterministic and probabilistic analyses and assessments to independently verify claims made by the applicants, setting safety limits in certain cases, inspection and audit support etc.

2. ROLES AND RESPONSIBILITIES REGARDING DECOMMISSIONING

The role of TSOs becomes very important even in policy decisions as the input may provide a clearer picture for the decision makers. There is a wide spectrum of activities that TSOs can be involved in. For example, a TSO to a Nuclear regulatory body may help it to chalk out National Regulations regarding Decommissioning. Technical division of Regulatory bodies have to review various submissions, programs and plans, but it may hire additional support of a Technical and/or Scientific Support Organization. TSOs to a regulator may have to review Environmental Impact Assessment report, Final Decommissioning Program, Fire protection program during Decommissioning, Emergency Management Program, Environmental Monitoring Program, Deterministic Analyses (e.g. Activation analysis), Safety Assessment for Decommissioning, Site Radiological Characterization estimate and survey reports, spent fuel handling, transport and storage (intermediate and final) plan, Radioactivewaste management plan, etc. A generic description of roles and responsibilities with varying level of involvement is given in table 1.

TABLE 1. ACTIVITIES TSOs T A REGULATORY BODY MAY BE INVOLVED IN RELATED TO DECOMMISSIONING

i.	Preparation of Regulations relevant to Decommissioning
ii.	Safety Assessments for Decommissioning (deterministic and probabilistic)
iii.	Site (radioactive) characterization
iv.	Site physical inventory estimates
v.	Initial and final decommissioning programs
vi.	Detailed Activity plans, procedures and scheduling
vii.	Reports on Financial planning, estimates and guarantees
viii.	Phase wise planning and skilled manpower retention plans
ix.	Facility data retention and storage plans
x.	Environmental Monitoring Programs
xi.	Fire Protection Program
xii.	Emergency Management Program
xiii.	Environmental Impact Assessment Reports
xiv.	Initial and interim storage measures and final disposal (design)
xv.	Operating Limits and conditions during Decommissioning
xvi.	Interaction and Liaison with external Technical and Scientific organizations for support
xvii.	Interaction with International / Foreign TSOs/ TSOs from supplier country for support
xviii.	Work and Activity management

There are two viable strategies, one of which may be adopted i.e. immediate dismantling and deferred dismantling. Each strategy has its own merits and demerits. A decision to adopt one of the approaches depend primarily on the priority of certain factors over the others for a particular management.

2.1. Immediate Dismantling

One of the advantages of immediate dismantling is that manpower resources with relevant experience are available and can be employed till the desired stage or phase e.g. end state condition (greenfield, brownfield etc.). The Operating Organization of the running plant may have skilled manpower resources in form of engineers, technicians, welders, cutters, crane operators, riggers who are aware of the radiation risks involved. Members of a TSO to a regulatory body that have been involved in assessment, review and oversight activities at various stages of a particular facility e.g. design, PSAR, Commissioning, QA plans, Emergency Planning and preparedness, FSAR, operations, shutdowns, start-ups, RFOs, maintenance, modifications etc. understand the philosophy and principles behind the regulatory requirements for these activities. In immediate dismantling, regulatory body can seek assistance from the expert services of these TSOs who are well verse with the technical documents, design specifications, operating statistics etc. of a particular facility. This assistance can be in rule making and regulations, assessment, review, audit, surveys and oversight.

Immediate dismantling strategy has its own challenges as well. While the activity levels may still be high and may cost extra during dismantling due to shielding and task time management requirements, special dismantling techniques and equipment may be required as well (such as under water remote handling). In case of developing countries with Nuclear Power Plants approaching end of their life cycle, decision to adopt immediate dismantling may bring, technological and economic challenges. In such cases special care must be exercised while evaluating various tasks in line with the National regulations. Procedure and worker qualifications must be required by the regulators. In this regard, collaboration with external TSOs may be required. High activity fuel and highly radioactive material may require special handling, transport and storage measures which necessitates specific regulatory requirements to be in place before such activities take place.

2.2. Deferred Dismantling

For some organizations deferred dismantling is a preferred strategy. After removing the fuel, contaminated liquid and resins, rest of the plant is left in a mothball condition. Surveillance is increased and access authorization is limited. Radioactive decay of key radionuclides to much lower levels may allow certain constraints related to the radioactivity and contamination to be removed. Manpower and staff requirements are reduced. This may result in considerable cost reductions. Deferred Dismantling strategy having completion timeline spanning decades brings in other considerations. One of the challenges is the retention of data and records. Documentation and records have to be preserved and archived for longer periods in form of hard bound and soft copies for use at later stages. It is likely that the members of the TSO at the initial stages of Decommissioning may no longer be present due to various factors and as this type of Decommissioning is divided into phases, transfer of facility data to the later stages in well preserved, organized and ready to use form is very important. TSO to a Regulatory body must lay down special requirements in this regard and establish an oversight mechanism to ensure that the preservation of documents is satisfactory.

Deferred dismantling of a facility may be spanned over decades, therefore ageing management of SSCs is another area which require special attention. Special requirements regarding condition monitoring and surveillance procedures must be prepared in order to ascertain safety. Phase-wise license requirements may change based on facility conditions as depicted in Figure 1.

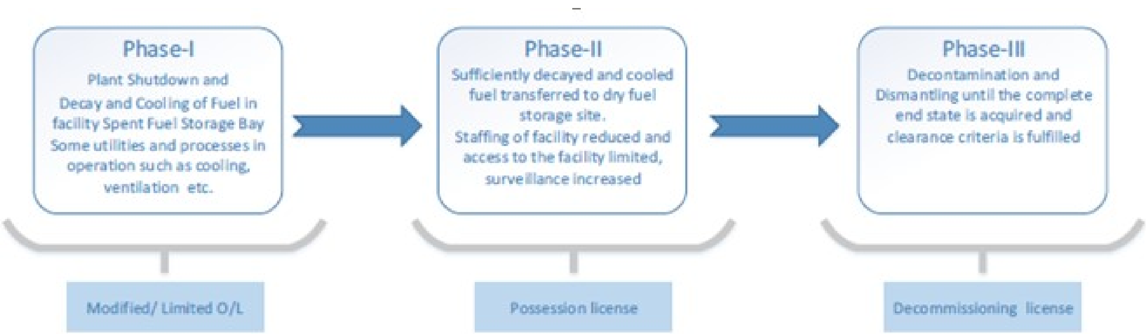

FIG.1 License conditions for different phases of decommissioning

2.3. Safety Assessment

One of the key tasks that a TSO to regulatory body is to review the Safety Assessment report submitted by the facility. There are different deterministic or probabilistic approaches to the Safety Assessment [2]. If necessary, expertise does not lie in the technical group of a regulatory body, assistance of technical experts based on review area requirements may be sought. Although safety assessment may have been performed during the preparation stage of Initial Decommissioning Plan, information on the latest condition and status of the plant necessitates a fresh Safety Assessment to be performed just before the start of the Decommissioning. In case, decommissioning is being done phase wise, safety assessment for each phase may be done independently. This is because as the Decommissioning proceeds, the state of the plant continuously changes and the safety role of Systems Structures and Components (SSCs) may differ from their roles during the operation and so may the nature and frequency of the associated hazards [3]. This may help in establishing the engineered and administrative safety control measures with much more confidence. Moreover, expert members of Technical Support Organization may be included in the Decommissioning activity in order for the regulatory body to gain more confidence. Safety Assessment and Planning should be done in such a manner that there is agreement on the methodology and outcomes among all the stake holders. At the very outset there may be some lack of accurate information which may be revealed during time. Attributes of a good safety assessment document and the topics that must be covered in a safety assessment report are delineated in International guidance documents [2]. In the beginning it is very important to forge a fairly adequate knowledgeable technical team in order to make a good safety assessment.

Results of a good Safety Assessment will result in identifying Engineered, operational and Administrative controls which can be ensured to be in place in SSCs procedures etc. by the regulatory bodies during Decommissioning to ensure Safety.

2.4 Plant Characterization and inventory database

Physical inventory database preparation and plant characterization is among the key tasks which are performed by the applicant. Physical inventory includes details of SSCs, material inventory, attributes (mass, length, material type e.g. SS 304 L), location (equipment name, building, floor, room no.). Plant SSCs may be contaminated through two processes i.e. activation and transport of contamination. Characterization of plant in these terms may be in terms of solid, liquid or gas, High Level, Low Level or Intermediate. Volume and mass of activated or contaminated SSCs will help estimate the space requirements in repositories and planning the jobs. The methodology involves evaluation of historical information (drawings, monitoring data, pictures, operating records, event records), development of characterization database (SSCs, rooms inventory etc.), activation analysis using deterministic codes, sampling and measurement.

Regulatory Body has to evaluate the accuracy of information provided by the facility. Specially in case of activation analysis, independent verification by experts in the field may be sought by the regulators.

Additionally, dose mapping and radiological surveys of some areas may include experts from a TSO to verify the claims made by the applicants in their submissions.

2.5 Phase-wise Task Planning

Most often the Decommissioning may be planned in a phase wise manner where different phases require proper phase wise Decommissioning plan, criteria for start and end phases, clearance criterion, associated QA, Emergency plans, Fire Protection, Surveillance and Physical Protection planning.

During each phase, project has to perform task planning and assessment, activity sequencing, workforce requirements assessment, planning specific work with respect to radiological hazard aspects (radiation dose on contact, dose with distance, radioactive particle inhalation, contamination), selecting appropriated PPEs and assessing the ease of work (ergonomics) planning the dismantling techniques appropriate to the job, tools specifications, chemical, mechanical cleaning to attain the clearance level criteria , requirement, maintenance and costs, rigging and handling, appropriate packaging and safe transportation.

Regulators have the task to see that safety aspects are not overlooked. Review of phase wise plan submissions require in depth review specially with regards to staffing requirements, data retention requirements, ageing management requirements, modifications requirements (e.g. special ventilation, utility and services, modification in SSCs etc.), radioactive waste handling, transport and storage requirements, access control and surveillance requirements.

2.6 Documentation and Record keeping

If the Decommissioning strategy is based on phase wise division of the project and the decontamination and dismantling of part other than fuel requires waiting for a few decades, then this brings a whole set of new challenges which the management has to think about. First and the foremost is the loss of technical staff that has experience of that particular facility. This necessitates the need for preservation and retention of facility data and records in a form that can be useful for the staff at Decontamination and Dismantling. Special requirements and guidance may be prepared by TSO of a Regulatory bodies and adherence may be checked by various means. Different types of data that may be preserved is listed in Table 2.

TABLE 2. FACILITY DATA THAT MAY BE PRESERVED IN CASE OF DELAYED DISMANTLING APPROACH

i.	Design specifications, Operating Manuals, Station instructions
ii.	Technical Documents, Operation Statistics and history, Operating Principles and Procedures
iii.	Technical Manuals, Technical Notes
iv.	Commissioning Procedures
v.	Flow sheets, P&IDs, Area Drawings
vi.	SER, EIAR, PSAR,FSAR, Decommissioning program
vii.	Monthly Technical Reports, Special Technical reports, Outage Reports, UORs, ENRs etc.
viii.	Annual Safety reports, Apparent Cause Analysis Reports, Root Cause Analysis Reports
ix.	Minutes of weekly meetings, Change approvals, internal Peer review records, International Peer review

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TOPICAL SESSION 5

KEY COMPONENTS TO DEVELOP AND MAINTAIN THE TECHNICAL AND SCIENTIFIC EXPERTISE

Chairperson
L. CIZELJ
Slovenia

Co-chairperson
G. H. CHAI
China

The fifth session acknowledged the need to develop and maintain core competencies. Examples of key components discussed during the session included training, tutoring and strategic planning of workload as necessary guidance for meeting future demands for technical and scientific expertise. It was agreed that training and tutoring programmes may be internal to TSOs or offered by different qualified national or international providers.

JSC VO “SAFETY” SUPPORT TO ROSTECHNADZOR IN ASSISTING EMBARKING COUNTRIES ON THEIR TECHNICAL AND SCIENTIFIC CAPABILITY DEVELOPMENT

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Abstract

JSC VO “Safety” is a technical and scientific support organization to Russian regulatory body – Rostechnadzor. It was established by the Order of Gosatomnadzor (predecessor of Rostechnadzor) № 96 of September 08, 1993. The mission of JSC VO “Safety” is to provide services in safety assurance of nuclear facilities in Russia and abroad. Within the frame of its mission, JSC VO “Safety” has been assisting embarking countries on their technical and scientific capacity building since the establishment, pursuing such goals as:

- Establishment of independent, competent, adequately staffed with qualified personnel and technically sound National Regulatory Body;
- Establishment of open and transparent Regulatory System with a clear division of responsibilities and rights between Stakeholders;
- Establishment of regular co-operation between National Regulatory Body and Vendor country’ Regulator (exchange of good practices, transfer of experience and knowledge pertaining to regulation of VVER-type reactors);
- Provision of full-scale technical assistance and training during National Regulatory Body’ development stage.

Up till now, JSC VO “Safety” has been participating in such projects as Bushehr NPP (Iran), Tianwan NPP (China), Kudankulam NPP (India), Akkuyu NPP (Turkey), Belarus NPP (Belarus), Rooppur NPP (Bangladesh) providing the services on: Compliance Assessment of Equipment for NPPs; Consulting, Safety Review (Nuclear and Other Hazardous Facilities); Engineering; Testing and Inspections; Certification; Audits; Training of specialists.
In this paper we will share the experience of JSC VO “Safety” in assisting the regulatory bodies of Iran and Bangladesh in their technical and scientific capability development.

1. INTRODUCTION

The achievement and maintenance of a high level of safety in the siting, design, construction, commissioning, operation and decommissioning of nuclear facilities, and in the closure of waste disposal facilities, requires a sound legal and governmental infrastructure. An appropriately organized and staffed independent regulatory body with well-defined responsibilities and functions and access to adequate resources is a key element of such an infrastructure. [1]

Nevertheless, it’s common and understandable that the countries embarking in the nuclear energy have to develop their nuclear safety infrastructure in a very short period, while facing such gaps as [2]:

- Inadequate inspector- and expert staff;
- Lack of competences;
- Lack of experience;
- Gaps in regulatory normative base;
- Absence of guides and manuals;
- Insufficient funding;
- Lack of independent status.

Fortunately, some of these gaps can be covered by the introduction of the technical-support organization assistance. One of the main activities of many TSOs is capacity building in the regulatory body. For example, VO “Safety” has a wide experience in competence development for the regulatory body, as for Russian one, and for foreign.

In this paper we will share some experience on competence development for the Iranian Nuclear Regulatory Authority (INRA) and Bangladesh Atomic Energy Regulatory Authority (BAERA).

2. CHALLENGES FOR THE INSPECTOR TRAINING PROGRAM

The Russian Federation has a system of training, refresher training of inspectors on the basis of Rostechnadzor (JSC VO "Safety" Training and Methodological Center) both for the Russian and foreign specialists. Long-term experience of the Training and Methodological Center activities allowed to single out three main difficulties of inspectors' training as related to the foreign specialists.

Firstly, each inspector should possess not only the knowledge of a specialist out of operating personnel, but also specific knowledge on probable occurrences in the inspector's field of supervision and control as well as knowledge related to procedures of supervision and control (in particular, inspections and audit). It refers both to the Russian and foreign specialists.

Inspector's training is rather specific not only while obtaining higher education, but also while mastering the procedures of inspections and audits at nuclear facilities. Gaining such experience takes all the time of the person's practical activities. Mastering of previous experience is a training process (theoretical knowledge acquisition, practical skill acquisition), that is why preparation of training materials requires particular meticulousness. Taking into account dynamics of the process (adding inspection experience), which envisages new facilities, introduction of new regulatory documents, new facts of the facility's behaviour during operation, it is required to constantly update training material. The inspection activity essentials can be taught based on theoretically completed materials through periodical updating of regulatory documentation, factual material is getting outdated practically on a day-to-day basis. For instance, almost every during the NPP unit construction day there are new types of activities and their results, such as concrete pouring, walls construction, equipment mounting and so on to be inspected.

