

REFLECTION GROUP 2017-2019 REPORT **ESARDA's relevance for the next decade**

Final Version, 16 December 2019

ESARDA's reflection on its future strategic direction in light of current and future non-proliferation and safeguards challenges.

The ESARDA Reflection Group RG2019 was established in 2017 with the objectives to:

1. Define ESARDA's short term priorities and activities (2019 to 2024);
2. Define ESARDA's medium term priorities and activities (2019-2029);
3. Review the ESARDA organisational structure, management tools and way of operating, and discuss how ESARDA can best address the identified priorities.

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EXECUTIVE SUMMARY

The Reflection Group 2019 (RG2019) was established in January 2017 with the objectives to develop a roadmap to improve and enhance the quality, effectiveness and efficiency of safeguards and non-proliferation in Europe and abroad; and to ensure that the future activities of ESARDA are both consistent with the Association's purpose, as stated in the ESARDA Agreement, and address the needs of the ESARDA members and/or stakeholders.

To fulfil these objectives, three specific goals were identified: First, to establish short term ESARDA Priorities (2019 to 2024) and prepare a roadmap (*what?*); second, to define ESARDA's medium-term future (2019-2029) activities based on the new landscape in Europe and internationally; and third, to review the ESARDA organisation, and discuss *how* ESARDA can implement/achieve the identified objectives and implement the identified roadmap.

Volunteers contributed to the Reflection Group from across the ESARDA Membership, including Working Group Chairs, Steering Committee and Executive Board members and ESARDA participants of both long-standing and recent activity. Outreach to the wider ESARDA community was achieved through a questionnaire and discussions within regular meetings of the ESARDA Working Groups and the 2018 Annual Meeting in Luxembourg, in order to ensure that the views of all those who drew benefit from the activities of ESARDA were considered and that all stakeholders, including operators, authorities and scientific institutions, could achieve ownership and influence the future of ESARDA.

The Reflection Group itself undertook its work through five dedicated meetings between October 2017 and January 2019, with considerable work undertaken in the interim by individuals and groups of members. The RG2019 identified, debated and analysed future requirements for ESARDA and agreed to present ten priorities from which to develop actions within a roadmap. Each priority is described with a short introduction and context and then a number of focus points are provided including the actions retained for the Roadmap.

ESARDA's short term priorities (2019-2024):

The short-term priorities for ESARDA are driven by the requirements of current EC safeguards policy and its evolution, and resource constraints in implementing safeguards. The overall goal for the short-term activities of ESARDA is to develop and facilitate the implementation of further improvements in safeguards effectiveness and efficiency at all levels:

1. Strengthen the focus on development, pilot-testing and evaluation of safeguards approaches for the **back-end of the fuel cycle** (including encapsulation plants and final repositories)
2. Fully exploit the potential of **remote data transfer, remote observation and control, artificial intelligence and machine learning** for enhancing the implementation of safeguards measurements and data evaluation, duly taking into account (cyber) security considerations
3. Enhance the use of **modern business analytics/intelligence and data science tools** to reach higher quality findings from current and future nuclear safeguards relevant data (all types)

4. Attract the **young generation** to and implement **knowledge transfer** from the field of nuclear safeguards and non-proliferation
5. Enhance the **awareness and visibility** of nuclear safeguards at the public and political level

Progress on the implementation of the short term priorities will be reviewed during each Executive Board meeting and reported at each annual meeting to the ESARDA members. Similarly the ESARDA WG chairs will report on the implementation of the respective roadmap actions that have been taken on by their WGs at the bi-annual meetings hosted by DG ENER. Achievements in the implementation of short term priorities will be shared with the membership via the ESARDA Connector.

ESARDA's medium term priorities (2019-2029):

Any action in the medium term vision of the medium term priorities will require review depending upon the results of the shorter term actions. Assuming that safeguards and non-proliferation related activities, in the next 10 to 30 years, will be very strongly influenced by further technological developments, the medium term priorities were identified as:

6. Continued **safeguards enhancement based on R&D** (key role for ESARDA)
7. Further **changes in nuclear fuel cycle strategies and operations in Europe**
8. Contribute safeguards expertise to **major nuclear developments outside Europe**

Progress on the implementation of the medium term priorities will be reviewed during each Executive Board meeting and reported during each bi-annual meeting hosted by DG ENER in Luxembourg to the ESARDA members.

ESARDA's structure and operation:

The RG2019 recommends two types of activities in regard to the structure and operation of ESARDA.

9. **Procedural**
10. **Operational**

This report provides a summary of the work of the Reflection Group and specific outcomes against the goals of the Group. The report is supported by a number of Annexes, which are largely intended as dynamic documents, to be reviewed and updated as required in order to maintain the relevance of the Reflection Process and to enable ESARDA to respond to future developments in the field of nuclear safeguards.

As a first step to take ownership of the ESARDA RG roadmap, an interactive World Café was held at the ESARDA Symposium 2019. The ultimate goal of the World Café was that participants not only take ownership of the RG2019 actions but contribute actively to their future implementation, ideally taking an action in their personal agenda. The results of the World Café were summarized in an extra report, which is also available via the ESARDA website.

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1. INTRODUCTION

The European Safeguards Research and Development Association (ESARDA) is a voluntary association of European organisations formed to foster, advance and harmonise research and development (R&D) in the area of nuclear safeguards. It provides a forum for the exchange of information and ideas between nuclear facility operators, safeguards national authorities and international inspectorates, and persons engaged in safeguards-related research and development.

ESARDA was established in 1969, shortly after the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) became open for ratification. As stated in the ESARDA agreement, its purpose is to facilitate collaboration in R&D in the field of nuclear safeguards and in the application of such R&D to the safeguarding of source and special fissile materials under the NPT. This co-operation is effected through co-ordination and harmonisation of the R&D work of the ESARDA partners, by the exchange of information and assistance at a technical level, and by the joint execution of programmes or parts thereof, including training related to nuclear safeguards. The key element of ESARDA's activities is the frequent interaction between R&D personnel, plant operators and safeguards authorities.

From its origins in 1969 as a partnership between the European Atomic Energy Community (Euratom) and the Kernforschungszentrum Karlsruhe (KfK), expanding in the following few years with the inclusion of a number of additional partners (or “Parties” to the ESARDA Agreement), by end-2018 ESARDA included 33 Parties from within the EU. In addition, a further eight laboratories, authorities, operators and academic institutions from outside the EU have joined ESARDA as Associate Members, whilst the Association signed a Memorandum of Understanding for cooperation and coordination with the Asia-Pacific Safeguards Network (APSN); and a Letter of Intent with the Institute for Nuclear Materials Management (INMM).

Whilst the fundamental principle of the Non-Proliferation Treaty (NPT) has remained unchanged since it entered into force on 5 March 1970, international developments over the following nearly five decades have brought with them significant changes to the role and application of nuclear safeguards in maintaining the NPT. ESARDA has adapted over this period to accommodate these changes, to target its activities to new priorities and initiatives improving the effectiveness and efficiency of safeguards: not only in consideration of inspection authorities and regulators, but also in terms of minimising the burden on plant operators. A clear example is the introduction of the Model Additional Protocol to the Comprehensive Safeguards Agreements with the IAEA and the subsequent implementation of Integrated safeguards. Active engagement of all those involved has always been a key feature of ESARDA, whilst maintaining the voluntary and in-kind nature of the Association as stated in the ESARDA Agreement. This has led to a number of notable achievements, highlighted in Annex B to this report that provides a summary of ESARDA's administrative and technical history since 1969.

ESARDA seeks to maintain a dynamic approach to the developing priorities, whilst ensuring that its activities continue to anticipate future needs. In order for ESARDA to achieve the latter, and to direct its activities most effectively to ensure that the Association remains relevant and

engages the full membership in determining priorities, the Association periodically undertakes a formal Reflection Group exercise.

After the activities and recommendations of the ESARDA Reflection Groups in 2000 and 2010, the Executive Board agreed, at its meeting of 23-24 January 2017, that the time had come to reassess ESARDA's future strategic direction, in light of current and anticipated future non-proliferation and safeguards challenges. Therefore, a new Reflection Group, RG2019, was established with the objectives to:

- develop a roadmap to improve and enhance the quality, effectiveness and efficiency of safeguards and non-proliferation in Europe and abroad; and
- ensure that the future activities of ESARDA are both consistent with the Association's purpose, as stated in the ESARDA Agreement, and address the needs of the ESARDA members and/or stakeholders.

To fulfil these objectives, three specific goals were identified:

RG2019 Objectives

1. Establish short term ESARDA Priorities (2019 to 2024) and prepare a ROADMAP (WHAT);
2. Define ESARDA's medium-term future (2019-2029) activities based on the new landscape in Europe and internationally - to be reviewed before 2025 to establish the next 5 year plan; and
3. Review the ESARDA organisation, and discuss HOW ESARDA can implement/achieve the identified objectives and implement the identified roadmap.

