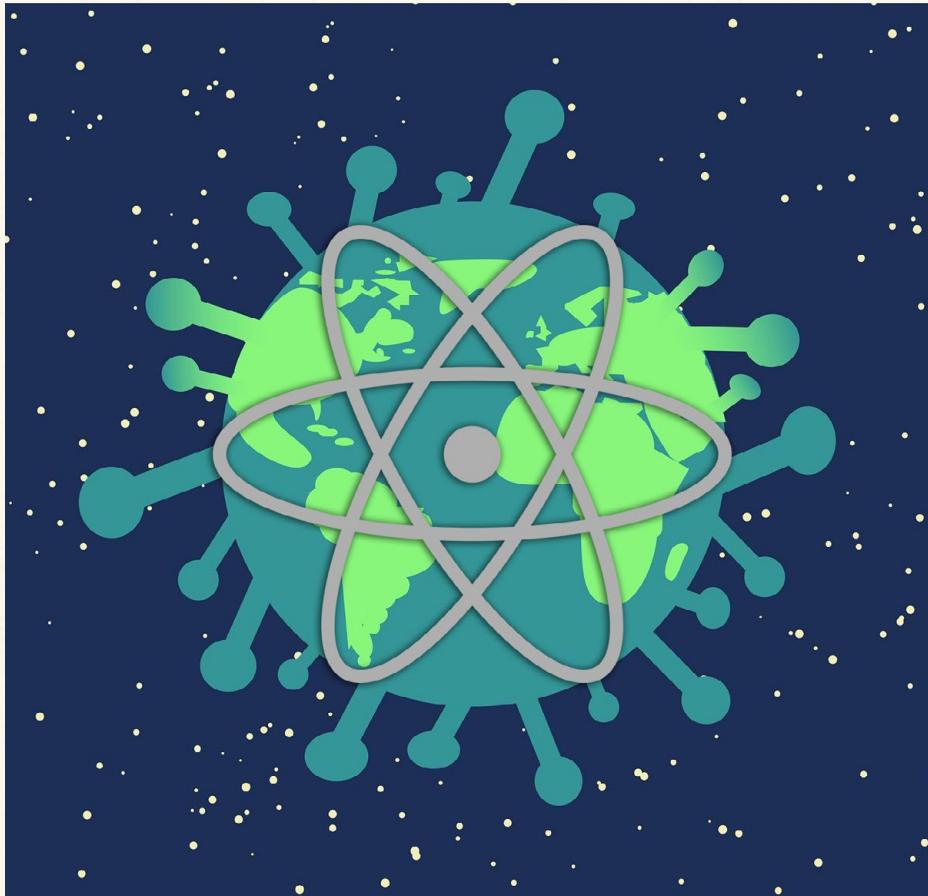


Connector

Issue 3 | Autumn 2020



EDITORIAL

by Willem Janssens (ESARDA President)

Dear Reader,

Since the publication of the Connector Issue 2, we moved from partial recovery of the COVID pandemic over the summer into an equally violent 2nd phase in the Fall, so we had to further adapt our way working. The traditional in person meetings with experts and friends were to be cancelled, rescheduled or replaced with virtual gatherings and conferences. It is therefore even more important now to cherish our Newsletter, which helps us all to stay Connected!

Importance of staying connected

I am very pleased that our editorial team gathered quite a substantial set of contributions for this third edition of the ESARDA Connector. In the news section you can discover how the community stays active, which are upcoming events and what happens in the world around us in our highly specialised niche of nuclear safeguards and non-proliferation. If you are curious to get to know some of our newest *continued on page 2...*

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This issue features the student article:

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...continued from front page

ESARDA partners, you will find the presentations of ANDRA and POSIVA in this edition! The continuous growth of the ESARDA family demonstrates both its relevance and impact, as we recently gained extra interest both from the specialists of the back-end of the nuclear fuel cycle and from academia.

Increased attention to safeguarding the back-end of the fuel cycle

The fact that ESARDA increases the focus on the challenges of safeguarding the encapsulation of spent nuclear fuel, the transport to the final storage location and the safeguards requirements for a deep geological repository, is fully consistent with the outcome of the ESARDA Reflection Group and the crowd sourcing done on that basis during the ESARDA World Cafe, just recalling that you find both these documents on our website. Considerations on the safeguards for the back-end of the fuel cycle started many years ago and multiple world-wide expert groups discussed this topic at length, the last one being e.g. the ASTOR group under guidance of IAEA. However, recently these groups were less active and because of the pressing needs to have ready-to-use solutions, especially for safeguarding some of the newest installations, e.g. in Finland and Sweden, which will be operational in the near future, ESARDA felt the requirement to establish a new Working Group on Final Disposal, which in the mean-time has already met twice since its creation early 2020. This “facility oriented” working group works in close collaboration with other ESARDA Working Groups like Implementation of Safeguards and Containment and Surveillance, and attracts considerable interest also from other international participants. The scope is to understand better the challenges and jointly work out solutions for those challenges counting on the input from R&D, the insights from the operators and the contributions from the inspectorates, i.e. to utilize to the full extent the potential of the ESARDA community. In the same light I am very pleased that the Steering Committee on November 16th, approved Mari Lahti, from POSIVA, as new ESARDA Vice-President. Welcome on board Mari and in addition to your strong professional profile and contribution, your election also strengthens further the



Overview of the ESARDA World Café topics highlighting the two priorities of back end of fuel cycle and knowledge management, including education and training

gender balance in the ESARDA management!



Logos of the two new ESARDA Parties dealing with the back-end of the fuel cycle

Enhancing the nuclear safeguards educational activities

Another “branch” of our ESARDA activities, that was strengthened recently is the one related to education and training. ESARDA has a very long tradition of providing a condensed, one week, university recognised education on nuclear safeguards and non-proliferation and has also exported that course in the past to South-East Asia and Africa. Based on this success the EC decided to award to ENEN, the European Nuclear Education Network, a MoU partner to ESARDA, a 4 year contract to both organise short term courses and especially to develop a full-fledged master (after master) curriculum for nuclear safeguards. The Politec-

nico di Milano, our newest academic ESARDA party, is coordinating the programme development, with support of a high level scientific committee that has so far defined the course structure, modules, objectives and learning outcomes. The first session of the master is scheduled to start in September 2021 and will be open both to non-European students, who can have access to the grants for travel, lodging etc, and also to European students, but without financial aid, seen that the budget comes from DG DEVCO (Development and Cooperation). Quite a few ESARDA parties will be collaborating in the implementation of this master programme, both by lecturing and by hosting students in their laboratories in the course of the academic year, to e.g. prepare the thesis work. Active outreach has started to attract students (and possibly also guest professors), both in South-East Asia, through the Asian Pacific Safeguards Network (APSN)



Latest ESARDA Parties involved in the safeguards educational activities

and in Africa, through the African Commission on nuclear energy (AFCONE), recognising that both APSN and AFCONE are ESARDA MoU partners.

Global outreach and recognition of ESARDA

In recent weeks in fact both our international MoU regional partners invited ESARDA to participate and present the organisation to their regional networks. AFCONE organised on November 23rd a webinar on 'Fostering and Sustaining Non-Proliferation Verification Systems through Development of National and Regional Nuclear Safeguards Capacities', with its Partners IAEA - NNSA - ESARDA & ISTC. APSN held on December 2nd its 11th Annual Meeting in virtual format under Indonesian Chairmanship of BAPETEN, with all participating countries and their partners in the network, and they announced the transition of the chair position, as of 01/01/2021 to VARANS, Vietnam for the next 2 years. Both regional networks, are keen to learn more about the ESARDA working methods, products and added value and are also interested to understand better the EURATOM type of regional set-up in the area of nuclear safeguards. Through this networking and contacts, the spin-off our work can thus find fertile ground in different areas around the globe which in fact also contributes to one of the key priorities of the European Commission, i.e. to foster a Stronger Europe in the World.



ESARDA MoU regional partners

The peer-reviewed ESARDA Bulletin indexed by SCOPUS

In the last couple of months, a very nice milestone was achieved through the recognition and final acceptance by SCOPUS of the ESARDA Bulletin, 'The International Journal of Nuclear Safeguards and Non-Proliferation'. The indexing process has started in order to include all the backlog of past Bulletin issues in the Scopus database. I like to congratulate strongly the ESARDA Editorial Committee colleagues who worked hard to achieve this and my thanks goes of course also to all authors of the article submissions which fill the Journal with substance. I like at the same time to make a strong appeal to spread the news and invite all colleagues, friends and professional connections who work in nuclear safeguards and non-proliferation across Europe and abroad to send in articles to our peer-reviewed journal.

ESARDA in line with new EU Commission Priorities

Seen the close relationship between ESARDA and DG ENER Euratom safeguards, it also worth recalling that during a large part of 2020 the EC developed the new Euratom R&D Work Programme for the period 2021-2027, in line also with the Ursula Von der Leyen Commission priorities and referring to the importance of nuclear power to contribute to the GREEN DEAL. This is in line e.g. with the strong claim by the Director General of IAEA, Rafael M. Grossi, to have a seat at the main table for the next UN Climate Change Climate Conference (COP 26) in Glasgow in November 2021. As already indicated above, the work under safeguards, non-proliferation and strategic trade control is also directly relevant to the EC priority to achieve a "Stronger Europe in the World", both by the highly valued contributions ESARDA and Euratom R&D deliver to IAEA (and thus effectively supporting multilateralism) and by reaching out beyond EU borders (near neighbors and also the African continent, in line with the high level European Union / African Union summit process).

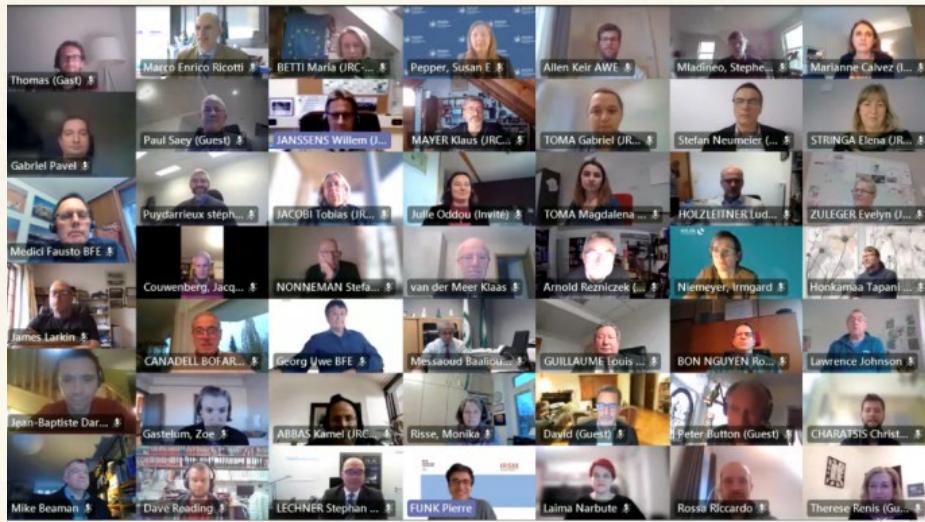
Strengthened collaboration with our sister organisation INMM

Over the summer, quite a few ESARDA members had the opportunity to virtually participate to the Annual Meeting of our sister organisation and MoU partner, the Institute for Nuclear Materials Management (INMM). In fact, this meeting had to be converted in quite short time from a fully in-person to a fully virtual meeting, which was very successfully accomplished and a record number of participants signed up. The programme was quite dense and many lively debates took place in most parallel sessions (supported by an active chat function). The virtual format offers certain advantages but also challenges. I e.g. remember presenting ESARDA, during the INMM President's Welcome Reception at 00:45 on Sunday night.



The 42nd ESARDA virtual annual meeting

Inspired by the above and also constraint by the reappearing pandemic early September 2020, we had to decide to also convert the ESARDA 42nd meeting into a fully virtual event, held from November 16 to 19 and hosted by IRSN in France, for which I like to express once more my strong gratitude. The meeting attracted 274 participants from over 25 countries and thanks to the excellent collaboration of the „conference organising team“, the invitations, presentations and discussions ran smoothly and efficiently. High level speakers from IAEA, DG ENER, IRSN, INMM and JRC animated the opening plenary. The two newly established working groups, Final Disposal and Material Balance Evaluation, presented their Terms of Reference and future work also during the opening plenary.



Screengrab of participants during the ESARDA 42nd Annual Meeting Plenary session

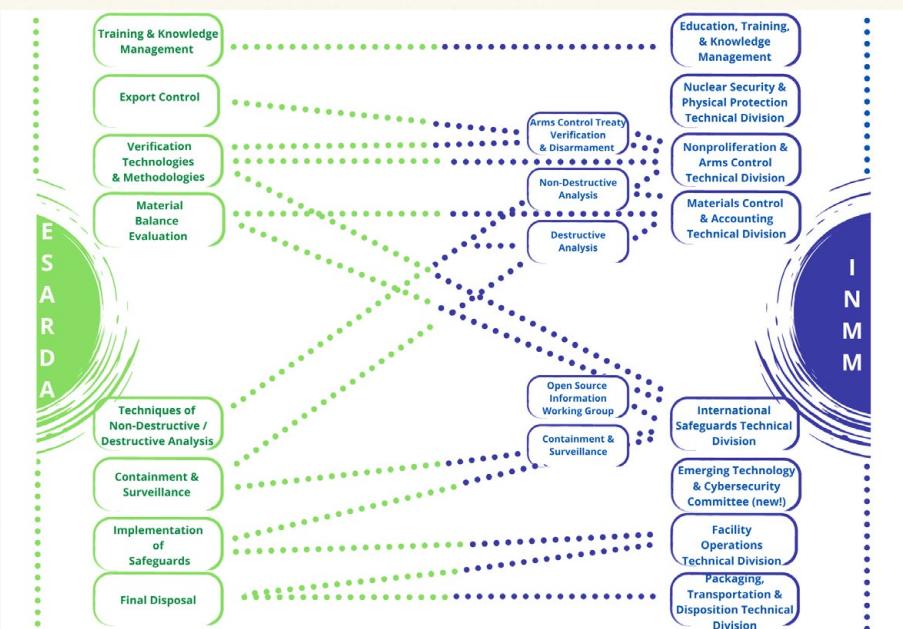
The ESARDA community was further updated on the progress made since the 50th Anniversary Symposium in 2019, w.r.t the World Cafe actions (a crowd sourcing activity that defined key activities for the future development of the association). Subsequently, during 1.5 days, the 10 different ESARDA Working groups met either individually or jointly and reported on the outcome of their discussions during the Closing Plenary, including an outlook for the future. Key novelties include, amongst many others, digitalisation, data science, focus on the back end of the fuel cycle, innovative technologies and further enhanced attention to training and education. Other points that were stressed included the role of emerging technologies in strategic trade control, new containment and surveillance technologies capable of remote data transmission, the 2020 International Target Values and the recognition that the link between soft science and safeguards is an unexplored field.

