ESARDA

European Safeguards Research & Development Association

Anniversary Booklet

ESARDA

European Safeguards Research & Development Association

Produced by the ESARDA Reflection Group 2019:

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50 years in the Cooperative Development of Safeguards

Dear ESARDA friends and colleagues,

It is both an honour and a pleasure to present, on the occasion of the 50th Anniversary of ESARDA, an overview of 50 years of key ESARDA achievements. This booklet is a product of the ESARDA 2019 Reflection Group, whose members I sincerely thank for their strong engagement on this topic. The first section illustrates 10 key achievements, over the 50 years' period, many of which are still fully pertinent today. Many more ESARDA products are included in this booklet, which also provides some insights into the organisational aspects and working methods of ESARDA.Emphasis has been placed on those achievements which resulted from specific ESARDA initiatives and/or jointly decided activities of ESARDA members, rather than individual achievements of single or multiple ESARDA parties. Greater detail on many of the achievements may be found within the ESARDA Bulletins, which are available from the ESARDA website.

When glancing through history, we can identify different phases in the evolution and activities of ESARDA.

In the first decade of ESARDA starting from 1969, safeguards was a relatively new concept, seeing implementation of the first ESARDA integrated experiments and safeguards approaches for European nuclear fuel cycle facilities, many of which later found application at the international level. Quite a few initial technological developments were started, and several ESARDA working groups find their roots in these first 10 years.

In the second decade of ESARDA, safeguards activities continued to expand due to the increasing number of nuclear fuel cycle facilities, in parallel with new proliferation challenges. ESARDA enhanced its activities by increasingly organizing inter-laboratory exercises. ESARDA decided also to issue regularly a bulletin with scientific papers and to organize an annual meeting, alternating between a fully open scientific symposium (organized by an ESARDA Member, typically the chairperson or president) and an internal meeting (organized by the Euratom Safeguards Directorate in Luxembourg). The European Commission, and several EU Member States, also commenced Support Programmes to IAEA safeguards during this decade, reinforcing the international dimension of ESARDA. A key deliverable by ESARDA was the publication of the expanded International Target Values for measurement uncertainties.

The third decade of ESARDA was marked first of all by the collapse of the former Soviet Union and thus the launch of many safeguards and nuclear material accounting and control projects in the Commonwealth of Independent States. A fundamental improvement in international safeguards was the introduction of the Additional Protocol (to IAEA safeguards agreements), mainly as a consequence of the discoveries in Iraq pertaining to nuclear proliferation. ESARDA working groups produce lots of tangible output like the final report on reprocessing input verification and also on non-destructive analysis and containment and surveillance.

During the fourth decade, ESARDA actively contributed to the preparation for, and experience exchange on, the implementation of the Additional Protocol in the EU and in other European non EU states. This resulted in the implementation of integrated safeguards in all EU Non-Nuclear Weapon States by 2010. During the same years, ESARDA began to engage very actively in academic outreach, including development of the ESARDA Safeguards and Non-proliferation course. This is still held today, attracting between 50 and 60 students each year. Due to external events, increased attention was also given to the synergies between nuclear safeguards and the fields of nuclear safety and security. With respect to the ESARDA organization itself, there was a significant increase in membership and international outreach during this decade.

At the onset of the fifth decade, the international nuclear safeguards and non-proliferation community received a boost from the Prague speech of the US president Obama, which called for a future world free of nuclear weapons. ESARDA responded through its discussions on verification methodologies and approaches supporting verification of nuclear material under arms control or nuclear disarmament treaties. In this decade, ESARDA plays an active role to enhance the understanding and collect implementation experiences of the IAEA on the State Level Approach. Also, in line with the earlier disclosure of clandestine nuclear proliferation trading networks, ESARDA created a dedicated working group on export control. A second working group, dealing with Novel Approaches/Novel Technologies, was established during the same period to address specific possible technical solutions to increasing safeguards challenges. In the last years, much attention was given to the Joint Comprehensive Plan of Action for Iran, whilst the international safeguards

50 years in the Cooperative Development of Safeguards

community prepares for a breakthrough in the DPRK file. As for safeguards implementation in Europe, the digital transformation offers both new opportunities and challenges in the testing, validation and performance evaluation of technological innovations. All of these issues continue to inspire key ESARDA activities.

From this history, we distilled in this booklet a collection of results that demonstrate how a professional organisation, fully based on voluntary contributions of its members, with an efficient and effective networking and implementation capability, has remained relevant to all stakeholders - at both European and an international level - over the last 50 years.

One good reason why ESARDA's impact continues to be significant, is its unique mixture of members from academia, research and technical support organizations, authorities, industry, and the wider international scientific community.

To maintain its relevance and significance as a dynamic professional organization, ESARDA periodically reviews its structure and direction. The latest such exercise, including recommendations on its organization and future, was made by the 2019 Reflection Group which takes into account past lessons, some of which are documented in this booklet.