Volunteers contributed to the Reflection Group from across the ESARDA Membership, including Working Group Chairs, Steering Committee and Executive Board members and ESARDA participants of both long-standing and recent activity. Outreach to the wider ESARDA community was achieved through a questionnaire and discussions within regular meetings of the ESARDA Working Groups and the 2018 Annual Meeting in Luxembourg, in order to ensure that the views of all those who drew benefit from the activities of ESARDA were considered and that all stakeholders, including operators, authorities and scientific institutions, could achieve ownership and influence the future of ESARDA.

The Reflection Group itself undertook its work through several dedicated meetings, with considerable work undertaken in the interim by individuals and groups of members. The first formal meeting, held from 2-3 October 2017 in Berlin, addressed the objectives of the Group, defining and prioritising activities in support of the overall goals through processes including PESTLE (Political, Economic, Sociological, Technological, Legal and Environmental) and SWOC (Strengths/Weaknesses/Opportunities/Challenges) analyses.

A second meeting, from 24-25 January 2018 in Ispra, reviewed progress and drew conclusions from a membership survey, which was used to identify gaps and priorities in the work of the Reflection Group. Progress was further reviewed by the Reflection Group on 18 May 2018 in Luxembourg, following ESARDA's Annual Meeting, whilst a fourth meeting, from 13-14 September 2018 in Bern, considered in detail the output from individual and Group

contributions, which had been received over the previous months, and further developed the strategy for the future direction and administration of ESARDA.

A final meeting, from 22-23 January 2019 in Ispra, reviewed progress and defined the structure and content of a formal report on the activities and conclusions of the Reflection Group. That report is presented here, providing a summary of the work of the Reflection Group and specific outcomes against the goals of the Group.

The report is supported by a number of Annexes, which are largely intended as dynamic documents, to be reviewed and updated as required in order to maintain the relevance of the Reflection Process and to enable ESARDA to respond to future developments in the field of nuclear safeguards.

2. PREPARATORY WORK

PESTLE & SWOC ANALYSIS

During its first meeting, the Reflection Group defined and prioritised activities in support of the overall goals through a structured brainstorming discussion, including PESTLE (political, economic, sociological, technological, legal and environmental (ecological)) and SWOC (strengths/weaknesses/opportunities/challenges) analyses.

First, by taking a bird's-eye view on ESARDA's external environment, the Reflection Group examined the key external trends and drivers that may have a positive or negative impact on ESARDA. Each of the group members individually reflected upon the most important positive trend or driver and the most negative trend or driver and associated them with one of the factors: political, economic, sociological, technological, legal and environmental (ecological) (PESTLE). Table 1 summarizes the outcome of the discussion.

Table 1: Main external trends and drivers with a positive or negative impact upon ESARDA, as derived from the PESTLE analysis

| | Positive | Negative |
|----------------------|--|--|
| Political | <ul style="list-style-type: none"> • Mechanism of nuclear security summits created a broader community, and awareness, of nuclear security and forensics • Progress in Euratom safeguards recognition at the international level | <ul style="list-style-type: none"> • Decline of nuclear share in electricity production in Europe; leading to decline of trained scientists in our field • Potential impact of a revision of the Euratom Treaty, if this would lead to a decrease in the importance of nuclear safeguards |
| Economic | <ul style="list-style-type: none"> • Need to increase safeguards efficiency and effectiveness pushes the R&D needs for innovation and new technologies | <ul style="list-style-type: none"> • Technological developments are constrained by resource issues and commercial constraints • Shrinking resources of stakeholders; reduction/cut in human resources might cause decrease in support or approval for organisations to engage in ESARDA |
| Sociological | <ul style="list-style-type: none"> • Committed and active young generation • Network, knowledge management, forum to discuss and exchange ideas | <ul style="list-style-type: none"> • Interest in 'nuclear' and safeguards is decreasing - How to compete for the interest of young people in a world full of so many other things? • Not enough young people entering the safeguards area and also not sufficient infrastructure to train and educate them |
| Technological | <ul style="list-style-type: none"> • Technology-driven association; acts as incubator for novel, cutting edge technologies • Emerging technologies that require case studies, feasibility studies, communication, training, etc. • Technology development enables ESARDA to more easily (efficiently and effectively) fulfil the purposes and activities stated in the Agreement. | <ul style="list-style-type: none"> • Not enough research & development activities compared to the past; • No mechanism to promote new R&D (i.e. ESARDA has no budget in this area and e.g. the EC is not centrally funding – e.g. through indirect actions – safeguards research) |
| Legal | <ul style="list-style-type: none"> • ESARDA is a well-established association with a strong legal foundation and objectives | <ul style="list-style-type: none"> • Very limited legal experience and support • Voluntary contributions, based on each organisation's commitments |

| | | |
|-------------|-----|-----|
| Environment | N/A | N/A |
|-------------|-----|-----|

Second, the Reflection Group conducted an analysis on the strengths, weaknesses, opportunities and challenges (SWOC) of ESARDA. Here, the group discussed factors that are likely to lead to positive change and further improvement within ESARDA, both inside the association (strengths) and outside (opportunities). They also discussed factors which may compromise further improvement within ESARDA, internally (weaknesses) and externally (challenges). For each of the factors, the group agreed on 3 to 4 top factors (Table 2)

Table 2: Top three to four strengths, weaknesses, opportunities and challenges of ESARDA, as derived from the SWOC analysis

| | Positive / Helpful: Factors likely to lead to positive change and further improvement within ESARDA | Negative / Harmful Factors which may compromise further improvement within ESARDA |
|--|--|--|
| Inside ESARDA (Internal Attributes) | <p>Top 3 Strengths</p> <ul style="list-style-type: none"> • Interconnected, successful network of diverse stakeholders, operating well for 50 years • Unique pool of expertise and competences • Atmosphere: ESARDA is approachable, friendly, easy to access, informal, “family” | <p>Top 4 Weaknesses</p> <ul style="list-style-type: none"> • Need to improve / explain roles and better apply internal procedures; • Systematic information sharing between WGs, knowledge on ESARDA members’ competences • Need to further expand breadth of the profession, age, gender and geographical coverage • Constraint of human resources due to the voluntary nature (both as internal and external) |
| Outside ESARDA (External Attributes) | <p>Top 3 Opportunities</p> <ul style="list-style-type: none"> • Provide (technical) expertise to outside Europe, in support to EURATOM programme • Responding to stakeholders needs (incl. through joint sessions of ESARDA WGs) with ESARDA expertise and viewpoints, and thus gaining visibility • Opportunities of new (communication) technologies for interaction between ESARDA members beyond physical meetings | <p>Top 3 Challenges</p> <ul style="list-style-type: none"> • Increase external visibility and recognition • Attracting younger generation/participants • Political anti-nuclear landscape, potential revision of Euratom Treaty and perception of potential safeguards failures/shortcomings on a world scale, threatening the positioning and reputation of ESARDA |

ESARDA MEMBERSHIP SURVEY

In order to get feedback from as many ESARDA members or stakeholders as possible on the objectives of the Reflection Group, a survey was launched at the end of 2017 in the form of a questionnaire to existing contributors to ESARDA’s activities and others that the Reflection Group identified as current or potential stakeholders.

The survey contained questions about the person/organisation participating in the survey (age, gender, status of organisation, etc.) for statistical purposes. In addition, the survey included two

sets of statements and questions: one set of statements concerned topics that might be addressed by ESARDA (**'what'-questionnaire**) whilst the other set looked at the way of working (**'how'-questionnaire**). Each question/statement was to be evaluated on a three-level scale (completely agree, partially agree, disagree/oppose), with a possibility to include text for justification/comments/suggestions. It was clearly emphasized in the survey that input would not be considered as criticism of current activities and procedures of ESARDA, but as an opportunity to proactively prepare for ESARDA's future.

The survey was completed by 54 participants (76 % male, 24 % female, 65 % between age 41-60 and only 2% below 30). The percentage of completed questionnaires from ESARDA parties was 58%, with 21 % associate or individual member and 21% non-member.

The results of the **'what'-questionnaire** were evaluated as an ordered list of topics included in the survey as topical statements based on the following quantification rule. The number of answers are weighted with a factor of 1 (completely agree), 0,5 (partially agree), -1 (disagree) and 0 (don't know), and the weighted sum of all answers is calculated using these weighting factors. The resulted ordered list of what ESARDA should do is shown in Table 3.

Table 3: Ordered list of topics ESARDA should focus on, derived from the 'what'-questionnaire

| Topic | Weighted sum |
|--|--------------|
| 1.1 R&D on innovative safeguards technologies, validation, testing and evaluation | 48 |
| 1.8 Safeguards for final disposal (e.g. reverification & monitoring challenges; link to ASTOR) | 44 |
| 1.6 (Continuing) challenge of a retiring workforce in nuclear (safeguards) | 40 |
| 1.7 Importance of legal issues related to safeguards, especially the different modalities of safeguards implementation in Europe | 39 |
| 1.3 The relevance of cybersecurity for safeguards and the interface with other security issues | 38 |
| 1.2 The impact of heightened security on safeguards implementation | 33 |
| 1.5 Potential of big data / data analytics techniques e.g. for inspection reports, nuclear measurement, evaluation of MBAs etc. | 32 |
| 1.10 Role of ESARDA in safeguards capacity building outside Europe | 31 |
| 1.9 Disarmament verification, verification of nuclear material removed from nuclear stockpiles | 27 |
| 1.4 Synergies with security in general | 23 |

The distribution of answers between the four categories for all the topics is shown in Figure 1.