In other words, factual materials should be varied from class to class. Moreover, during training inspection there are a lot of questions to be promptly resolved in the real conditions, which imposes additional responsibility on the author of the training inspection tasks in terms of approximation to the truth.

In this situation the instructor acts not only as an observer over the trainees' practical activity, but also as an analyst of the actions and behaviour of each trainee in the created situation. Level of inspector's education, depth of understanding during the inspection, ability to communicate with personnel, safety culture knowledge plays significant role in the inspector's behaviour.

Secondly, experience in training foreign specialists shows that translated training material cannot convey the depth of experience, that the specialist, preparing training materials, possesses.

Only real-life communication after theoretical preparation in the language of training is capable to convey specific moments of inspector's activity.

Experience of communication with the trainees shows (interactive component, dialogue mode) that much time is spent on mastering and understanding of specific terms used by the Russian-speaking specialists in the process of control, operation, pre-commissioning activities, prophylaxis, maintenance.

Not all the trainees have the same language proficiency and level of general training, therefore additional time is devoted not only to interpretation of the terms into the native language, but also to explanation of conceptual meaning of the term, its practical meaning. This is the reason, why program intended for 1000 training hours, takes around 1200 hours.

Thirdly, the best training results are achieved with the use of individual approach. Judging from the training experience, the best possible option is to have 3-5 trainees in the group to create atmosphere of fruitful dialogue in it. Besides, trainees with the same major in inspections should be grouped together. Common interests encourage active dialogue with the instructor to solve arising tasks and to obtain answers to the questions of shared interests.

3. TRAINING EXPERIENCE

Considering the challenges mentioned in the previous chapter and taking for the basis relevant IAEA recommendations and Rostechnadzor' practical experience at Russian NPPs' nuclear and radiation safety regulation, the Educational and Methodical Center that in 2014 was merged into JSC VO "Safety" has developed its own training program for the personnel of foreign regulatory body.

This program consists out of 1000 hours of training and lectures for each student performed by Educational and Methodical Center personnel, experienced staff from Rostechnadzor, VO "Safety", SEC NRS and Training Center of Kalinin NPP, which allows to share their experience. For the first time this training was performed in 2013 for the personnel of INRA. It had 13 specializations, such as [3]:

- Nuclear safety;
- Radiation protection;
- Radioactive waste management;
- Equipment working under pressure;
- Transport-technological equipment;
- Control systems;
- Electromechanical systems;
- Engineering and constructions;
- Fire safety;
- Emergency preparedness and planning;
- Containments;
- Ventilation and special gas cleaning;
- Water treatment.

The studying material was updated according to the unique experience of Rostechnadzor inspectors. Each course consisted out of general and special modules. General modules had 106 theoretical and 128 practical hours each, while special modules had from 6 to 16 theoretical and from 8 to 32 practical hours depending on the specialization. Then depending on the function of the INRA personnel trained at the Center was developed a training program for each person. This program considered the general information needed for the inspector to perform his/her functions and more detailed one. For the better effect the training was performed in small groups out of 3-5 people, except the time when general lectures were provided. In the end, each person trained at the Center received around 1000 hours of lectures and practical exercises for his/her own specialization. This way, 32 persons from INRA were trained and received the Certificates. Currently, they are performing their regulatory functions at INRA.

Besides this program, the Comprehensive Modular Program has been developed by JSC VO “Safety”. It takes for the basis:

- IAEA Safety Series SSG-16 (Establishing the Safety Infrastructure for a Nuclear Power Programme);
- IAEA Milestones in the Development of a National Infrastructure for Nuclear Power (NG-G-3.1);
- IAEA Recommendations on capacity building for safe, secure and sustainable nuclear power programmes;
- Rostechnadzor’ practical experience at Russian NPPs’ nuclear and radiation safety regulation

The Comprehensive Modular Program is based on a modular principle, consisting of self-contained conceptual units (modules) that collectively contain knowledge of all regulatory competences groups according to the IAEA approaches. The modular principle enables the development of a specific training program upon request on the basis of Program topics according to the specialization of a trainee group in a concerted scope.

The topics and content of the Program’s lectures are aimed at developing basic competence of trainees, which can be further developed during additional advanced level courses.

The Program’s topics cover relevant types of activities of all life cycle stages of the different nuclear facilities as follows:

- NPPs with VVER-type reactors;
- nuclear research installations;
- radiation sources;
- mobile reactor installations, including floating ones;
- nuclear fuel cycle facilities related to spent nuclear fuel and radioactive waste management at NPP.

The Comprehensive Modular Program is about to be launched for the training of BAERA staff. Though the training plan is currently under development, VO “Safety” specialists have been training the on-site inspectors of BAERA from the very beginning of pre-construction works on the site. There have been two permanent inspectors on the Rooppur NPP site from VO “Safety” since 2016. These inspectors have been performing not only direct inspections, but also job training for the BAERA staff. After receiving necessary knowledge and experience through the practice of joint inspections, some of the BAERA personnel started to perform inspection work independently from VO “Safety” inspections. Currently there are normally five inspectors on the site: two from VO “Safety”, two permanent inspectors and one trainee-inspector from BAERA, who are changed over half a year shifts. It should be noted that BAERA finds such practice as very effective way of inspectors training.

4. CONCLUSION

For decades JSC VO “Safety” has supported Rostechnadzor in assisting embarking countries in capacity building. In particular, it has been successfully providing full-scale technical assistance and training during National Regulatory Body’ development stage, despite certain challenges for the training of the foreign regulatory body’s personnel

In general, there are two training programs provided by VO “Safety”. The first one is a training program developed specially for the INRA, which is more technically specific and directed to the practical competences of inspectors. This program was successfully performed and received positive feedback from the customer. The second one is the Comprehensive Modular Program, which covers a full-scale range of regulatory competences and activities for different nuclear facilities, but it is contains more theoretical hours than practical. It is also complimented by the inspectors’ job training on NPP construction site, which received a wide support from BAERA due to its effectiveness. This program is to be launched for new customers of JSC VO “Safety” such as BAERA and Egyptian Nuclear and Radiological Regulatory Authority (ENRRA).

Considering previous training experience and the advantages of both programs, it is planned to perform in the future updates of the first program and its further integration into the second one.

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THE EXPERIENCE OF THE ENSTTI INITIATIVE IN MEETING CHALLENGES OF PROFESSIONAL DEVELOPMENT OF TECHNICAL SAFETY ORGANISATIONS EXPERTS

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Abstract

The support provided by Technical Safety Organizations (TSOs) to Nuclear Regulatory Authorities (NRAs) in carrying out their designated functions, depends on highly qualified personnel who are competent in many disciplines. The development and maintenance of this workforce needs on-going attention from governments and stakeholders to ensure that adequately skilled and competent personnel are available at any time, taking into consideration retirements and the continuous need for personnel resulting from natural fluctuation, from new developments or national requirements. For the last 8 years, the European Nuclear Safety Training and Tutoring Institute (ENSTTI), an initiative of the European Technical Safety Organizations Network-ETSON, addressed the above-mentioned issues by providing vocational training and tutoring in methods and practices required to perform assessments in nuclear safety, nuclear security and radiation protection. ENSTTI gradually transformed into a recognised training and tutoring centre specialized in meeting the growing need for highly qualified personnel with adequate knowledge and skills in nuclear safety and security at nuclear regulatory authorities and Technical Safety Organizations (TSOs). All along its development, ENSTTI assessed and monitored the respective training needs and continuously developed and improved the training and tutoring programme to meet the standard requirements of today's trainers and learners regarding lifelong learning across border mobility. In presenting the results of ENSTTI education since its creation, the paper questioned the validity and the sustainability of its model and introduces ideas for further evolution.

1. INTRODUCTION

As stated in the IAEA TECDOC SERIES on Technical and Scientific Support Organisations Providing Support to regulatory Functions [1], education and training and human resources development are major contributors to knowledge management and capacity building within a Technical Safety Organization (TSO). In addition to initial education, training, and work experience, continuing professional development and refresher training are to be integrated in a competency development plan for TSO staff. IAEA Safety Reports Series No. 79, Managing Regulatory Body Competence [2], provides the framework for the identification of the competences required across a TSO and links these to the design, development and implementation of the required training. Further information can be also found in the IAEA Report on Capacity Building for Nuclear Safety [3] and in the recently published IAEA Safety Report Series No.93, A Methodology for Establishing a National Strategy for Education and Training in Radiation, Transport and Waste Safety [4].
Capacity Building in nuclear safety, nuclear security and radiation protection integrates a wide range of scientific and technological disciplines. Moreover, nuclear and radiation safety requires highly professional expertise in broad areas of nuclear technology. The construction of this expertise is more than a matter of education as it involves transfer of practical knowledge and culture. This practical knowledge transfer is best done by senior experts from Nuclear Regulatory Authorities (NRAs) and TSOs that actually work in the areas that are pertinent to regulatory practices. Training in safety and security assessment depends upon the practical expertise of the trainers and nuclear safety training has to be implemented in educational planning through NRA and TSO informed teaching programmes.
To this aim, with the support of the European Technical Safety Organizations Network-ETSON, some European Union TSOs created in 2010 the European Nuclear Safety Training and Tutoring Institute, ENSTTI. ENSTTI objectives were to set up a high-quality training mechanism to tackle the training needs of experts at NRAs and TSOs; to ensure the continuous development of qualified experts in this area; and to foster harmonization of technical practices in nuclear safety, nuclear security and radiation protection. This was expected to be achieved through the regular provision of vocational training and tutoring exclusively delivered by senior professionals of European TSOs that take into consideration latest technical developments and is continuously up-dated and improved by applying a systematic approach to training.

2. ACTIVITIES HIGHLIGHT

Since its creation, ENSTTI has delivered more 8 500 000 students.days of training and 210 000 students.days of tutoring. Around 800 experts from European TSOs have served as lecturers or tutors.
Participants to training and tutoring activities were from Europe, 35%, Asia, 30%, Africa, 20%, Middle East, 10%, and America, 5%.
Overall, ENSTTI has developed 46 training modules: 26 in Nuclear Safety; 14 in Radiation, Waste and Transport Safety; 3 in Nuclear Security; and 3 in Emergency Preparedness & Response.
Despite ENSTTI was originally meant to serve EU safety organisations, a large portion of participants to ENSTTI activities during these last eight years were coming from outside Europe.

3. INPUT TO NUCLEAR SAFETY CAPACITY BUILDING

The NUSHARE project for Sharing & Growing Nuclear Safety Competences originated as a EURATOM Education & Training initiative proposed by Commissioner for Research and Innovation and Commissioner for Energy after the Fukushima Daiichi accident in Japan 11 March 2011. It was a Euratom FP7 support action of four years, launched under the work programme 2012. The main objective of this project was to develop and implement education, training and information (ETI) activities aimed at sharing and growing nuclear safety culture across the EU in all nuclear installations and in all applications of ionizing radiation, including security aspects. One of the NUSHARE Working Package was dedicated to the development of a training scheme for new and existing staff working at NRAs and TSOs and to the subsequent delivery within a qualification system. This task was entrusted to ENSTTI. Based on an ENSTTI study's findings [5], the need for a consistent training approach for this expert group was recognized. As a first step, ENSTTI developed a well-structured Basic Training Programme covering regulatory functions as well as all technical areas of activities.
In 2015, the EC Directorate for Energy launched a Feasibility Study in support of the development of a level playing field for nuclear safety assessment by Regulators and Technical Safety Organisations in the European Union to foster and evaluate the potential of pilot training in establishing a harmonised set of skills and competences for safety assessment carried out by safety authorities/regulators and technical safety organisations in the EU Member States. The study which was done by ENSTTI, used the results of a concrete Pilot Test Case that was implemented on the basis of an existing training programme for safety authorities and TSOs in the field of nuclear safety. The Pilot Test Case included the constitution of the trainees' group, the preparation and implementation of the three training modules: Module I on legal and regulatory framework and the functions of regulatory body; Module II on technical concepts, techniques, methods and tools for the assessment of nuclear safety and radiation protection; and Module III, a tutoring period at the participants' home organisations and related to their working position. It was completed by an evaluation module, Module IV, which had the objective to gather and exchange feedback, experiences, opinions, and suggestions on the Pilot Test Case. The results of the Feasibility Study on establishing a level playing field in safety assessment were both at the policy and technical levels: financing staff training; sensitising junior staff to the importance of the EU Directives; running on a regular basis and at the EU level a Basic Training Programme; generating a EU network of safety assessors capable to understand and support each other; developing a set of professional development curriculum that could be shared by EU safety organisation; creating at the EU level, a platform to inform and update the staff of EU NRAs and TSOs of training and tutoring opportunities inside and outside the EU, and support networking initiative.
The SITEX Project was initiated within the EC Horizon 2020 programme to develop the Sustainable Independent Expertise Function Network in the field of deep geological disposal safety. One of the Work Package, implemented by ENSTTI, aimed to set up a practical demonstration of training services that may be provided by the foreseen SITEX network. The pilot training module focused on the development of training at a generalist assessment level, with emphasis on the technical review of the safety case for geological disposal. The training programme proposed as a pilot scheme postulated a potentially limited number of trainees, a range of technical specialisations involved in the safety of geological disposal and the need to ensure sustainability. The first pilot ran in 2017 with 25 participants form EU NRAs and TSOs.
Set up as part of the European Commission's Development and Cooperation Programme, the Instrument for Nuclear Safety Cooperation (INSC) is a major EU contribution to the improvement of nuclear safety levels as well as efficient and effective nuclear safeguards in non-EU countries. The INSC includes a Training & Tutoring (T&T) initiative meant to provide capacity building in nuclear safety, security and radiation protection through a wide range of disciplines that require highly professional expertise. Since 2012, ENSTTI has implemented a large portion of this T&T project, also providing input for its development and coverage.
Since 2010, ENSTTI has served as a training and tutoring center for the IAEA Technical Cooperation Programme. It has also collaborated with the Department of Nuclear Safety and Security to propose practical responses to IAEA Member States training needs in nuclear, radiation, transport, and waste safety and nuclear

security. More recently, the recognition of the importance of leadership for safety has led IAEA to develop formal safety requirements, which are now implemented in its member states. This evolution brought about the need to develop training for both beginning and middle career managers with nuclear safety responsibilities. In 2016/17 IAEA and the European Commission have developed a cooperative framework to jointly address this major challenge. Their cooperation has led to the co-funded development of a “pilot school” for safety leadership, which was held at the University Côte d’Azur (Nice, France) in October 2017 with the technical support of ENSTTI.

4. EXPERIENCE FEEDBACK

Participants feedback on ENSTTI training and tutoring activities has always been very positive. The high practical expertise of the trainers is the main strength of the Institute. The face-to-face dialogue with the expert is what the future experts are looking for in following ENSTTI training. Most of the training and tutoring standards and forms used by ENSTTI seem appropriate to transfer competences to assessors and inspectors in nuclear and radiation safety.

In the European Union, one important aspect for knowledge creation and competence building is to integrate the requirements of borderless mobility. The ENSTTI initiative has proven to be one of the important elements in harmonisation of competences in safety assessment.

Maintaining and continuously improving the expertise of nuclear safety professionals is a constant challenge that requires an advanced training system and this has a cost. However, financing staff training is an issue for public bodies like Nuclear Regulatory Authorities. Many Safety organisations have no or little infrastructure to train their safety staff and also have limited resources and cannot afford to send their staff to training on a regular basis. Several projects developed and implemented by ENSTTI allowed training and tutoring participants to be funded to attend ENSTTI activities. Overall, less than 10% of the experts trained were directly funded by their own organisations.