At the 50th Anniversary Symposium in Stresa, in May 2019, a World Café session will provide the opportunity for all ESARDA Members to engage in the outcome of the 2019 Reflection Group, provide essential input and feedback to the implementation of the reflection process.

We are therefore confident that, based on solid and fundamental achievements presented in this 50 year historical overview and inspired by the vision and ambition for the future, ESARDA will continue to be a highly valuable organization for all its members and stakeholders. I take this opportunity to thank all colleagues who contributed to ESARDA in the last 50 years, and invite the young generation to be motivated by the fascinating future we have in front of us; one where ESARDA can and will continue to make a real difference!

50 years in the Cooperative Development of Safeguards

I felt it appropriate to complete these introductory words with a quote from a review paper published to mark the first 10 years of ESARDA, which is still very relevant and to the point today:

“The partners have brought to the ESARDA diversified R&D capabilities, research set-ups and commercial fuel cycles and reactor systems. They have understood to forge these capabilities into a coherent whole without losing the stimulating effect of the diverse inputs. They have used flexibility with caution, shown courage without being rash, imagination without losing the sight of reality in solving and tackling a varied range of safeguards problems. Above all, they have always provided maximum possible assistance and support to make the international safeguards system function in a credible manner.”

The strength and added value of ESARDA lies indeed in this combination of diversity and collaboration, based on underpinning R&D, from Europe and abroad, and working in close partnership with the EU Member State Authorities, plant operators and both European and International Inspection Agencies.

I wish the Association all the best, and raise a toast to congratulate ESARDA on its 50th Anniversary!

Yours sincerely,

Willem Janssens
ESARDA President 2019-2020

ESARDA
European Safeguards Research & Development Association

Top 10 Achievements

Completion of a “Pioneering Phase” of Safeguards R&D

#1

From 1969 to 1973, ESARDA members completed R&D to demonstrate that the technical conditions foreseen in the NPT safeguards system could be fulfilled. Between the ESARDA members, an estimated total of 320 man-years effort was expended on systems analysis, NDA and DA methods, containment studies and integral experiments, including reprocessing and inter-laboratory tests.

The first ESARDA-sponsored integral experiment is completed at the Eurochemic Reprocessing Plant, Mol, Belgium

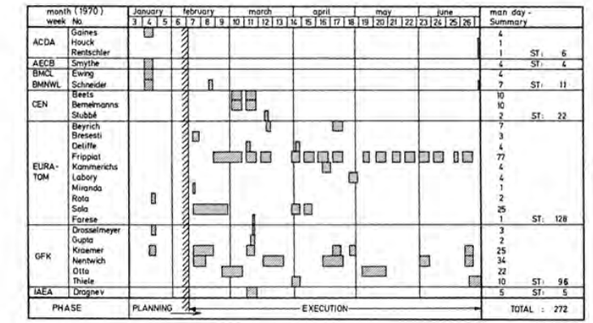


Fig. 1-1 Review of visits at EUROCHEMIC, Mol, Belgium during the joint experiment (JEX -70)

Isotope Correlation Studies

Results from experimental measurements

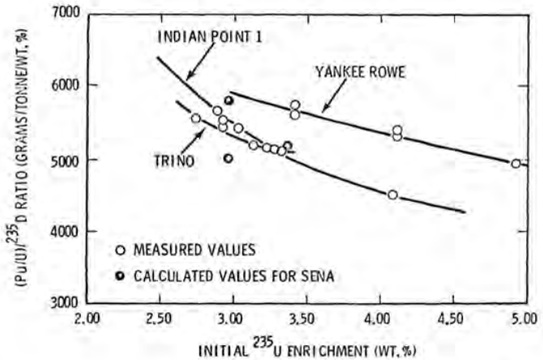


Figure 1. Comparison of Calculated (Pu/U)/^{235}U Values for SENA

#2

The Isotope Correlations WG collected, on a European scale, data on fuel isotopic composition generated during reprocessing campaigns and post-irradiation fuel analyses. This data was subsequently incorporated within a data bank established within the JRC-Ispra in 1976 and, in 1978, a data bank established by the IAEA. In 1985, the Isotope Correlations WG concluded its activity with publication of a final report on the Isotope Correlation Experiment (ICE), utilising data from five irradiated fuel assemblies dissolved during a reprocessing campaign at the WAK facility in 1978 and subsequent measurements and evaluation from 1978-1981.