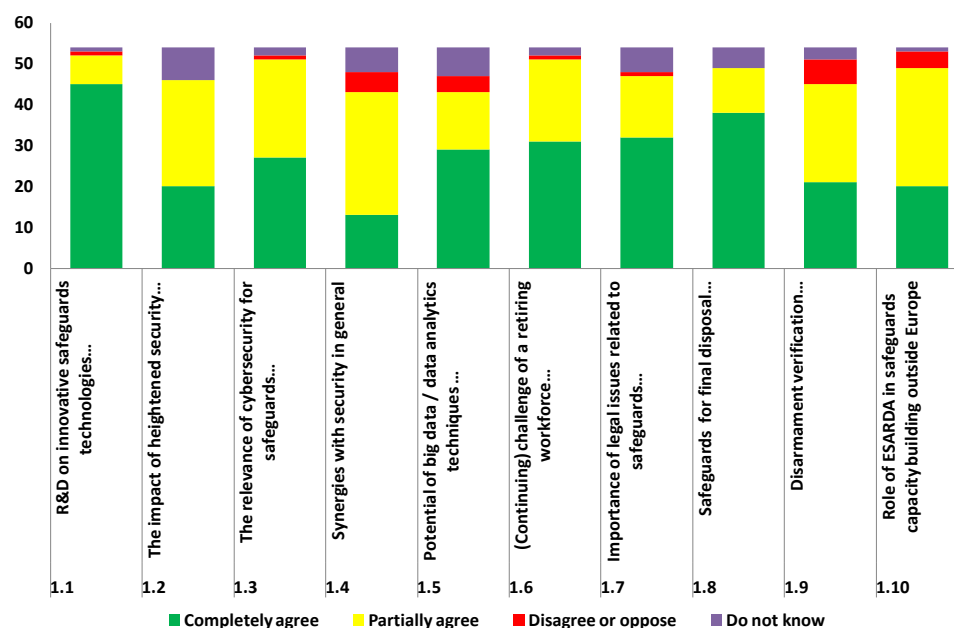


Figure 1: Distribution of answers between the four categories for all the topics

In the **'how'-questionnaire**, the four categories of answers were: 'Yes', 'No', 'Don't have an opinion', and 'Don't know'. Table 4 lists the questions in order of the percentage of respondents that responded 'No'.

Table 4: Ordered list of how ESARDA works, derived from the 'how'-questionnaire

| Question | NO | YES | No opinion |
|--|-----|-----|------------|
| Do you feel that ESARDA is sufficiently (externally) visible? | 56% | 15% | 26% |
| Is the current ESARDA internal communication sufficient? | 41% | 30% | 26% |
| Is the current ESARDA external communication sufficient? | 33% | 28% | 37% |
| Is ESARDA properly implementing knowledge management, both inside ESARDA and for the stakeholders? | 33% | 28% | 37% |
| Is the current composition of ESARDA members satisfactory? | 31% | 41% | 26% |
| Does ESARDA have sufficient means to function (e.g. funding/support)? | 30% | 28% | 41% |
| Is ESARDA sufficiently prepared and positioned to face the changing nuclear, technical and political landscape? | 30% | 28% | 39% |
| Is ESARDA currently well-positioned to serve as an incubator for cutting edge technologies, for safeguards and beyond? | 28% | 44% | 26% |
| Does ESARDA sufficiently bridge the gaps between different disciplines? | 28% | 43% | 28% |
| Is ESARDA output (Bulletin, website, symposium, technical sheets, ESARDA course, Joint Workshops ESARDA-INMM, etc.) sufficient to have an impact and provide an added value for the ESARDA members and stakeholders? | 22% | 69% | 7% |
| Is there enough attention within ESARDA to evaluate different options for synergies between Safeguards and other nuclear disciplines (safety, security), both technically and organisationally? | 20% | 41% | 37% |
| Is the safeguards infrastructure (laboratories, facilities, etc.) adequately available for ESARDA members? | 17% | 24% | 56% |
| Is the current structure of ESARDA (Working Groups, Steering committee, Executive Board ...) fit for purpose? | 17% | 63% | 15% |
| Is the ESARDA Agreement properly covering your expectations from ESARDA? | 11% | 50% | 33% |
| Do you think that ESARDA should (continue to) operate as platform and/or test bed for pilot exercises, validation of new approaches, inter-comparison exercises, etc.? | 0% | 89% | 6% |

For the question of “**what is the most important benefit you see from your personal perspective**”, the answers included the following benefits:

- Exchange with experts from other disciplines in Safeguards
- Interaction with others (ESARDA is a good platform for that)
- Knowledge/experience sharing
- Networking
- Learning the current/new R&D activities
- Learning the challenges in Safeguards
- To get an overview about the whole field of Safeguards
- Informal way of discussions (should be kept like this)
- WGs, interactions on technical level
- ESARDA Bulletin/symposium

There were some points made relating to **additional topics**, for the RG2019 to consider in developing its recommendations for ESARDA as follows:

- Members should be more actively involved in WGs, committees, etc.
- Review of EURATOM treaty, legal issues
- Safeguards culture
- Do not expand the scope of ESARDA too much (e.g. disarmament & security issues). There are other fora for such topics.

ESARDA REFLECTION GROUP 2010 (RG2010)

The previous ESARDA Reflection Group exercise was launched in 2010. During the 2000-2010 decade, important developments in the field of global security impacted upon international safeguards, nuclear non-proliferation, nuclear security and nuclear disarmament verification. At the same time, the concept of a nuclear “renaissance” took root with an expansion in ambitions for the civil use of nuclear energy and nuclear fuel cycles, both within the EU and worldwide.

The specific terms of reference (ToR) of RG2010, read as follows: ToR 1, to review the status of implementation of the decisions taken by ESARDA, based on the proposals of the RG 2000; ToR 2, to assess the international and European context and trends in nuclear non- proliferation and safeguards, security and disarmament verification areas and their impact on ESARDA’s research and development activities; ToR 3, to analyze whether further actions and activities are needed in order to meet ESARDA members’ needs at European and international level; ToR 4, to make proposals to the Steering Committee regarding possible improvements in the objectives, scope, structure and operations/management of the Association.

The RG2010 comprised 14 members from the ESARDA Steering Committee, from working groups; direct beneficiaries of the R&D activities of ESARDA and, finally, individuals with major involvement in international safeguards activities. The methodology was based on a three-stage approach: Stage 1: Analysis of the status of the Association, also from the point of view of implementing the recommendations of the previous Reflection Group 2000; Stage 2: Identification of needs and challenges; Stage 3: Coping with identified challenges and opportunities.

The collective work of RG2010 led to an executive summary, whilst a final report was compiled during the RG2019 exercise. The RG2019 took due notice of the recommendations from

RG2010, listed below, evaluated what was or was not implemented, and analysed the non-implemented recommendations w.r.t. how they might be included in the dynamic action list of the RG2019.

RG2010 Recommendations

1. RG2010 recommended that system analysis was implemented to support a consistent objectives-based safeguards and verification approach: application of the physical model, misuse and diversion scenarios with plausibility checks were indicated as elements which should be considered together with classical safeguards.
2. RG2010 observed the lack of facility-specific Working Groups (WGs) and saw in the newly created "Implementation of safeguards" (IS) WG the ideal forum for dealing with the definition of new safeguards concepts for final repositories.
3. ESARDA should continue developing safeguards by design activities to support the IAEA and Member States in the development of safeguards concepts for new facilities.
4. IS WG could also serve as a contact point, to establish connections between operators of similar plants in different States, for discussing problems and experiences.
5. RG2010 recommended a detailed assessment of the possibility of expanding from solely safeguards towards nuclear security (broad sense) R&D. It was proposed that ESARDA should have a permanent Nuclear Security WG, dealing with collection of information / best-practices, including e.g. border monitoring and detection of illicit trafficking.
6. ESARDA should emphasise the technical convergence of nuclear safeguards, nuclear forensics and nuclear security by defining methodologies that serve all three purposes.
7. RG2010 recommended the creation of a WG on dual use goods export control.
8. RG2010 recommended that, contingent upon the launching of FMCT negotiations, ESARDA should draw on the expertise of its members to initiate preliminary work on cut-off and disarmament verification, with the objective of providing the Conference on Disarmament with professional advice.
9. RG2010 recommended that ESARDA keep close watch on cyber-security topics and assist the safeguards community. This could be dealt with by the Containment and Surveillance WG
10. ESARDA WGs should maintain and reinforce their role in research and training, and respond to the inspectorates' needs; National authorities should be invited to attend ESARDA Symposia or WGs, to benefit from ESARDA competences, helping to maintain national competence in areas currently not pursued in a particular country (e. g. final disposal).
11. RG2010 also proposed that ESARDA act as an independent reviewer for proposed research projects.
12. ESARDA should expand its membership base in order to increase its role in the promotion of nuclear security and non-proliferation in the world. More industrial companies active in the supply of nuclear equipment, fuel and services should be invited to join. Other national authorities in the new Member States of the European Union should also be approached. Academic institutions should also be invited to join ESARDA.
13. RG2010 recommended that the Steering Committee evaluate the opportunity and benefits to formalise a collaboration agreement with the INMM. Possible fields of collaboration include the identification of R&D topics for improved safeguards and nuclear security, information exchange, common actions (e.g. training), etc.
14. RG2010 considered that the present management structure and ESARDA contract serve very well the needs of the association.