5. CONCLUSIONS

After height years of existence, ENSTTI has met the objective of setting up a high-quality training mechanism to tackle the training needs of experts at NRAs and TSOs. This mechanism is however extremely dependant from international programmes and projects for funding the development and the implementation of training and tutoring curricula.

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MAINTAINING CAPABILITIES OF TECHNICAL SUPPORT ORGANIZATIONS IN A DYNAMIC ENVIRONMENT: *perspectives of the U.S. nuclear regulatory commission*

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Abstract

As the technical support organization for the U.S. Nuclear Regulatory Commission (NRC), the Office of Nuclear Regulatory Research (RES) supports the agency's safety and security objectives. RES focuses on performing the right research at the right time, and for the right investment, within a dynamic period for the U.S. commercial nuclear industry. While some plants are pursuing subsequent license renewal for operation of up to 80 years, a number of closures are also anticipated within the next five years. Further, there is high variability in the potential timing and extent of new construction for light-water reactors (LWR) and small-modular reactors, and the development of mature, advanced non-LWR designs. Emerging technologies, such as advanced manufacturing and accident-tolerant fuel are under consideration as well. In this changing environment, RES remains committed to carry out its statutory mission in accordance with the Principles of Good Regulation. RES is taking a strategic and multi-faceted approach to ensure a continuity of staff knowledge in critical technical disciplines and to maintain needed laboratory research facilities and other external research supports. The paper will provide an overview of some initiatives being undertaken by RES, to include strategic workforce planning, research project prioritization, engagement with industry and other domestic government agencies, and international cooperative research.

1. INTRODUCTION

IAEA-TECDOC-1835, "Technical and Scientific Support Organizations Providing Support to Regulatory Functions," describes technical support organizations (TSOs) as entities that provide technical and scientific support to regulatory bodies in matters related to safety. TSOs can be incorporated internal or external to the legally competent regulatory body [1]. The U.S. Nuclear Regulatory Commission (NRC) is structured such that the TSO is an organizational unit within the agency called the Office of Nuclear Regulatory Research (RES). The formation of RES was mandated by Congressional statute in the Energy Reorganization Act of 1974 and codified in Title 10 of the Code of Federal Regulations, Part 1, "Statement of Organization and General Information." Further details about the structure of RES can be found in the NRC paper from the 2014 IAEA TSO Symposium.

To concisely encapsulate the RES function, the Office adheres to a mission statement that is in close accordance with the description for the roles of TSOs in IAEA-TECDOC-1835. The mission of RES is to:

> "...provide technical advice, tools, and information for meeting the NRC's mission, including resolving safety and security issues, making regulatory decisions, and promulgating regulations and guidance."

RES undertakes this mission in line with the NRC's Principles of Good Regulation, which are a key aspect of the organizational culture. The Principles of Good Regulation were authored by then-NRC Commissioner Kenneth Rogers in 1991 [2]. In a memorandum to NRC staff, Commissioner Rogers described good regulation as that which:

"…identifies the conditions necessary to ensure safety and creates an environment which insists on compliance with established standards while allowing and encouraging licensees to take the lead in maintain excellence and to exercise initiative in identify and solving potential as well as actual problems."

The Principles set forth by Commissioner Rogers are:

- Independence – making unbiased assessments based on all available information
- Openness – conducting business publically and candidly
- Efficiency – making decisions in a timely and resource-conscious manner
- Clarity – making regulations that are coherent, logical, and practical
- Reliability – ensuring regulatory actions are promptly, fairly, and decisively administered

The Principles of Good Regulation inspire RES staff to focus on delivering high-quality, sound technical guidance to NRC regulatory offices, to be diligent in sharing research findings with members of the public and other stakeholders, and to be responsible stewards of agency resources.

RES provides technical support to NRC for the full scope of the agency's regulatory responsibility, including power reactors, research and test reactors, fuel cycle facilities, waste storage, medical isotopes, radioactive sources, decommissioning, and site remediation. Greater than 80 percent of the Office work, however, is related to power reactors, both for operating plants and new reactor design and construction. This strong dependence means that the RES workload is directly affected by the dynamics of the U.S. commercial power reactor fleet.

Most commercial power reactor units in the U.S., all of which are light water reactors (LWRs), began operation between the 1970s and 1990s. The units are required to renew their operating license after 40 years, then every 20 years for subsequent license renewal. To date, NRC has issued renewed licenses for 90 reactor units and recently received the first application for a second license renewal. Since 2010, however, six reactor units have closed, and licensees have announced plans to cease operation at approximately 10 additional units within the next 10 years, including some for which a license renewal has already been granted. Only two new AP-1000 units are currently under construction in the U.S. Licensees have indicated that continued commercial viability of LWRs will depend, in part, on technological upgrades, notably the replacement of analog systems with digital instrumentation and controls (DI&C) and the adoption of advanced technology fuel (ATF). Finally, the development and deployment of small modular reactors (SMRs) and advanced non-light water reactors (ANLWRs) is a strategic objective of industry and the U.S. Department of Energy (DOE), but technological and economic considerations contribute to significant uncertainties in the timing and scope of this enterprise.

In general terms, NRC is anticipating the potential for a steadily contracting commercial nuclear power sector in the U.S over the next decade or more, and a correlated decrease in agency staffing and funding. This trend will affect RES in proportion to its utilization of agency resources. In light of such a scenario and the challenges it presents, it remains incumbent upon RES to continue executing its mission in accordance with the Principles of Good Regulation. Key objectives of RES are to: (1) maintain the technical expertise to conduct confirmatory and anticipatory research to support safety and security outcomes, (2) leverage RES resources by engaging in effective partnerships with external collaborators, (3) keep abreast of new developments and innovation in nuclear technologies, and (4) allocate resources to optimize cost, value, and agility. RES is undertaking a number of initiatives to meet these goals, which are described in the following section.

2. STRATEGIC INITIATIVES

2.1 Strategic Workforce Planning

RES is participating in the pilot for an NRC-wide initiative referred to as Strategic Workforce Planning (SWP), the objective of which is to ensure that the organization has the right number of staff with the right skills in the right positions at the right time. SWP is a multi-stage process that considers such factors as anticipated future workload, staff competencies, and demographic trends to align the workforce with the mission demand.

The first stage of SWP is to develop an environmental scan that forecasts key business drivers (e.g., plant relicensing, closures, new technologies). This information is then used to develop near-term (~1 year) and long-term (~5 year) workload forecasts. The forecasts recognize the uncertainties inherent in such projections but provide a baseline from which future adjustments can be made. As referenced previously, RES considers the most likely scenario to be a decreasing workload as plants close and not offset by an equivalent amount of new reactor licensing and construction activity. Therefore, RES anticipates the need for fewer staff within 5 years than currently employed.

The next stage of SWP identifies critical skills and the number of staff needed in core positions to successfully execute the organizational mission for the anticipated workload. RES refers to critical skills as “core competencies,” and these represent unique technical disciplines or work functions. In SWP pilot process, RES determined the following core positions:

- Materials Engineer
- Instrumentation and Controls Engineer
- Electrical Engineer
- Seismologist
- Structural Engineer
- Geotechnical Engineer
- Program Manager
- Reactor Systems Engineer
- Fire Protection Engineer
- Health Physicist
- Human Factors Analyst
- Reliability and Risk Engineer
- Program Analyst
- Management Analyst

The analysis also considers that the appropriate skill level mix for staff within a core competency should vary from subject matter experts to junior staff. This facilitates continuity of research program management and knowledge transfer. Further, it recognizes that the skill level of staff assigned to a project should depend, in part, on its technical complexity.

The final stage of SWP analyzes the supply of staff anticipated to be in the organization within the future planning window to determine the correlation with the potential future core position needs. This assessment can consider factors including demographic trends, staff hiring, and attrition. By this process, RES will recognize if there are critical skills and core positions for which it appears that there will be a deficient or excess supply of staff for the anticipated workload. This will provide input into a workforce development plan that can strategically address hiring, training, and other approaches to balance the workforce supply and demand.

2.2 Research Prioritization

RES is also implementing approaches to better align resource allocations with workload priorities. Budget planning and execution for RES is a multi-year process wherein a number of stakeholders provide direction or input. These include regulatory program offices, the NRC Chief Financial Officer, NRC Commissioners, and the U.S. Congress. Research workload prioritization is a process that weighs various factors to identify those programs that are most important to meeting the NRC’s safety and security mission. The prioritization can be used as an internal planning tool and also used for outreach to external stakeholders

Workload prioritization first assesses what can be referred to as mission impact. This includes a consideration of the safety and security risk significance of the technical issue, the extent of associated uncertainty, and the degree to which the issue is generically applicable to the reactor fleet. Risk can be characterized in term of the correlation between a technical issue and, in the case of work relating to operating reactors, the probability or consequences of an accident scenario. For the purposes of this exercise, the mission impact priority ratings are based on RES staff judgment rather than a formal risk assessment. Intuitively, greater prioritization is given to research activities with higher risk significance, uncertainty, or broad applicability.

Workload prioritization then evaluates the demand or driver for research activities. Certain work is given the highest demand rating because it is required by law, Commission policy, or in response to Congressional oversight. This includes, for example, the RES program for evaluating generic safety issues and the Accident

Sequence Precursor program. Still important to the NRC mission but given a lower demand rating, is work related to requests from NRC program offices to support licensing and inspection functions. This constitutes the large majority of the work in RES, and are governed by what are referred to internally as Research Assistance Requests (RARs) or User Need Requests (UNRs). The RARs and UNRs address a specific technical issue and define the scope of support and expected level of effort that RES could provide. Finally, the lowest demand rating is given to anticipatory research or technical feasibility studies that are not directly related to an imminent regulatory need. Staff skill development is also considered in the workload demand assessment, where higher demand ratings may be given to projects that are needed to enhance or maintain staff competencies in particular disciplines.

Lastly, workload prioritization assesses the anticipated resource needs and timeframe required to complete the research activity. Higher priority is generally given to projects with lower resource demands, those near to completion, or those for which NRC is contributing in a multi-party funding arrangement.

In the prioritization scheme, each research activity is given a numerical rating for the factors described above that, when combined, results in an overall prioritization score. In this manner, the full range of office research activities can be sorted and ranked according to a standardized prioritization metric. The prioritization ranking is not used to rigorously add and shed research activities, such as to terminate research activities below a certain priority score, but rather to provide a quantitative measure that can be used to better inform staff and management decision-making.

2.3 Research Partnerships

Maintaining the vitality of research programs when NRC resources are limited requires a systematic approach for engaging and cooperating with external partners. Resources of multiple parties can be leveraged to undertake research activities that would be beyond the capabilities of any one individually. Domestically, RES has put in place formal agreements with the Electric Power Research Institute (EPRI) and DOE to specify the terms of such arrangements. The agreements are referred to as Memoranda of Understanding (MOU). The MOUs outline the scope of responsibilities for the respective parties and give legal provisions for the sharing of data and use of research products. It is critical to note that while the MOU permits cooperation to generate research data, the development of joint conclusions and regulatory analyses is expressly prohibited to avoid the potential for a conflict of interest between NRC and entities working on behalf of licensees. Moreover, the MOUs are time-limited to provide the opportunity for periodic review and to ensure that the needs of the respective organizations continue to be met as the research progresses. Examples of technical issues for which there are MOUs between NRC and EPRI include non-destructive examination, electrical cable aging [3], probabilistic risk assessment [4], and human factors [5]. MOUs between NRC and DOE address long-term reactor operation [6], sharing of computer codes, and ATF. Though at this time not officially governed by a MOU, a key area of cooperation between NRC, EPRI, and DOE is also ANLWRs. A number of technological concepts are under consideration for design and eventual licensing by commercial entities, including molten salt reactors, high temperature gas reactors, pebble bed reactors, and fast reactors. RES may coordinate with EPRI and DOE on computer safety code development and materials performance assessments, among other topics.

In addition to forming domestic research partnerships, RES also engages broadly with the international research community. NRC staff are directed by the Commission to develop an international strategy which reflects the agency's role as a world leader in nuclear safety and security regulation. An element of the strategy is to leverage technical exchanges through cooperation and assistance. Through the exchanges, NRC gains valuable information to use as a benchmark for the agency's domestic activities. By fostering new relationships, NRC is able to positively influence new entrant countries in their development of a sound, independent nuclear safety and security infrastructure that mirrors key tenets of the NRC's infrastructure.

RES participates in a large number of bilateral and multilateral research agreements. Bilateral agreements, for example, include cooperation with the Japan Nuclear Energy Safety Organization on materials degradation research, the Institut de Radioprotection et de Surete Nucleaire (IRSN) on accident analyses, and the Federal lnstitute for Materials Research and Testing of Germany on spent fuel cask structural analyses. Examples of multilateral arrangements include the RES nuclear safety code sharing groups: Code Application and Maintenance Program (CAMP), Cooperative Severe Accident Research Program (CSARP), and Radiation Protection Code Analysis and Maintenance Program (RAMP). CAMP involves thermal-hydraulics and neutronics codes such as TRAC RELAP Advanced Computational Engine (TRACE) and Perdue Advance

Reactor Core Simulator (PARCS). CSARP addresses severe accident progression and consequence analysis through MELCOR and MELCOR Accident Consequence Code System (MACCS). RAMP covers radiological dose assessment and emergency response with, among other codes, RASCAL and RADTRAN. Through these arrangements, NRC and partners benefit from a larger user base to resolve problems and enhance the codes. Other examples of multilateral international research collaborations include the Program to Assess the Reliability of Advanced Non-Destructive Examination Techniques (PARENT), the IMPACT program to evaluate impact loading on nuclear structures, and human factors research through the Nuclear Energy Agency (NEA) Working Group on Human and Organizational Factors (WGHOF).

2.4 Sustaining Experimental Facilities

Finally, RES recognizes that maintaining technical support capabilities into the future requires the maintenance of critical experimental facilities for nuclear safety research. Of particular interest are facilities in which a substantial financial and time investment has been made and those with capabilities that would be difficult to replicate elsewhere. These include, for instance, test reactors, facilities that simulate the thermal-hydraulics of reactor coolant systems for LWRs, and those that permit for accident testing. RES does not, itself, manage experimental facilities. Most such facilities in the U.S. are at DOE national laboratories and universities, and may be utilized by NRC under a contractual agreement. Internationally, NRC has participated in projects involving experimental facilities at the Halden Reactor Project (HRP), the Advanced Thermal-Hydraulic Test Loop for Accident Simulation (ATLAS), and CABRI, among others.

Uncertainties in continued funding to sustain and enhance the capabilities of the facilities represents a systematic risk to the RES mission. The closure of HRP in 2018 may substantially affect the progress of jointly funded projects on testing of irradiated materials and ATF. Initial efforts by NRC, DOE, EPRI, and other stakeholders are underway to bring an orderly closure to projects at HRP, as well as to consider the programmatic impacts and alternative testing approaches, for instance using the Advanced Test Reactor at Idaho National Laboratory or the BR2 reactor in Belgium. The impending closure of HRP highlights the need to be proactively engaged in initiatives to assess research facility availability and to identify actions that might be taken to ensure their continuity. One such effort is the Nuclear Energy Agency Senior Expert Group on Safety Research – Capabilities and Facilities (SESAR/CAF), which met in November 2017. The past success of HRP was due, in large part, to the collaborative nature of the research programs and multi-party funding agreements. These are likely to be key tools for sustaining other research facilities.

3. CASE STUDY

To illustrate the strategic principles outlined in Section 2 of the paper, a case study is presented here using the example of materials performance research. This is the technical area that concerns mechanically and environmentally induced degradation that could lead to the failure of components in reactors or other licensed facilities.