During the Steering Committee this year, apart from welcoming 3 new ESARDA Parties referred to already above, we also got the green light to make a Memorandum of Understanding with ABACC, the Argentinian-Brazilian regional safeguards authority, based on the already very good collaboration with Euratom



Flags of ABACC member states

for the first time will emerge in the next decade. I like to refer to this explicitly to introduce our next years Joint Annual Meeting between INMM and ESARDA under the theme „Advancing Together, Innovation and Resilience in Nuclear Materials Management“, to be held in Vienna from August 21 to 26, 2021. The Symposium Technical Programme Committee, jointly led by Carrie Mathews for INMM and Julie Oddou for ESARDA, has just recently finalised the call for papers. A special effort will be done to reach out, not only to the traditional participants of INMM and ESARDA meetings, but to other, more diverse communities, both geographically (across the globe and to the future nuclear newcomers) and topic-wise (e.g. to business intelligence community, developers and users of AI, imaging technologies and many other sectors, the knowledge and skills of which could serve very well the safeguards community). Due to the large uncertainties w.r.t. the evolution of the pandemic, and also due to the enhanced flexibility for some type of participants to attend the meeting, a hybrid option is foreseen, combining in-person gathering (if allowed by then) and virtual contributions. This Joint Annual Meeting, which is currently in full preparation, constitutes also an excellent opportunity for the ESARDA Working Groups to reach out to their homologues in the INMM organisation (Technical Divisions, Committees and Working Groups) to discover additional opportunities for collaboration and the potential for synergies between them. All have



Graph mapping INMM TD/Comm/WG to ESARDA WG connections

been invited to set-up joint special sessions, round tables, panel discussions and alike for this upcoming annual meeting and, in addition, reach out to non-traditional partners and seek for their contributions also. The Symposium committee will meet around Easter to shape the final programme based on the submitted abstracts and targeted invitations, and up to that time, all ESARDA members are kindly invited, or should I say challenged, to think about how to best use this unique opportunity and get most added value out of this Joint Annual Meeting and of course to submit papers, the deadline for submission of abstracts being set on February 20, 2021. Also ideas for sponsors, exhibitors or proposals for live demonstrations are highly welcome. In addition, we are convinced that by organising the meeting in the Austria Convention Centre, just next to the Vienna International Centre hosting IAEA, many of the colleagues from IAEA nuclear safeguards, security, nuclear energy and technical cooperation can participate. We truly look forward to make that event a memorable occasion and cross fingers that next summer, live has returned to „more normal“ again and

that we can shake hands, discuss in person and enjoy the personal company of the big INMM and ESARDA family and friends. Schertorte, Wienerschnitzel and Gruener Veltiner are waiting for you!

Transitioning the ESARDA Presidency

Finally I like to conclude this editorial by expressing my personal thanks to the great ESARDA management team and to all ESARDA members, parties, associated and individual members and MoU partners, for the fantastic collaboration we had in the last 2 years. It has been a very interesting and rewarding experience to serve as ESARDA President and I am fully committed, together with the team at the European Commission Joint Research Centre to also in the future continue to strongly support ESARDA. I am both proud and pleased to be able to pass the “flame” to our incoming ESARDA president Julie Oddou, head of the French Committee Technique Euratom, whose support in the last 2 years is greatly acknowledged, and who will be assisted by the new

Vice President Mari Lahti from Posiva. I like to thank also Irmie Niemeyer who continued to very actively contribute as ESARDA past-president in the last years and with whom we continue the strong collaboration with our INMM friends. And last but not least a special word of thanks to the ESARDA secretary, Veronique Berthou, the ESARDA Webmaster, Andrea de Luca, the main editors of the ESARDA Bulletin Editor and Connector, resp. Elena Stringa and Guido Renda, my own secretary Eva-Maria Koslowsky and to all colleagues who contributed actively to the continued functioning and success of ESARDA. We all know the organisation functions based on voluntary contributions but again e.g. just in our last annual meeting, you could feel the energizing enthusiasm, the serious efforts and hard work that all ESARDA members put into our organisation, realizing that our multi-faceted character is our strength and value to allow all of us to continuing advancing and improving the very challenging and highly relevant field of nuclear safeguards.

Christmas Greetings

After an unusual year, requiring lots of special efforts to assure business continuity and to establish a new-normal, it is now time to relax and enjoy. Even if perhaps not all family visits can take place as usual and ski slopes might remain closed for a while, I really hope that the charm of Christmas and wishes for good health at New Year, now even more important than ever, can accompany and comfort you. Perhaps there is some time for catching a fresh nose during a nice winter-walk in the forest, or for getting inspired while reading a fascinating book at the open fire place or also just for enjoying those small but important things in life that usually run by without being noticed. I thus wish and your families a fine holiday, with love of family and friends that fill you with joy and happiness and an excellent start in the New Year. All the best and please, take good care and stay healthy!

Kindest regards, Willem



news & events

Keeping you up to date with all the latest news of the association and its partners, as well as all the upcoming events in the near future.



NEWS

New ESARDA Working Group on Material Balance Evaluation

During the 42nd ESARDA annual meeting in November, ESARDA launched a new WG related to Material Balance Evaluation in bulk handling facilities.

The main objectives of this WG are:

- To establish some reference and guidelines on Material Balance Evaluation,
- To provide a reference and robust methodology for in-process inventory verification and Material Balance Evaluation within each Material Balance Area,
- To identify and share best practices and knowledge within the safeguards community (operators and inspectorates). It will be the main goal of the WG,
- This WG will also contribute to international reference through guidelines and ESARDA publications. It will provide a basis for relevant education and training.

The scope of this Working Group includes the Material Balance Evaluation, the determination of the related uncertainties and their interpretation.

The tasks of this Working Group will be distributed in 4 sub-WGs

1. Regulations for Material Balance Evaluation
2. Methodologies and statistical assumptions for Material Balance Evaluation as well as uncertainties, examples and tools
3. Best practices for Material Balance Evaluation, Material Balance monitoring and Material Balance accuracy improvement
4. NRTA / Near Real Time Accountancy studies and perspectives.

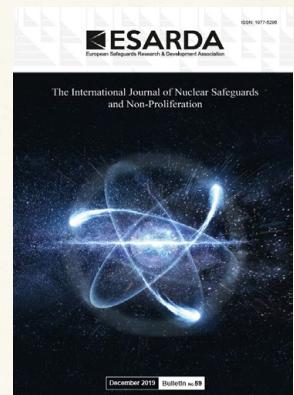
This 4th Sub Working Group will be interested in the potential development made possible by machine learning algorithms and in the mathematical methods allowing to combine physical models and statistical models.

To achieve these goals, experts are welcome:

- Experts from supranational and international inspectorates (Euratom, IAEA,...),
- Experts from national authorities,
- Experts from research centers, laboratories and safeguards associations,
- Experts in statistics/ measurements,
- Industrial/operator experts: from bulk handling facilities.

ESARDA Bulletin Scopus Citation Index Update

After a process of two years, the Editorial Committee is pleased to announce that the indexation process has commenced. This November, the Scopus Content Account Manager informed us that the upload of all the content is taking place, and all past issues will be readily available in the Scopus database. This historical achievement marks a new phase for the ESARDA Bulletin, in terms of quality and timeliness of release. In order to facilitate the authors who would like to publish in the Bulletin, the editors will shortly make available a publication policy document that will outline the criteria for submitting. This will assist authors to publish academic topics which are not strictly related to Nuclear Safeguards in the Bulletin.



New ESARDA Bulletin cover

EVENTS

2021 April 12-16	12 th - 16 th April 2021 19th ESARDA Course (Online) Joint Research Centre of the European Commission, Ispra (VA), Italy The JRC announces the 19th ESARDA COURSE on Nuclear Safeguards and Non Proliferation to be held in spring 2021. Organised by the Training, Knowledge Management Working Group. [Read more]	 ESARDA Course
2021 May 10-13	10 th - 13 th May 2021 International Conference on Fast Reactors and Related Fuel Cycles (FR21) Beijing, China The International Atomic Energy Agency (IAEA) once again brings together the fast reactor and related fuel cycle community by organizing the International Conference on Fast Reactors and Related Fuel Cycles. [Read more]	
2021 August 21-26	21 st - 26 th August 2021 INMM & ESARDA Joint Annual Meetings Vienna, Austria The INMM and ESARDA joint annual meetings provides a unique opportunity for research organisations, safeguards authorities and nuclear plant operators to exchange information on new aspects of international safeguards and non-proliferation, as well as recent developments in nuclear safeguards and non-proliferation related research activities and their implications for the safeguards community. [Read more]	



new partners

New partners have the opportunity to present their organisation's activities and how they can contribute to ESARDA.



View of the CSA surface disposal facility designed for low- and intermediate-level, short-lived radioactive waste situated in the Aube district, in north-eastern France and operated by Andra since 1992



ANDRA - AGENCE NATIONALE POUR LA GESTION DES DÉCHETS RADIOACTIFS

Andra is the agency responsible for the management of all the French nuclear waste. Andra is an independent establishment created by the law of 30 December 1991. Independent from waste producers, Andra is under the supervision of the ministries of energy, of the environment and of research.

Andra's mission was last amended and stipulated in the law of the 28 June 2006

- Operation of existing disposal facilities, in the Aube district, specific to Short Lived Low and Intermediate Level radioactive

waste and Very Low Level radioactive waste;

- Ensure the monitoring of the Manche center, the first French surface disposal facility for low and intermediate waste, now closed;
- Study and develop management solutions for waste that has no identified repository:
 - The disposal of Low Level Long Lived waste (such as Graphite waste or Radium bearing waste) with 2 alternatives, above or below ground.
 - The reversible disposal of High and Intermediate Level waste in a deep geological formation (Cigéo).
 - The management of radioactive waste coming from other industries than that of the production of electricity (hospitals, research establishments, universities, ...) and radioactive objects that the general public possesses (luminescent clocks, medical radium-bearing objects, certain minerals, ...). Upon request of owners or local authorities, Andra also deals with the rehabilitation of contaminated sites, such as the laboratories built by Marie Curie;
- Contribute to the distribution of scientific

and technical knowledge related to waste through documents, expositions and visits to its facilities, distribute its knowledge in France and abroad.

Every three years, Andra publishes a national inventory of radioactive waste and materials (article 14 of the law).

Andra contributes to the preparation of the National Plan for the Management of Radioactive waste and materials (article 6 of the law). This document identifies all management activities for radioactive waste, identifies needs for storage or disposal facilities and for waste that has no management solution so far, describes the goals that must be attained.

Concerning Deep Geological Disposal, Andra, designated by Law as the Programme Management Entity, is in charge of:

- Conducting R&D and design studies as needed to demonstrate the safety of the disposal solution; the programme includes the design, construction and operation of an URL (CMHM, construction started in 2000), Evaluating the cost and defining the operation planning and investment phased plan of the Deep Geologic Disposal
- Managing the overall converging siting

- process of the Deep Geologic Disposal (from a 250 km² zone to a restricted zone of interest (of about 30km²) to site underground installations,
- Conducting a consultation and information programme for the local populations, through the introduction of social sciences in the repository siting process,
- Preparing a license application of reversible repository for commissioning in 2025, if authorized
- Working on long-term memory conservation (sites and waste inventory).

Andra is a long-standing partner of the European Commission, the European Bank for Reconstruction and Development, and other European and International institutions providing financial assistance to countries creating or developing their waste management capabilities. Recently, Andra has carried out waste repository conceptual design and waste management studies in Lithuania (on-going) and Argentina. Andra is also accompanying countries, where a Deep Geologic Disposal programme and roadmap are under establishment (South Korea, Hungary). Andra has also been strongly involved in the project regarding the development of the waste management strategy for Ukraine.

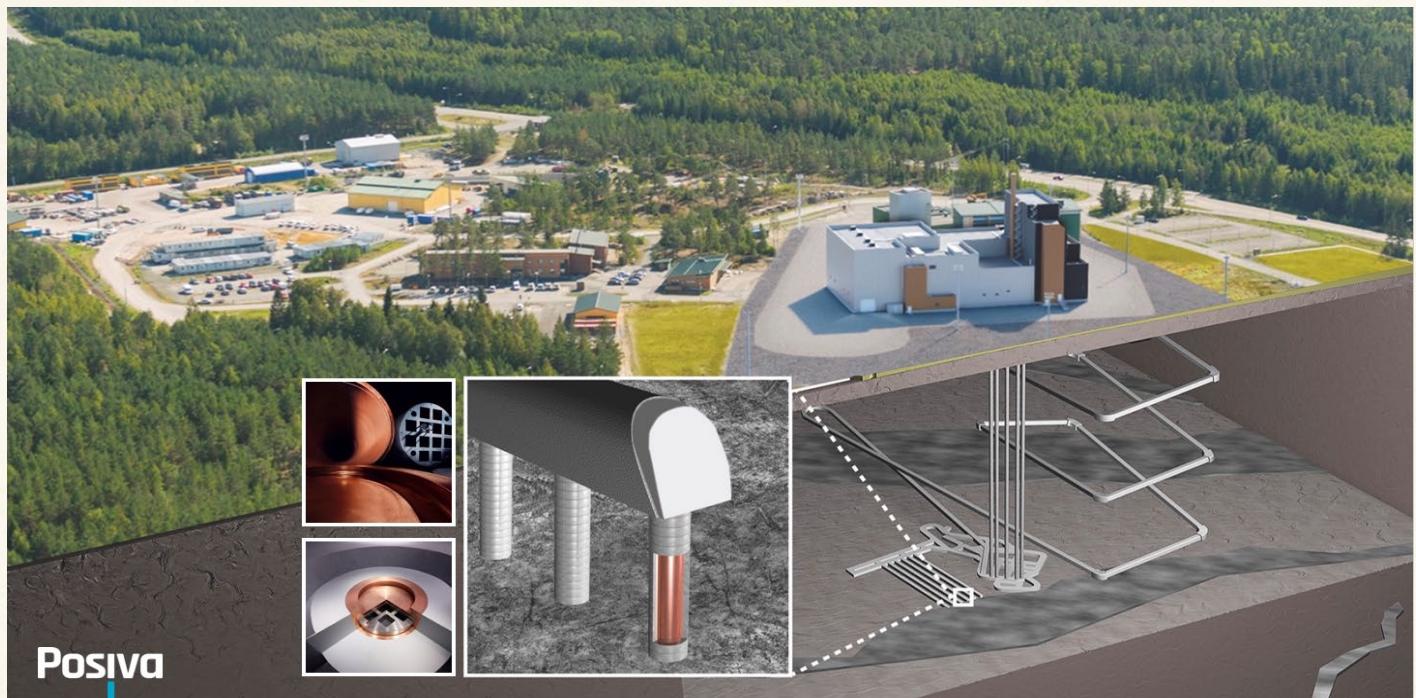
Andra is also very active in bi-lateral contracts, bringing its experience in assisting foreign agencies to design and review their waste management and disposal projects. Recent projects include cooperation with Belgium, United Kingdom, Slovenia, and Romania.

Andra is certified according to SS-EN ISO 9001 and ISO 14001.

Detailed information is available on the internet web site: www.international.andra.fr.



Andra: pictures of the galleries of the underground laboratory @Andrien Datse/Andra



View of the the repository located deep inside the bedrock, in which the most important section are the tunnels where the encapsulated spent nuclear fuel is disposed of.



POSIVA Oy

Posiva Oy (Posiva) is a nuclear waste management company whose main task is the disposal of the spent fuel of its owners' NPPs. Posiva is owned by Teollisuuden Voima Oyj (60%) and Fortum Power & Heat Oy (40%), both of which share the cost of nuclear waste management. Posiva employs around 100 people.

The company is headquartered in Olkiluoto in the municipality of Eurajoki, western Finland. Posiva works together with numerous Finnish and foreign expert organisations from a multitude of fields, and commissions studies related to nuclear waste management from universities and other institutions of higher education as well as from research institutes and consulting businesses. Posiva has been planning the final disposal of spent nuclear fuel produced by its owners starting from its establishment in 1995. Posiva aims to start the disposal of spent nuclear fuel during the 2020s.