3. DISCUSSION AND RESULTS, OUTCOME OF THE REFLECTION GROUP

PREAMBLE

The RG2019 identified, debated and analysed future requirements for ESARDA. The RG2019 decided to present ten priorities from which to develop actions within a ROADMAP. These ten priorities are presented in this chapter. Each priority is introduced with a short background and rationale, after which the links to the Actions in the ROADMAP are listed.

Upfront, it should be noted that ESARDA aims to serve all safeguards stakeholders: the operators of nuclear facilities; technical support organisations; national inspectorates and authorities; regional inspectorates (EURATOM); and the International Atomic Energy Agency (IAEA). As the interests, roles, objectives and mandates of these different stakeholders may differ, the R&D and academic community seeks to provide results and products that can satisfy multiple demands. This means that not all proposed priorities are of the same relevance to all stakeholders. Moreover, ESARDA will continue to be constrained by the voluntary nature of the Association and reliance upon its members' activities. Where relevant, an explicit reference to a group of stakeholders (e.g. the operators) is provided.

This document follows ongoing developments in the implementation of safeguards, i.e. moving from a mechanistic, criteria-driven assessment of compliance at the facility level with specific verification measures (traditional safeguards and Euratom safeguards) to a more global assessment of compliance based on the overall coherence and consistency of all safeguards-relevant information regarding a State's nuclear programme (the State Level Approach). This evolution has its origins in evidence of limitations in the traditional facility-based safeguards approach, and by the potential for additional information to contribute to the overall safeguards conclusions at the State level. Many of the proposed research aspects result directly from associated new needs (more information, more data to be analysed, need for better visualisation and processing tools). At the same time, a focus was maintained on the further optimisation of existing tasks that are now carried out much quicker and more effectively (e.g. BTC verification using laser technology).

When compliance is assessed via coherence and consistency of all safeguards-relevant information regarding a State's nuclear programme, it becomes important to acknowledge that not all the information that will be processed will be "equal", but has different degrees of veracity (e.g. information provided by the States, such as declarations and reports by the State, information from safeguards activities conducted by the Inspectorates, other relevant information such as open source data, etc.). The document thus covers business analytics techniques and automatic data processing and analysis in quite some depth, albeit going into less detail on human factors: i.e. how analysis is performed and visualisation is prepared to make sure that the meaning of the information is clearer to the analyst. How the human brain perceives, elaborates and makes judgements or decisions on data and information is one of the most influential links in the entire process chain and proved a major contribution to the failure of some of the most high-profile intelligence and non-proliferation analyses of the past. Whilst this topic has been studied in the intelligence community since the 1970s, the safeguards community is starting to approach it only now. Any business analytics tool or technique would

have to take the human factor into account, which might be an additional area where ESARDA can play a role in the medium term.

Coherence and consistency of the picture of a State's current and planned nuclear programme are not enough for international safeguards, as completeness is as much important. Also here, there is an important role for innovative research tools and approaches for inspection and analysis. It is clear that these two functions will still be required in the future, but the skills and competences of inspectors and analysts will be different from those currently required. This needs to be taken into account when reaching out to the young generation and training of future inspectors and analysts.

SHORT TERM PRIORITIES

The short-term priorities for ESARDA are driven by the requirements of current EC safeguards policy and its evolution, and resource constraints in implementing safeguards. The latter is complicated by the increased scope and complexity of duties for both European and International inspection authorities and State authorities responsible for safeguards (e.g. due to the increased demands of the back-end of the fuel cycle and the number of facilities under decommissioning) and their potential burden upon facility operators. The overall goal for the short-term activities of ESARDA is to develop and facilitate the implementation of further improvements in safeguards effectiveness and efficiency at all levels.

Measures seeking to address this overall goal include:

- Contribution to the enhanced use of “on-site physical inspection time-saving” approaches
- Integration of multiple sensors and data sources
- Improvement in the analysis of available safeguards data

The challenge of sustaining human resources - attracting the younger generation and dealing with a retiring workforce - is an important issue to be resolved. In addition, achieving adequate awareness and visibility of safeguards at both public and internal/EC policy level needs to be considered, to ensure appropriate budget attributions for both inspections and underpinning R&D.

The short term priorities are therefore grouped into 5 categories:

- Increased focus on back-end of the fuel cycle (encapsulation and final disposal)
- Increased share of automated and remote inspection activities in line with digital transformation
- Extraction of more safeguards-relevant information from collected data (while ensuring the safeguards data security on site, during transport/transmission or in inspectorate headquarters)
- Preparation of the next generation of safeguards specialists
- Increased awareness and visibility of safeguards at the public and political level

These are elaborated below.

Action 1. Strengthen the focus on development, pilot-testing and evaluation of safeguards approaches for the **back-end of the fuel cycle** (incl. encapsulation plants and final repositories)

Based on the continued operation of a large number of nuclear fuel-cycle facilities worldwide, with new entries only partially offset by the very few countries (mainly Finland and Sweden) that have a viable concept so far for final disposal of spent nuclear fuel, the amount of nuclear material under safeguards continues to increase.

This is especially visible and challenging when considering spent nuclear fuel in the back-end of the fuel cycle, where the amount of fuel in wet storage at the facilities, dry storage in dedicated locations or undergoing transportation, continues to increase with corresponding requirements for verification and reverification of the fuel. The storage containers used present a quite recent and technologically very difficult challenge, as these containers have typically been designed for maximum shielding which constrains traditional monitoring and measurements through NDA.

In addition, the facilities where spent nuclear fuel will be encapsulated for final storage are new type of facilities, so almost no previous safeguards implementation experience is available. Highly automated facilities, working 24/7, will require specific developments if they are to be safeguarded in a reliable manner, with the additional challenge of accurately quantifying a potentially diverse range of materials being handled (i.e. spent fuel elements with a variety of compositions, burn-ups, burnable poisons, irradiation histories and potential inhomogeneity etc.).

The issue of a range of spent fuel compositions holds true also for the final disposal facilities, which provide additional and very specific challenges: e.g. monitoring of the geographical area; the unusual combined operations of drilling tunnels, filling some with casks containing spent nuclear fuel whilst backfilling others with natural materials; the enormously long time over which records and historical knowledge of the content of the facility will need to be maintained; and the extreme difficulty in re-establishing continuity of knowledge in case this would be lost.

Several international working groups have worked on these topics in the past, such as the IAEA expert groups SAGOR and ASTOR from 1994-2017. However, ESARDA considers it a short-term priority to provide input to safeguards approaches for final disposal facilities as, in the very near future, disposal operations in at least two countries are scheduled to commence and, therefore, capabilities have to transition from research to implementation very soon. ESARDA has a strong interest and is very well-placed, having the relevant countries on board as partners in ESARDA, to jointly develop optimum solutions. ESARDA can be a forum for discussion between specialists in developing safeguards approaches for these types of facilities.

Specific actions

- 1.1. Enhance techniques for verification and characterisation of spent fuel (e.g. passive gamma emission tomography)
- 1.2. Enhance the development of smart safeguards approaches for encapsulation plants (e.g. multispectral cameras, smart seals, identification of canisters, etc.)

- 1.3. Give attention to proper safeguards for the transport of loaded final storage containers
- 1.4. Develop technologies for (re)verification of loaded spent fuel canisters (e.g. muon tomography)
- 1.5. Improve and evaluate the approaches for safeguarding of deep geological repositories, including long-term storage of data and the use of special verification techniques

Action 2. Fully exploit the potential of remote data transfer, remote observation and control, artificial intelligence and machine learning for enhancing the implementation of safeguards measurements and data evaluation, duly taking into account (cyber) security considerations

When today it is possible to send robotised probes to distant planets, collect soil and environment samples and send back the related data to earth, it should be possible to significantly enhance also the way safeguards is implemented in declared nuclear facilities without having to send inspectors into the field for routine inspections (especially on a purely verification mission). However, whilst the burden on the in-field inspector might be reduced, albeit with a partial shift to the analyst, inspectors are still essential to address certain anomalies, solve unexpected questions, implement short notice unannounced inspections and, of course, inspect sites that are suspected to have clandestine, non-declared or fully hidden activities or facilities.