3.1 Strategic Workforce Planning for Materials Degradation Research

Strategic workforce planning for materials performance research involved the identification of core competencies and critical skills needed to achieve the RES mission. From the list in Section 2.1, Materials Engineer is the only core competency related to materials performance research. It was recognized, however, that materials engineering is a broad discipline such that all of the staff whose job title is Materials Engineer do not have the skill set to do the full scope of work in this area. To ensure the maintenance of capabilities, a further level of refinement is needed. Therefore, for this core competency, three sub-competencies were defined: (1) non-destructive examination (NDE), (2) metallurgy, and (3) component integrity. Staff with the NDE sub-competency have knowledge of NDE technologies and methodologies used by licensees for in-service inspections. Staff with the metallurgy sub-competency have knowledge of component fabrication, welding, mechanical performance of materials, corrosion, and irradiation-assisted degradation. Staff with the component integrity sub-competency have knowledge of fracture mechanics, stress analyses, and finite element modelling. For each of the sub-competencies, job descriptions were developed to specify the knowledge, skills, and abilities needed for a staff member. The job descriptions reflected greater expectations for more senior staff relative to junior staff.

For each of the sub-competencies, workload forecasts were performed to anticipate the staffing needs in one year and five years, respectively, from the present date. The workload forecasts were largely based on the current understanding of industry trends and the need for support to licensing offices. The general expectation within each of the sub-competencies is for a lower workload in five years than at present because of a number of plant closures, but with uncertainty in the degree to which this will be offset by work on ANLWRs. For staff presently in RES, an attrition risk profile was made based on the time until retirement eligibility. This provides a reference for the number of staff who may be in the organization within the one- and five-year planning windows, and this was then compared to the projected staffing need based on the workload forecast. A preliminary assessment of this comparison indicates that staffing reductions associated with a decreased workload will largely be met by retirements and resignations There are sufficient numbers of staff currently in RES or other NRC offices to meet the anticipated staffing needs within one and five years. In some cases, however, focused professional development and cross-training may be appropriate to enhance staff skills. Little to no hiring of new staff by NRC should be required.

3.2 Prioritization for Materials Degradation Research

For the prioritization initiative, research within the materials performance area was broken down into approximately 30 distinct work activities that could be individually ranked according to the prioritization criteria. Example activities include the assessment of reactor pressure vessel (RPV) embrittlement, development of probabilistic fracture mechanics (PFM) computer codes, assessment of NDE reliability, testing for the irradiation-induced degradation of reactor internals, and steam generator tube integrity assessments. Each activity was first rated in accordance with its mission impact, which generally correlates with its risk significance and generic fleet applicability. Materials performance activities that rated highly according to these criteria included those relating to RPV and internals integrity.

The activities were then rated for their demand. As mentioned in Section 2.2, highest demand ratings are given to activities mandated by law, policy, or Commission direction. There are no materials performance activities that fall within this category. A medium priority is given to technical research requested by licensing offices to support their regulatory functions. This constitutes the large majority of materials performance research. The demand rating also considers research activities that support the maintenance of core capabilities and staff skill development. This is the primary distinguishing factor for the demand rating of materials performance research. Activities that received high demand ratings include the assessment of NDE reliability, PFM code development, and primary water stress corrosion cracking testing (PWSCC).

3.3 Partnerships for Materials Degradation Research

RES has a robust program for collaborative partnerships with domestic and international organizations. As discussed in Section 2.3, most domestic collaborations are organized through MOUs with EPRI and DOE. These can involve joint funding of mutually beneficial research projects or the sharing of data from otherwise independent projects. For the materials performance research area, Table 1 lists the active MOUs between RES and EPRI. RES has one materials performance MOU with DOE entitled “Cooperative Nuclear Safety Research Related to Long-Term Operations,” which is similar to the EPRI MOU on long term operations.

TABLE 1. MOUs BETWEEN RES AND EPRI FOR MATERIALS PERFORMANCE RESEARCH

MOU Title	Scope
Acquisition and Testing of Zion Spent Fuel Pool Neutron Absorber Materials	In-pool surveillance, harvesting, shipping, and laboratory testing of Boral panels from the Zion power plant
Extremely Low Probability of Rupture	Joint development of a PFM computer code for plant piping integrity analyses
Long Term Operations Beyond 60 Years	General coordination and information sharing on aging-related degradation of reactor materials beyond a plant life of 60 years
Nondestructive Examination	Coordination on research activities related to NDE methods, procedures, equipment, and personnel
Primary Water Stress Corrosion Cracking – Crack Initiation	Joint funding of PWSCC initiation tests for nickel-based alloys
Primary Water Stress Corrosion Cracking Expert Panel Activities	Participation in an expert panel to evaluate the international database of crack growth rate date for nickel-based alloys

Steam Generator Tube Base Research Program	Participation in the International Steam Generator Tube Integrity Program (ISG TIP)

International partnerships are, in many respects, analogous to the partnerships with EPRI and DOE, but governed by what are referred to as International Agreements or Implementing Agreements rather than MOUs. For the materials performance research area, Table 2 lists some of the International Agreements.

TABLE 2. RES INTERNATIONAL AGREEMENTS FOR MATERIALS PERFORMANCE RESEARCH

Subject Area	International Partnerships
NDE	PARENT, IRSN
PFM	Probabilistic Analysis as a Regulatory Tool for Risk-Informed Decision Guidance (PARTRIDGE), Japan Atomic Energy Agency (JAEA)
Operational experience	Component Operation Experience, Degradation, and Aging Program (CODAP)
Steam generator tube integrity	ISG TIP-5
Irradiated materials testing	HRP
Materials aging	International Forum for Reactor Aging Management (IFRAM), Nuclear Energy Agency Working Group on Integrity and Ageing of Components and Structures (WGIAGE)

3.4 Sustaining Experimental Facilities for Materials Degradation Research

RES makes regular use of experimental facilities for materials performance research. Domestically, these are largely performed at national laboratories managed by DOE, including for NDE capability assessments, PWSCC testing, steam generator tube integrity testing, neutron absorbing material testing, and irradiated materials testing. With the exception of the neutron absorbing material testing, which is a new and relatively small effort, the associated experimental facilities have been built up over more than ten years and at a cost to RES of multiple million dollars. As such, they are a valuable asset to RES and not readily reproducible. RES is cognizant of the need for sustaining certain capabilities in these areas, but the facilities are not substantially unique. There exist other domestic and international facilities that can be used to similar purposes.

The materials performance research program with greatest risk in the loss of experimental facilities is, as discussed in Section 2.4, the irradiated materials testing program. The impending closure of HRP is likely to have a substantial impact on this program. HRP is used to irradiate materials to simulate the fluence of reactor internals components, particularly looking at plant life up to 80 years. Materials in test at HRP included those harvested from the closed José Cabrera (Zorita) Nuclear Power Station in Spain. The benefit of HRP to RES was not only the uniqueness of the experimental facility, but the cooperative nature of funding arrangements, recognizing the substantial costs associated with irradiated materials testing. In looking forward to potential research for ANLWRs, RES recognizes that there may be limited facilities for testing of materials in simulated operating conditions and will look for strategic approaches to mitigate this risk.

4. CONCLUSION

In summary, while RES anticipates the possibility of changes within the U.S. commercial nuclear industry that could affect its workload over the next several years, the organization remains committed to executing its mission in accordance with the Principals of Good Regulation. The capability of proving expert support on complex technical issues to regulatory program offices should not be compromised. To that end, RES is strategically analyzing its workforce, its workload, and external research supports to prepare for a range of scenarios that could include a contracting fleet of large LWRs, a growing portfolio of SMRs and ANLWRs, and the adoption of new technologies such as ATF. Adaptability and agility are key organizational attributes that will allow RES to successfully navigate this dynamic period. The initiatives described in this paper are intended to be continual processes, where new information and lessons learned are regularly applied to refine and improve subsequent efforts. Further, RES hopes that these will provide useful insights to TSOs in established and embarking countries, as they may approach similar challenges.

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TOPICAL SESSION 6

HOW TO BUILD YOUR TECHNICAL AND SCIENTIFIC CAPABILITY

Chairperson
M. MKHOSI
South Africa

Co-chairperson
M. BETTI
European Commission

The sixth session highlighted the capacity of national TSO as a powerful tool which can consolidate the medium and long-term sustainability of effective regulatory control, particularly in countries where new-build programmes have benefited from extensive technical support from foreign expertise. The IAEA TSO Initiative was also presented, including the different tools that are currently being developed to support Member States in the design of a national TSO development strategy. It was stressed that a national TSO capacity building strategy should be adapted to the institutional landscape of the country while taking into account a realistic evaluation of needs in terms of priorities and time frames. The necessity to include an open approach to the communication needed to link together stakeholders with different cultures (e.g. mission, language, work practice) was noted. These stakeholders include suppliers, the regulator, academia, TSOs, etc. The importance of the best use of available possibilities for international cooperation was also highlighted, including through the IAEA, in order to optimize their TSO development decisions in terms of organization, funding system, technical and scientific priorities, staffing and training methods. IAEA Member States were encouraged to make the best use of the IAEA TSO Initiative to help design their national strategy for TSO capacity building, and to contribute to the ongoing activities of the TSO Forum.

DEVELOPING TSO CAPABILITIES: SPECIFIC CHALLENGES FOR EMBARKING COUNTRIES

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Abstract

The role of TSO structures as an integral component of the national regulatory infrastructure for nuclear safety, security, and radiation protection has been on the agenda of international discussions in the context of IAEA for over a decade. It is today commonly understood that a TSO capability is an essential instrument to successfully implement over time the science-based nature of nuclear safety, in a proactive manner in the context of ever evolving technologies, environmental and economic conditions, as well as societal expectations for protection. However, there is no “one size fits all” model for a TSO national construct. Indeed, the attributions and missions, resources, and governance of TSO’s differ widely from one country to another. Moreover, there is little publicly available information about the historic processes that led to the current TSO systems as they can be seen to operate today in mature nuclear countries. The paper recalls how nuclear safety in the context of a country equipped with nuclear power plants is a long-Term challenge that requires specific policies to ensure sustainability. It further explains how, in the case of embarking countries in particular, the development of a national TSO capability may help contribute to ensuring this necessary sustainability and can therefore form part of a pertinent national strategy. It draws attention on the usefulness of international cooperation in this field.

1. INTRODUCTION

In the early 2000s, the deepening cooperation between European TSO’s led to the creation of ETSON, as an association of national TSO’s where common issues and challenges could be effectively addressed. Although the members of ETSON were very different from one another, in size, missions, status, governance and funding schemes, their network was successfully founded on common values, and on a largely shared scientific corpus of knowledge, developed through long term research cooperation programs, either bilateral or international, particularly in the frame of OECD/NEA.

Although the acronym “TSO” was then not often used outside Europe in the context of regulatory organisations, it seemed logical that the European experience should be brought to the attention of the international community, in the framework of IAEA. This was in particular justified by the rapid expansion of the number of “embarking” IAEA member states. Thus, a first IAEA TSO conference took place in 2006, which for the first time brought into light the specific challenges related to the development and operation of the scientific and technical support that, often behind the scenes, were essential for a good and sustainable performance of nuclear safety authorities. The two following TSO Conferences confirmed that international cooperation in this field was fully justified and would be particularly helpful for embarking countries. This effort led to the recent publication of IAEA-TECDOC-1835.

Recognising that there is no “one size fits all” solution to technical support issues, this TECDOC does not provide any reference solution, or even a reference “recipe” to build a national TSO capability. It does however explicit the values and necessary foundations that should preside to the setting up of a national TSO and offers ample documentation on existing experience gathered in IAEA member states in this field.

2. NUCLEAR SAFETY: A LONG-TERM CHALLENGE

From an embarking country perspective, nuclear safety is a long-term challenge in more than one way:

- Nuclear power technologies are today designed for a period of operation of at least 60 years. Adding a decade for the plant construction, and another few decades for the decommissioning and deconstruction phases, the nuclear safety supervision challenge is set for well above a full century.

- Furthermore, the nature of the tasks to be performed will undergo substantial changes in that long period of time, requiring adequate anticipation and planning. If these tasks can appear similar from a legal or administrative point of view, the technical competences and knowledge required differ from one phase to the next and need advance planning.

- The regulatory oversight of the same plant will be passed on from one generation to another across the decades. This poses specific problems in terms of knowledge management in particular. Beyond this issue of continuity, there is also one of managing change: during such a long period, societal concerns and expectations can be expected to evolve, and the national economy will have ups and downs and major technological evolutions are to be expected, which can impact safety.

Of course, the prime responsibility in managing the technical and scientific information required by such evolutions rests with the licensee. However, the regulatory body can hardly let itself outflanked by inevitable change. It therefore needs to plan for its own sustainability, not only in legislative terms of national institutional governance and funding mechanisms but also on scientific and technical issues. To achieve this requires a holistic approach to sustainability issues, considering how the regulatory body, whilst maintaining independence, can be rooted to the national scientific community in order to retain and maintain the necessary knowledge basis for its own operations.

3. THE IMPORTANCE OF AN INCLUSIVE LINKAGE OF SCIENCE-BASED NUCLEAR SAFETY REGULATORY ACTIVITIES

Nuclear safety is primarily a science-based function, nourished by experience feed-back and current scientific knowledge. Its control by competent authorities is in essence exercised by operating a "link" between administrative / technical provisions provided by national legislation and the scientific analysis of the licensee' safety files, in order to evaluate risks and the possible need for additional measures in order to consolidate defence-in-depth of the considered nuclear facility. The capability to operate this link effectively is therefore dependant on the processes through which the regulatory body ensures it has appropriate access to expertise commensurate with that of the licensee (or technology vendor), and sufficiently independent from it.

In order to provide an adequate degree of independence, the expertise which the regulator relies upon should itself be generated and maintained in the direct environment of the regulatory body, within itself or through institutions sharing its values and objectives. The key supporting functions to consider for this purpose are the training, education and knowledge management, research, and international cooperation. If they are managed with a holistic and strategic approach, through mechanisms linking the different types of regulatory related activities, permanent improvement and natural adaptation of expertise to changing environments will result, thus enabling the long-term sustainability of the regulatory organisation.

However, it is important to note that such « linkage » of activities does not occur successfully unless it is planned, organised and resourced, and imbedded in relevant national cultures. One main reason for this is thatthese activities (administration of nuclear safety, operational expertise for safety analysis, education and training, research and development), although closely related and in part interdependent, belong to separate cultural environments: *public affairs culture* for regulatory administration of licensees and protection of the public, *engineering culture* for safety experts, and *academic culture* for education and research. These three cultural backgrounds cannot be ignored or merged, but if appropriate strategies provide effective pathways or "links" between the respective activities where they are naturally present, then the regulatory body will not only be able to access the resources it needs, but these resources will learn and respect the values of nuclear safety, and build up the capacity for independence of judgment.

It is clear that all such activities can never be completely integrated within the regulatory body itself, and will depend on universities, research centres, as well as partner institutions outside the country. This is the reason why the acronym "TSO" has been used in this context: more than a specific form of organisation, it describes the capability of the regulatory body to reach out and effectively control external resources which complement its internal capacity, in accordance with its key values, whilst and respecting the specific cultural background of such external resource., In well-established nuclear countries, current support resources result from long evolutions t which gradually shaped the external resources into a "TSO" function. In embarking countries however, the question arises of how to conduct successfully such a process over a shorter period.