The Finnish solution for disposal of spent nuclear fuel is based on the KBS-3 concept, developed by SKB (Swedish Nuclear Fuel and Waste Management Co), the company responsible for nuclear waste management in Sweden. The solution is based on the multiple barriers principle. Radioactive substances are contained within several overlapping protective barriers so that no deficiency in one barrier and no predictable geological or climatic change will endanger the isolation. Spent nuclear fuel will be encapsulated into copper and cast iron disposal canisters and stored inside crystalline bedrock, in the depth of about 400-450 meters.

Posiva has been carrying out a research, development and technical design programme in ONKALO® since the construction for the underground rock characterisation purposes started in 2004. The confirming site investigation phase culminated in 2012 when Posiva submitted the construction licence application for the encapsulation plant and disposal facility. At the end of 2015, the Finnish Government granted a construction licence for the facility complex for geological disposal of spent nuclear fuel. This enabled extension of the underground excavations to construct the

tunnels leading to the deposition areas as well construction of the vertical shaft to serve the disposal canister transfers. Construction of the encapsulation plant started in June 2019, and proceeds in schedule aiming the building to complete in 2022. According to the current schedule, Posiva's goal is to achieve the readiness to submit the operating licence application at the end of 2021.

Posiva's main objectives since receiving the construction licence have been to bring the plans for the encapsulation plant and disposal facility as well as the disposal concept to such a state of readiness that the implementation of the project can start. Among other things, open issues referred in the safety assessment related to the disposal concept need to be resolved and the operating licence application and the associated documents produced. The objectives for the coming years is to have the engineered barriers of the disposal system ready for production, achieve the operational readiness of the encapsulation plant, manufacture the disposal operation equipment and construct the disposal facility to a point allowing the commissioning tests to be carried out and the disposal operations to be started.

As a part of the preparations for the start of the operations, Posiva has carried out and continues a series of various full-scale tests and demonstrations on disposal technologies. Posiva has participated in many Euratom projects related to geological disposal since 4th framework programme. In addition, Posiva is an end user in several other European R&D projects. Posiva has also acted as the coordinator of SeclGD and DOPAS projects and has led several work packages.

An important part in the preparations for the start of the disposal operations is developing the safeguards concept and measures for final disposal. This has been started in Finland in early phase. STUK (Radiation and Nuclear Safety Authority in Finland) has been implementing safeguards measures from the start of ONKALO® construction. Technical cooperation between the international authorities, IAEA and European Commission, and STUK and Posiva have been active for about

10 years already. Planning the safeguards measures requires active discussion and extensive exchange of design and operational information. Posiva's final disposal project is progressing to a phase where implementation of safeguards measures become topical. By becoming member of ESARDA Posiva sees an opportunity to strengthen its role in the development and harmonisation of final disposal safeguards.

working group reports

This section of the Connector has the objective to inform the ESARDA Community about the latest undertaking of the Working Groups' activities during the last six months. Each Working Group Chair has been invited to provide a brief article describing their findings in their fields of interest.

TRILATERAL WORKING GROUP MEETING BETWEEN FINAL DISPOSAL (FD), IMPLEMENTATION OF SAFEGUARDS (IS) & CONTAINMENT AND SURVEILLANCE (C/S)

by Katharina Aymanns,
(C/S Working Group Chair),
Klaas van der Meer
(FD Working Group Chair),
Walid M'Rad Dali
(IS Working Group Chair)

Within the 42nd ESARDA Annual Meeting three WGs FD, IS and C/S, held a joint meeting dedicated to "Safeguards by Design practices for the Encapsulation Plant and Geological Repository (EPGR) and the associated activities considering the evolution of the C/S technologies and Remote Data Transmission (RDT)". The intention of this trilateral meeting was to come together on a broader scale and to discuss possibilities for a future collaboration based on the specific missions and interests that all three WGs have in common. Furthermore, the aim to initiate such a meeting results from one of the last years World Café actions encouraging the WGs to organise more joint activities. About 60 colleagues from different areas of safeguards attended this meeting.

In the first part of the meeting, the following three presentations addressing different aspects of the overall topic were held:

Remote data transmission and automation of signal processing and event detection

Presentation given by Andreas Smejkal (Euratom, DG ENER)

The implementation of Unattended Monitoring Systems (UMS), which operate via Remote Data Transmission (RDT) is progressing in nuclear facilities of the EU. The inspectorates are planning to upgrade the existing RDT systems with the aim to achieve a common RDT infrastructure throughout the facilities in the different Member States. UMS operate without needing any human intervention. Those

systems are usually installed permanently in nuclear facilities and are continuously measuring safeguards-relevant nuclear materials and facility processes. For safeguards purposes a variety of sensors are used such as cameras, seals, radiation monitoring, weight measuring, process flow monitoring and more. The huge amount of data and information produced by devices require automated tools to allow a timely evaluation. Therefore, Euratom develops automated data acquisition and review software such as the Integrated Monitoring and Acquisition Platform (IMAP), the Integrated Review and Analysis Package (IRAP) and the New Generation Surveillance Review (NGSR). IRAP and NGSR are jointly developed by Euratom and the IAEA.

Laser Curtain for Containment and Tracking

Presentation given by Vitor Sequeira (JRC, Ispra)

The Laser Curtain for Containment and Tracking (LCCT) system is an active, continuous surveillance system based on real-time laser scanners, which allows an automatic event-based monitoring of a facility. It supports single and multiple line laser sensors. This laser system is capable to detect and track movements of objects like spent fuel casks and the penetration of a virtual fence. LCCT is able to interact with the Next Generation Surveillance System (NGSS) or other surveillance systems. Event detection is possible by reviewing and analysing the data of the LCCT using IRAP software or other systems. In addition, LCCT can be used to unattendedly monitor an automated nuclear material flow in a facility. This technology supports the inspectorates in their ability to carry out inspections remotely. The simulation of two application cases of



Next Generation Surveillance System (NGSS)
Source: Dr. Neumann

LCCT systems, the first one in a dry spent fuel storage facility and the second one in an encapsulation plant, were demonstrated.

Fibre optic sensing for containment verification

Presentation given by Tom Weber & Will Ray (Sandia National Laboratories, USA)

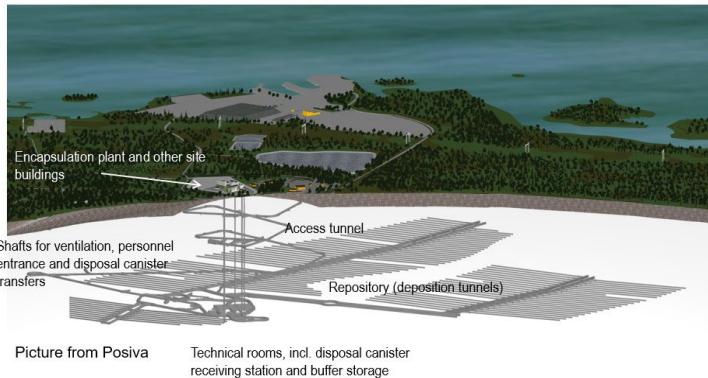
A research project currently investigates the use of coated optical fibre cable to detect the leakage of spent fuel casks stored in an underground repository. Cask breaches are indicated by the presence of alpha particles in the nearby of a spent fuel casks due to their short travel length. Coated optical fiber is sensitive to alpha particles as the interaction causes a specific signal that can be detected. Therefore, a combination of these coated fiber with special electronics located at the surface to monitor such a system might be capable to detect a spent fuel cask leakage after a repository is closed. Furthermore, seismic and thermal sensing using a distributed acoustic sensing system are under investigation. The research focuses on developing smart algorithms to distinguish localized cask-level disturbances from sources in the environment. In this regard, this candidate technology could be able to monitor thousands of locations throughout a repository.

In the second part of the meeting, a discussion on "Safeguards by Design practices for the EPGR facilities and the associated activities considering the evolution of the C/S technologies and RDT" took place.

The participants discussed and agreed that there is a future need to develop C/S devices in a way that enhances the modularity of such systems. The integration of different sensor technologies such as C/S, NDA, seismic monitoring and other new technologies as well as the further development of software able to interact and process data from different devices is becoming more and more important. Furthermore, it was stated that a sealing system, which can be applied and removed by the operator would be of high importance with regard to geological repositories.

In order to continue and to further deepen this first joint exchange the chairs of the tri-

Repository Layout at Olkiluoto



lateral meeting are planning to organize a roundtable discussion at the upcoming INMM/ESARDA Annual Meeting next year. The aim of this roundtable discussion is to share experiences, to discuss ideas and to define next steps addressing this challenge by gathering colleagues involved in this process such as inspectors, operators, and authorities.

STANDARDS AND TECHNIQUES FOR DESTRUCTIVE ANALYSIS WORKING GROUP (DA)

by Stefan Neumeier
(DA Working Group Chair)
by Evelyn Zuleger
(DA Working Group Vice-Chair)

The ESARDA Working Group on Standards and Techniques for Destructive Analysis (WG DA) meeting was held within the 42nd ESARDA Annual virtual Meeting with around 50 participants mainly from Europe and USA. 18 contributions on the status and perspectives of DA activities were presented to provide the Safeguards Community with expert advice on reference standards, procedures and analytical techniques for the analysis of a wide range of safeguards samples. S. Neumeier and E. Zuleger gratefully acknowledge the presenters contributing to the WG DA meeting making it a very interesting and diverse event.

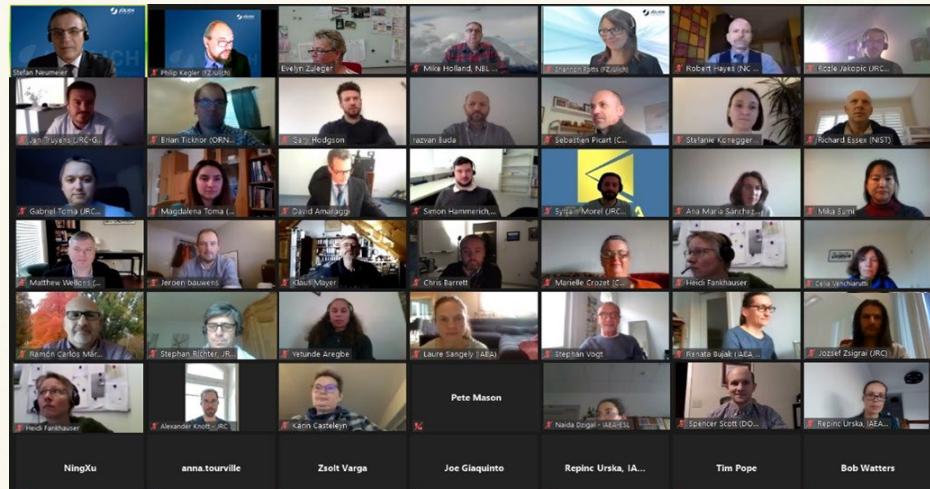
Organisationally, Stefan Neumeier

Pete Mason (NBL programme Office, US DOE) informed the community about the move of the office and the nuclear material from DOE Office of Science at the Argonne National Laboratory, Chicago to the National Nuclear Security Administration in Oak Ridge, Tennessee. The plutonium recertification effort is resuming after pausing due to COVID, and Mr. Mason reported on the status of analytical and lab renovation work at Oak Ridge National Laboratory. Yearly annual meetings with the customers are planned to resume. In addition the NBL PO proficiency testing program (SME) has resumed. Further updates will be announced via a new website and quarterly updates.

(Forschungszentrum Jülich GmbH) and Evelyn Zuleger (EC-JRC-Karlsruhe) are appointed Chair and Vice-Chair, respectively for the next 2 years.

Due to the virtual format of the meeting a large number of experts from USA participated in and significantly contributed to the WG meeting. The DA WG chair (Brian W. Ticknor, Oak Ridge National Laboratory, TN, USA) of the INMM's technical division on Materials Control and Accountability participated to inform about their activities. A significant overlap of the goals and activities of both working groups was identified. Therefore, a joint WG DA meeting within the framework of the joint INMM/ESARDA Annual Meetings 2021 in Vienna is initiated.

Despite of the influence of Covid-19, particularly on activities that require experimental procedures in laboratories, a remarkable progress was presented on the preparation, characterisation and certification of reference materials, the organisation of inter-laboratory exercises and proficiency testing (PT). Furthermore, progress on the development and optimisation of methods and technologies as quality control measures of analytical measurements performed by the IAEA's Network of Analytical Laboratories (NWAL), verifying the absence of undeclared nuclear materials and activities are shown. For instance the shelf life of Large Size Dried (LSD) spikes was significantly increased by the joint activities of the EC-JRC-Karlsruhe and Geel, allowing in the future to extend certificates of these reference



Screen shot of participants of the virtual WG DA meeting.

materials.

Additionally impressive progress regarding the production of microparticulate reference materials in Europe (Forschungszentrum Jülich) and USA (Pacific Northwest and Savannah River National Laboratories) was reported. Due to the complementary activities microparticle reference materials in a wide range of composition, size and amount are accessible. Very recently the safeguards laboratory of Forschungszentrum Jülich became a qualified member of the IAEA's NWAL for the provision of micro-particle reference materials.

Furthermore, the optically stimulated luminescence method was presented by North Carolina State University allowing for the determination of source energy and position as well as for retrospective imaging and characterisation of special nuclear materials.

Finally, the WG DA contributes significantly in cooperation with the WG NDA to the revision of the International Target Values (ITV) for measurement uncertainties in safeguarding nuclear materials. To this very important purpose the CETAMA (Commission d'ETABLISSEMENT des Méthodes d'Analyse, CEA, France) is evaluating data of PTs (Quality Evaluation of Analytical results in the Nuclear Industry (EQRAIN)) from the last 20 years in the context of the revision of the ITV 2010 values. Additionally, new ITV values are suggested from recent results of Hybrid K-Edge Densitometer (HKED) measurements performed at EC-JRC-Karlsruhe. Recently, more often measurements of uranium solutions with concentration <150 g U/L have shown that the uranium ITV for U KED in this concentration range are not feasible.



Set of Large Size Dried (LSD) spikes prepared at EC-JRC-Geel.

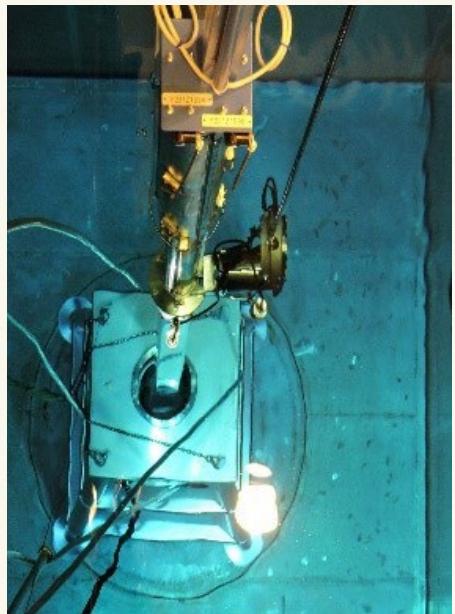
The results, discussions and the evolution of the WG DA itself are aligned to the implementation of findings of the ESARDA 2019 Reflection Group and the actions identified by the participants of the World Café during the 2019 ESARDA Symposium in Stresa.

The ESARDA WG DA will meet and discuss again together with the INMM counterpart at the Joint INMM/ESARDA Annual Meetings in August, 21 – 26, 2021 in Vienna.