To allow the implementation of many “inspector time-saving” approaches, it will be necessary to involve the operators of the facilities and their national authorities to consider the development of such enhanced and real-time “safeguards monitoring” approaches in a win-win arrangement with the operator.

The more that relevant data can reliably be made available to the inspectors/analysts, the more unlikely it becomes that errors or anomalies within a single instrument, sensor or measurement would disturb the capacity to draw credible safeguards conclusions.

This approach might, however, require a fundamental rethinking of safeguards: from the independent – enforcement-like – inspection and verification that seeks to confirm correctness or detect wrongdoing by the operator, towards a pre-established safeguards model and approach that involves a partnership with the operator, where a much more reliable and complete picture of the facility can be monitored (e.g. including information on the facility’s process control), which should in turn allow higher-quality conclusions to be drawn (e.g. conclusions with a higher confidence level). The shift from compliance through verification to compliance through coherence and completeness will require a data intake of less “pristine” reliability and credibility, and it will be up to the analysis and evaluation approaches in place to take the accuracy of such data into account.

When transferring massive amounts of potentially sensitive data from the facilities to the inspectorate headquarters, specific attention needs to be paid to communications security,

authentication, timeliness (not necessarily implying real-time), immutability, traceability etc. Distributed ledger technologies, and other approaches supporting advanced encryption and data protection, might find their place here. Some might only become available in the medium term, which is why this priority is represented both in the short term (because a lot can already be done) and in the medium term (to accommodate anticipated future developments and technological breakthroughs).

Modelling will be needed, to support both the algorithms for data correlations, outlier or anomaly detection, and the overall decision-making on the “state of operation” of a facility (e.g. green, orange or red, akin to normal, slightly deviating and anomalous operation). A signaling of anomalous operation might not result in an order to halt a process, but could determine the material sampling rate or another increased inspection frequency/attention measure, as appropriate.

In this area, techniques and approaches such as machine learning, neural networks, artificial intelligence, self-organising sensor networks and other innovations will find application, i.e. a full embracement of the digital transformation by nuclear safeguards.

Finally, further technological developments, for example those that allow on-line measurements rather than more tedious (and potentially error prone) sample taking and off-line analysis, should be strived for. These technological developments should not only be less intensive on human resources, but should also minimise difficult areas like stability, transport, storage costs and waste of safeguards samples being taken and analysed in-field or in central laboratories.

Specific actions:

- 2.1. Develop and promote enhanced inspection and sampling schemes to optimize the use of human and other resources through remote operations and control
- 2.2. Pursue the deployment of smart process-monitoring and remote monitoring for a variety of fuel cycle facilities, including the use of advanced statistics, quality control, machine learning, artificial intelligence etc.
- 2.3. Address security issues, in particular cybersecurity, data traceability and immutability in the collection, transfer, storage and handling of safeguards-relevant data

Action 3. Enhance the use of modern business analytics/intelligence and data science tools to reach higher quality findings from current and future nuclear safeguards relevant data (all types)

Large amounts of safeguards-relevant data are being recorded across Europe and worldwide, and many of the data have been chosen because they have a very specific function (quantification, verification, confirmation scope etc. of a certain parameter in an overall safeguards equation). In addition to evaluating the actual value at a specific point in time for safeguards purposes, it could be highly informative to follow the variation of these values over time, their potential relations (consistency/coherency etc.) to other parameters, their error bars

due to the chosen sensor technique or inspector or facility dependency. At a time when human resources are scarce and computing power large, it is deemed appropriate to rethink the way data are being analysed, recognising that each value provided by a safeguards system can contain valuable information also over time and even more when analysed together with all other data.

It is therefore considered appropriate to assess the benefits of developing approaches that allow for processing very large sets of data, e.g. those transmitted with relatively high frequencies from the operator process control, in near real-time, and using them in trend analysis, pattern recognition, statistical evaluation and benchmarking, e.g. between facilities, KMPs in the same facility, between inspectors, etc.

The way in which data are to be visualised and analyzed depends upon the intended objective of the analysis and the “eye” that is going to analyze it. The human factor, i.e. the way the human brain perceives and processes the information, coupled with how it makes decisions, needs to be considered. In addition, by visualizing large sets of data in different ways, including without reproducing pre-established relations between these data, anomalous patterns might be discovered which would otherwise remain hidden. Another “common denominator” for many data might be the spatial coordinates of the sampling points, materials, inspectors etc. which could allow detection of spatial links, patterns, trends etc. previously not identified or recognised. Collecting, structuring and storing of spatial data might also be instrumental in more effectively preparing inspection missions, undertaking on-site verifications and recognising changes from the past (ideally in an automated manner – see medium term trends).

Modern business analytics and/or business intelligence tools exist, for which the application to safeguards is worthwhile investigating. These tools can be combined with data evaluation software that identifies outliers, anomalies etc. in those large data sets and combines these with other – independent – signals to facilitate, in an intelligent manner, estimation of the type of error margin associated with one or the other measurement, safeguards hypothesis etc.

It is believed that the integrated data analysis of a large set of data, not a priori each of them individually being safeguards relevant, but when putting them together allowing to grasp the larger picture, can support a real paradigm shift to safeguards. From a situation where single analysis, measurements or surveillance points are monitored and analysed by safeguards, one could arrive at having a full facility picture, allowing to confirm the correct operation of the facility (from a safeguards perspective) , even if a number of parameters are missing or showing anomalous values (e.g. due to equipment failure, sensor breakdown etc.). This overall objective also motivates the short term priority 2 described above and even spills over into the medium term’s priority 6.

Specific actions:

- 3.1. Reach out to the business intelligence and data science community and seek for expertise, tools and insights to apply to safeguards.
- 3.2. Consider the benefits of using geographic information systems & enhanced data visualisation and interconnected databases for mapping, storing, presenting, analyzing

safeguards data (with due attention to the sensitivity and/or classification of certain types of information)

- 3.3. Consider establishing a new sub-working group in ESARDA on modern business analytics, and data science and in general analytical tools in support of the safeguards analyst.

Action 4. Attract the **young generation** to and implement **knowledge transfer** from the field of nuclear safeguards and non-proliferation

The challenge to engage with the young generation, and at the same time assure the transfer of knowledge and experience from retiring staff, is a well-recognised challenge in the nuclear world, in particular in Western Europe and the US. Because of the niche area of nuclear safeguards as described below, this challenge is further aggravated in the field of activities of ESARDA.

It was already recognised over 15 years ago that typical academic nuclear programmes and nuclear summer schools or training courses for professionals in general do not cover the field of nuclear safeguards and non-proliferation.

Moreover, the IAEA reports that it is experiencing difficulty in finding sufficient qualified persons in a number of States to operate the national systems of safeguards and NMAC, or to take up jobs in nuclear safeguards at IAEA.

Specific actions:

- 4.1. Launch specific outreach activities to other (nuclear) communities and networks such as European Nuclear Society, International Young Nuclear Congress, etc. to promote R&D and careers in nuclear safeguards and non-proliferation, and increase the diversity of the ESARDA Membership
- 4.2. Review, revise and implement the initial concept of operating a Young Generation Initiative within ESARDA
- 4.3. Continue to give and develop training courses on safeguards and enhance outreach activities in close collaboration with the IAEA and other players (e.g. ENEN at European level) in both education and training, if possible including external funding
- 4.4. To assure knowledge transfer from the retiring generation to the young generation through the development of an effective knowledge management concept.

Action 5. Enhance the **awareness and visibility** of nuclear safeguards at the public and political level

Nuclear safeguards is an extreme niche activity which is not well known, not even to many nuclear specialists, let alone politicians, authorities or the broader public. It is also a discipline

where a high level of technical complexity is combined with engineering aspects of facility operation, legal aspects, statistics, modelling, chemistry, physics and IT and political insights (and for the IAEA, for example also the understanding of the very complex nuclear weaponisation process).

The problem of a lack of safeguards awareness also goes back to the conception of many nuclear facilities, where the safeguards concerns and requirements were historically seldom taken into account in the design or operational manuals.

ESARDA considers it worthwhile to identify and address technical synergies between nuclear safeguards and safety and security. One such example of a synergy with safety is in the area of nuclear waste characterisation, where the increase in number of facilities undergoing decommissioning brings an increasing challenge to both safety and safeguards communities. The capabilities to be put in place for waste characterisation in terms of safety and radiation protection and those required to quantify traces of fissile materials go hand-in-hand. This topic is also relevant for the medium-term priority 7, as decommissioning activities will continue to grow over time. An obvious area for synergies with security is the containment and surveillance field, but also in the area of particle analysis and nuclear forensics there exist ample opportunities to enhance interactions between safeguards and security.

Pursuing this road further, we might also be able to come to a situation where the plant operator or national authority (e.g. in the case of grouped small holders, such as hospitals and research institutes) embraces safeguards with greater emphasis and seeks to further increase its efficiency and effectiveness in a win-win approach with the inspectorates. This in line e.g. with the process in which DG ENER seeks to increase cooperation with the national authorities for the case of grouped small holders by investigating different approaches in terms of safeguards verification responsibility.