Providing Direction to Reference Material Suppliers

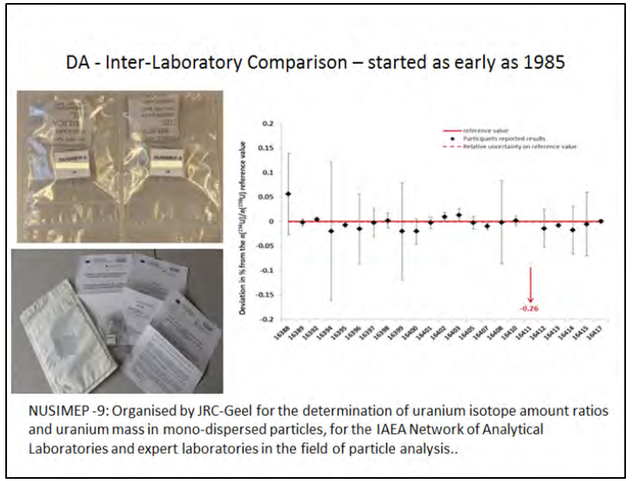
#3

In 1978, JRC-Geel (CBNM, then IRMM) responded to a review by the DA WG of the status of reference materials for safeguards measurements with the preparation of new reference materials, a process that would continue in the years ahead. The NDA WG completed a similar review of reference materials for NDA measurements, and also compiled a report on NDA methods for accountancy and verification purposes. The NDA WG commenced direction of a project to prepare primary standard uranium oxide reference materials for gamma spectrometry. In the years that followed, the working groups continued to have a significant input into the provision of reference materials, for example through the NDA WG managing a programme to develop a set of standard waste drums for calibrating waste assay and the DA WG discussing and monitoring priorities on CRM provision respective to safeguards authorities and operators' needs. In 2016-2018, the DA WG facilitated the cooperation to improve stability of CMRs and to develop the first CRMs relevant in nuclear safeguards and nuclear forensics.

Starting from the center and continuing around clockwise, European Community Certified Nuclear Reference Material 171/New Brunswick Laboratory Certified Reference Material (CRM) 969 (briefcase); Segmented Gamma-Ray Scanning Standards (tall stainless steel containers); Plutonium Isotopic Determination Intercomparison Exercise (PIDIE) Standards; Central Bureau of Nuclear Measurements Nuclear Reference Material 271 (lower left of briefcase); and CRM 136, 137, and 138, formerly National Bureau of Standards 946, 947, and 948

Inter-Laboratory Measurement Campaigns

#4

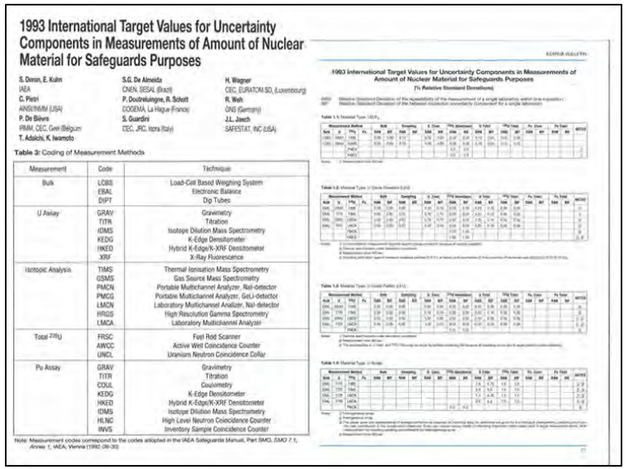


NUSIMEP -9: Organised by JRC-Geel for the determination of uranium isotope amount ratios and uranium mass in mono-dispersed particles, for the IAEA Network of Analytical Laboratories and expert laboratories in the field of particle analysis..

In 1981, the NDA WG reported on an Inter-laboratory Exercise on the Determination of Plutonium Isotopic Ratios by Gamma Spectrometry. Ten years later, Intercomparison of Plutonium Isotopic Composition Measurements by X-Ray and Gamma-Ray Spectrometry: Results from the PIDIE Exercise involved seven of the ESARDA Parties, with additional US and IAEA participation. The NDA WG continues to fulfil a lead role in the organisation and promotion of intercomparison exercises. Meanwhile, in 1985, the DA WG presented final results from the IDA-80 inter-laboratory programme conducted under the auspices of ESARDA and with the support of the IAEA. A Regular European Inter-laboratory Measurement Evaluation Programme (REIMEP) was subsequently established, to obtain a state-of-the-practice picture for the assay of nuclear materials. It was agreed that the CBNM Geel (now JRC-Geel) would organise the programme, supported by other DA WG members. Results from the first two REIMEP exercises, involving inter-laboratory comparison of measurements on UF6 and PuO2, samples were reported in 1987, with further exercises in subsequent years and expansion of the programme to incorporate environmental sample-level measurements and 'age-dating', responding to the technical convergence of nuclear safeguards & security.