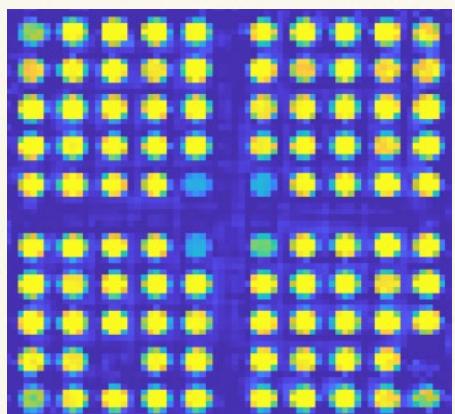
STANDARDS AND TECHNIQUES FOR NON-DESTRUCTIVE ANALYSIS WORKING GROUP (NDA)

by Hamid Tagziria
(NDA Working Group Chair)

ics, Fi) reported on a project aiming to quantify gamma emission tomography (QuantGET)



Passive gamma emission tomograph (PGET)



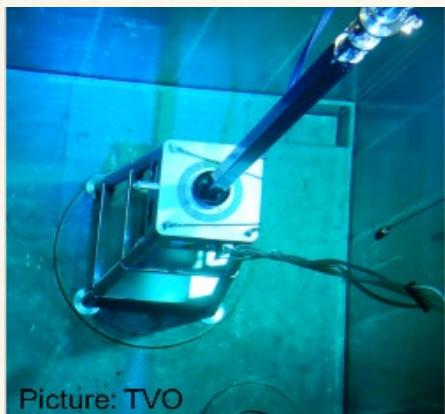
Imaging of a fuel assembly with pins missing

following the approval of PGET for safeguards inspections which itself provides qualitative images of spent fuel. Quantitative imaging is expected to yield more information not only for nuclear safeguards but also for other applications.

The latest developments regarding Passive Neutron Albedo Reactivity (PNAR) were presented to the NDA WG by T. Tupasela (STUK,Fi). PNAR has been built and shown to perform as intended for assaying fissile material in spent fuel whereby neutron multiplication is measured with great precision thus able to show clearly changes within a single assembly.

An update on International Target Value 2020 was given Claude Norman of the IAEA in which the scope of ITV, its history , the role of the stakeholders as well as the organisation, programme and current status , future and beyond 2020 were all presented.

Peter Dendooven (Helsinki Institute of Phys-

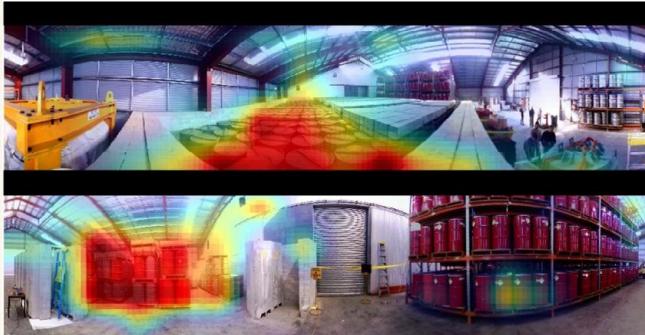


Picture: TVO

Passive Neutron Albedo Reactivity (PNAR)

The Potential applications of Gamma-Neutron Imaging in nuclear safeguards, nuclear security, decommissioning, waste management and non proliferation has been shown by D. Boardman (ANSTO,Au) and H. Tagziria (JRC,It). Good results of a gamma-neutron imager built by ANSTO based on compressed sensing with many positive attributes of current commercial systems (360° x 90° field of view, 40 keV - 3 MeV, fast,..) have been demonstrated in a number of situations and applications. A R&D collaboration with ANSTO- JRC to add neutron imaging and high resolution gamma-ray spectrometry capabilities is ongoing.

A activity reported on to the NDA WG by B. Cederwall (KTH,Se) concerned sensitive detection and 3D imaging of SNM using fast n-gamma correlations whereby an organic scintillators based gamma ray and neutron detection system for nuclear security (RPMs) and safeguards applications which has low background rates – low False Alarm Rates in RPMs and “simultaneously” perform detection and 3D Imaging.



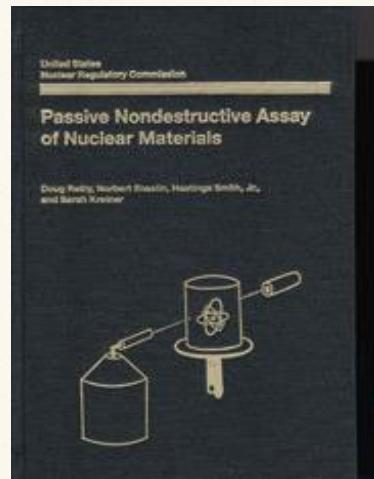
Imaging of a store

Still on imaging but this time of anti-neutrinos, A. Vacheret (Imperial College) Imaging anti-neutrino interaction using their detector called SoLid (based LiF:ZnS(Ag) and solid PVT) which has been operated successfully at the BR2 research reactor at SCK (Be) since 2018 with no loss of performance and which demonstrated the extraction of antineutrino signal with high significance and first directionality measurement and showed promising results for other application of the technology.

Recent NDA Developments at LANL Report were reported by D. Henzlova. In particular a) a suite of next-generation safeguards data acquisition electronics was developed to replace obsolete equipment, provide improved unattended features (Ethernet, RAINSTORM) and enhance list mode capability. B) UNCL capability to measure modern fresh fuel assemblies with high Gd content was enhanced via improved poison rod correction leading to reduction of the assay bias by an order of magnitude. C) MCNP reference book and updated PANDA manual are under development to enhance and update resources for safeguards personnel all of which would be very valuable tools for practitioners as well as in education and training.

The results of disarmament verification technology demonstration at SCK CEN (International partnership for Nuclear Disarmament Verification -PNDV) were presented by A. Borella (SCK/CEN, Be) . During 3 full weeks, 10 international measurement teams deployed and number of technologies such as Coincidence and total neutron counting, Gamma-ray spectroscopy and imaging and Imaging devices. A summary report is expected by early 2021.

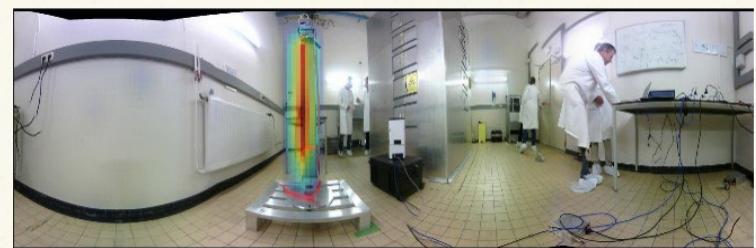
Another important topic and activity for the ES-



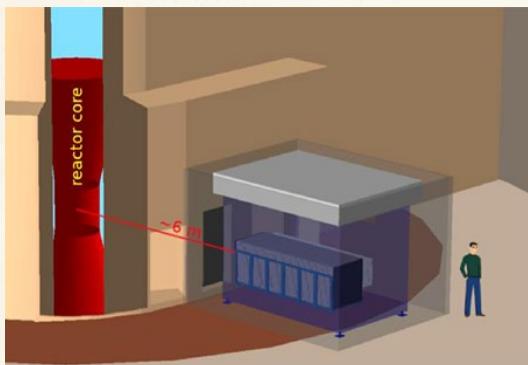
The Passive Non Destructive Assay of Nuclear Materials (PANDA) Book

ARDA community at large was presented by P. Chard and G. White (Mirion) concerning methodologies for NDA uncertainty assessment and reduction . It described and discussed advanced easy-to-use modelling tools which allow operators and practitioners to perform a robust uncertainty evaluations, reduce model simplifications, Improve accuracy by combining multiple measurements. It showed and stressed the importance of careful appraisal of waste distributions and an implementation which requires careful assessment per application.

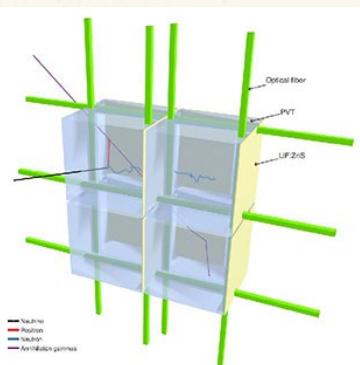
An update Good Practice Guide in Modelling was given P. Chard aiming to revive this important task and activity which has somewhat suffered from COVID situation. The previous work published and available to read and download from ESARDA bulletin no. 42 is a well respected work still referenced by other GPGs and other NDA industries, is still in need only an update e.g. to include any newer codes, techniques and methods and take into account an increasing emphasis on use for uncertainties. For a way forward it is proposed to create an NDA WG Sub-group of experts



Imaging of fuel elements IPNDV SCK/CEN



Artist view of SoLid antineutrino detector and the reactor



to refresh existing guide (Phase I) followed in Phase II by a “marketing drive” in order to gain wider audience for refreshed guide at universities, ESARDA training, new NDA professionals in industry, share with ASTM in US etc..

Moderated by J. Zsigrai (JRC-KRH) and continuing on work started in previous meetings the topics “NDA WG safeguards challenges & NDA solutions” were debated and discussed based on the so called “Stresa Table” which aims to bring together inspectors and scientists. The table need to be further developed and updated and the input from inspectors and scientists and the safeguards community at large including from the IAEA and EURATOM are all very important and much needed.

In summary, while it is recognised that as would be expected COVID-19 had a negative effect on the group activities, work by members of the NDA WG who has reported excellent progress and results.

Amongst the current and potential future activities I would mention the ITV2020 follow-up, further elaborate on NDA challenges and potential solutions, good Practice Guide in Modelling Update and marketing, specific topics and technologies of mutual interest such as imaging, tomography, data acquisition electronics, Synergies with other ESARDA WGs, INMM, World café, ASTM, the PANDA (Passive NDA of Nuclear Materials) and MCNP manual books which excellent for education and training.

A rich and ambitious programme indeed the NDA WG is embarking on with the imminent reinforcement of the group with vice chairs to support with the management, planning and the drive forward.

fer to various aspects of the potential benefit of applying data science tools to safeguards applications. The group discussed two aspects;

1. Use of business analytics tools and techniques to better interrogate the current extent of safeguards data, to more efficiently and effectively exploit it. Examples might include the use existing data to investigate trends through time, or across facility types; or to look at factors such as trends in reporting timeliness, or variance in the reporting outcomes from different inspectors. It might be that existing, standard business analytics packages could be applied to safeguards data to fulfil this type of analytical function. To date, the two main issues perceived by researchers attempting to help with this area are that: 1) The problems, challenges and requirements to be addressed are not well understood or defined. 2) Access to data for research and development is limited. As a result, researchers don't understand what the data looks like – its structure or content and fields. Even if real data is not available, to produce useful proxy or fabricated data, researchers need to know what the structure.
2. Development of advanced analytics tools and methods, to analyze safeguards data in new ways or integrate data that is not usually combined, or that could lead to the more effective fulfillment of current technical objectives. We noted that there is great R&D across WG members in this area, and the research community is generally eager to share the results of its work. Nonetheless, there was a need to better communicate what this research entails and its potential uses to other stakeholder communities.

On Thursday 19th, the group held a productive meeting with the EXP WG. Approximately 30 participants joined this joint meeting. The intention was to consider how the Safeguards and Export Controls regimes could bolster mutual benefits. In practice, the discussion focused on sharing ideas about data analytics using sources of trade data. It's important here to acknowledge the remit and ability of different user groups to use export control data in support of safeguards. For instance, Euratom

does not have a remit that extends to looking at the completeness of declarations made by its member states and so has no legal basis for using trade data. Notwithstanding this observation, the discussion proceeded considering how export control data is used to improve to IAEA safeguards.

A notable point of the discussion was the need to work on methods to clean and process existing trade data to improve its quality since it currently typically contains of reporting errors. Examples include human input errors such as typographical mistakes and the attribution of incorrect category codes to export items since some of the codes can be difficult to interpret. An overarching theme that emerged from the two days of meeting was that a stronger conceptual framework is needed to structure the discussion and our understanding of how, when and where data analytics could broadly support safeguards, if a coordinated, efficient research agenda is to be developed. Such a framework could highlight the objectives, interests and needs of the different user communities with respect to the types of data used and how improved analytical techniques could increase the efficiency and/or effectiveness of the methods currently employed to fulfil the users objectives.

Noting the need to improve communication and develop a better framework for understanding user group needs, we proposed to use both the ESARDA Bulletin and Connector to strengthen links between the user and developer communities. We hope to engage user communities to publish their needs and visions for how data analytics could improve the fulfilment of their objectives, and research communities to publish developments in their research, which some consideration of how advances could be applied to the fulfil the needs of different user groups.

Given the interest of our WG members in advanced data analytics tools, we plan to hold an off-cycle VTM meeting prior to the next Annual Meeting to discuss the potential to submit a special issue of the ESARDA Bulletin on data analytics topics, focusing on novel methods for existing data.

A new vice-chair was nominated to support the incoming chair, Zoe Gastelum, and is await-

ing confirmation by the EB. Keir Allen (AWE) expressed his thanks to the group for the support and engagement shown during his time as Chair and the WG thanked Keir for his 2.5 years of service.

IMPLEMENTATION OF SAFEGUARDS WORKING GROUP (IS)

by Walid M'Rad Dali
 (IS Working Group Chair)
 by Marko Hämäläinen
 (IS Working Group Vice-Chair)

The Implementation of Safeguards Working Group (IS WG) is a horizontal issues working group of ESARDA. Its objective is to provide the Safeguards Community with proposals and expert advice on the implementation of safeguards concepts, methodologies and approaches aiming at enhancing the effectiveness and efficiency of safeguards on all levels. This WG is also a forum for exchange of information and experiences on safeguards implementation.

The IS WG normally organises at least twice a year a two-days meeting. This year, due to the COVID-19 pandemic, the WG met only once in the margins of the 42nd ESARDA annual meeting that was held through a videoconference format from 17th to 19th of November 2020.

This one-day meeting was hosted by the French Institut de Radioprotection et de Sûreté Nucléaire (the IRSN) and organised in two parts, the first part being open to anyone while the second part was open only to the IS WG members or other members of ESARDA upon request. The IS WG had also the opportunity to organise jointly during an afternoon a trilateral meeting with the FD WG and the C&S WG.

The IS WG part 1 meeting, organised in an open format and during which more than sixty people took actively part in the discussions, was the opportunity, inter alia, to discuss about the current status of the two main themes the group is thoroughly involved in since 2019 and for which lots of work have been provided by

the Project Managers during 2020, in particular:

- Inspection regime in “ESARDA countries”: A finalised questionnaire was sent in June 2020 to the regulatory bodies of many countries in Europe, but also to some countries outside the continent. This is the first step of a study for which the WG hopes to deliver first results during the next INMM & ESARDA Joint Annual Meeting. 9 answers were already provided.
- Safeguards by Design in “ESARDA countries”: A finalised questionnaire was sent to the regulatory bodies of many countries in Europe in November 2020. This questionnaire will also be sent to other countries soon. The gathered results will be processed in order to deliver first outputs during the next INMM & ESARDA Joint Annual Meeting.

It is also expected that the IS WG will release for this joint meeting a 3S paper.

For all those projects, there were implementation delays due to the pandemic. Nonetheless, it is hoped that the first expected results will be released on time.

Regarding the World Café, five members of the group also presented on the activities performed within their organisation also as a follow-up of actions from the World Café report they decided to pick up to implement in 2020. This part of the meeting was also the opportunity to strongly encourage the participants to read the report and to apply actions they could implement in 2021.