4. INTERNATIONAL COOPERATION AS A STIMULUS TO OVERCOME INHERENT DIFFICULTIES IN ESTABLISHING A NATIONAL TSO CAPABILITY

International cooperation is an essential instrument for all countries without exception, for the simple and major reason that no country is host on its own to the whole knowledge pertinent to conduct national advanced nuclear safety policies. Another key remark is that in the long term, such cooperation can only remain effective and cost-efficient if there is sufficient mutual benefit for all parties concerned. One of the approaches to uphold this condition is to have a regional or international approach, such as that provided by the IAEA, which can reduce the participating threshold, and also provide common language and practice to newcomers.

During the initial phases of an embarking country's nuclear energy programme, an often-unavoidable option is to rely on the vendor country to provide the required scientific and technical support. However, experience shows that progressively, over the years, this approach can limit the national learning curve, if it remains chiefly run as a "procurement process". The costs of such foreign external provision of services can become burdensome, all the more as the nuclear program progressively develops. In a similar way, the choice to

train national experts abroad is an endless process, sometimes frustrating as the overall learning curve through collective knowledge management may remain low due to the cultural distance between the overseas training institutions and the national background of other employees.
If the provision of foreign expertise can be a good practice for key issues of safety file analysis for new installations, for practical and budgetary reasons this can often not be reproduced for a continuous process of safety surveillance. But even if it were, there is another major issue to consider: the gradual development of a potentially damaging gap, within the ranks of the safety authority, between those having access to recognised foreign expertise for training or analysis services, and those having to refer to limited national competencies for their missions, noting that "strength in depth" requires excellence at all levels and that a shared safety culture based on the collective spirit of the institution is a key to its success and the trust society places in it.

Cooperation should then be sought not only as a source of procurement as an "intelligent customer", but as a strategy towards long term building up of a national expertise resource. After an initial stage where the procurement approach may be inevitable a more inclusive cooperation strategy should be defined with the goal to progressively ensure that relations with vendor and other countries contribute to the development of national self-sufficiency in scientific and technical support. This can be obtained, with the ongoing support of periodic evaluations using the tools provided by IAEA, by gradually reorienting the cooperation with the vendor country in order to link together its often separate functions: training of experts, provision of safety analysis, provision of safety analysis software and other tools such as laboratory or emergency management capability, in order to approach these services from abroad not just as a consumer, but as an investor using them to help build his own technical capability. This requires to implement a second direction: to initiate, on the basis of what resources are available in the country (university, research or technical center, academies,…) a core group of persons who should be associated to the ongoing cooperation, with the medium term goal to develop a pertinent national scientific and technical support able to take over tasks initially procured abroad. Once initiated, this process will over time have a lasting impact on the collective culture of the group of experts, made up of an in depth understanding of the key values which underpin the missions of nuclear safety supervision, including independence of judgement, even when academic links are maintained with their peers, and remain essential for their career and ongoing scientific development.

5. THE DEVELOPMENT OF A TSO NATIONAL CAPABILITY: A PERTINENT RESPONSE TO CHALLENGES MET BY EMBARKING COUNTRIES, REQUIRING A NATIONAL STRATEGY

In order to achieve its sustainability, as the national nuclear power program unfolds, the safety authority should develop a strategy in order to ensure its access to three key resources: professional technical training for its officers and inspectors; scientific and technical expertise to match the licensee's own expertise in analysing the most sensitive aspects of the safety files provided; and as much as possible, access to recent knowledge resulting from safety research, often conducted internationally.

Careful consideration of goals and constraints as well as opportunities and inherent risks is an essential step of the strategy's elaboration. In this initial phase, the analysis of experience gained in other countries having faced a similar challenge is an important step, although in the end the solution chosen will need to be well suited to the national scientific culture and general organisation of its public institutions.

In April 2018, a workshop took place at the initiative of IAEA to discuss TSO development issues between experts from a set of embarking countries and from countries with mature nuclear programs and safety related institutions. One of the sessions was dedicated to analysing the TSO development processes in two countries, described in "case study" documentation prepared for this purpose. Both case studies illustrate that success is dependent on a careful prioritization of the missions and tasks expected from the emerging TSO, following a clear strategy at national level.

6. CONCLUSION

The control of nuclear safety and radiation protection is essentially a science-based activity. The long-term sustainability of the institutions in charge of this control therefore depends on their capacity to have access to an infrastructure of competent expertise to perform their duties with the required independence.

Beyond the provision of specialised analysis of key aspects safety files, two other functions are also essential in the long term: the professional training of technical officers and inspectors, and an access to research, key to remain abreast with technology evolutions and scientific developments of importance for nuclear safety These three functions should always be considered together as they are very much complementary in a proficient national TSO capability.

Although technical support needs can initially be provided from abroad, experience shows that the development of a national TSO capability is an effective and in the long run cost-effective approach to consolidate the national safety authority and develop trust in the policies towards nuclear safety.

However, developing a national TSO capability requires following a carefully prepared national strategy, involving the safety authority as well as other institutions which can contribute to creating "an ecosystem" where the maturation of the expertise capacity required will be facilitated by maintaining a mix of cultural backgrounds which allow a successful human development.

Effective planning for such a national TSO development strategy can be facilitated by taking advantage of the assistance made available to its embarking member states by the IAEA, through its publications, its services, and the collective environment dedicated to TSO development issues which the Agency is currently enhancing with the cooperation of its member states.

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TSO FORUM INITIATIVE – SUPPORTING MEMBER STATES IN DEVELOPING THEIR TECHNICAL AND SCIENTIFIC CAPACITY IN SUPPORTING REGULATORY FUNCTIONS

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Abstract

As a follow-up to the TSO Conference deliberations in Beijing, the Steering Committee of TSOF decided in March 2016 to develop an action plan to support member States in developing and strengthening their technical and scientific capacity in nuclear and radiation safety. Consequently, the IAEA under the auspices of the TSO Forum developed the so-called TSO initiative which aims at supporting Member States in developing national strategies related to the development or the strengthening of an effective technical and scientific capacity in support of the regulatory functions. Based on the Technical Document IAEA-TECDOC-1835 published in March 2018 and describing core characteristics and activities of TSOs supporting regulatory functions, the TSO initiative comprises a set of tools including a TSO self-assessment methodology based on a questionnaire and a web-spider, a library of case studies based on the experiences gained by Member States and TSO national workshops to be implemented upon request to address specific needs of Member States. The TSO initiative will be aimed at regulatory bodies and organisations that are part of the TSO "ecosystem" such as universities, labs and support organisations and at the level of relevant organisations involved in the decision making of the national TSO related strategy in Member States embarking nuclear programmes or in already nuclear countries in the process of strengthening their scientific and technical capacity supporting regulatory functions.

1. INTRODUCTION

The scientific and technical capacity support to the regulatory functions was stressed as another key issue for embarking countries. In particular, the International Conference on Challenges Faced by Technical and Scientific Support Organization (TSOs) in Enhancing Nuclear Safety and Security, held in Beijing in October 2014 with 200 participants from 42 Member States, recognized that the Technical and Scientific Support function is a critical component of an effective regulatory system. The conference concluded that Member States should have the possibility to evaluate the capabilities of their national technical and scientific support function through peer review missions, either within the scope and context of the IAEA Integrated Regulatory Review Service (IRRS) Missions or in any other way, to be identified and developed (e.g. dedicated TSO self-assessment missions). The effectiveness of the TSOs was also highlighted by the 8th International Expert Meeting on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant. The need to support the Member States in developing their TSO related strategies and evaluation was also stressed by the IAEA General Conference resolutions, most recently in 2017 in GC(61)/RES/8.1 (e.g. OP 32 and 33). Consequently, a number of activities, within the overall framework of the so-called TSO Initiative, were initiated through the IAEA TSO Forum, including the development of the IAEA-TECDOC-1835 on Technical and Scientific Support Organizations Providing Support to Regulatory Functions TECDOC, the development of case studies and TSO self-assessment methodology.

The IAEA, in cooperation with donor countries and relevant international organisation such as the Joint Research Center of the European Commission (JRC) and the European Technical Safety Organisation Network (ETSON), provides the Secretariat for the TSO Forum, the main platform addressing the technical issues of the TSOs supporting regulatory functions in coordination with other relevant networks such as the RCF.

1. IAEA TECDOC-1835 title
2. TSO self-assessment questionnaire

Under the TSO initiative, the IAEA has developed a self-assessment questionnaire to help determine the effectiveness of TSO capabilities supporting regulatory functions. The questionnaire was developed using the principles of the IRRS and INIR missions and framed in line with questions applicable under SARIS.

It is intended to help performing a self-assessment of TSO capabilities, both for countries developing their regulatory system and or TSO capabilities, and for countries where these are already established. For countries in the process of developing their regulatory system and/or TSO capabilities, the questionnaire is intended to provide a support tool to identify needs, gaps and recommendations for actions, and to help in the development of a national strategy. With respect to countries where the regulatory system is already established, the questionnaire would enable them to identify their strengths and weaknesses, to determine whether their TSO(s) is performing its role and responsibilities effectively, and to identify recommendations for improvements.

2. GENERAL CONSIDERATIONS

According to the purpose of questionnaire, the questions are defined with a view to assessing current or future scientific & technical capabilities of the TSO and their role in the regulatory system:

- What are the existing, planned and/or envisioned scientific & technical capabilities of the TSO(s)?
- How are they planned, developed, managed and sustained?
- How are they or will they be applied in regulatory functions, in particular in assessments?

The questionnaire could be used as a self-assessment tool, or in workshops with Member States developing their TSO capabilities, or in connection with peer review missions such as IRRS.

The structure of the questionnaire follows closely the contents of the document Technical and Scientific Support Organizations Providing Support to Regulatory Functions (IAEA-TECDOC-1835), which provides a comprehensive description of the role and functions of TSOs in the regulatory system. Most questions in the questionnaire thus correspond to a specific section of TECDOC-1835. However, to focus the analysis and facilitate synthetic conclusions, they have been grouped according to 8 key areas covering:

- Technical capabilities supporting regulatory functions:
  - 1. Expertise for Safety Assessment and Inspections (Questions 17 and 19),
  - 2. Support to the Development of Regulation (Question 18),
  - 3. Dose and Environment Assessment and Surveillance (Questions 22 and 23),
  - 4. Assessment of Operational Experience Feedback (Question 24),
  - 5. Emergency Preparedness and Response (Question 21)
- Enabling issues:
  - 6. Institutional Factors, Resources and Management (Questions 1 to 12, 15 and 16),
  - 7. Capacity Building including Human Resources Development (Questions 13 and 14);
  - 8. Research and Development (Question 20), which is both a technical and an enabling function.

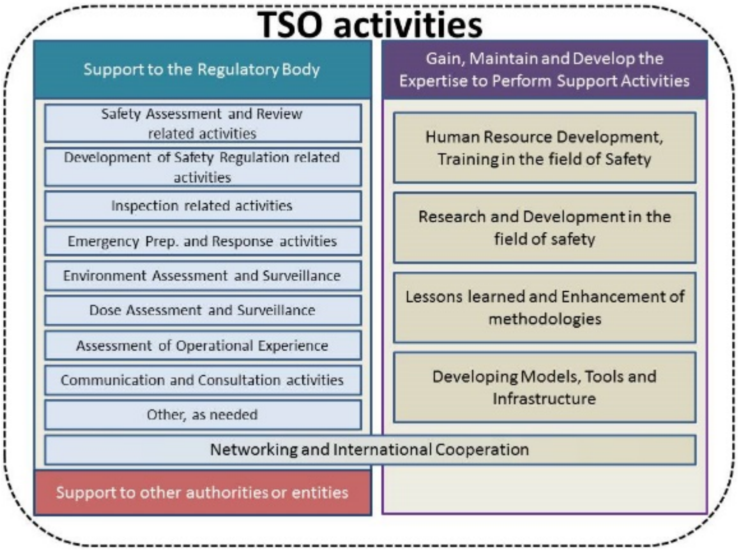
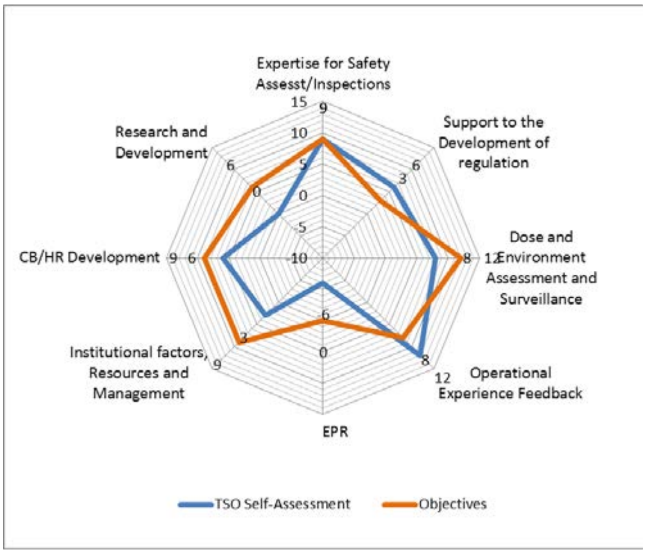


FIG.1 TSO activities

As a support for assessment, the questionnaire is primarily intended to foster analysis and reflection and comprises a limited number of primary questions, which are generally open questions calling for synthetic written answers. However, in order to facilitate presenting results, deriving concrete conclusions and producing proposals for actions, these questions are complemented by a number of focused closed questions to be answered by yes or no (or with a limited range of possible answers).

As a self-assessment tool, the questionnaire is intended to be filled by the TSO or the organization performing TSO functions, whether internal or external to the Regulatory Body. However, in Member States where the TSO is separate from the Regulatory Body, certain questions in the questionnaire could be answered by both. If there are several organizations carrying out TSO functions in the country, operating in a coordinated manner, the designation "TSO" should when necessary be understood as referring to "TSOs" or "the TSO system"; the questionnaire could be answered by the organization coordinating the various TSOs, with contributions from those organizations as appropriate.



In countries that are in the process of developing their nuclear programme, including their TSO functions and capabilities, the questionnaire is intended to address existing capabilities as well as any future capabilities, planned or under consideration.

It should be noted that the questions may be of varying relevance and importance according to the nature of the country's nuclear activities and to the stage of development of its TSO capabilities, e.g. between countries already having nuclear activities along with a well-established regulatory system and TSO capabilities, and those in the process of developing them. Accordingly, it is recommended, when relevant, to refer to the situation and context of the country according to the following typical situations:

- Country without nuclear activities, using only radioelements and radioactive sources (designated as NN)
- Embarking country in Phase 1[13] (N1)
- Embarking country in Phase 2[1] (N2)
- Embarking country in Phase 3[1] (N3)
- Country having nuclear facilities, Nuclear Power Plant and/or Research Reactor (NR)

3. LIBRARY OF CASE-STUDIES

The TSO Initiative includes several actions aimed at sharing feedback on experience and lessons learned, providing tools and support to interested Member States, organizing national and international workshops. It includes in particular the development of a collection of "case studies" allowing to explore and analyse, on the basis of real situations, the process that was followed in the case countries to develop their TSO capacity.

3.1 Objectives of the TSO Case Studies

IAEA TECDOC 1835 clearly illustrates that although key TSO missions and core values can be described in a rather well-defined manner, practical solutions to implement these missions and core values vary a lot from country to country. This is not due to the fact that such a development must by nature reflect the circumstances of each country, not only in its nuclear policy choices, but also in the nature of its scientific and technical institutions from which the TSO expert force will be expected to emerge and develop itself in a sustainable fashion, and in such a way as to ensure the independency of the regulatory process.

Another important aspect is that, over a long period of time (decades), any national TSO structure is likely to evolve significantly, as it matures in the accomplishment of its missions and in its own development, to respond to the national needs for nuclear safety or radiological expertise. Thus, observing a currently very mature TSO structure does not give clues to how it was initiated, and how it gradually grew to that present status.