International Target Values (ITVs)

#5



1993 International Target Values for Uncertainty Components in Measurements of Amount of Nuclear Material for Safeguards Purposes

S. Deron, E. Kuhn — IAEA
C. Pietri — ANS/RWM (USA)
P. De Bièvre — IRMM, CEC, Geel (Belgium)
T. Adachi, K. Iwamoto
S.G. De Almeida — CNEN, SESAL (Brazil)
P. Doubleulngne, R. Schott — DOEMA, La Haye (France)
S. Guardini — CEC, JRC, Ispra (Italy)
H. Wagner — CEC, EURATOM SD, (Luxembourg)
R. Weh — GNS (Germany)
J.L. Jeech — SAFESTAT, INC (USA)

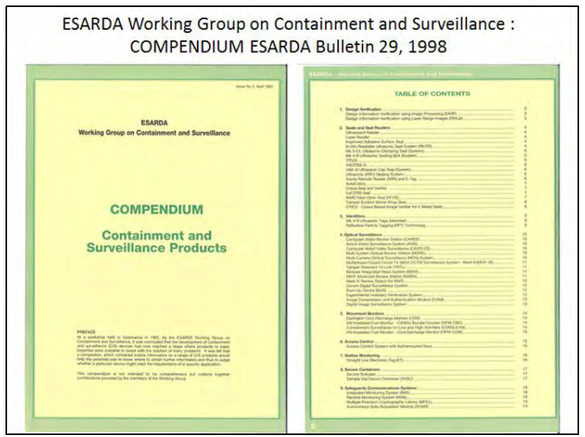
Table 3: Coding of Measurement Methods

Measurement	Code	Technique
Bulk	LQBS	Load-Cell Based Weighing System
	EBAL	Electronic Balance
	DIPT	Dip Tubes
U Assay	GRAV	Gravimetry
	TITR	Titration
	IDMS	Isotope Dilution Mass Spectrometry
	KEDG	K-Edge Densitometer
	HKED	Hybrid K-Edge/K-XRF Densitometer
	XRF	X-Ray Fluorescence
Isotopic Analysis	TIMS	Thermal Ionisation Mass Spectrometry
	GSMS	Gas Source Mass Spectrometry
	PMCN	Portable Multichannel Analyzer, NaI-detector
	PMCG	Portable Multichannel Analyzer, GeLi-detector
	LMCN	Laboratory Multichannel Analizer, NaI-detector
	RMGD	High Resolution Gamma Spectrometry
	LMCA	Laboratory Multichannel Analyzer
Total (Pu)	FRSC	Fuel Rod Scanner
	AWCC	Active Well Coincidence Counter
	UNCL	Uranium Neutron Coincidence Collar
Pu Assay	GRAV	Gravimetry
	TITR	Titration
	COUL	Coulometry
	KEDG	K-Edge Densitometer
	HKED	Hybrid K-Edge/K-XRF Densitometer
	IDMS	Isotope Dilution Mass Spectrometry
	HLNC	High Level Neutron Coincidence Counter
	INVS	Inventory Sample Coincidence Counter

Note: Measurement codes correspond to the codes adopted in the IAEA Safeguards Manual, Part SMO, STAO 7.1, Annex 1, IAEA, Vienna (1992) 08-30)

Following an earlier exercise in 1977, the DA WG published "1983 Target Values for Uncertainty Components in Fissile Element and Isotope Assay", with the recommendation that they be used by safeguards authorities in their evaluations of the performance of measurement systems. The initiative was subsequently adopted by both Euratom and the IAEA, with revision and expansion in 1988, 1993, 2000 and 2010. Following a request from SAGSI for an "International Standard of Measurements" in 1988, the 1AEA held a Consultants Group Meeting in 1991, asking for advice. The Group recommended to adopt the approach taken for the ESARDA Target Values. In 1993 the International Target Values were published, which incorporated internationally agreed uncertainty components for NDA measurement techniques in addition to those for DA. Fifteen years later, the NDA WG published a major review: Performance Values for NDA Techniques Applied to Safeguards: The 2002 Evaluation by the ESARDA NDA Working Group, and and in 2010 International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials (ESARDA Bulletin, No. 48, December 2012). Plans are in progress within the IAEA to provide a further revision of the International Target Values around 2020.