The IS WG part 2 was organised in a closed format. More than 25 people were present, including the core group of the WG. During this second part, the WG proceeded to the traditional roundtable discussions during which each participant from authorities, facilities or research institutions can present the last developments in the safeguards fields in its respective country/facility/institution and was informed about the last safeguards status updates of Euratom and the International Atomic Energy Agency. A major topic addressed was the consequences of the COVID-19 pandemic on the safeguards inspections regimes.

About the coordinating role of the IS WG in the drafting process of a new State Level Safeguards chapter for the next edition of the ESARDA Syllabus currently under revision, the group reported on the current status of the drafting process. The draft chapter, which is supposed to be subdivided in four subchapters, will be delivered at the beginning of next year. This work involves members of the International Atomic Energy Agency, the Joint Research Centre, the US Department of State, the US Department of Energy and the Federal Agency for Nuclear Control.

Finally, the trilateral meeting with the FD WG and the C&S WG was considered a big success. The three WGs decided to further collaborate in 2021 on the topic "Safeguards by Design practices for the EPGR facilities and the associated activities considering the evolution of the C/S technologies and measures and the RDT" and to proceed as a first step to the organisation of a roundtable on this subject during the next INMM & ESARDA Joint Annual Meeting.

EXPORT CONTROL WORKING GROUP (EXP)

by Christos Charatsis
(EXP Working Group Chair)

The A New Era for Export Control Capacity Building Programmes.

As the COVID-19 pandemic continues having an impact on all aspects of our life, traditional providers of capacity building activities in export controls move forward to offer online trainings and e-learning curricula in order to respond effectively to current challenges. For example, the EU Partner to Partner Programme (EU P2P) plans to convert its basic awareness-raising curriculum to e-learning modules while several of its specialised trainings have been transformed into webinars. Among these activities, the 6th EU P2P Summer University on Strategic Trade Controls was organised by the EU from 17 to 21 August, 2020. The University stands out as a flagship initiative offering to non-EU export control ad-

ministrators a one-week full-immersion in contemporary export control topics. This year the University gathered officials from Middle-East, North Africa, South East Asia and Central Asia and covered topics such as legal aspects of a trade control system, reconciling academic freedom with export control objectives, data mining approaches for targeting risk assessment techniques as well as the usefulness of export control instruments in the fight against the COVID-19 pandemic.

Capacity Building in the EU

On the internal front, the 13th JRC-NSA Licensing Seminar was organised in six online modules, in the period from September 15 to October, 6, 2020. During the seminar, an average of 40 experts connected to follow each session and engage in discussions on Covid-19 crisis and export controls, the [Strategic Trade Atlas](#), the [Tools for Innovation Monitoring \(TIM\)](#) and its dual-use space, the [Export Control Handbook for Chemicals](#), cyber surveillance controls and emerging technologies, end-use/end-user assessment and trade controls in research. Since 2007, more than 300 licensing officers from the EU have attended the seminar.

12th ESARDA EXP-WG Meeting

On December 4, the ESARDA Export Control Working Group (EXP-WG) convened for second time in 2019 in order to examine, this time, the usefulness of data driven approaches for implementing trade controls as well as for designing and assessing capacity building activities in the area of trade controls.

The discussions revolved around three main topics:

1. Methodologies for assessing trade control systems including identifying risk areas and key stakeholders;
2. Data management to the benefit of both safeguards and trade controls implementation and;
3. Data mining examples for Customs targeting and profiling. The meeting provided also an opportunity to consider options for future research initiatives to be taken in the framework of the ESARDA EXP-WG.

In connection to the second topic, a recurrent focus of the group's activities is the mutually reinforcing role of safeguards and trade controls for nuclear security and non-proliferation purposes. In this context, the group initiated a discussion, as whether data gathered for either purpose (i.e. under export control or safeguards obligations) need to be shared on systematic basis among different users (nuclear regulators, nuclear operators and export control authorities).

A diverse audience of more than 25 people from nuclear regulators to non-proliferation academics, from nuclear service providers to export control experts participated in the discussion centred on the usefulness of export control data and systematic approaches for implementing risk-based trade controls and targeted capacity building activities. A more detailed account of the Group's deliberation is provided in the Communication Report, now available in CIRCA BC.

13th ESARDA EXP-WG Meeting

Initially foreseen for May 2020, the 13th EXP-WG was eventually held by online means on November 18-19. Dual-Use licensing authorities, nuclear regulators, EU-based academia and NGOs, US national laboratories, European Commission, and the IAEA and, last but not least industry representatives came together to conduct a virtual meeting and address in a timely and open manner an agenda of high relevance to the export control and broader ESARDA community.

The main topics of the discussion addressed all those factors shaping the present and future of export controls in the nuclear sector and beyond: geopolitics, export compliance in research and industry settings, the suitability of export controls to tackle challenges linked to emerging technologies as well as the interplay of nuclear safeguards with export controls. The latter was also addressed in a Joint Session organised by the Chairs of the VTM and EXP WGs, Keir Allen and Christos Charatsis with a view to bringing closer the two communities and furthering exchanges on joint exercises and ways ahead to enhance the effectiveness and efficiency of safeguards implementation.

Furthermore, the EXP-WG discussed initial ideas of a closer collaboration with the INMM's counterpart Working Group in view also of the joint ESARDA-INMM Annual Meeting, in August 2021. The Chair presented also the outcomes of the World Café exercise and discussed with the Group ideas to take up additional actions from the World Café report.

Additional information on the main points and outcomes of the discussion will follow soon in a communication report to be published in CIRCA BC.

TRAINING AND KNOWLEDGE MANAGEMENT WORKING GROUP (TKM)

by Thomas Krieger
 (TKM Working Group Chair), and
 Riccardo Rossa
 (TKM Working Group Vice-Chair)

This report summarizes the presentations held during the TKM Working Group (WG) meeting at the 42nd ESARDA Annual Meeting (November 16 – 19, 2020) including central discussion points as well as actions to be envisaged within the next years. At this occasion, Riccardo Rossa from the Belgian nuclear research centre (SCK CEN, Belgium), was elected as new vice-chair of the TKM WG. About 20 participant attended the TKM WG meeting.

To recall, the main objectives of the TKM WG that will be further intensively pursued in the next years are to promote nuclear safeguards and non-proliferation education and training, and to organize the ESARDA course on nuclear safeguards and non-proliferation.

In the first part of the TKM WG meeting, four presentations were given. First, Thomas Krieger (Forschungszentrum Jülich (FZJ) GmbH, Germany) gave an update on the ANNETTE (Advanced Networking for Nuclear Education and Training and Transfer of Expertise) project that was carried out from January 2016 till December 2019, and that pursued the goal to enhance the Europe-wide efforts initiated in the past decades by different organizations

belonging to academia, research centres and industry to maintain and develop education and training in the different nuclear areas. In his presentation the contributions of TKM WG members within ANNETTE were shortly described: 1) Lectures on Nuclear Safeguards and Nuclear Security at the ANNETTE Summer School, 2) ANNETTE course on Nuclear Safeguards at SCK CEN and FZJ, 3) Workshops on Safeguarding the nuclear fuel cycle, State-level safeguards concept, and Proliferation resistance methodologies, and 4) Collection of short videos (<https://www.youtube.com/playlist?list=PLBoj6IWqIZNFT-brkuslnhHX-mAzPi7chS>) on Nuclear Safeguards topics.

Second, Kamel Abbas (JRC Ispra, Italy) gave an update on the ESARDA course on Nuclear Safeguards and Non-Proliferation. He recapped its 18th edition in April 2019 with 50 participants from Africa, Americas, Europa and Asia and 20 nationalities. Due to COVID 19, this year's ESARDA Course had to be cancelled and it is planned to have a remote ESARDA Course in April 2021. Therefore, practical exercises and visits of laboratories at JRC cannot be performed as usually and Kamel proposed as a TKM WG action to develop a remote "Hands-On" training. Then Kamel gave an update on the preparation of a New Edition of the ESARDA Course Syllabus: Only two chapters are missing that will be provided by the end of February 2021. There was, however, a lively discussion on the structure and content of the Syllabus, for example:

- 1) important topics such as "Nuclear Fuel Cycle", "Final disposal of Nuclear Spent Fuel" and "Technology foresight and upcoming challenges in Nuclear Safeguards" are not covered,
- 2) the length of some chapters do not reflect the time slot of their respective presentations during the ESARDA course, and
- 3) some chapters are not presented at the ESARDA course at all. These issues are planned to be addressed in short term. For the proofreading of the chapters Environmental Remote Sampling, Environmental Sample Analysis, EURATOM: Historical facts, Non-Destructive Assay in Nuclear Safeguards, SLC/A, and CS Kamel asked for volunteers. It was proposed that the presenters of the respective lectures at the ESARDA course should be asked to proofread the Syllabus chapter as long as they are not co-authors.

Third, Gabriel Pavel (ENEN, European Nuclear Education Network, Belgium) presented SaTE (Safeguards Training and Education) advancements. The objective of the SaTE project is to strengthen the capabilities of the beneficiary national regulatory agencies and their support organizations (Ministries and any other associated organizations) in charge of nuclear safeguards. The training and education for the (potential) staff of these organizations will be done by 1-week and/or 2-week courses and/or by a one year master program (first round Sept. 2021 – Sept. 2022) coordinated by Politecnico di Milano (<https://www.nuclearsafeguards.test.polimi.it/>). Gabriel reported that the scientific committee has 1) defined the topics to be taught during the courses resp. the master program, and has 2) created the Intended Learning Outcomes (ILOs) for all topics. Currently the lecturers are identified and invited to contribute. The discussion here was mainly focused on the format of the master program: What is the work load of the full time master, and can it be studied while working full time? Would it be possible to study half-time and finish the master in two years? Is it foreseen to include both professionals with a technical as well as non-technical background in the same master education?

Fourth, Mike Beaman (ONR, Office for Nuclear Regulation, United Kingdom) gave a presentation on "Training and Knowledge Management in the ONR safeguards team". In order to build a team of safeguards inspectors, nuclear material accountants and specialist support staff (9 in mid-2017 and more than 30 at the start of 2021), the capabilities of a suitably qualified and experienced person as well as 12 safeguards competencies (such as UK Safeguards policy and non-proliferation, Measurement Techniques and Equipment, Safeguards Obligations and NCAs, and Domestic Legal Framework) were defined. Trainings are performed depending on the competence-level of individuals and related sub-divisions.

In the second part of the TKM WG meeting, past and future WORLD CAFÉ actions have been discussed. Selected results are presented here (the action numbers refer to the respective numbers of the WORLD CAFÉ report):

- In order to cooperate with organisations such as INMM (action 4.2), the TKM WG continues the collaboration with the respective counterpart at INMM, especially supporting the INMM/ESARDA conference 2021, and will make contact with VERTIC (Verification Research, Training and Information Centre). Also it is envisaged to take part at ENEN's General Assembly (March 2021) and NESTet (November 2021) both held in Brussels (Belgium). Furthermore TKM WG members will contribute to trainings in Nuclear Safeguards (see SaTE, action 4.7).
- Regarding "Modernise CIRCABC and consider consolidating exchange platforms" (action 6.2), "Create a safeguards knowledge dataset" (action 6.5), and "Create a database of opportunities (organisations, job opportunities, fellowship...)" (action 6.6), it was recommended to take advantage of INSEN (International Nuclear Security Education Network) experiences.
- Some TKM WG members showed interest in becoming a member of the INMM Certification Program Working Group for International Safeguards Professionals.
- It is envisaged to give a feedback on the 3-hour "Basic Training Course on IAEA Safeguards" which is an online training course aiming to provide a basic understanding of IAEA Safeguards and to give an overview of the resources that are available for States to strengthen the safeguards implementation in their countries.
- Willem Janssens (JRC Ispra, Italy) emphasized the importance of knowledge retention (related to action 4.4 of the Reflection Group 2019) for teaching and training, e.g., regarding the documentation of real cases of nuclear safeguards and (non-)proliferation. That allows to understand 1) where do treaties/rules/practices come from, 2) why were they made like they are (i.e., some things might have been left out for good reasons, or others might not have been included because not yet available 20+ years ago), and 3) how they need to be interpreted. Willem asked for volunteers from the nuclear safeguards and the strategic trade control community who would like to contribute to this knowledge retention effort.

EDITORIAL COMMITTEE WORKING GROUP (ED-CTEE)

by Andrea De Luca
 (ED-CTEE Working Group Member)

Since the last issue of the ESARDA Connector, the Editorial Committee has strived to improve the work output and continuity of the ESARDA Publications, even in these challenging times. Here below are some of the main activities and achievements.

ESARDA Bulletin Indexation

In July, the Bulletin Editors were informed that Scopus had given us a positive outcome for the selection of the Bulletin to be indexed with them. All documents were sent back signed, and in November after having provided the docu-sign form to Elsevier, agreeing on providing them access to our content, we have received confirmation that the indexing process has started in order to include all the backlog of past Bulletin issues in the Scopus database. Furthermore, the Bulletin has also been submitted to other citation-index databases.

- Web of Science (pending)
- DOAJ (rejected for not having DOI on single articles)

ESARDA Annual Meeting Working Group

As is the case for every annual meeting, the ESARDA Working Groups have met in parallel to the main event, including the ESARDA Committee that now counts a wide group of people from a broad array of nuclear safeguards disciplines. This has ensured the quality of the latest achievements in ESARDA publications, providing valuable feedback in terms of content and to the peer-reviewing process. Overall, the Committee now counts approximately 20 people and keeps on growing thanks to the lively discussions taking place.

During the November meeting Elena Stringa, the exiting Chair, presented a broad overview of the activities that took place in the last six months, and brought up certain issues that needed to be discussed, and decided upon, during this meeting. One such issue regarded the difficulty in ensuring the inclusion of articles from certain nuclear safeguards topics that not necessarily deemed academic enough to ensure the inclu-

sion in the ESARDA Bulletin. As such, the Bulletin will now be going through a yearly review by Scopus, to evaluate the quality of its content. However, this delicate issue, whether to include articles from less academic topics, started a lively debate, as it is clear to all that nuclear safeguards is a multi-faceted discipline, composed of academic/scientific topics and of legal/political issues that co-exist to complete the sphere of safeguards. As a colleague quoted: "*Nuclear safeguards is too political to be scientific and too scientific to be political!*"

This debate was discussed at length, and all agreed that one cannot exist without the other, so all articles are welcome to be submitted to the Bulletin as long as certain guidelines are followed. Guidelines that will be provided in a Publication Policy document that will be drawn up by the Committee and made public for all interested authors to refer to before submitting a paper. As proposed and discussed during the meeting, the guidelines will take into account existing manuals exploring the evaluation of scientific R&D. Along this line, possible criteria that the article will need to meet - whatever the discipline of origin – might be:

- Novelty/Innovation
- Creativity
- Systematicity
- Transferability/reproducibility

Aspects that are expected to be covered by the contributions are e.g.