This is why the TSO initiative has identified the need to help embarking countries in assessing not only the generic types of solutions which are available to perform TSO tasks, but also in anticipating as much as

[13] As defined in "Milestones in the Development of a National Infrastructure for Nuclear Power" (the "Milestones document"), NG-G-3.1 (Rev. 1), 2015.

possible the planning of the processes that are necessary to achieve the successful formation of such scientific and technical capabilities. Again, such process will be essentially country dependant, and no standard roadmap could easily be established in this respect. However, it is proposed to develop a small collection of national Case Studies to provide valuable evidence, on the basis of actual historical experience in a country, on the successive steps that led to the TSO development, and on the hurdles, which had to be overcome. Although each case study describes rather precisely the development process that actually took place in the country concerned, the case study documentation aims to eliminate all references to this particular country, and the specific institutions and people concerned in the country, as the objective is to develop a pedagogic tool to illustrate the important role of the TSO development process, and to identify key steps and success factors which are to be anticipated in a embarking country.

Two countries (PNRA - Pakistan and NNR-CNSS South Africa) kindly volunteered to establish such a pilot case study to share lessons learnt from their experience sin establishing their own TSOs.

AN EFFECTIVE APPROACH TO ASSESSING THE NEEDS AND AVAILABILITIES OF CAPABILITY FOR NUCLEAR SAFETY AT THE CNSC

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Abstract

The Canadian Nuclear Safety Commission (CNSC) has undertaken several initiatives to maintain core capabilities and organizational competencies that are essential to carrying out our important mandate over the long term. One such initiative is to rigorously evaluate our access to required scientific and technical expertise and infrastructure, both internally and externally. A self-assessment method of comprehensively collecting required capability information from CNSC operational staff will be described and the catalogue that was created from the capability information will be explained. Further, the approach used to evaluate CNSC existing and future technical needs, based on a changing environment, will be discussed. Some potential capability needs and remedial steps will be presented.

Complementary to this work, the CNSC is investing effort to identify critical regulatory and technical competencies and articulate development and succession plans as a part of its strategic workforce planning activities. The implementation of our knowledge management strategy will ensure that both tacit and explicit knowledge, particularly at-risk knowledge, is safeguarded, accessible, and shared. The differences and similarities between these initiatives will be discussed as continuous improvements for the organization to maintain a healthy regulatory safety oversight culture.

1. INTRODUCTION

The Canadian Nuclear Safety Commission (CNSC) regulates the use of nuclear energy and materials to protect health, safety, security and the environment; to implement Canada's international commitments on the peaceful use of nuclear energy; and to disseminate objective scientific, technical and regulatory information to the public. While the CNSC is successfully delivering on its mandate, CNSC staff need to be cognizant of the emerging new nuclear technologies, changing external environment, evolving industry and research and development infrastructure, changing regulatory and technical standards and regulatory practices. The CNSC has to continuously evaluate its capability to regulate for safety now and in the foreseeable future. The three-year project, Capability for Nuclear Safety (CfNS), is part of the CNSC Strategic Planning Framework (SPF) and aims to ensure that the CNSC takes the necessary steps to ensure access to required scientific and technical expertise, knowledge and research infrastructure. This project has assessed capabilities of the technical and operational divisions that conduct various activities related to uranium mines and mills; uranium fuel fabrication and processing; nuclear power plants; nuclear substance processing; industrial and medical applications; nuclear research and educational activities; transportation of nuclear substances; nuclear security and safeguards; import and export activities; waste management facilities.

The deliverables of the project include:

- a catalogue of the capabilities required,
- identification of future needs based on emerging or changing technologies or activities, including a prioritization of needs/gaps,
- a strengthened strategy for accessing required capability outside the CNSC and
- a final report summarizing the capability internal and external to the CNSC, identifying any gaps and proposed remedial actions.

2. METHOD OF CAPABILITY ASSESSMENT

Capability is defined as "The sum of the knowledge, expertise and capacity of an organization to achieve its goals" [1]. While "capacity" and "capability" are used interchangeably in some contexts, capacity of an organization is better expressed in terms of resourcing, staffing, or a talent pool. The Capability for Nuclear Safety project is not limited to the capacity of CNSC to fulfill its mandate. An organization may have the capacity to act or change, but lack certain key capabilities. The scope of the CNSC capability assessment was limited to the CNSC needs with respect to technical and scientific expertise, analytical/experimental capability and physical infrastructure required to effectively conduct pre-licensing, licensing and compliance activities including technical assessment required for the CNSC to discharge its mandate. Figure 1 shows a high level schematic of how the capability data collection and subsequent gap analysis is being carried out.

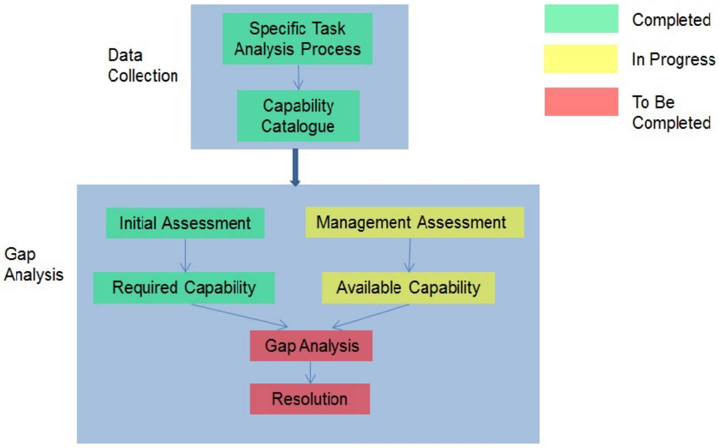

FIG. 1 Method of CNSC Capability Assessment

The project consists of two main stages: data collection followed by data assessment and gap analysis. The data collection method involves the use of a bottom-up task analysis approach to collect required capability information from the divisional leads representing all operational areas of the CNSC. The divisional leads were asked to conduct their task analyses in the context of CNSC core processes, divisional sub-mandates, and then identify the required technical expertise, internal and external tools, codes, standards, and regulatory framework, specialized courses/training, infrastructure (namely, physical facilities or structures), as well as, research, support, external relationships, and future technical needs. All the required divisional capability information was documented in a unique Excel spreadsheet labelled as the divisional capability form. The CfNS project staff consolidated the 36 divisional capability forms and created the capability catalogue.

After collecting the required capability information from the divisions, the next step was to assess the required capabilities and identify any gaps and risks. The initial assessment was carried out by reviewing all the capability forms and capturing the key and unique capabilities in terms of internal and external tools, infrastructure, training, as well as research, support, relationships, technical expertise and future technical needs. Meanwhile, the CfNS project team created an interview guide and has interviewed all directors of participating divisions to obtain management assessment on key capabilities required from their divisions in the future to ensure that proper mitigation strategies are already in place or are developed as required.

From the required key capabilities and the interviews with directors, the goal is to identify any possible gaps or risks in their divisional capabilities and seek the most efficient ways of resolving them. Throughout this project, the capabilities required are identified based on task analysis and the availabilities of required capabilities are examined and assessed through interviews with directors. The capability risks and gaps will be compiled to identify common themes at the directorate level and across the organization. Some gap-closing strategies may be proposed to identify the scope of any required investment in terms of people, time or funding. This project will help CNSC understand our capability and maintain a high level of scientific and technical expertise, knowledge, and research infrastructure required to conduct regulatory activities effectively in the changing environment.

3. CAPABILITY CATALOGUE

As the first step of this project, a standard template was created to identify all required technical capability information to meet the CNSC's mandate. Initially, a pilot project consisting of 10 divisions was assembled and used to establish an optimal capability data collection methodology and finalize a data collection template. This methodology was then rolled out to the remaining divisions. Each division was required to first identify the related core process of the divisional activities; then from each core process, identify the divisional sub-mandate; from the sub-mandate, further break down to the detailed tasks; for each task, identify the corresponding technical areas, required technical expertise, tools, codes and standards, training, infrastructure, internal and external to CNSC, as well as any research, support and relationships. Future technical needs are also captured in the template. One example is, for the task of conducting seismic review, we need experienced seismic specialists, relevant codes, standards and procedures, some training, expert input from the broader government departments (e.g. Geological Survey of Canada) for seismic hazard, as well as support from some environmental specialists.

36 divisions and 8 directorates at CNSC have been tasked to complete the capability information templates and to create the divisional capability forms. Finally, all the capability forms have been consolidated to create the capability catalogue, which is shared with the organization.

4. MANAGEMENT ASSESSMENT

Based on the initial assessment of each divisional capability form, the capability highlights have been captured in a condensed form by focusing on the key capabilities involving technical expertise, tools, infrastructure, training, research & support. Each director is being interviewed to discuss the availability of the required capability and to focus specifically on capability gaps and risks that may arise based on future demands. A fulsome discussion has been conducted with directors about the nature of the gaps and risks, their relative priority and possible mitigation methods. The flow chart that is the foundation of the interview survey is shown as in Figure 2.

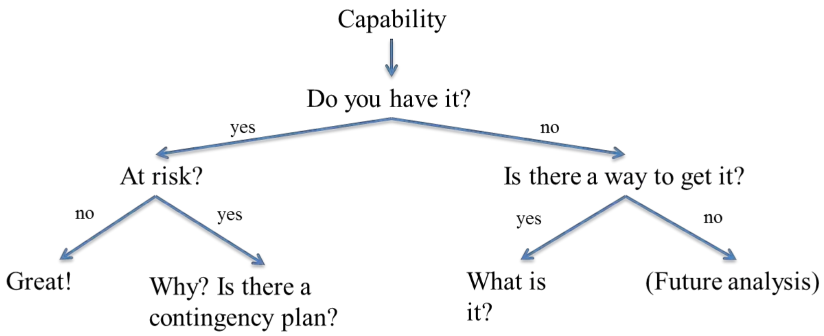

FIG. 2 Flow Chart of the Interview Survey

5. PRELIMINARY CAPABILITY ANALYSIS

As of September 2018, the CfNS project team has completed the required interviews. Some capability risks and gaps have been identified in the following areas: retaining unique technical expertise, development and maintenance of capability associated with small modular reactor technologies, deep geologic repositories, waste characterization, cyber security, etc. Some mitigation strategies have been proposed to address the risks and gaps. The next step is to complete all interviews and compile the interview results to assess the collective gaps that have been identified. While the detailed plans for future project deliverables is subject to broad consultation within the organization, it is envisaged that the gaps identified will be prioritized and an action plan implemented to address the higher priority issues. This future work will be captured in an updated version of the CNSC’s Strategic Planning Framework and associated project plans. Now that the framework for this work has been established it is intended that the capability catalogue and future technical needs will be updated on a periodic basis.

6. INTERACTIONS WITH OTHER INITIATIVES

The CfNS project team is collaborating with other CNSC staff involved in related projects, such as the WorkForce of the Future (WFOF) and Knowledge Management (KM). In 2014, the CNSC has launched the WFOF Initiative to anticipate the workforce requirements of the future and to define and implement concrete actions that ensure CNSC’s continued capacity to effectively deliver on its mandate. The key elements of this initiative are 1) the development of a workforce strategy, 2) the conduct of an organizational review, and 3) the mapping of career paths. The results of the CfNS project can he used to influence these elements. Additionally, in 2016, the CNSC initiated a KM review to obtain reliable information about CNSC’s KM culture, best practices and areas of improvement. The KM project is now at Phase II to conduct KM risk analysis drawing upon workforce planning and capability for nuclear safety initiatives, to develop KM strategies and objectives and to carry out a KM plan to bridge gaps and meet objectives [4]. CNSC staff have compared the CfNS project with WFOF and KM and identified the synergy between initiatives, as shown in Figure 3.

CNSC staff will share our project progress and results with other initiative leads to ensure continuous improvements for the organization to maintain a healthy regulatory safety oversight culture.

FIG. 3 Synergy between Initiatives

6. CONCLUSION

This paper has described an effective approach to assessing Capability for Nuclear Safety at the CNSC. The self-assessment method of comprehensively collecting required capability information from CNSC operational staff was first described and then the catalogue created from the collected capability information was demonstrated. Further, the approach used to evaluate CNSC capability risks or gaps through interviews was discussed. Some preliminary capability analysis was presented. Finally the paper has discussed the links with other CNSC initiatives as continuous improvements for the organization to maintain a healthy regulatory safety oversight culture. The self-assessment method of collecting capability information based on task analysis and the management interviews of assessing required capability information have effectively identified some capability risks and gaps internally and externally, as well as some mitigation strategies to address them.

REFERENCE

[1] Nuclear Industry Code of Practice (NICoP), Nuclear Baseline and the Management of Organisational Change – A Nuclear Industry Code of Practice, 2017

CLOSING SESSION

The closing session provided an opportunity to acknowledge the on-going developments undertaken under the auspices of the IAEA TSO Forum which addressed the conclusions of past TSO Conferences. Indeed, the TSO Initiative based on the IAEA Technical Document IAEA-TECDOC-1835 "Technical and ScientificSupport Organizations Providing Support to Regulatory Functions", provides a set of tools to support IAEA Member States in developing and strengthening their technical and scientific capacity:

(a) A TSO self-assessment tool and case-studies based methodology should enable Member States to practically perform an assessment of their national TSO strategy in reference to IAEA-TECDOC-1835.

(b) A "TSO national workshop" approach as recommended by the TSO Forum should be carried out in the near future in cooperation with a candidate Member State.

The Conference President presented the summary and conclusions of the conference.

Among the conference's main conclusions were that existing IAEA advisory services (including Integrated Regulatory Review Service missions) could be implemented in such a way as to encompass with appropriate in-depth analysis the contribution of TSOs to the challenges faced by the national regulatory system.

It was also agreed that the work of the TSO Forum, including the TSO initiative, should be more widely promoted. Member States could take advantage of the specialized advice on strategic issues relevant to TSOs, in order to contribute to setting up a suitable TSO capability at national level.

Aspects of potential TSO contribution to the independence and sustainable effectiveness of the national regulatory system could be further addressed by highlighting:

(c) The role of TSOs in activities of regulatory bodies communicating with stakeholders, noting that the openness and transparency of the safety expertise may enhance nuclear safety.

(d) The role of TSO expertise in providing independent advice or recommendations to the regulatory bodies about state-of-the-art safety assessment tools and methodologies, and technical and staff capabilities.

TSOs' needs for effective and sustainable research, education and training, and knowledge management to feed and sustain expertise in the long term, to better support regulatory systems were also highlighted. The TSO Forum was invited to consider how to encourage embarking countries to address the above-mentioned priorities in the development of strategic plans and roadmaps for building up an independent and sustainable TSO in the long term.

ACKNOWLEDGEMENTS

The IAEA wishes to thank all the hosts and participants who contributed to the conference. Upon the successful completion of the conference IAEA would like to thank the Government of Belgium for hosting the conference in Brussels, for their outstanding organization and provision of excellent facilities, and for their hospitality extended to everyone involved in the conference (participants, IAEA staff, speakers and chairpersons). The IAEA would also like to thank Bel V for its commitment in making this conference such a success. A special thanks and appreciation go to Mr Michel Van Haesendonck, Mr Benoit De Boeck and Ms Marika Roobaert from Bel V as the point of contact for the IAEA and for their involvement and valuable support prior to and during the conference. IAEA would also like to extend further thanks to Mr J. Jambon, Deputy Prime Minister and Minister of Security and the Interior of Belgium for his opening speech. Their professionalism and kind support were very much appreciated. Finally, IAEA would like to thank the European Technical Safety Organization Network (ETSON) for its excellent contribution.