ESARDA a testbed and platform of exchange and communication



ESARDA Working Group on Containment and Surveillance : COMPENDIUM ESARDA Bulletin 29, 1998

ESARDA
Working Group on Containment and Surveillance

COMPENDIUM
Containment and Surveillance Products

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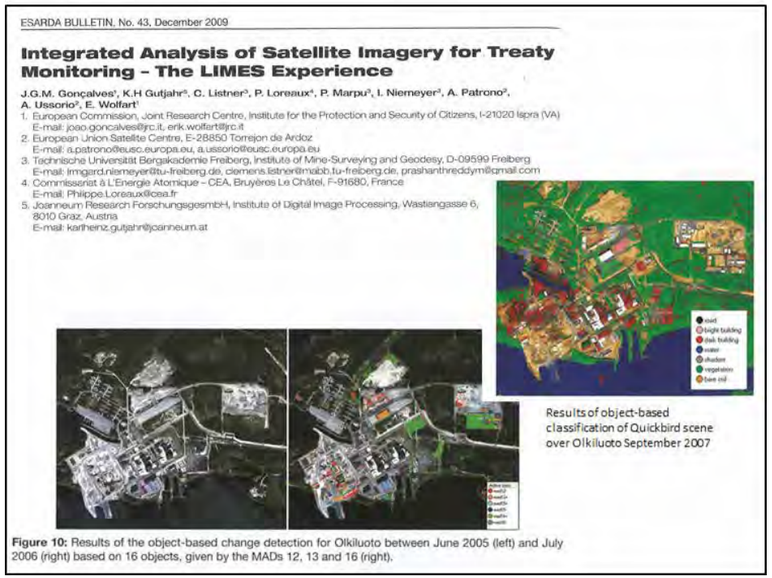
ESARDA has throughout the years increasingly put the focus on establishing a regular exchange on relevant R&D across working groups but also reaching out to experts beyond the nuclear field. The ESARDA working groups represent a unique and informal platform of cooperation to the benefit of of all ESARDA stakeholders and beyond. This has been acknowledged in the most recent survey by the ESARDA members, and the benefit of intensifying cooperation is also recognised by decision makers in nuclear safeguards and industry. Examples are the numerous joint and dedicated workshops, cooperation in method validations, inter-laboratory measurement benchmark exercises, numerical modelling benchmark exercises, libraries of certified reference materials and the containment and surveillance (C/S) compendium. The results from all these activities are compiled in papers, reports, performance or target values and good practice guides. One example is that to date a library of certified uranium or plutonium samples and HRGS spectra is available to users and developers of NDA equipment. Parallel to experimental benchmark benchmarking of numerical modelling is done. Another example is the successful NA/NT, DA and NDA WGs dedicated workshop on Reference Material needs and Evaluation of Measurement Uncertainties in Destructive and Non-Destructive Analysis hosted at DG ENER in 2013.

Additional Protocol Implementation

#7

Preparation for implementation of the Additional Protocol within the EU involved activities within the framework of the IS Working Group with discussions between Members States, the IAEA and the European Commission. Beyond 30th April 2004, the first feedback experiences (declarations, questions, CA etc) shared between participants of the Working Group were also very useful to facilitate and improve the implementation of the AP, leading eventually to integrated safeguards in EU NNWS.



ESARDA BULLETIN, No. 43, December 2009

Integrated Analysis of Satellite Imagery for Treaty Monitoring - The LIMES Experience

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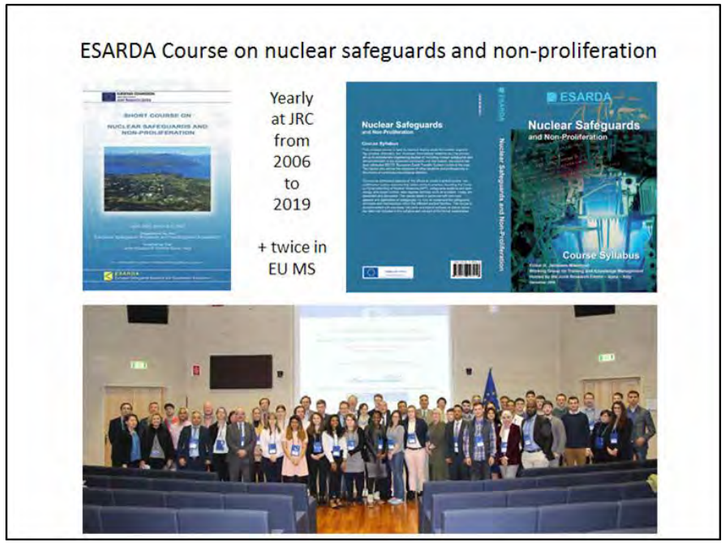
Results of object-based classification of Quickbird scene over Olkiluoto September 2007

Figure 10: Results of the object-based change detection for Olkiluoto between June 2005 (left) and July 2006 (right) based on 16 objects, given by the MADs 12, 13 and 16 (right).