- Objectives of the contribution
- Description of the novelty brought by the contribution
- Method/technique used
- How generally applicable are the findings or the results described

New Editorial Committee Leadership

After the great work that has been put into reshaping the Committee, the Chair of the Editorial Committee for the past four years, Elena Stringa of the JRC, has officially handed over the role of Chair to Joshua Rutkowski from Sandia National Labs, and taking his place as Vice-chair is Guido Renda of the JRC. We are sure that the excellent work will continue and that more members will be willing to submit their interest in key roles of this fundamental working group of ESARDA.

featured articles

This section presents prominent articles on the latest news and topics of interest in the safeguards community

PREMIER MINISTRE



COMITE TECHNIQUE EURATOM

IMPACT OF THE COVID-19 PANDEMIC ON THE IMPLEMENTATION OF INTERNATIONAL SAFEGUARDS IN FRANCE

by F. Bonino, J. Oddou, E. Vial,
C. Calvez

The sanitary crisis due to the Covid-19 pandemic had several significant impacts on the implementation of international safeguards in France during the first semester of 2020. They were due to the:

- Restrictions on travels for French authorities and operators' staff,
- Limitation of access to the national territory and to nuclear sites for international inspectors,
- Modified programs of activities on nuclear sites, including delays on planned inventories,
- Suspension of Euratom "physical" inspections for about 2 months,
- Declaration obligations and deadlines unchanged.

At the end of February 2020, the situation of the coronavirus Covid-19 infection deteriorated in Europe and the French authorities put in place specific measures, especially for people coming from infected areas who were requested to respect a quarantine of 14 days. Beginning of March, the Comité technique Euratom (CTE) and its technical support staff (IRSN) had to cancel any travel to risk areas, in France and abroad. A state of health emergency was declared in France on March 11th and the general containment of the population was implemented as of March 17th until May 11th, implying the generalization of teleworking and specific licences for the strategic staff of the nuclear operators who

needed to be on site.

The European Commission informed the Member States that all physical verification inspections of nuclear installations in the EU would be temporarily suspended as of March 16th, 2020, including for joint inspections with the IAEA. Nevertheless, declarations by operators pursuant to Regulation n° 302/2005 remained an obligation under the same deadlines. The IAEA did not suspend its inspections and national declarations pursuant to the Safeguards Agreement and the Additional protocol (AP) had to be provided as usual.

During this period, because of strict legal measures limiting the geographical mobility, the staff present on site was in a very limited number and the activity was exclusively dedicated to ensuring the operator's industrial mission taking into account nuclear safety and security of the facilities. As the nuclear material management was not in the top priorities, practical arrangements had to be found with the facilities, for example:

- On Georges Besse II gas centrifuge enrichment plant, the operator (Orano) proposed to suspend the daily deliveries to the IAEA mailbox, because it required a competent person on site, unnecessary otherwise. As a compensatory measure, the Agency accepted the French authorities' proposal, agreed with Orano, to receive by encrypted emails, on a daily basis, the non-sensitive data that are usually posted in the mailboxonsite;
- Orano staff usually dedicated to the Euratom and IAEA inspections being at home, without the possibility to come for a short notice inspection, we faced difficulties to escort IAEA inspections. CTE and the operator agreed specific exceptional measures to be able to welcome an IAEA inspection in good conditions;
- Due to the suspension of on-site inspections by Euratom, nuclear material containers could not be verified and sealed as planned but the delivery time could not be delayed. In order to maintain the economic activity, the Euratom inspectorate agreed to follow an alternative procedure to adapt to this exceptional situation: the

operator put its own seals on the containers, scan the weigh tickets, provided the seals references and the weigh tickets to the Commission, the receiver checked the seals references and sent a written report transmitted to the inspectorate;

- Due to the containment measures, to the limited staff on site and to material constraints, some inventories planned in April and May could not be carried out and had to be postponed in June or during the summer 2020. In some cases (less than 5), the limit of 14 months between two inventories (article 13 of Regulation n° 302/2005) was not respected and official argued requests for specific derogations had to be made by the operator with the support of the CTE.

Concerning international declarations, deadlines were unchanged despite the sanitary crisis and the operators kept on with their declarations as usual (e.g. advance notifications). As far as the AP is concerned, the deadline for the annual declaration (15th of May) could be respected without any difficulty. The first quarterly declaration for 2020 was sent in time (May 30th) but had to be complemented later because not all information could be gathered on time.

The French authorities (CTE) had to provide information to the inspectors on the specific modalities to travel in France (attestation by the employer, personal certificate). In these particular circumstances, CTE insisted on the necessity to have at least one inspector fluent in French to be able to exchange with the police and the operator staff who were not the usual contact points.

During the containment, only one Euratom inspection took place in Melox facility (simplified by the fact that the Euratom inspector happened to live in France). The objective was to avoid a time consuming knowledge acquisition following a technical failure on surveillance equipment. At the end of April, inspectorates started to plan inspections again in view of the decontainment as of May 11th. A lot of effort was spent to prepare the conditions for a smooth access to nuclear sites taking into account all the practical constraints (8 inspections were planned during the week

starting on May 11th). The specific case of Euratom and IAEA inspections not being foreseen in the situations covered by the exceptional international travel certificate, CTE had to request to an Interdepartmental Commission a nominative derogatory authorization to enter the French territory for each travel and for each inspector who needed to cross the French border until the end of June (delay of instruction of approximately 48 hours including nights, holidays and week-ends).

On April 28, the French Prime Minister presented the national strategy for progressive decontainment, based on two phases:

- First phase from May 12 to June 2,
- Second phase from June 2 to summer.

During the travels in France, the inspectors had to present the employer's certificates provided by the IAEA or the Commission and a personal certificate for each travel out of home or hotel, and to explain to the French police that their travel was related to imperative professional reasons in case of control. These attestations were in theory sufficient, however international inspections constitute a very specific case which was not specifically listed. In order to facilitate the control by the police on the French territory, the CTE decided to provide a supplementary letter issued in French by the CTE as Prime Minister's entity (with the phone numbers of the CTE's staff) which could be shown to the police in case of question concerning the specificity of the Commission and IAEA inspector's mission.

In practice, the international inspectors who travelled in France during this troubled period did not experience any difficulties.



Schweizerische Eidgenossenschaft
 Confédération suisse
 Confederazione Svizzera
 Confederazion svizra

Swiss Federal Office of Energy SFOE

SAFEGUARDS ACTIVITIES IN SWITZERLAND DURING THE PANDEMIC 2020

by Fausto Medici

Despite all the constraints given by the current pandemic situation, all "regular" inspections during 2020 have been performed so far without any significant delay. Therefore, it is expected that the broader conclusion will be confirmed also for 2020.

Some "support" inspections and IAEA equipment upgrades were postponed. Two transport campaigns from one NPP to the interim storage facility were postponed for technical reasons not bound to the pandemic. This fact helped also to have less inspections than planned.

Especially during springtime restrictions and requirements due to the pandemic changed rather frequently. This aspect made the planning of inspections quite a challenge. During the lockdown it was necessary to coordinate among others with the border control authorities communicating date, time and location of the entry point into Switzerland of the IAEA inspectors. Concerning the quarantine requirements the Swiss SSAC got the confirmation from the health authorities that for IAEA inspectors the foreseen exemptions according to the Swiss legislation could be applied especially if the stay in the country is less than five days. The Swiss legislation requires the presence of a state inspector during IAEA activities. From this point of view there were no significant difficulties since all state inspectors could easily fulfil the required measures and conduct all inspections with the IAEA. It must be noted that the lockdown regime in Switzerland was not so severe compared to other European countries.

However, since Switzerland is a federal state, in addition to the federal rules each canton can add additional ones. This is happening from the beginning of the pandemic since the regional differences concerning infection rates

were/are quite big. Furthermore, it is required by Swiss legislation that companies have the duty to protect their workers. This means that companies can also require additional measures and these can vary considerably from one company to the other. For example one NPP requires IAEA inspectors to travel by car from Vienna to Switzerland and during the lockdown a test by a local physician before inspecting the facility was mandatory. All other nuclear facilities do not have up to now special requirements that need special organisational or logistical efforts. Since the beginning of the crisis all IAEA inspections were performed by two inspectors. From the SSAC side, besides few exceptions, only one state inspector was present. All in all, besides the additional organisational efforts, the according to the SLA planned IAEA activities in Switzerland could be performed relatively smoothly, even an unannounced inspection (2 hour-notice) and a complementary access (24 hour-notice).

sck cen

IMPACT AND CAUSES OF COVID-19 PANDEMIC FOR BELGIUM BASED SCK CEN

by Alessandro Borella

1. What impact did C-19 cause in terms of external and internal communication in your organisation?

High need for information: from internal and external employees to healthcare customers

2. What communication strategy did you deploy towards your various stakeholders?

Urgent in-house communication

We set up a process for reaching employees through combinations of emails, intranet postings, flyers/posters, FAQs, digital signage... The plan identified simple key messages, a reliable process and the vehicles for providing continual updates and collecting feedback from employees.

- **Stating the facts:** sharing timely, accu-

- rate information. Providing clear instructions about what to do.
- **Demystify the fear:** communicating preventive actions we took to avert or contain transmission of the coronavirus at work. Focusing on technology and techniques for employee safety, hygiene, biohazard disposal...
- **Promoting safety steps** that employees can take at work: use posters, emails; intranet postings, supervisor talking points, FAQs/Q&A's. Describing the potential impact of an outbreak on our operations, services, travel, supply chain, business, restaurant, events... so employees can plan accordingly.
- **Promoting safe travel policies:** communicating about the organization's stance on employee travel and restrictions. Promoting alternatives to travel such as web conferencing and phone meetings. If employees must travel, we offer clear guidance on safety protocols, augmenting with guidance from federal institutes.
- **Supporting employees:** the COVID-19 crisis has been emotionally challenging for many people, changing day-to-day life in unprecedented ways. We acknowledge these difficulties, thanked everyone individually for flexibility and creativity, try to empower them to deal with quickly evolving situations and provide a safe space for employees to express if they are feeling unsafe for any reason.
- **Promoting efficient home working:** sharing helpful tips and tricks to tackle work at home (while taking care of the children), paying specific attention to ergonomics at home and providing online tools to eliminate technological barriers in online communication. Communication is key.
- **Ensuring team spirit:** You could consider it the biggest HR experiment ever. The coronavirus keeps hundreds of thousands of office workers glued to an improvised home office. The use of VPN is booming. Also at SCK CEN. In these difficult times, 'Together strong' applies more than ever. How can you continue to be a strong team when half the team is working on the site and the other half at home? We shared practical tips, organ-

ized accessible challenges and offering possibilities to support a colleague.

<https://twitter.com/agamzec>

<https://twitter.com/Schreini82>

- **Tone of voice:** serious, tact and attitude, communicate only if you have something useful to say, listen and keep up the dialogue.

Tools:

- Interactive via Q&A (video conferencing)
- Daily/weekly internal updates via direct mailing
- New intranet

External communication

Clear communication for reaching external stakeholders, customers, suppliers...

- **Objective:** stay close to customers to not worry them, be transparent about business impact on services and production and to make sure our company is presented in the right light at all times. Specifically for the production of medical radioisotopes, we installed a close contact providing our partners a daily update. Medical radioisotopes can only reach the patient, if each link in the chain is properly working (SCK CEN for the irradiation services, IRE for the chemical purification process, TRANSRAD for the transport).
- **Tone of voice:** communication made for people not consumers, showing expertise, being cautious, but positive

Tools:

- One-to-one contact within the usual network (mail/phone)
- Digital communication via
 - 1) Website: one page for external audience on which measures and information about business continuity is continuously updated.
<https://www.sckcen.be>
 - 2) Social media: as an extender of key messages and trigger to website portal with extensive info Twitter,e.g:
<https://twitter.com/SCKCEN/Covid19-1>
<https://twitter.com/SCKCEN/Covid19-2>
<https://www.linkedin.com/>
- Direct mailing: with clear measures and their impact at service level

3. What feedback, questions and concerns (about safety for example) from the stakeholders did you deal with?

It was quickly clearly stated for external stakeholders that SCK CEN remains 100% operational during the coronavirus crisis. As for our employees, the main question is how the federal government's advice would be practically implemented at our research center. This is a continuous process, as the federal government was introducing more stringent measures in March, gradually relaxed those (in the framework of an exit strategy) and had to step up the measures due to the fact that Europa is experiencing a fresh spike in COVID-19 cases.

4. Any interesting good practice or experimentation...

We set up a cross-functional COVID-19 crisis/response team with appointed members from every function and discipline to assist. Team members were needed to step out of their day-to-day roles and dedicate most of their time to virus response. Give them time, space and tools to do so.

5. The new tools used?

- It paid to test and monitor home-working technology before providing it en masse. Having the right technology, systems and process in place has always ensured being business-critical.
- In tandem with HR we developed and implemented clear communications sharply focused on creating a distinct source of truth for employees in the crisis. It is critical that this is empathetic in tone and allows two-way discussion so worries and difficulties can be raised and addressed.



COVID-19 AND IAEA SAFEGUARDS IMPLEMENTATION IN 2020

Jeremy Whitlock
(IAEA)

Throughout the COVID-19 pandemic, despite unprecedented challenges to travel planning, office access, and the need to protect the health and safety of staff, the IAEA has continued to implement safeguards across the world. It accomplished this partly by focusing its in-field safeguards verification work on the most time-critical needs, and rescheduling less urgent activities, such as equipment installation and maintenance. In some cases novel solutions were required, for example, the chartering of aircraft to transport inspectors to and from their destinations.

Despite these efforts, numerous technical challenges to verification were encountered in many States due to the unique circumstances of a global pandemic. Every effort was made to address these challenges in a timely manner on a case-by-case basis, relying upon the essential cooperation of the States concerned (including support for any increase in the frequency and intensity of planned activities), while ensuring consistency through the early establishment of an ad hoc IAEA review group of safeguards experts.

Unfortunately, the COVID-19 pandemic continues its stranglehold on global activities as 2020 draws to a close, and 2021 begins. The IAEA will continue to rely on the resilience of its infrastructure, the professionalism of its staff, and the support of State and Regional authorities, operators, and contractors, with an expectation of being able to draw soundly-based safeguards conclusions at the end of the year for all States.



HOW THE COVID-19 PANDEMIC Affected THE SAFEGUARDS IMPLEMENTATION IN CZECH REPUBLIC

Šťastný Ondřej, Alois Tichy and Adam Pavlik
(SUJB)

COVID-19 pandemic affected the whole world and safeguards implementation was no exception. The responsibility for safeguards implementation in the Czech Republic is carried out by the State Office for Nuclear Safety, specifically by the Nuclear Non-Proliferation Division.

During times of lock-downs when the state of emergency has been declared at the national level, the Division implemented a set of measures to ensure that the implementation of safeguards will be kept uninterrupted. Those measures specifically consisted of staff allocation into three groups to minimize the risk of contracting COVID-19 and quarantine for the whole team. Two groups alternated between work and home-office and there was always only one person present within the office/room. The third (smaller) group was kept on permanent home-office as a reserve for such case of the both rotating groups getting infected and ending up in quarantine. Face masks were mandatory indoors at all times. The Division provided periodic updates for the IAEA and Euratom on new restrictions impacting inspections and number of positive cases in the Czech NPPs.

During the spring lock-down the IAEA and Euratom inspectors were added to a special white-list for persons allowed to cross Czech borders. The Division also issued written confirmations for inspectors transiting Czech Republic for inspections in third countries. Despite these measures, several routine PIVs were postponed (but the 14 months limit be-

tween the PIVs was kept) in order to reduce the risk during times when the amount of positive cases was peaking.

At Czech NPPs, non-essential staff worked from home. Face masks and disinfection were mandatory for all staff, temperature measurements were carried out at the gates and all non-essential visits were prohibited. The spread of COVID-19 at NPPs was contained and the operation and safety including safeguards implementation was maintained. All the safeguards inspections planned at the both NPPs were carried out as planned. All the training and equipment testing planned to be performed at the both NPPs under the framework of the Czech Republic Support Programme to the IAEA safeguards was suspended this year.