SUMMARY AND CONCLUSIONS OF THE CONFERENCE

Nestor MASRIERA
President of the Conference

BACKGROUND OF THE CONFERENCE

The International Conference on Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security, held in Brussels, Belgium, in October 2018, continued the practice established by the three preceding conferences on this subject that were held, respectively, in Beijing in 2014, in Tokyo in 2010, and in Aix-en-Provence in 2007. Like those of earlier conferences, the outcomes of this conference will play a vital part in the national and international efforts made to ensure the effectiveness of nuclear safety and security regulatory systems. These outcomes will focus in particular on ways to strengthen the actions of TSOs in supporting the enhancement of safety and security worldwide.
Over 228 participants from 54 member states and five organizations attended the conference. Throughout the event, 62 posters and 47 presentations highlighted specific areas within each of the six topical sessions and stimulated discussions among participants.

OBJECTIVES OF THE CONFERENCE

The Conference highlighted the importance of scientific and technical capabilities to support regulatory decision making for enhanced nuclear and radiation safety and security. While addressing challenges to the development, maintenance and enhancement of such capacities, the discussions focused on the following objectives:

- Evaluate actions undertaken to address the recommendations from previous TSO conferences;
- Promote understanding of the roles, functions and value of TSOs in enhancing nuclear and radiation safety and security and, in particular, addressing challenges related to embarking, existing or expanding nuclear power programmes, with a particular focus on capacity building;
- Discuss the role and achievements of the Technical and Scientific Support Organization Forum (TSO Forum);
- Present the need for, and benefits of, self-assessment for TSOs to maintain and enhance their technical and scientific capabilities to support regulatory bodies' decision-making process;
- Discuss the significant contribution of the TSOs' safety assessment work to the continuous updating and revision of the IAEA Safety Standards;
- Address the role of TSOs in enhancing nuclear and radiation safety in applications other than nuclear power;
- Highlight the main methods for supporting the development of scientific and technical expertise, including research and development;
- Facilitate the exchange of experience and good practices in capacity building activities, and in the recipient countries' arrangements for identifying areas in which they require assistance;

- Discuss ways to enhance international cooperation through IAEA safety and security networks, bilateral cooperation and Nuclear Security Training and Support Centres (NSSCs) or centres of excellence.

OPENING SESSION

The International Conference on the Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security: Ensuring Effective and Sustainable Expertise, highlighted initiatives to develop and strengthen the capability of TSOs. TSOs are independent organizations that provide expertise and services to national regulatory bodies on scientific and technical issues related to nuclear safety and security.

M. Van haesendonck, Director General of Bel V, the Belgian TSO that conducts inspections as well as safety assessments for nuclear projects and host of the conference, outlined the work of his organization, explaining that its mission is to contribute towards protecting people and the environment against the danger of ionizing radiation on the basis of experience built up over 50 years.

J. Jambon, Deputy Prime Minister and Minister of Security and the Interior of Belgium, highlighted that competent safety authorities — supported by TSOs — are key to safe nuclear activities. He noted that there is a need for experts passionate about nuclear safety, who work every day to make sure that nuclear technology works for the benefit of the people, and that they do not have to worry about accidents.

J.C. Lentijo, IAEA Deputy Director General and Head of the Department of Nuclear Safety and Security, pointed to the diversity of TSOs in his opening remarks, remarking that there is no ‘one size fits all’ for the organizations. He noted that the Conference would discuss the wide range of formats for the organizations and their cooperation with regulatory bodies.

Other speakers at the opening session included N. Masriera, President of the Board of Directors of Argentina’s Nuclear Regulatory Authority, and M. Huebel, Head of the European Commission’s Unit on Radiation Protection and Nuclear Safety.

N. Masriera, as the President of the Conference, gave a welcome to the participants of the fourth TSO Conference, and highlighted the importance of promoting the understanding of the roles, functions and values of TSOs, explaining the framework focused on regulatory bodies. He also described the design of the conference structure and declared the Conference open.

KEYNOTE SPEECHES

Following their opening addresses, there were keynote addresses:

B. De Boeck, Belgium, President of the TSO Conference 2014, presented an update on the implementation of the conclusions and recommendations of the TSO Conference 2014.

G. Caruso, IAEA, Director of the Office of Safety and Security Coordination, presented an overview of IAEA activities related to TSOs.

OVERVIEW OF TOPICAL SESSIONS

Topical Issue 1: Roles of the TSOs supporting regulatory functions

The presenters discussed various examples of roles and models of cooperation between regulatory bodies and TSOs, including the experience, challenges and opportunities relating to the different existing models of cooperation. It is commonly understood that the existence of core capabilities/technical expertise within the regulatory bodies is a precondition for successful cooperation with domestic and international TSOs.

The principal theme concerned the modalities of cooperation between the regulators and TSOs, including international cooperation with respect to the following challenges:

- Newcomer countries and countries with expanding nuclear power programmes are seeking international cooperation to strengthen regulator and domestic TSO capabilities and to access the expertise not (yet) available domestically.
- Countries with established nuclear programmes are trying to optimize TSO effectiveness. In these cases, the motivation for international cooperation may also be access to cost effective, timely or more specialized expertise.
- The establishment and/or selection of TSOs by a regulatory body was highlighted as a challenge, as it has an impact on the preservation and further development of sustainable national expertise.

Recommendation

- The Conference recommended that the IAEA consider continuing a forum for promoting cooperation among TSOs with special emphasis on the needs of embarking countries seeking international cooperation to strengthen regulator and domestic TSO capabilities.
- Member States are encouraged to look for opportunities to increase the dialogue between civil society and technical experts so as to contribute to the trust and confidence in the technical basis supporting regulatory decisions.

Topical Issue 2.1: Safety assessment

Safety assessment is a fundamental element of nuclear regulation, and TSO support to regulatory bodies plays an important role in this area. After an introductory presentation by the IAEA, six presentations by TSOs and regulatory bodies illustrated different elements of this support.

Work is ongoing by the IAEA to facilitate the application of new safety requirements for advanced water-cooled reactor designs and SMRs and to support sharing of experiences on implementing safety improvements at existing nuclear power plants aiming at minimizing radioactive releases in the event of a nuclear accident.

The presentations covered the following aspects of safety assessment:

- Tools aimed at systematic technical review of licensing documents;
- The increasing use of PSA as a supplement to deterministic analyses;
- The role of experiments to better understand physical and chemical phenomena;
- Development and validation of computer codes;
- Tests of high energy arcing fault events with potential of explosion and ensuing fires;
- Independent confirmatory calculations supporting technical reviews.

The presentations and discussions during this session highlighted the importance of increasing awareness on TSO contributions in support of the regulatory bodies.

Topical Issue 2.2: Radiation and waste management safety

This session covered a wide range of topics linked to radiation and waste management safety. The three presentations discussed the role TSOs can have in enhancing safety by developing new ideas and techniques as well as through collaboration. They covered how to formalize

the practical elimination of large releases, the development of an expert network on waste management safety, and the modernization of a remote monitoring network.
It is important that TSOs be part of the development of IAEA Safety Standards in these fields.
In summary:

- TSOs play an important role in defining guidance on safety principles;
- There is value in wider networks that include TSOs, regulatory bodies and civil society, especially in the area of waste management;
- In some areas, such as radiation monitoring, there is a need to balance the diverse needs of the regulatory body and the public.

Topical Issue 2.3: International cooperation

International cooperation, whether bilateral or within frameworks and networks, is a necessary tool to enhance the expertise and capabilities of TSOs. The approaches and objectives of these cooperation tools complement each other in order to satisfy the targets of the regulatory bodies and their TSOs.
In this session, the European Commission's Directorate-General for International Cooperation and Development (DG DEVCO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the ETSON Research Group and the OECD/NEA Multinational Design Evaluation Programme (MDEP) made presentations that demonstrated the significance and value of continuous international collaboration.
Strong cooperation among the international organizations is pertinent and necessary to optimize efforts and to make the best use of the available resources and expertise.
In summary:

- The importance of increasing awareness on TSO contributions in support of the regulatory bodies was highlighted.
- Multilateral cooperation among TSOs, in areas such as international R&D activities involving TSOs (e.g. the European Commission Instrument for Nuclear Safety Cooperation, the OECD/NEA Committee on the Safety of Nuclear Installations, ETSON), or support to MDEP, helps ensure a high level of global nuclear safety. Moreover, these activities are necessary to build up and maintain a high level of competence and expertise in a challenging scientific context to support the respective national regulatory needs.

Recommendation

The IAEA should consider continuing to promote awareness on TSO contributions in support of the regulatory bodies and encouraging embarking countries to participate in networks involving TSOs.

Topical Issue 3: Role of the TSOs in emergency preparedness and response

Six presentations were made, by Argentina, France, Germany, Romania, Russian Federation and Thailand.
This session discussed the roles of and challenges faced by TSOs in terms of providing support to government authorities competent in emergency preparedness and response. This support is related to assessment, prognosis and monitoring, including managing or supporting

the emergency centres in some Member States during an emergency response or related drills and exercises.
TSOs play a wide range of roles in emergency preparedness and response at the national level. This often goes beyond support to the regulatory body.

Recommendations

- Embarking countries are encouraged to define the role of TSOs in the context of national emergency preparedness and response approaches, taking into account the roles of all involved stakeholders as appropriate.
- The IAEA should consider facilitating the sharing of experience at regional (e.g. ETSON, ASEAN) and international levels, as well as on a bilateral basis. In particular, experience gained through involvement in emergency drills and exercises could be shared at the level of the TSO Forum in a dedicated working group.
- The IAEA should consider developing guidance on the role of TSOs in emergency preparedness and response.

Topical Issue 4: Other challenges of TSOs

This session addressed other areas, such as: public engagement, openness and transparency, communication with stakeholders, interfaces between safety and security, safety and security culture, physical protection and capacity building.

Recommendations

The Conference recognized:
- The need for clarification of the role of TSOs in these other areas: transparency versus security, and safety and security interfaces;
- The useful role of TSO expertise in stakeholder involvement in regulatory body activities, noting that the openness and transparency of the TSO safety expertise may enhance regulatory effectiveness;
- That IAEA international cooperation mechanisms (e.g. TSO Forum, Regulatory Cooperation Forum, Global Safety and Security Network) have proven to be very effective platforms and should be continued to address those challenges.

Topical Issue 5: Key components to develop and maintain the technical and scientific expertise

It was discussed and recognized that there is a need to develop and maintain core competencies.
Examples of key components discussed at the Conference include training, tutoring and strategic planning of workload as necessary guidance for meeting future demands for technical and scientific expertise. Training and tutoring programmes may be internal to TSOs or offered by different qualified national or international providers.
Strong partnership with academia (research and higher education), although not elaborated further during the Conference, may in some circumstances add to the long-term preservation and improvement of the expertise.

Recommendations

It is recommended that national TSO:

- Define the core competencies, which need to be developed and maintained nationally;
- Develop the strategic plan of the anticipated workload including the core competencies needed to meet future demands;
- Define or identify qualified national or international providers of education training and tutoring;
- Define or identify appropriate strategic partnerships with domestic or international academia (higher education and research organisations;
- Sharing of experience and best practices internationally, in particular through IAEA TSO Forum, is also recommended.

Topical Issue 6: How to build your technical and scientific capability

This session emphasized that the availability of a national TSO capacity is a powerful tool to consolidate the medium and long-term sustainability of effective regulatory control, particularly in countries where new-build programmes have benefited from extensive technical support from foreign expertise.
The IAEA TSO Initiative was also presented, including the different tools that are currently being developed to support Member States in the design of a national TSO development strategy.

Recommendations

It was stressed that a national TSO capacity building strategy should:

- Be adapted to the institutional landscape of the country.
- Take into account a realistic evaluation of needs in terms of priorities and time frames.
- Include an open approach to the communication needed to link together stakeholders with different cultures (e.g. mission, language, work practice). These stakeholders include suppliers, the regulator, academia, TSOs, etc..
- Make the best use of available possibilities for international cooperation, including through the IAEA, in order to optimize their TSO development decisions in terms of organization, funding system, technical and scientific priorities, staffing and training methods.

IAEA Member States are encouraged to make the best use of the IAEA TSO Initiative to help design their national strategy for TSO capacity building, and to contribute to the ongoing activities of the TSO Forum.

General conclusions of the Conference

1. The Conference acknowledges the results of the developments undertaken under the auspices of the IAEA TSO Forum on the basis of past TSO Conference conclusions, notably the TSO Initiative, and encourages further progress on them in the following directions:

(a) Based on TECDOC-1835, existing IAEA advisory services (including Integrated Regulatory Review Service missions) could be implemented in such a way as to encompass with appropriate in-depth analysis the contribution of TSOs to the challenges faced by the national regulatory system.
(b) The finalization and field test of the draft TSO self-assessment tool should enable Member States to practically perform an assessment of their national TSO strategy in reference to TECDOC-1835.
(c) A test of the "national TSO workshop" approach as recommended by the TSO Forum should be carried out in the near future in cooperation with a candidate Member State.

2. The Conference encourages Member States to support the TSO Initiative and to take advantage of the specialized advice on strategic issues relevant to TSOs, in order to contribute to setting up a suitable TSO capability at national level.
3. The Conference recommends that the TSO Forum further address the following aspects of potential TSO contribution to the independence and sustainable effectiveness of the national regulatory system:
   (a) The role of TSOs in activities of regulatory bodies communicating with stakeholders, noting that the openness and transparency of the safety expertise may enhance nuclear safety.
   (b) The role of TSO expertise in providing independent advice or recommendations to the regulatory bodies about state-of-the-art safety assessment tools and methodologies, and technical and staff capabilities.
4. The Conference highlighted TSOs' need for effective and sustainable research, education and training, and knowledge management to feed and sustain expertise in the long term, to better support regulatory systems. The TSO Forum could consider how to encourage embarking countries to address the above-mentioned priorities in the development of strategic plans and roadmaps for building up an independent and sustainable TSO in the long term.