Also relevant in this area is that the outreach of the safeguards community to beyond Europe is expected to grow in emphasis in the years to come. This can be seen by the genuine interest of new areas across the globe for capacity building in nuclear safeguards and non-proliferation.

Finally, new means of communication will be used (like social media, twitter etc.) both to enhance the profile of the Association and to collect information which may be used by ESARDA parties.

Specific actions:

- 5.1. Engage with external partners/organisations/academia/policy-makers to increase awareness and visibility of ESARDA (nuclear safeguards and non-proliferation); including promotion, communication, dissemination, continuation and foresight of ESARDA success stories
- 5.2. Address the technical synergies between safeguards and safety / security
- 5.3. Promote the collaboration between inspectorates and State authorities, e.g. also in the area of characterization of waste from nuclear decommissioning and with small holders.

5.4. Contribute to the transparent and recognized positioning of European safeguards in the policy context with EU Member States

5.5. Support the liaison between Euratom and IAEA on safeguards implementation

MEDIUM TERM VISION

It is clear that any actions in the medium term vision will require review depending upon the results of the shorter term actions. The RG2019 expects that safeguards and non-proliferation related activities, in the next 10 to 30 years, will be very strongly influenced by further technological developments and, therefore, only a few ideas are presented here. The introduction of novel technologies on the international scene (e.g. by the IAEA) will also be closely followed and supported by ESARDA.

The three resulting priorities build from the short-term priorities are described in the following sections addressing three future questions:

- How innovation will continue to influence safeguards implementation?
- How the changes of the nuclear landscape in Europe will influence key requirements for ESARDA?
- How relevant international developments will bring new challenges to ESARDA?

As for the short term priorities, each priority is described with a short introduction and context and then a number of focus points are provided including the actions retained for the Roadmap. The specificity and focus of these developments would have to be reviewed after three to five years and then would be expected to result in a specific, results- and impact-oriented action for the Roadmap.

Action 6. Continued **safeguards enhancement based on R&D** (key role for ESARDA)

This obvious priority for ESARDA, without however being specific at this level, is included to stress that “blue sky” research is also needed to identify potential solutions in the future, for problems that might not yet have been recognised. This includes fundamental research on how to address possible challenges in the safeguards approach, even if such potential is still far away in time. It also covers fully new ways of working that might become possible as a result of breakthroughs that are not yet envisaged.

Some of the proposals below are already available in a prototype version or might have demonstrated their theoretical potential, but in order for them to find a wider application and/or become typical safeguards “work-horse” technologies, it is estimated that at least a couple of years’ development will be required. In addition, some proposals might only be practical to be implemented in new facilities (e.g. under a safeguards by design concept), whereas others might already find application in a very specific current situation.

One source of inspiration to this medium term R&D driven priority for ESARDA was the outcome of the IAEA 2017 Emerging Technologies Workshop (Trends and Implications for

Safeguards), and the latest – November 2018 – IAEA Safeguards Symposium, where several ESARDA members participated, and keywords from that workshop were added to the focus points below as deemed appropriate. In addition, a specific consultation with DG ENER Safeguards Directorate took place just before finalizing the Reflection Group Report to collect the medium/long term R&D needs from EURATOM.

Specific actions:

- 6.1. Maintain and promote ESARDA as testbed and platform for exchange and communication
- 6.2. Explore to what extent the internet of things, distributed and self-organising networks of sensors, smart data and equipment, and the use of distributed ledger technology etc. are suitable tools to support the implementation of nuclear safeguards with less inspector presence on site in future.
- 6.3. Develop and promote the use of augmented reality, ambient intelligence, enhanced self-localisation, virtual reality tools, next generation of robotics, for future in-field inspections
- 6.4. Investigate the potential of future and emerging technologies such as artificial intelligence, enhanced cognitive systems, data analysis, block chain, robotics, biotechnologies, new materials, nanotechnologies, quantum technologies, 'green' technologies, etc. to support safeguards evaluations and approaches.
- 6.5. Stimulate 'out-of-the box' thinking and encourage engaging with global system science, behavioral sciences, social media, crowdsourcing, all-information analysis, arts & science, etc. to bring in new ideas into safeguards

Action 7. Further **changes in nuclear fuel cycle strategies and operations in Europe**

In continuation of the short term priority 1, ESARDA expects that, over the next 10 years or so, challenges will increase still further in terms of decommissioning, problematic (special) waste types, massive amounts of spent nuclear fuel and, perhaps, one or more innovative reactor design that might be introduced on the EU territory. It is not clear to what extent a future enhanced closed nuclear fuel cycle can be actually deployed in Europe, but the knowledge gathered under this umbrella may also be applied outside the EU.

In these fields, the synergies with safety R&D will also be explored, for example in waste characterisation, transport and storage. At the level of safeguards for future nuclear technologies, the concept of 'safeguards by design' needs to be connected closer to the safety design studies, concepts and methodologies.

Specific actions:

- 7.1. Evaluate techniques to screen final disposal sites after closure

- 7.2. Develop, validate and promote the application of characterisation techniques that are of mutual benefit for safeguards, decommissioning and waste management, which might lead one day to the definition of exemption levels of fissile materials from safeguards
- 7.3. Keep ESARDA's R&D appraised of possible new and or advanced concepts of nuclear facilities which might require adapted or new safeguards approaches (e.g. small modular reactors, Generation IV, and safeguards for accelerator driven systems like Myrrha)

Action 8. Contribute safeguards expertise to **major nuclear developments outside Europe**

In the context of international safeguards, all aspects of the future generation of nuclear technologies, including transportable reactors, SMRs etc. will be relevant.

This priority also connects to the short term priority 4 above w.r.t. capacity building, as a number of the potential geographical areas for new-build do not have existing experience of international safeguards implementation. The training, education and knowledge management activities of ESARDA can thus be expected to provide a major contribution to this in the medium term.

Specific actions:

- 8.1. Support and exchange with 'nuclear newcomer' countries i.e. those without pre-existing nuclear safeguards infrastructure.
- 8.2. Follow-up closely in which aspects ESARDA could support (new) sensitive nuclear fuel cycles from a safeguards and non-proliferation point of view, including transportable NPPs, pyroprocessing, molten salt reactors etc.

ESARDA'S STRUCTURE AND OPERATION

The RG2019 recommends two types of activities in regard to the structure and operation of ESARDA: those of a more procedural nature and those that we can classify under the header "enhanced operational features".

Action 9. **Procedural**

Specific actions:

- 9.1. Issue a final version of the rules and procedures, describing in more detail the working methods; revise the ESARDA agreement as appropriate to assure that operational practices based on the rules and procedures are in compliance ; prepare additional documents to better explain the ESARDA agreement as well as rules and procedures to the ESARDA community, e.g. ESARDA welcome package for new members, guidance document for WG chairs about tasks & duties, etc...

- 9.2. Develop and implement an ESARDA (internal and external) communication strategy; including short communications to attract new members; improved use of the website, the ESARDA document repository CIRCABC and social media
- 9.3. Evaluate the opportunities of a peer-reviewed, SCOPUS indexed, open-access journal supplementary to a monthly/bi-annual ESARDA Newsletter/Report
- 9.4. Develop guidance on organising, hosting and evaluating ESARDA annual meetings/symposia
- 9.5. Implement a harmonised mechanism for ESARDA Reflection Group actions progress review; including a mechanism to follow-up on open issues from the ESARDA membership survey on ESARDA's activities and future priorities

Action 10. Operational

Specific actions:

- 10.1. Envisage modernisation approaches for the open ESARDA symposium, such as the use of live-web streaming and interactive/participatory session formats and tools
- 10.2. Encourage EURATOM safeguards and the IAEA upfront of the closed ESARDA meetings (even years) to propose specific topics for the ESARDA WGs to reflect and work on
- 10.3. Strengthen and enhance synergies between ESARDA WGs
- 10.4. Continue the successful series of joint workshops on dedicated topics, of interest to multiple ESARDA WGs but also to invited experts beyond the safeguards and/or nuclear field, to further provide integrated solutions and advice to safeguards stakeholders
- 10.5. Motivate more ESARDA WG members to engage and guarantee a fair distribution of WG tasks, e.g. in the production of ESARDA Technical sheets and other actions

4. NEXT STEPS

RATIONALE

ESARDA aims to bring together all those involved in safeguards, so that progress and continuous improvement in international safeguards can be achieved efficiently and to a professional standard. ESARDA also provides a forum for the exchange of information and ideas between nuclear facility operators, safeguards authorities and persons engaged in research and development. The Parties and Associated members are the asset of ESARDA. The success of ESARDA therefore strongly depends on the commitment of each organisation and the voluntarily engagement of each member actively involved in the research and development of nuclear safeguards. In addition representatives from other organisations that are not member parties, amongst them the IAEA, ABACC, APSN and INMM, regularly take part in ESARDA's activities. The RG2019 aims to embrace this diversity for the mutual benefit of ESARDA and all its contributors.