It can be concluded that COVID-19 pandemic posed a great challenge for all parties involved in safeguards implementation. At all the levels – operators, State Authority and the international inspectorates, the Euratom and the IAEA, have been facing difficult times. But the safeguards implementation and inspection efforts were carried out with the same level of assurances, that nuclear materials were not diverted for non-peaceful purposes. Moreover, such challenges brought specific opportunities – there was increased need of effective allocation of resources, usage of modern communication technologies, on-line meetings etc.



COVID-19 AND FINLAND-20

Olli Okko
(STUK)

Due to the coronavirus, The Radiation and Nuclear Safety Authority (STUK) adjusted its operations in March 2020 so that it can perform its duty also when the coronavirus epidemic spreads in Finland. Most of STUK's employees, like other employees in the whole country, were asked to work remotely as much

as possible to avoid infections. The “digitalisation” and new working practices were adopted within a few days using the telecommunication networks in Finland. Employees were able to bring their laptops and other office equipment to home offices. The Government ICT Centre was overloaded for a few weeks but was able facilitate a major change in the Finnish society amazingly well. Most of the covid-19 infections were reported in the capital area; and in order avoid spreading of the decease, the capital region - where STUK is located - was isolated for 3 weeks by the Government's decision based on emergency legislation. The internal cross-border traffic was controlled, and the international travel was restricted or limited to minimal necessity particularly during March-July. The return to “normal life” was expected already after the summer vacations, but the reality is keeping the whole society back in the home offices as much as possible. We have been able to live without total lockdown of shops.

The sites overseen by STUK include undertakings critical to the overall safety and security of society, such as healthcare and nuclear power, so the risk of infection is taken very seriously. Therefore, STUK also ensured that nuclear power companies have prepared for the coronavirus situation. The most significant possible consequence of the coronavirus

would be the simultaneous infection of operating personnel, which would have impacts on the operations of plants. Consequently, STUK's on-site inspections will, for the time being, only be carried out at sites which are the most significant for safety, and the health authorities' guidelines on avoiding close contact will be considered in the inspection arrangements. The use of face mask was adopted to the inspections. The annual outages at the NPPs were oversighted with inspector presence. Safeguards inspection followed the same principle.

The IAEA stated in March that it would continue to perform inspections of nuclear materials also during the coronavirus pandemic. This means that the countries and facilities to be inspected will have to take care of the arrangements required in this situation. The entry of IAEA's inspectors into the country, for example, was arranged in cooperation with the Finnish Border Guard. The IAEA has performed the expected routine inspections at the NPP's and one short-noticed inspection during autumn. Euratom cancelled its inspection in spring but continued its inspection work at the NPP's after the main lockdown in spring. Inspection at holders of small amounts of nuclear material were cancelled or postponed. The oversight of the construction of new facilities needs inspector presence at the site. The

construction of the disposal facility for spent nuclear fuel is advancing, and thus the IAEA and Euratom carried out design information verification within a team of 7 inspectors in October as planned earlier. The already common health safety rules, i.e., testing, keeping distance, using mask were applied. The second wave of the coronavirus reached Finland in October, and in November new restrictions were issued by the authorities. However, the planned visit by IAEA's DG Rafael Mariano Grossi to the Olkiluoto new reactor and disposal facility was hosted by the Ministries and Stakeholders in late November. In December the safeguards directors, headed by DDG Massimo Aparo visited the new kind of nuclear installation in order to familiarise themselves with the new practices and to facilitate the installation of safeguards equipment at the encapsulation plant and geological repository. The construction is progressing despite some new precautions due to the coronavirus.

(While waiting for Christmas holidays and being aware of the acceleration of the second wave, I hope that all of you can stay healthy and safe under the “new normal” circumstances.)



THE 2020 INMM ANNUAL MEETING TECHNICAL PROGRAM

Carrie Mathews
(Technical Program Committee Chair)

In a year marked by isolation and separation, the INMM Annual Meeting, with its theme of Connection and Collaboration, was a welcome respite and timely reminder that we are a resilient community of nuclear materials management professionals. The meeting



Massimo Aparo (2nd left) visited Onkalo, the world's first spent fuel repository, and discussed safeguards of this new type of nuclear facility with STUK experts. Source: twitter.com/STUK_FI

gathered more than 700 people together for rich discussions and discourse in 75 sessions over five days. Five keynote addresses were delivered in daily plenary sessions, on topics ranging from the nuclear nonproliferation regime to advancements in the nuclear fuel cycle, from long-term disposition of spent fuel to strengthening international safeguards and nuclear security.

Pivoting to a virtual platform just 7 weeks before the meeting started was certainly a challenge. But a small team of organizers had been meeting every other week starting in late March, gathering information and making decisions that ultimately led to the announcement on 21 May 2020 that for the first time ever, the INMM would be held virtually. INMM partnered with Falcon and BlueSky to create a platform that felt as close to our in-person meeting as we could manage. Presenters were asked to upload their pre-recorded slideshows to create online poster and oral sessions. Panelists were invited to participate in live streamed sessions. The student paper competition was launched, with judges viewing presentations live and on-demand. A 'virtual hotel café' was created to facilitate interaction among participants.

The entire process was dynamic, with everyone learning as they went, adjusting as information ebbed and flowed. Tech checks were scheduled with plenary speakers, and moderators prepared their scripts to coordinate virtual panels. Everyone learned new audio-visual terminology and downloaded new apps like Slack and Zoom and Slido. Flexibility, teamwork and faith were needed in equal measure. The uncertainty surrounding the Annual Meeting led to many withdrawals of accepted abstracts, from ~320 accepted to 242 presented, but a few last-minute panel sessions were organized to address timely topics of great interest. One panel discussed how organizations – an inspectorate, a regulator, a production facility and a research laboratory - continued operating and fulfilled their critical missions during the pandemic. Another described response and remediation of a Cesium source leak at a medical center. A special 'women of mass distinction' event was organized by INMM Vice President Susan Pepper, featuring Ambassador Bonnie Jenkins who shared

her lessons and insights she's gleaned from a long and distinguished career.

The technical program featured diversity: of topics, geography, gender, familiarity with INMM and career levels. Of the more than 700 attendees, about half were not INMM members and many were first time attendees. 81 were students, and 104 were from outside the United States. The most well-attended sessions included 'Nuclear Security – Looking Ahead', 'Emerging Technology in Safeguards', 'Small Modular Reactors: Changing the Game', 'The Nonproliferation Regime', and 'Machine Learning and AI for Safeguards and Nuclear Material Accountancy'. If you missed some sessions or plenary speakers, don't worry – you can purchase packages for on-demand viewing at inmm.org, through July of 2021, and the proceedings are available for members on the website as well.

The 2020 Annual Meeting was a success and the INMM community was grateful to gather together as we have done every year since 1959. But we learned a lot that will help us better serve our community in future virtual meetings. For example, participants want to interact with one another via video chat and/or live audio conversations. Although interaction among participants and with speakers was enabled through a Q&A/chat app (Slido) within the sessions, the platform did not enable live connections. In addition, more time was needed in the schedule for breaks and side meetings. The exhibitors' program for live interactions/demonstrations needed to be easier to access. But the most important lesson we learned was that through a virtual platform, the INMM community grew, and will continue to grow as we reach beyond borders and eliminate obstacles to Annual Meeting attendance. This challenging experience ultimately taught us just how much we can achieve and how far we can go - through Connection and Collaboration.

We are now busy planning the 2021 joint INMM-ESARDA Annual Meeting, to be held in Vienna, Austria (and we are working to have an online option as well), from 22-26 August. The theme is 'Advancing Together: Innovation and Resilience in Nuclear Materials Management'. We will need our members' help to

make the meeting a success. Would you like to get involved? Contact [INMM](#) or [ESARDA](#) and check the organizations' websites to learn more.

technical articles

Technical articles covering the latest findings of our community of experts on fundamental issues

PROLIFERATION RELATED ISSUES OF SODIUM-COOLED FAST BREEDER REACTORS

by Vaibhav Mishra

(Uppsala University, Sweden)

(Participant of the 18th ESARDA Course, selected student essay)

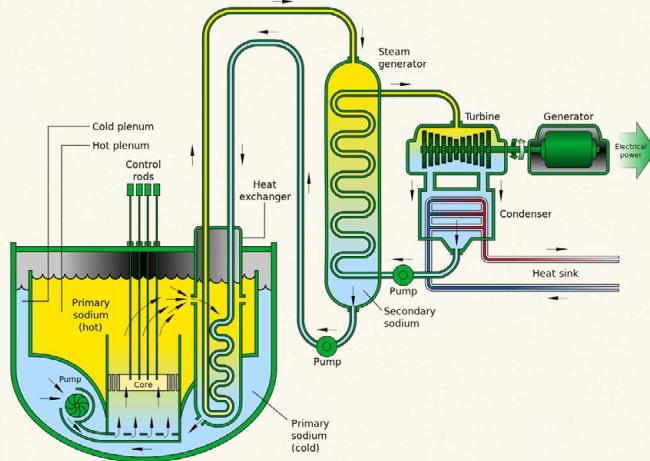
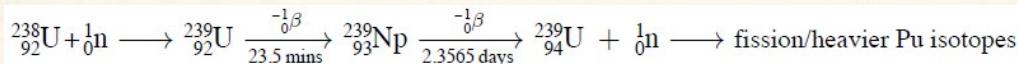
Abstract

The purpose of this study is to assess the diversion attractiveness of the spent fuel material of a selected sodium-cooled fast reactor (SFR) by modeling the plutonium buildup in the fuel and to model the neutron flux to assess safeguards verification of the fuel. The study will extrapolate on the research conducted in [1] and build on previous work to estimate spontaneous fission neutron flux values and propose detection instrumentation for a safeguards verification. The Finnish monte-carlo neutron transport code SERPENT was used in [1] to obtain the isotopes which were used in the present study to estimate the spontaneous fission rates..

1 Introduction

1.1 Key objectives

The present study is centered around estimation of spontaneous fission neutron flux values from nuclides in the spent fuel discharged from a typical Liquid Metal-Cooled Fast Breeder Reactor (LMFBR) and will be used to assess if a measurement based on the estimated neutron flux could be used to make a safeguards verification using existing techniques and equipment. For this purpose, the spontaneous neutron flux will be computed from isotopes for the spent fuel calculated in [1]. It is a well known fact that fresh LMFBR fuel contains U-238 in the core as driver and blanket fuel assemblies which, after consecutive neutron absorption and beta decays, can lead to the buildup of heavier actinides and trans-uraniacs such as Pu-239, Pu-240 and others. The chain resulting in buildup of heavier isotopes is shown below:



Pool type sodium-cooled fast reactor (SFR), source: Wikipedia.com

1.2 Nuclear safeguards

The idea of nuclear safeguards was conceptualized to act as a deterrent from diversion of nuclear material for non-peaceful purposes by state and non-state actors. They comprise of a set of legal and technical measures through which, regulatory bodies such as the IAEA can verify that the states are honoring their legal obligations to use nuclear

material and technology for peaceful purposes and to assess that states live up to their international agreement and treaties.

According to the IAEA's definition [2]:

"... the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection."

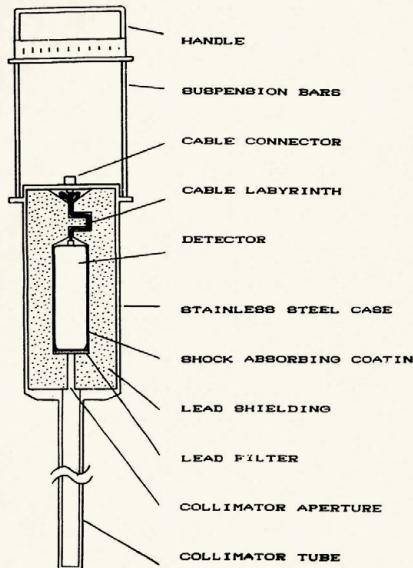
The premise of nuclear safeguards hinges on nuclear material accountancy, and verification and characterization of nuclear material is done largely with the help of NDA (Non-Destructive Analysis) and DA (Destructive Analysis) methods. Inspectors count fuel assemblies and perform measurements using non-destructive assay techniques which do not physically or chemically alter the item that is being verified. The outcome of such

measurement campaigns are typically compared against operator declarations in order to verify completeness and correctness of operator declarations. Examples of NDA methods include calorimetry, gamma spectrometry, and neutron assay (both active or passive).

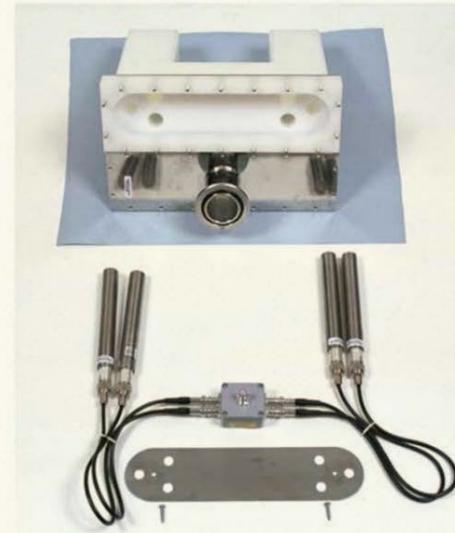
In safeguards assessments, safeguards relevant information can be considered; such information could for instance include read-out from in-core flux monitoring instrumentation such as that described in [5].

1.2.1 Safeguards measures - Non-Destructive Assay methods

Non-Destructive Assay methods employ techniques and instruments which can be used to verify spent fuel without changing the properties of the fuel. These techniques employ instrumentation that can measure gamma and neutron radiation emitted by spent fuel which are used to predict spent fuel properties like burnup, enrichment, and cooling time. Some of the instruments currently in use for such purposes are the SFAT (Spent Fuel Attribute Tester) [3] and the FDET (FORK detector system) [3]. While the SFAT detector is used only for gamma measurements of the spent fuel, a FORK detector (FDET) may be employed for safeguards verification by means of both, neutron and gamma measurements. SFAT is employed for gross defect verification (to verify the presence of spent nuclear fuel) whereas the FORK detector has been long in use for



(a) The BWR SFAT system used by the IAEA for attribute verification of spent fuel assemblies in their storage racks. [3]



(b) The FORK detector in use under water in a spent fuel storage pool. It may be noted here that the fuel has been lifted out of its storage location in the pool. [3]

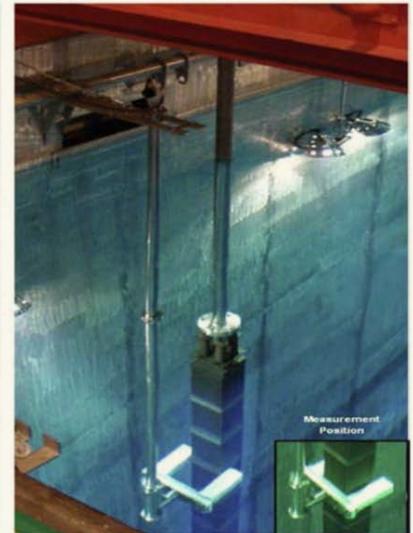


Figure 1.1: NDA instruments used by IAEA inspectors for safeguards verification

estimation of fuel parameters. Additionally, the FDET is used to make measurements under water in the spent fuel storage pool requires the assembly to be partially lifted from its storage location. As mentioned previously, FDET is sensitive to both, gamma and neutrons and makes simultaneous measurements using ionization (for gamma) and fission chambers (for neutrons). The design and the measurement setup of the FDET system is shown in Figure 1.1. The figure shows a standard BWR FORK detector.