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CONTRIBUTORS TO DRAFTING AND REVIEW

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APPENDIX I: CONFERENCE PROGRAMME

MONDAY, 15 OCTOBER 2018

11:00-13:00 **SESSION 1**
ROLES OF THE TSOs SUPPORTING REGULATORY FUNCTIONS

Chairperson: **U. Stoll, Germany**
Co-chairperson: **N. Masriera, Argentina**

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
11:00-11:15	90	N. Masriera	Argentina	The experience of the Argentina Nuclear Regulatory Body using external TSOs for licensing nuclear power plants
11:15-11:30	34	B. Poubeau	France	Leading nuclear safety and radiation protection expert assessment in France
11:30-11:45	45	B. Thomas	United States of America	The Mission of a Technical Support Organization: Perspectives of the U.S. Nuclear Regulatory Commission
11:45-12:00	94	Z. Trafimchik	Belarus	TSO system development in Republic of Belarus

12:00-13:45 *TSO Café*

13:45-15:45 **SESSION 1 (cont'd)**

13:45-14:00	15	A. Kubiak	Poland	Technical Support Organisations in the Polish Nuclear Power Programme
14:00-14:15	3	S. Prasad	India	Challenges for Regulatory Body and Technical Support Organisations during the expansion of Nuclear Power Programme in India
14:15-14:30	79	M. Kund	Germany	Support to European Nuclear Regulatory Authorities in the Field of Nuclear Safety
14:30-14:45	107	P. Bester	South Africa	Diversification of Services offers by Nuclear Regulatory Organizations through the use of Technical Support Organization; Lessons learnt from South Africa

14:45-15:45 *Panel discussion (Session 1)*

15:45-16:15 *Coffee Break*

16:15-18:15	Side event of the European Technical Safety Organisations Network (ETSON)
16:15-16:40	Presentation by ETSON B. De Boeck, President of ETSON
16:40-17:15	ETSON Award 2018
17:15-18:00	Technical presentations by ETSON:

K. Herviou	France	Technical Board on Reactors Safety (TBRS)
M. Adorni	Belgium	ETSON Research Group (ERG)
B. Autrusson	France	Institut de Radiation et de la Sûreté Nucléaire (IRSN)
F. Russo	Belgium	Bel V
J.-C. Niel	France	Support Activities to the IAEA through the TSO Forum

18:00-18:15	ETSON - JRC Collaboration

TUESDAY, 16 OCTOBER 2018

09:00-10:20 SESSION 2.1
SAFETY ASSESSMENT

Chairperson: B. Thomas, United States of America
Co-chairperson: K. Tomita, Japan

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
09:00-09:20	x	C. Spitzer	IAEA	IAEA Int’l Conference on Topical Issues in Nuclear Installation Safety, June 2017 - Key Insights and Recommendations
09:20-09:40	46	P. Mach	Czech Republic	Systematic Approach to Regulatory Review and Assessment of Safety Documentation for Imported Nuclear Technology
09:40-10:00	109	M. Roewekamp	Germany	PSA Lessons Learned from Viewpoint of the ETSON TSOs
10:00-10:20	83	G. Repetto	France	R&D project investigating the filtering system in the sump of a PWR NPP during a Loss of Coolant Accident: VIKTORIA experiments

10:20-10:50 *Coffee Break and Poster Viewing Session*

10:50-12:30 SESSION 2.1 (cont’d)

10:50-11:10	82	M. Sonnenkalb	Germany	Current challenges in nuclear safety R&D especially code development
11:10-11:30	93	H. Kabashima	Japan	Fire Safety Regulation on High Energy Arcing Faults (HEAF)
11:30-11:50	20	L. Ovdiienko	Ukraine	Support of Ukrainian Regulatory Authority in Licensing Process of Nuclear Fuel Supplier Diversification
11:50-12:30	*Panel discussion (Session 2.1)*			

12:30-13:30 *Lunch break*

TUESDAY, 16 OCTOBER 2018

13:30-15:00 SESSION 2.2
RADIATION AND WASTE MANAGEMENT SAFETY

Chairperson: P. Elder, Canada
Co-chairperson A. Koteng, Kenya

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
13:30-13:50	113	G. H. Chai	China	Nuclear and Radiation Safety as higher as reasonably achievable
13:50-14:10	51	V. Detilleux	Belgium	SITEX_Network for the development of Sustainable and Independent Technical Expertise on radioactive waste management
14:10-14:30	87	C. Debayle	France	Modernization of the IRSN's remote sensing network
14:30-15:00	*Panel discussion (Session 2.2)*			

15:00-15:30	*Coffee Break and Poster Viewing Session*

15:30-17:30 SESSION 2.3
INTERNATIONAL COOPERATION

Chairperson: P. Daures, European Commission DG/DEVCO
Co-chairperson: C.Eibl-Schwaeger, Germany

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
15:30-15:50	111	P. Daures	DG/DEVCO	DG/DEVCO activities
15:50-16:10	112	M. Beilmann	OECD/NEA	OECD/NEA's activities
16:10-16:30	86	M. Adorni	Belgium	Overview of ETSON modelling and experimental capabilities for R&D on nuclear safety
16:30-16:50	17	S. Bogdan	Russian Federation	Scientific and Technical Support to the Regulatory Body within the Framework of MDEP VVERWG Activity

16:50-17:30 *Panel discussion (Session 2.2)*

19:15 ***Dinner at the restaurant "Chez Léon"***
(self-paying basis)

WEDNESDAY, 17 OCTOBER 2018

09:00-10:20 SESSION 3
ROLE OF THE TSOS IN EMERGENCY PREPAREDNESS AND RESPONSE

Chairperson: J.-L. Lachaume, France
Co-chairperson: A. Kuryndin, Russian Federation

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
09:00-09:20	84	J.-L. Lachaume	France	Emergency, Preparedness and Response, an important stake for IRSN
09:20-09:40	80	S. Kus	Germany	Enhancing Emergency Preparedness and Response in Germany
09:40-10:00	36	A. Toma	Romania	The role and responsibilities of RATEN ICN as TSO for the Romanian Nuclear Regulatory Authority
10:00-10:20	18	A. Shapovalov	Russian Federation	SEC NRS activities in Support to Rostechnadzor's Information and Analytical Centre
10:20-10:50	*Coffee Break and Poster Viewing Session*			
10:50-12:30	**SESSION 3 (cont'd)**			
10:50-11:10	7	K. Silva	Thailand	R&D Activities to be conducted by TSO in embarking countries: R&D to support understanding of severe accident and planning of emergency response
11:10-11:30	89	N. Puerta Yepes	Argentina	Special monitoring response capacities developed at the internal dosimetry laboratory of the Argentine Nuclear Regulatory Authority
11:30-12:30	*Panel discussion (Session 3)*			
12:30-14:00	*Lunch break*			

WEDNESDAY, 17 OCTOBER 2018

14:00-17:30 SESSION 4
OTHER CHALLENGES OF TSOs

Chairperson: Y. Lee, Republic of Korea
Co-chairperson: M. Skrzypek, Poland

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
14:00-14:20	x	K. Mrabit	Morocco	Synergies between safety and security
14:20-14:40	56	O. Elhefnawy	Egypt	Scientific and technical support in enhancement nuclear security: roles, capabilities and challenges
14:40-15:00	47	Z. Zhao	China	The Challenges Faced by TSOs in the field of Nuclear Facility Physical Protection
15:00-15:20	*Coffee Break and Poster Viewing Session*			
15:20- 17:30	**SESSION 4 (cont'd)**			
15:20-15:40	85	V. Leroyer and Y. Lheureux	France	Openness to civil society: which challenges for a TSO?
15:40-16:00	28	A. Imtiaz	Bangladesh	Impact of External Influences to the Development of Culture for Safety in Nuclear Organizations of Bangladesh
16:00-16:20	110	M. Naseer	Pakistan	Role of Technical Support Organization in Decommissioning of a Nuclear Power Plant
16:20-17:30	*Panel discussion (Session 4)*			

THURSDAY, 18 OCTOBER 2018

09:00-10:00 SESSION 5
KEY COMPONENTS TO DEVELOP AND MAINTAIN THE TECHNICAL AND SCIENTIFIC EXPERTISE

Chairperson: L. Cizelj, Slovenia
Co-chairperson: G. H. Chai, China

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
09:00-09:20	48	M. Demeshko	Russian Federation	JSC VO Safety support to Rostechnadzor in assisting embarking countries on their technical and scientific capability development

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
09:20-09:40	73	D. Louvat	ENSTTI	The experience of the ENSTTI initiative in meeting challenges of professional development of Technical Safety Organisations experts
09:40-10:00	44	B. Thomas	United States of America	Maintaining Capabilities of Technical Support Organizations in a Dynamic Environment: Perspectives of the U.S. Nuclear Regulatory Commission

10:00-10:30 *Coffee Break and Poster Viewing Session*

10:30-12:30 SESSION 6

HOW TO BUILD YOUR TECHNICAL AND SCIENTIFIC CAPABILITY?

Chairperson: M. Mkhosi, South Africa

Co-chairperson: M. Betti, European Commission

Time	*INDICO ID*	*Name*	*Designating Member State/Organization*	*Title of Paper*
10:30-10:50	92	J. Repussard	France	Keynote speech on TSO challenges and cultures
10:50-11:10	x	K. Ben Ouaghrem	IAEA	Presentation of the IAEA TSO initiative to support Member States in developing and strengthening Technical and Scientific Support Capacity
11:10-11:30	68	S. Yao	Canada	An Effective Approach to Assessing the Needs and Availabilities of Capability for Nuclear Safety at the CNSC

11:30-12:30 *Panel discussion (Sessions 5 and 6)*

12:30-14:00 *Lunch break*

14:00-16:00 *Conclusion of the Conference*

APPENDIX II: LIST OF POSTER-PRESENTATIONS

SESSION 1 - ROLES OF THE TSOs SUPPORTING REGULATORY FUNCTIONS

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
8	H. F. Randrianseheno	Madagascar	The technical body in radiation protection in Madagascar
9	M. Kandil	Egypt	The Role of Technical and Scientific Support Organizations in Enhancing Nuclear Safety
10	E. Eisawy	Egypt	The Increasing Role of TSO in Supporting the Safe and Secure Application for New Nuclear Power Countries
14	R. E. Hariento	Indonesia	Indonesia Nuclear Energy Regulatory Agency experience in utilize TSOs supports for nuclear reactor Licensing process activity
35	D. H. Nugroho	Indonesia	Challenge of P2STPIBN to transform into a world-class internal TSO in the Indonesian Nuclear Energy Regulatory Agency
55	I. Mirsaidov	Tajikistan	Experience of Tajikistan regulatory body on receiving support from its TSO
62	D. Taufiq	Indonesia	A strong technical support organization to enhance the nuclear regulatory; from Indonesia perspective
67	C. Matteoli	Netherlands	The Collaboration of the Dutch nuclear regulatory body with its TSO
95	N. Choudhury	Bangladesh	Interaction with TSO for developing Technical Support Structure in the field of Nuclear Safety and Security: Bangladesh Perspective
98	P. Stefania	Romania	Areas in which regulatory bodies require assistance
102	M. Surur Kedir	Ethiopia	The experience of TSOs and regulatory bodies in working together
106	N. Zeleznik	Slovenia	Experiences of EIMV as one of the Slovene TSO
x	T. Li	China	Discussion on the role, challenge and Improvement of TSOs in Enhancing Nuclear Safety
x	F. Wastin	European Commission	The JRC’s Technical and Scientific support to the European Commission, Member States and external partners

SESSION 2.1 - SAFETY ASSESSMENT

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
23	N. Helal	Egypt	Support required for safety management of decommissioning of research reactors.
25	O. Dybach	Ukraine	Scientific and Technical Support to the Licensing Process for the Construction of New Spent Fuel Storage Facilities in Ukraine: Achievements, Challenges and R&D Need
26	P. Ampornrat	Thailand	Development of research program for aging management for Thai research reactor TRR-1/M1
31	O. Balashevskyi	Ukraine	Scientific and Technical Support to the Ukrainian State Enterprise National Nuclear Energy Generating Company Energoatom
33	P. Ampornrat	Thailand	Development of strategy of research and development to support nuclear safety regulation
77	M. K. Abdul Karim	Malaysia	Evaluating the requirement for Nuclear Security Control of Radioactive Sources at medical Facilities in Malaysia
88	E. Negrenti	Italy	Advanced Multi-Purpose Engineering Simulators
100	M. Maskin	Malaysia	COMPASS-M: Probabilistic Safety Assessment of Existing Facility to Develop Skills for Evaluation of Nuclear Power Plant Safety
101	Z. Y. Yang	China	Current Challenges in Nuclear Safety Review on Hydrogen Management in Severe Accident
103	S. Mohamed	Egypt	Designing ageing Management System for Safety Related SSC's in Hypothetical Nuclear fuel cycle Facility
114	H. F. Yang	China	The current status and planning of Nuclear Radiation Safety Regulatory Capacity in China
x	Y. Wei	China	Core Damage Assessment System for NSSA of the PRC

SESSION 2.2 - RADIATION AND WASTE MANAGEMENT SAFETY

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
4	M. A. Addo	Ghana	GHARR-1 Core Conversion Project: Environmental Radiation Dose Monitoring Aspect for Irradiated Fuel Transfer from Temporal to Final Storage at NRRC
6	N. Autsavapromporn	Thailand	A correlation study of indoor radon environment caused by climate change and air pollution in Chiang Mai: a pilot study
16	I. Ali	Bangladesh	Development of Countrywide Baseline Gamma Radiation Mapping Database for the Nuclear Power Program in Bangladesh
19	A. Madonna	Italy	EC cooperation to enhance regulatory and TSO capabilities for regulation and safety review of radioactive waste management facilities and activities at Armenian NPP
21	Q. Chu	China	Quality management system for radiation measurement in China
22	I. Nikolaiev	Ukraine	Safety Review of Legacy Sites: National Experience, Guidelines and Methods Applied by the Technical Safety Organization
24	N. Helal	Egypt	Study of Gamma Ray and Fast Neutron Shielding Properties of some Concrete Materials
49	M. El Ashmawy	Egypt	Constraints on using NaCl salt for precise retrospective dose construction in radiation accidents
52	N. Mohlala	South Africa	Development of Radio-analytical Services in Support of Independent Verification for Regulatory Environmental Monitoring Programme Challenges and Lessons Learnt
65	M. Atogo	Kenya	Impact of Inadequate Technical Capabilities on TSOs in Provision of Effective Radiological Services in Kenya
74	A. Niane	Senegal	Compensate the gap of Technical Support Organization by the regulatory authority for the diagnostic reference levels in medical radiology
78	J. Fluegge	Germany	Challenges on the way to Final Disposal of High Level Radioactive Waste
105	K. Issa	Niger	Radiation Protection Activities in Niger and its challenges with the embarking of the Country in Nuclear Power Program (NPP)

SESSION 2.3 - INTERNATIONAL COOPERATION

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
32	C. D. Le	Vietnam	Lessons learned from the Ninh Thuan Nuclear Power Project in Vietnam and Proposals for the use of research for developing national regulations

SESSION 3 - ROLE OF THE TSOS IN EMERGENCY PREPAREDNESS AND RESPONSE

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
1	J. Zhang	China	Experiences and Challenges in the Development of Emergency Assessment tools in China
42	F. Rocchi	Italy	A Statistical Method to Compare Severe Accident Off-site Consequences on a given Country from different NPP Sites
76	M. Wafaa	Egypt	Safety Culture Development in Radiation Accidents - Arrangements for Communication with the Public
91	S. Gossio	Argentina	Regional Multiparametric Intercomparison Exercise on Physical, Biological and Computational Dosimetry in a gammagraphy scenario

SESSION 4 - OTHER CHALLENGES OF THE TSOS

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
43	D. Branco	Portugal	Translation and Interpretation
96	M. H. Mogahed	Sudan	Sudanese Nuclear & Radiological Regulatory Authority to enhancing TSOs for Nuclear Security
97	E. Dagorn	France	Supporting regulators with construction inspections: the inspection organization's perspective

SESSION 5 - KEY COMPONENTS TO DEVELOP AND MAINTAIN THE TECHNICAL AND SCIENTIFIC EXPERTISE

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
29	A. Madonna	Italy	Training and Tutoring for experts of NRA and their TSOs to strengthen regulatory and technical capabilities

30	A. Elmessiry	Egypt	Technical Support and Regulatory Activity: Challenges faced by ENRRA
58	D. O. Kpeglo	Ghana	Over A Decade of Post-Graduate Education and Training in Radiation Protection in Ghana
63	A. Rizea	Romania	Enhancing Technical and Scientific Capabilities of TSOs in Romania to Support Regulator and Nuclear Industry
116	L. Cizelj	Slovenia	Jožef Stefan Institute as a scientific and technical support organization to the nuclear regulatory body in Slovenia

SESSION 6 - HOW TO BUILD YOUR TECHNICAL AND SCIENTIFIC CAPABILITY?

INDICO ID	*Name*	*Designating Member State/Organization*	*Title of Poster*
40	S. Sommer	Poland	Technical Support Organization (TSO) for Nuclear Power Plant in Poland: the view of Research Institute
59	C. M. Papp	Argentina	Actions and challenges in Latin America and the Caribbean to improve and strengthen TSOs in overexposure situations
64	Y. Pramono	Indonesia	Concept of Indonesian national policy and strategy concerning Nuclear Safety
117	L. Cizelj	Slovenia	The European Nuclear Education Network ENEN: 15 years

ANNEX: SUPPLEMENTARY FILES

The supplementary material contains the technical programme of the conference, the list of participants, all available papers as well as presentations and posters provided during the conference. The “CN-266 Book of Synopsis and structure of sessions” document reflects all contributions in the order they were given at the conference. The “CN-266 Book of all contributions” lists the abstracts of all contributions in the order they were registered.

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