IMPLEMENTATION OF THE ROAD MAP

The RG2019 puts forward actions within a ROADMAP towards the ten priorities as outlined in Chapter 3. Several approaches have been discussed concerning the implementation of those actions, all having advantages and disadvantages, but there is a consensus that implementation will only successfully serve all safeguards stakeholders when each organisation, member and/or contributor to ESARDA takes ownership of the ROADMAP and its implementation. Therefore, the RG2019 is proposing means to this end, of introducing mechanisms and tools that enable organisations and individuals to commit to well-defined actions and tasks in respect to their fields of expertise and mandate. In addition, empowerment of ESARDA members and contributors is encouraged, to leave their comfort zones, bringing in new ideas whilst using ESARDA as platform for exchange to its full extent.

ESARDA SYMPOSIUM 2019: ROUNDTABLE

During the 2019 Symposium, and in line with the actions defined by the RG 2019, a round table is organised on ESARDA outreach and partnership on the following topics:

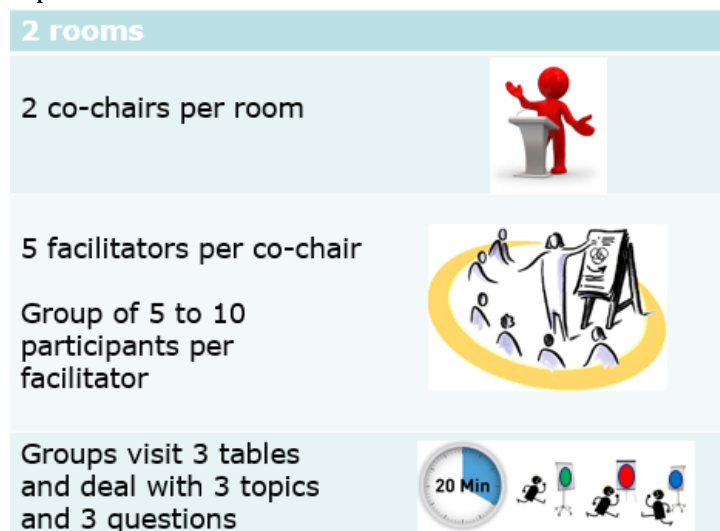
- The international dimension: e.g. how to bring on board nuclear newcomers?
- The multidisciplinary character: e.g. how to embrace the different technical (physics, chemistry, engineering, IT, ...), legal and political aspects in an efficient and effective manner?
- The strong impact of innovation : e.g. how to deal with digital transformation?
- The rejuvenation : how to attract and engage the young generation?
- Knowledge preservation, management and transfer : best practices?

ESARDA SYMPOSIUM 2019: WORLD CAFÉ ON ESARDA REFLECTION GROUP OUTCOME

As a first step to take ownership of the ESARDA RG ROADMAP, an interactive World Café session will be organised at the ESARDA Symposium 2019. The ultimate goal is that participants not only take ownership of the RG2019 actions but contribute actively to their future implementation, ideally taking an action in their personal agenda.

THE MECHANICS OF THE WORLD CAFÉ SESSION

In two rooms, about 200 people are going to be organised in groups of up to 10 individuals, and each group is associated with a facilitator. Four groups of five facilitators are then connected to the four world-Café co-chairs. Therefore, in each of the two rooms, 2 co-chairs and 10 facilitators will discuss within the groups the World-Café topics.



Building upon previous ESARDA WG World-Café experiences, and given the RG2019 recommendations, it was decided to propose the following set of World-Café questions:

- 1. Wishes**
What do we really want and why?
Where do we want to be?
- 2. Challenges**
Limitations and obstacles: what may not work? Where are unpaved roads?
- 3. Actions**
Recommendations: what can we do? (as individuals, organisations, and ESARDA members) How do we get there?

As a result of the World Café process, participants will be invited to take concrete implementation steps answering the questions:

- **WHAT CAN I DO** to implement the RG2019 actions (within my organisation)?
- **WHAT CAN ESARDA AS AN ORGANISATION DO** to implement the RG2019 actions?

This approach was proposed considering that ESARDA has made a **survey** (see Annex C) among its members that fed into the RG2019 report, actions and roadmap. However, a number of ESARDA symposium participants have not

ESARDA SHORT TERM PRIORITIES (2019-2024)

are driven by the requirements of current EC safeguards policy and its near-time evolution, and resource constraints in implementing safeguards. Progress on their implementation will be reviewed during each Executive Board meeting and reported at each annual meeting to the ESARDA members. Similarly the ESARDA WG chairs will report on the implementation of the respective ROADMAP actions that have been taken on by their WGs at the bi-annual meetings hosted by DG ENER. Achievements in the implementation of short term priorities will be shared with the membership via the ESARDA Bulletin (or new tool).

ESARDA MEDIUM TERM PRIORITIES (2019-2029)

will be very strongly influenced from further technological developments and the introduction of novel technologies. Progress on the implementation will be reviewed during each Executive Board meeting and reported during each bi-annual meeting hosted by DG ENER in Luxembourg to the ESARDA members.

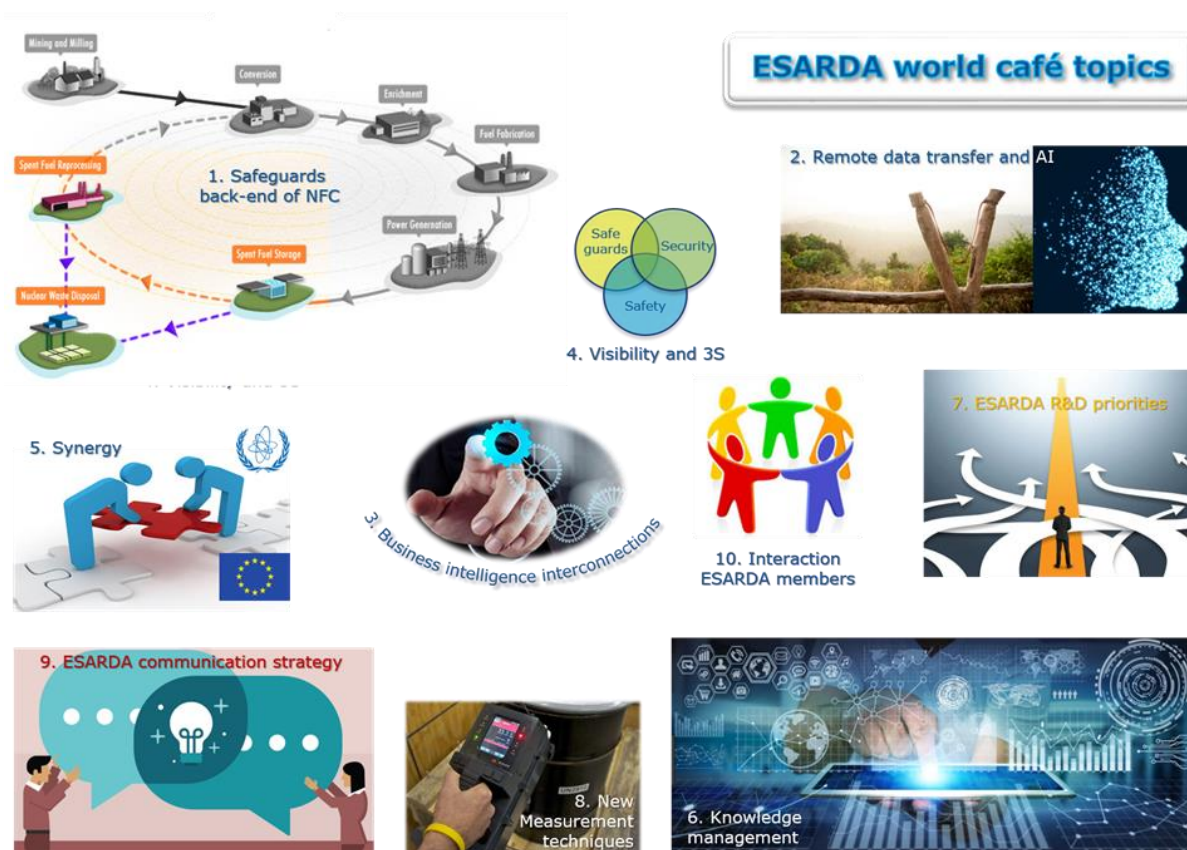
THE IMPLEMENTATION OF ESARDA STRUCTURES AND OPERATION

of a procedural nature will be regularly reviewed by the ESARDA Executive Board. The implementation of operational Actions will be reviewed in all the ESARDA WGs and reported to the Executive Board.

expressed their views in this survey, and also the RG2019 members do not represent the full spectrum of ESARDA members and contributors. At this 50th anniversary, distinguished guests and representatives from stakeholders not party to ESARDA will be invited to feed into the implementation of ESARDA priorities, such as INMM, operators, IAEA, ABACC, universities, education networks.

THE 10 WORLD CAFÉ TOPICS

The 10 World Café topics are identified as the most salient challenges (see graphic below) stemming from the priorities in Chapter IV.