1.3 Fast Neutron Reactors (FNRs)

As the name suggests, liquid metal-cooled reactors use liquid metals like sodium as coolant to remove heat from the reactor core. This allows for a high power density with low coolant volume and operability at low pressure since metals have high boiling points which further eliminates the requirement for pressurization. Liquid sodium, lead and several eutectic compositions have been proposed as coolants for these reactors. Since these metals have a very low absorption cross section for neutrons, the spectrum inside the core is very hard as there is barely any moderation. This has several benefits since a hard spectrum can be utilized to burn heavier actinides (in a burner) and sec-

ondly, also convert fertile isotopes (like Th-232 and U-238) into fissile isotopes (in a breeder) which can be used as fuel. Therefore, a fast reactor can work as both, a burner as well as a breeder. A reactor which breeds more fuel than it consumes is called a “breeder” reactor. A breeder reactor core has special regions which contain assemblies comprising solely of fertile material like U-238 or Th-232 which transmute to fissile material upon irradiation with fast neutrons. The SFR closed fuel cycle assists in reuse of actinides and greatly reduces the long-lived radio-toxicity of the spent fuel. As an added benefit, the fast neutron spectrum better utilizes the uranium resources compared to traditional thermal reactors. The SFR is by far considered to

be the nearest-term deployable system for actinide management since it makes better use of the fuel than traditional LWRs. Much of the basic technology for the SFR has been developed and to an extent has also been deployed successfully in former fast reactor programmes, and is being put through its paces by the Phenix end-of-life tests in France, at Monju in Japan where the restart of the reactor is being contemplated and the lifetime extension of BN-600 in Russia. New programs including the Chinese experimental fast reac-

tor (CEFR) and India’s prototype fast breeder reactor (PFBR) are also well on their way to demonstrating the success of this reactor technology.

SFRs, particularly the breeder concept is an attractive alternative to LWRs for states with limited access to enrichment technology or enriched fuel and enable them to have thriving nuclear energy programs by making use of uranium deposits and reducing the radioactive waste volume more efficiently than any LWR technology ever could. Although the breeder reactors’ sustainability is limited to availability of driver fuel which can either be enriched uranium or reactor grade plutonium from reprocessed LWR fuel from old spent fuel or from decommissioning and dismantling of nuclear warheads.

1.3.1 Plutonium production in fast reactors

As mentioned in the preceding section, fertile isotopes such as U-238 and Th-232 absorb fast neutrons and convert to fissile isotopes like Pu-239 and U-233 respectively, which can be used as fissile fuel in the core. Such reactions take place even in LWRs where the majority of neutrons are thermalized but a small proportion are fast and undergo capture in fertile isotopes instead of causing fission of fissile material. In fast reactors, where a larger proportion of neutrons fall in the fast region, neutron capture in fertile material present in

the core is the preferred reaction channel. In breeder reactors wherein there exist entire regions (breeding blanket) in the core with fertile material, significant fissile material breeding takes place due to the abundance of fast neutrons and fertile atoms. If production of fissile atoms (such as Pu-239) exceeds the consumption of fissile atoms in the core, the reactor is called a breeder and can in principle breed more fuel than it consumes. It is also understood that the plutonium bred in the blanket assemblies is of a very high grade (containing >97% Pu-239) making it a diversion attractive material. According to the IAEA [2], the significant quantity of plutonium stands at a mere 8 kg thereby making the problem of safeguarding it highly critical. However, the presence of heavier plutonium isotopes such as Pu-240 degrades the plutonium grade since it makes the material susceptible to spontaneous fission (and thereby prone to self detonation) and reduces its attractiveness.

2 Computation

2.1 SERPENT model of LMFBR core

The model of the LMFBR core has been taken from [1]. A succinct summary of the key features of the LMFBR core model is as follows: 310 hexagonal assemblies are packed in an overall hexagonal arrangement with the core divided into regions composed of breeding assemblies and driver fuel assemblies (numbers vary for different configurations). Apart from these, the core also has control locations for control rod assemblies (16) as well as reflector assemblies (90) and the remaining are shielding assemblies in the periphery of the core.

2.2 Computation in earlier study

The evaluation conducted in [1] investigated with the impact of placement of blanket and driver fuel assemblies on rate of buildup of Pu-240 in the SFR core. This was done to assess a scenario where a state entity might try to place blanket assemblies in certain locations in the core to breed high grade plutonium for a possible clandestine weapons program. To summarize the methodology employed in [1], two different core arrangements were evaluated (a.) homogeneous, wherein all driver fuel

Isotope	Spontaneous Fission Multiplicity (ν_f)
Th-232	2.14
U-232	1.71
U-233	1.76
U-234	1.81
U-235	1.86
U-236	1.91
U-238	2.01
Np-237	2.05
Pu-238	2.21
Pu-239	2.16
Pu-240	2.16
Pu-241	2.25
Pu-242	2.15
Am-241	3.22
Cm-242	2.54
Cm-244	2.72
Bk-249	3.40
Cf-252	3.76

Table 2.1: Spontaneous fission neutron yields [7]

assemblies are placed in the center of the core and the core is surrounded by the blanket assemblies, and (b.) heterogeneous in which both driver fuel and blanket fuel assemblies are intermixed and are distributed throughout the core region as evenly as possible. Further details of SERPENT modeling and core configurations analyzed are included in [1].

2.3 Computation in current study

Based on the spontaneous fission rate values obtained from SERPENT in [1], in the current study, spontaneous fission neutron flux values from blanket and driver fuel assemblies were calculated. These calculations were made using the spontaneous fission multiplicity factors obtained from Table 2.1. Additionally a comparison can be drawn between spontaneous neutron flux values of spent fuel from blanket and driver fuel assemblies.

3 Results

3.1 Results from previous study

3.1.1 Heterogeneous - homogeneous core arrangements

In [1], it was found that different core arrangements lead to different rates of buildup of spontaneously fissioning nuclei like Pu-240 (along with some more heavier nuclei). Since these isotopes build up at different rates with burnup (and the effect is more pronounced at

higher values of burnup i.e. > 20 GWd/MTU and the difference can reach about 17% in some configurations), this feature can be used to fingerprint or identify fuel assemblies from each of these configurations. This is important since this fact makes some core configurations more attractive than others from a proliferation standpoint.

3.1.2 Contribution of Pu-240 to total spontaneous fission rate

It was observed in [1] that total spontaneous fission rates are much higher in driver fuel assemblies and climb steadily with burnup as compared to blanket fuel assemblies. In fact, the total spontaneous fission rates are several orders of magnitude higher in driver fuel than blankets. This fact can be used to distinguish the blanket fuel from the driver fuel assemblies during verification since the two have significantly different spontaneous fission rates. A more detailed explanation of the behavior and the evolution of total spontaneous fission rates with burnup in driver and blanket fuel is included in [1].

3.1.3 Super weapons grade Pu-239 breeding potential

It was also shown in [1] that the blanket fuel assemblies are capable of breeding very high-grade plutonium (> 95% Pu-239 and < 1% Pu-240) which confirms the attractiveness of this material for a proliferator. Further details of the analysis and possible degradation of the blanket fuel material with increasing burnup is included in [1].

3.2 Results from current study

3.2.1 Total spontaneous fission neutron flux rates

As mentioned previously, the isotopic number densities for a select group of isotopes were used to estimate the spontaneous neutron flux values in the current study. To achieve this, the spontaneous fission neutron multiplicity values (from Table 2.1) can be used to obtain the neutron flux rates from the spontaneous fission rates calculated by SERPENT. A total of 17 nuclides were deemed important for computing the spontaneous fission neutron flux

rates since neutron multiplicity values were available for them with Cf-252 as an exception.

Isotopes			
Th-232	U-236	Pu-240	Cm-244
U-232	U-238	Pu-241	Bk-249
U-233	Np-237	Pu-242	Cf-252
U-234	Pu-238	Am-241	
U-235	Pu-239	Cm-242	

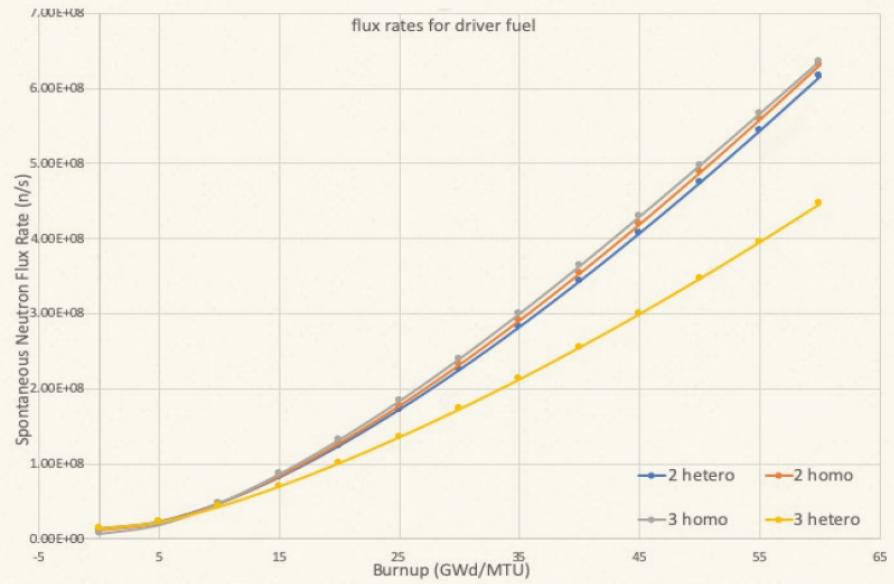
Table 3.1: Nuclides contributing to spontaneous fission rate

Core configuration and fuel type	Flux rate (n/sec)
2 blanket rows - homogeneous	driver 6.32E+08 blanket 1.48E+05
2 blanket rows - heterogeneous	driver 6.16E+08 blanket 2.34E+05
3 blanket rows - homogeneous	driver 6.37E+08 blanket 3.35E+05
3 blanket rows - heterogeneous	driver 4.47E+08 blanket 2.25E+05

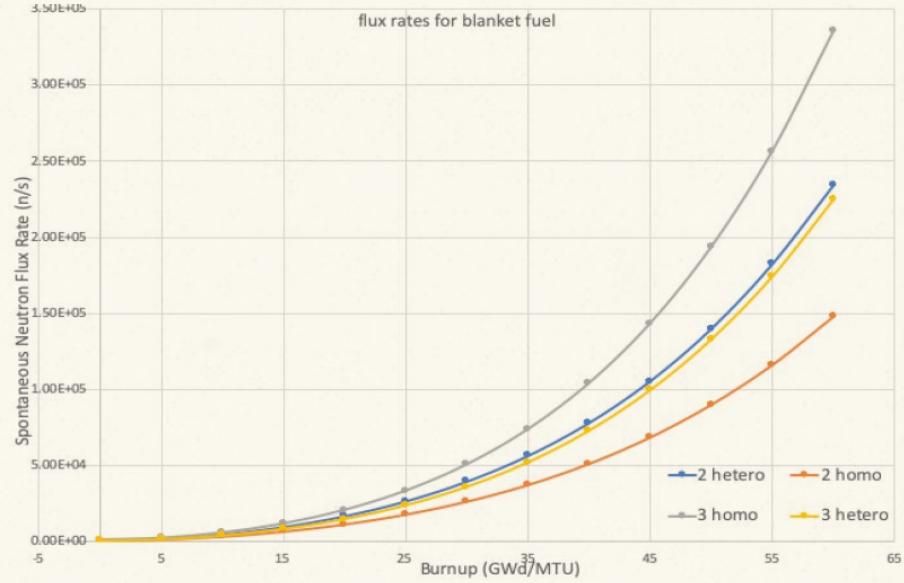
Table 3.2: Neutron flux rates from driver and blanket fuel (at burnup = 60 MWd/kgU)

tion since it was not built up in the spent fuel. The selected isotopes are listed in Table 3.1. These isotopes were selected for this study because they dominate the spontaneous neutron flux spectrum in spent fuel.

Figure 3.1 shows the variation of spontaneous neutron flux rate for different core configurations in both, driver and blanket fuel. The naming convention for the configurations has been borrowed from [1] and indicates the number of rows of blanket fuel assemblies and whether they are placed homogeneously or heterogeneously in the core. As can be observed from Figure 3.1, the spontaneous neutron flux rates from driver fuel is higher by order of about 10³ when compared to the neutron flux rates from the blanket fuel material. The neutron flux rates for both driver and blanket fuel were obtained by multiplying the spontaneous fission rates from [1] with the spontaneous fission neutron multiplicity values from Table 2.1. The variation of the spontaneous fission neutron flux rates with increasing burnup for both blanket and driver fuel have been shown in Figure 3.1. It may be inferred that the neutron flux rates increase linearly with burnup for driver fuel and somewhat exponentially for blanket fuel from Figure 3.1.



a: Neutron flux rate from driver fuel.



b: Neutron flux rate from blanket fuel.

3.3 Figure 3.1: Spontaneous fission neutron flux rates

Discussion and recommendations

From a safeguards standpoint, it is of tremendous interest to limit the buildup of weapons-grade Pu-239 in the blanket material used in SFRs largely due to the fact that plutonium bred in the blankets is of super weapons grade. In [1], it was established that a large proportion (up to 90% at some values of burnup) of the spontaneous fission occurring in the blanket arise from Pu-240 which confirms that it is indeed the major cause of degradation in the grade of plutonium bred in the

blankets. As far as the spontaneous fission neutron flux rates from driver and blanket fuel are concerned, the current study shows that the neutron flux rates increase markedly with burnup and reach values of up to 6E10⁸ neutrons/sec for high burnup values in case of driver fuel and upto 4E10⁵ neutrons/sec in case of blanket fuel for burnup reaching 65 GWd/MTU. Flux rates of this order are expected to be detectable by the FORK detector system which is known to be sensitive to much lower neutron count rates. Further information about neutron flux regimes that lie in the detectable range for the FDET system

is provided in [4]. It is also imperative to note that since the blanket and breeder assemblies have neutron flux rates which are significantly different from one another, a blanket assembly cannot be substituted with a driver fuel assembly without being detected in using NDA techniques. Additionally, fuel movements within the core to produce more weapons usable material are detectable since they significantly alter the core flux profile which is monitored by in-core flux detectors [5] and thereby provide supplement data which could be used in conjunction with measurements made post fuel discharge for a successful safeguards verification. Lastly, as mentioned preceding sections, in-core flux monitoring systems which monitor neutron flux in several locations in the reactor core during operation can also provide safeguards-relevant information during the course of a safeguards verification.

3.4 Sources of error

It is suspected that the simplifying assumptions made during preparation of the SFR core model in SERPENT could lead to errors in the results. Some examples of such assumptions include: zero power production in the blanket assemblies (which is inaccurate in a real SFR where blankets have a significant contribution to total power output), no control material assumed present in the core (fully depleted control rods i.e. only B-11 present in the absorber), and adjustment of fissile material in driver fuel when blanket fuel was introduced in the core to keep the core neutron multiplication factor roughly the same at the beginning of life (BOL). In addition, a simple irradiation

scheme was used with no cycle downtime or outages. This is expected to have a significant impact on the core physics thereby impacting the rate at which the isotopes studied in this evaluation build up. Thus, these assumptions are expected to introduce errors in the results however those errors were not quantified.

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