Education and Training



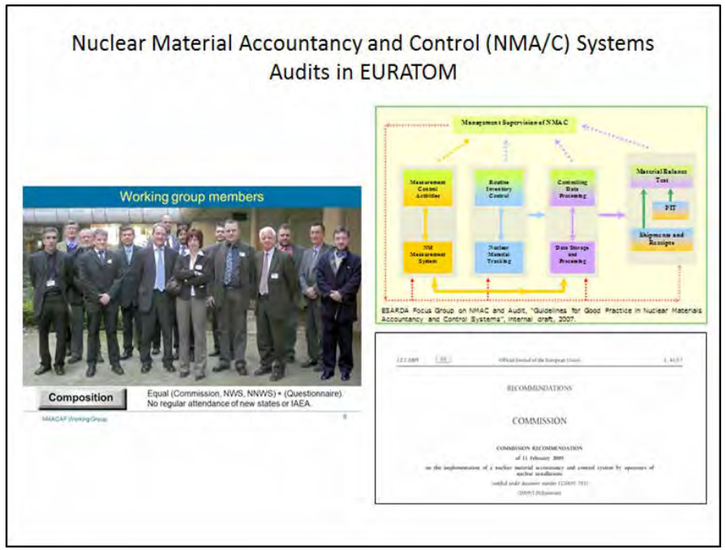
#8

In 2006, the first ESARDA Course on Nuclear Safeguards and Non-Proliferation is held at JRC-Ispra, with 47 participants from 12 European countries. By 2011, growing interest in the ESARDA Course results in two deliveries of the course that year, at JRC-Ispra and Uppsala University, Sweden. The same year, the TKM WG and INMM collaborate to establish NuSaSET (Nuclear Safeguards and Security Education and Training) with a web portal offering global support to professionals. In 2014, with funding provided by the EC's DG DEVCO, the ESARDA course was provided the first time outside Europe for the Asian region. It has since then been provided once more in South-East Asia and twice on the African Continent (both for Southern African countries, in South Africa, and for Northern African countries and Sahel, in Algiers).

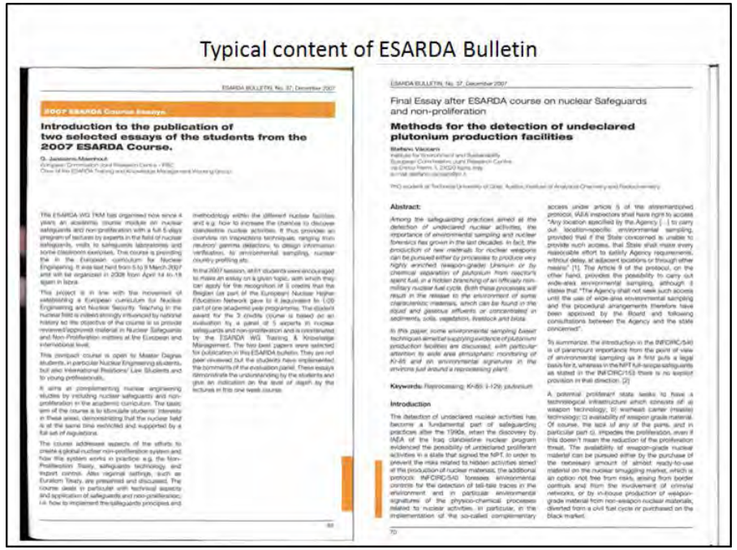
Advice to Safeguards Authorities

#9

In 2009, a new ESARDA NMAC Audit Working Group (NMACA WG) was established, to review the applicability under real operating conditions of audit criteria expressed in a Commission recommendation of February 2009 on the implementation of NMAC. Within a year, the WG provided the results of its work on an audit approach to safeguards within three reports. EC DG TREN used the results when drafting the recommendations related to the audit part of a new document "Implementing Euratom Treaty Safeguards". In 2010, the NMACA WG completes its activity in response to the EC document with publication of a further three reports.



The ESARDA Bulletin



#10

Since publication of its first issue in 1981, the ESARDA Bulletin has provided a dedicated forum for documenting findings of the ESARDA Working Groups and for the publication of articles, including peer-reviewed scientific papers, on nuclear safeguards and relevant technologies. Both through the Bulletin and periodic meetings of Working Groups, ESARDA continues to act as a forum for communication between safeguards authorities, operators and the scientific community.