The World Café results will be presented by the co-chairs at the ESARDA symposium closing plenary to all the ESARDA symposium participants. A detailed report on the session's outcome, including feedback from participants will be published in the ESARDA Bulletin

5. ACTION LIST / ROADMAP / TIME-LINE

ACTION LIST

SHORT TERM PRIORITIES (2019-2024)

Action 1. Strengthen the focus on development, pilot-testing and evaluation of safeguards approaches for the **back-end of the fuel cycle** (incl. encapsulation plants and final repositories)

- 1.1. Enhance techniques for verification and characterisation of spent fuel (e.g. passive gamma emission tomography)
 - 1.2. Enhance the development of smart safeguards approaches for encapsulation plants (e.g. multispectral cameras, smart seals, identification of canisters, etc.)
 - 1.3. Give attention to proper safeguards for the transport of loaded final storage containers
 - 1.4. Develop technologies for (re)verification of loaded spent fuel canisters (e.g. muon tomography)
 - 1.5. Improve and evaluate the approaches for safeguarding of deep geological repositories, including long-term storage of data and the use of special verification techniques
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Action 2. Fully exploit the potential of **remote data transfer, remote observation and control, artificial intelligence and machine learning** for enhancing the implementation of safeguards measurements and data evaluation, duly taking into account (cyber) security considerations

- 2.1 Develop and promote enhanced inspection and sampling schemes to optimize the use of human and other resources through remote operations and control
 - 2.2 Pursue the deployment of smart process-monitoring and remote monitoring for a variety of fuel cycle facilities, including the use of advanced statistics, quality control, machine learning, artificial intelligence etc.
 - 2.3 Address security issues, in particular cybersecurity, data traceability and immutability in the collection, transfer, storage and handling of safeguards-relevant data
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Action 3. Enhance the use of **modern business analytics/intelligence and data science tools** to reach higher quality findings from current and future nuclear safeguards relevant data (all types)

- 3.1. Reach out to the business intelligence and data science community and seek for expertise, tools and insights to apply to safeguards.
- 3.2. Consider the benefits of using geographic information systems & enhanced data visualisation and interconnected databases for mapping, storing, presenting, analyzing safeguards data (with due attention to the sensitivity and/or classification of certain types of information)
- 3.3. Consider establishing a new sub-working group in ESARDA on modern business analytics, and data science and in general analytical tools in support of the safeguards analyst

Action 4. Attract the **young generation** to and implement **knowledge transfer** from the field of nuclear safeguards and non-proliferation

- 4.1 Launch specific outreach activities to other (nuclear) communities and networks such as European Nuclear Society, International Young Nuclear Congress, etc. to promote R&D and careers in nuclear safeguards and non-proliferation, and increase the diversity of the ESARDA Membership
- 4.2 Review, revise and implement the initial concept of operating a Young Generation Initiative within ESARDA
- 4.3 Continue to give and develop training courses on safeguards and enhance outreach activities in close collaboration with the IAEA and other players (e.g. ENEN at European level) in both education and training, if possible including external funding
- 4.4 To assure knowledge transfer from the retiring generation to the young generation through the development of an effective knowledge management concept.

Action 5. Enhance the **awareness and visibility** of nuclear safeguards at the public and political level

- 5.1. Engage with external partners/organisations/academia/policy-makers to increase awareness and visibility of ESARDA (nuclear safeguards and non-proliferation); including promotion, communication, dissemination, continuation and foresight of ESARDA success stories
- 5.2. Address the technical synergies between safeguards and safety / security
- 5.3. Promote the collaboration between inspectorates and State authorities, e.g. also in the area of characterization of waste from nuclear decommissioning and with small holders.
- 5.4. Contribute to the transparent and recognized positioning of European safeguards in the policy context with EU Member States
- 5.5. Support the liaison between Euratom and IAEA on safeguards implementation

MEDIUM TERM PRIORITIES (2019-2029)

Action 6. Continued **safeguards enhancement based on R&D** (key role for ESARDA)

- 6.1. Maintain and promote ESARDA as testbed and platform for exchange and communication
- 6.2. Explore to what extent the internet of things, distributed and self-organising networks of sensors, smart data and equipment, and the use of distributed ledger technology etc. are suitable tools to support the implementation of nuclear safeguards with less inspector presence on site in future.
- 6.3. Develop and promote the use of augmented reality, ambient intelligence, enhanced self-localisation, virtual reality tools, next generation of robotics, for future in-field inspections
- 6.4. Investigate the potential of future and emerging technologies such as artificial intelligence, enhanced cognitive systems, data analysis, block chain, robotics, biotechnologies, new materials, nanotechnologies, quantum technologies, 'green' technologies, etc. to support safeguards evaluations and approaches.
- 6.5. Stimulate 'out-of-the box' thinking and encourage engaging with global system science, behavioral sciences, social media, crowdsourcing, all-information analysis, arts & science, etc. to bring in new ideas into safeguards

Action 7. Further **changes of nuclear fuel cycle strategies and operations** in Europe

- 7.1. Evaluate techniques to screen final disposal sites after closure
- 7.2. Develop, validate and promote the application of characterisation techniques that are of mutual benefit for safeguards, decommissioning and waste management, which might lead one day to the definition of exemption levels of fissile materials from safeguards
- 7.3. Keep ESARDA's R&D appraised of possible new and or advanced concepts of nuclear facilities which might require adapted or new safeguards approaches (e.g. small modular reactors, Generation IV, and safeguards for accelerator driven systems like Myrrha)

Action 8. The **major nuclear developments** are expected to happen **outside Europe**

- 8.1. Support and exchange with 'nuclear newcomer' countries i.e. those without pre-existing nuclear safeguards infrastructure.

- 8.2. Follow-up closely in which aspects ESARDA could support (new) sensitive nuclear fuel cycles from a safeguards and non-proliferation point of view, including transportable NPPs, pyroprocessing, molten salt reactors etc.

ESARDA'S STRUCTURE AND OPERATION

Action 9. Procedural

- 9.1. Issue a final version of the rules and procedures, describing in more detail the working methods; revise the ESARDA agreement as appropriate to assure that operational practices based on the rules and procedures are in compliance ; prepare additional documents to better explain the ESARDA agreement as well as rules and procedures to the ESARDA community, e.g. ESARDA welcome package for new members, guidance document for WG chairs about tasks & duties, etc...
- 9.2. Develop and implement an ESARDA (internal and external) communication strategy; including short communications to attract new members; improved use of the website, the ESARDA document repository CIRCABC and social media
- 9.3. Evaluate the opportunities of a peer-reviewed, SCOPUS indexed, open-access journal supplementary to a monthly/bi-annual ESARDA Newsletter/Report
- 9.4. Develop guidance on organising, hosting and evaluating ESARDA annual meetings/symposia
- 9.5. Implement a harmonised mechanism for ESARDA Reflection Group actions progress review; including a mechanism to follow-up on open issues from the ESARDA membership survey on ESARDA's activities and future priorities

Action 10. Operational

- 10.1. Envisage modernisation approaches for the open ESARDA symposium, such as the use of live-web streaming and interactive/participatory session formats and tools
- 10.2. Encourage EURATOM safeguards and the IAEA upfront of the closed ESARDA meetings (even years) to propose specific topics for the ESARDA WGs to reflect and work on
- 10.3. Strengthen and enhance synergies between ESARDA WGs
- 10.4. Continue the successful series of joint workshops on dedicated topics, of interest to multiple ESARDA WGs but also to invited experts beyond the safeguards and/or nuclear field, to further provide integrated solutions and advice to safeguards stakeholders
- 10.5. Motivate more ESARDA WG members to engage and guarantee a fair distribution of WG tasks, e.g. in the production of ESARDA Technical sheets and other actions

ROAD-MAP

In follow-up to the World Cafe, held during the ESARDA 50th Anniversary Symposium in Stresa in May 2019, focussing on the outcome of the ESARDA Reflection Group, a very detailed report has been published, containing all recorded actions, colour coded according to their time plan for implementation.

The workflow for the follow-up, implementation and reporting on these actions is clearly documented in the World Cafe Report. The list of actions and follow-up procedure in the World Cafe Report will thus be used as Roadmap to guide the implementation of the ESARDA Reflection Group outcome.

ANNEXES

The Annexes are made available on CIRCABC

- A. ESARDA RG 10 FINAL REPORT**
- B. ESARDA 50 YEAR SUCCESS STORIES & TOP 10**
- C. ESARDA MEMBERSHIP SURVEY RESULTS**
- D. ESARDA MEMBERSHIP DISTRIBUTION AND ATTENDANCE**
- E. ESARDA SAFEGUARDS INFRASTRUCTURE**
- F. ESARDA OUTREACH ACTIVITIES DOCUMENT**
- G. ESARDA COMMUNICATION STRATEGY**
- H. ESARDA AGREEMENT (PROPOSED REVISED VERSION)**
- I. ESARDA RULES AND PROCEDURES (DRAFT)**
- J. ESARDA WELCOME BROCHURE**
- K. ESARDA WG CHAIR GUIDANCE DOCUMENT (IN PREPARATION)**