Appendix

The Development of ESARDA and its Achievements, taken from the ESARDA Bulletin

Year	Developments within ESARDA	Technical Highlights
1969	Establishment of the European Safeguards Research and Development Association (ESARDA) as a joint venture between the European Atomic Energy Community (Euratom) and the Karlsruhe Nuclear Research Centre (KfK, Germany) "to harmonise the R&D activities in the area of international safeguards and ensure a mutual exchange of information and technical assistance.	
1970	CEN/SCK, Belgium, joins ESARDA.	The first ESARDA-sponsored integral experiment is completed at the Eurochemic Reprocessing Plant, Mol, Belgium in a collaboration between ESARDA, the Eurochemic management and US and Canadian partners.
1971	CNEN, Italy, and ECN, Netherlands, join ESARDA.	The first ESARDA technical meeting, International Meeting on Non-Destructive Measurements and Identification Techniques in Nuclear Safeguards, is held at JRC-Ispra.
1972	Systems Analysis and Integral Experiments Working Groups are established, both operating from 1972-1974. Destructive Analysis (DA) Working Group established, operating continuously to date. Isotopic Correlation Techniques (ICT) Working Group established, operating for ten years before being re-orientated to the Reprocessing Input Verification (RIV) WG.	
1973	UKAEA and ENS, Denmark, join ESARDA. Identification and Sealing Techniques Working Group established, operating from 1973-1975.	ESARDA members complete a "pioneering phase" of R&D to demonstrate that the technical conditions foreseen in the NPT safeguards system can be fulfilled. Between the ESARDA members, an estimated total of 320 man-years effort is expended on systems analysis, NDA and DA methods, containment studies and integral experiments, including reprocessing and inter-laboratory tests.
1974	ESARDA holds its first symposium on Practical Application of R&D in the Field of Safeguards.	The Systems Analysis WG publishes: Guidelines for the Treatment of Errors in Nuclear Material Accountancy and Safeguards; Sample Sizes for Statistical Estimation and Discrepancy Detection; and Sample Sizes for Statistical Estimation and Discrepancy Detection.
1975	Non-Destructive Analysis Working Group established, operating continuously to date.	The Identification and Sealing Techniques WG completes its work and reports on tamper-resistant identification and sealing techniques at an IAEA Symposium on Safeguarding Nuclear Materials.
1976	ESARDA seeks a re-orientation from R&D to implementation and the practical problems of specific installations or types of installation, requiring closer interaction with plant operators. Issue of the first ESARDA Newsletter.	The Isotopic Correlations WG collects, on a European scale, data on fuel isotopic composition generated during reprocessing campaigns and post-irradiation fuel analyses. This data will be incorporated within a data bank established within the JRC-Ispra. The Systems Analysis WG contributes towards Model Facility Attachments, Computerised Information Systems and Inventory-Taking Procedures. The Integral Experiments WG turns its focus to problems with an immediate bearing on the implementation of safeguards, reporting on unattended instrumentation within a reprocessing facility.
1977	ESARDA begins to support conceptual investigations including diversion strategies and safeguards concepts for large or advanced facilities.	The DA WG establishes values for differences between measurements from laboratories to be regarded as significant – the forerunner of International Target Values. The DA WG reports on inter-laboratory UF_6 measurements by mass spectrometry.
1978	ESARDA hosts a specialised symposium on Isotopic Correlation and its Application to the Nuclear Fuel Cycle. The LEU Conversion/Fabrication Plants Working Group is established: the first plant-orientated working group.	JRC-Geel (CBNM) responds to a review by the DA WG of the status of reference materials for safeguards measurements with the preparation of new reference materials, a process that would continue in the years ahead. The NDA WG completes a similar review of reference materials for NDA measurements, and also compiles a report on NDA methods for accountancy and verification purposes. It commences a project to prepare primary standard uranium oxide reference materials for gamma spectrometry. The Isotopic Correlations WG supports establishment of a second data bank of isotopic correlations at the IAEA.

Year	Developments within ESARDA	Technical Highlights
1979	The Containment and Surveillance Working Group (CS WG) is established, operating continuously to date. The LEU WG identifies the need for a sintered uranium oxide pellet reference material.	ESARDA holds its first Safeguards Symposium, Brussels, Belgium, in what will continue as an annual event in the years that follow. The DA WG publishes Target Values for Uncertainty Components 1979 of Destructive Analysis Methods, attracting considerable interest from the IAEA. The LEU WG publishes The ESARDA Approach to Facility-Orientated Safeguards Approaches at the INMM 20th Annual Meeting.
1980	ESARDA holds the First Seminar on Containment and Surveillance Techniques for International Safeguards, at the JRC-Ispra.	

Year	Developments within ESARDA	Technical Highlights
1981	From 1 January 1981, ESARDA is re-constituted to afford participation in the Steering Committee of any organisation having substantial interest in the application of safeguards. Thus, nuclear plant operators may have direct representation on the Steering Committee of ESARDA. CEA, France, joins ESARDA. The first issue of the ESARDA Bulletin is published. Sub-groups of the CS WG take over work on an exhaustive inventory of C/S techniques within a joint US/ESARDA Compendium. Mixed Oxide Fabrication Plant Working Group, is established (complementing the LEU/Fuel Fabrication WG and providing a second forum for the exchange of plant-specific safeguards and nuclear materials management practices).	The NDA WG reports on an Inter-laboratory Exercise on the Determination of Plutonium Isotopic Ratios by Gamma Spectrometry.
1982	A Statistical/Mathematical Working Group is formed, to deal with practical solutions to specialised issues raised within other working groups. The Isotopic Correlations WG is re-orientated to form a new plant-specific working group, Reprocessing Input Verification (RIV WG).	The fourth Annual ESARDA Symposium is held as a specialised meeting on harmonisation and standardisation in nuclear safeguards. ESARDA begins to consider the potential of word processing, electronic transmission and automated evaluation of data. The Statistical/Mathematical WG holds its first meeting, covering optimisation of verification in MOX plants, simulation of an NRTA measurement system, statistical methods for reprocessing input verification and statistical methods for seal verification.

Year	Developments within ESARDA	Technical Highlights
1983	Following a recommendation of SAGSI for integration of developers and safeguards authorities' ideas and requirements, the C/S WG dedicates its activity over a two-year period to the technicalities of C/S devices, field testing and iterative specification processes. The WG is representative of all European development work in the field of C/S for international safeguards.	The Isotopic Correlations WG publishes its final report on the Isotope Correlation Experiment (ICE), utilising data from five irradiated fuel assemblies dissolved during a reprocessing campaign at the WAK facility in 1978 and subsequent measurements and evaluation from 1978-1981. The JRC-Ispra hosts a first training course on "Nuclear Material Safeguards: Techniques, Procedures and Prospects" including lecturers drawn from the ESARDA members. The RIV WG holds a workshop on Volume Determination of Reprocessing Input Solutions by Tracer Techniques at the JRC-Ispra. The Statistical/Mathematical WG organises a workshop in collaboration with INMM on NDA Statistical Problems.
1984	ESARDA and INMM hold a Joint Specialist Meeting on NDA Statistical Problems, at the JRC-Ispra.	The DA WG publishes 1983 Target Values for Uncertainty Components in Fissile Element and Isotope Assay, with the recommendation that they be used by safeguards authorities in their evaluations of the performance of measurement systems. The RIV WG reports on The ESARDA Exercise to Test the Performance of Isotope Correlation Technique Procedures. INMM and ESARDA jointly convene a specialist meeting on statistical problems encountered in the evaluation of NDA measurements, held at JRC-Ispra, involving 30 expert participants.

Year	Developments within ESARDA	Technical Highlights
1985	The DA WG establishes a Regular European Interlaboratory Measurement Evaluation Programme (REIMEP), to obtain a state-of-the-practice picture for the assay of nuclear materials. It is agreed that the CBNM Geel will organise the programme, supported by other DA WG members.	ESARDA reports on the first international certified reference material for NDA, a set of five standards prepared and certified by CBNM and NBS. The work involved contributions from members of the NDA and DA WGs and the US, Euratom and IAEA safeguards inspectorates, following a need identified by two IAEA advisory groups and endorsed by the NDA WG in 1978. The DA WG presents final results from the IDA-80 inter-laboratory programme conducted under the auspices of ESARDA and with the support of the IAEA.
1986	BNFL, UK, joins ESARDA. The 8th ESARDA Annual Meeting entitled Capabilities and Objectives of the Use of NDA-DA-C/S Measures in Safeguards, is the first to be a meeting with participation restricted to ESARDA members and observers. The Annual Meetings thereafter alternates between an open symposium and a restricted/closed meeting.	The RIV WG reports on the Reprocessing Input Tank Calibration Exercise (RITCEX). The ESARDA Annual Meeting provides the first forum for the producers of technical results within the ESARDA WGs to be openly confronted with the users of those results.
1987	CIEMAT, Spain, and KFA Julich, Germany, join ESARDA.	Results from the first two REIMEP exercises, an initiative from the DA WG in 1985, involving inter-laboratory comparison of measurements on UF_6 and PuO_2 samples are reported.
1988	The 10th ESARDA Annual Meeting, the second closed meeting of the ESARDA WGs, focuses on future WG activities in the light of expected nuclear fuel cycle evolution up to the year 2000. ESARDA launches a Reflection Group.	The DA WG publishes Random Uncertainties in Sampling and Element Assay of Nuclear Materials. Target Values 1988, expanded from earlier publications to include uncertainties associated with the sampling operation. Experience of Euratom and IAEA safeguards authorities with the earlier Target Values for Uncertainty Components in the Assay of Nuclear Material is presented by the two authorities to members of the DA WG.
1989	Following on from its 1988 Annual Meeting, ESARDA publishes its Analysis of the Nuclear Fuel Cycle in European Community Countries up to the Year 2000. The study provided a clear indication of the future R&D needs for safeguards techniques to be considered within the WGs.	The RIV WG holds the Calibration Demonstration Exercise Workshop on reprocessing Plant Tank Measurements, at Hannover, Germany.
1990	The ESARDA Steering Committee recommends preparation of an R&D database and analysis of ongoing R&D activities in different areas.	The C/S WG holds a Special Topical Meeting on Optical Surveillance Data Reduction.

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1991	ESTABANK (ESarda Tasks BANK) is established within the JRC to record essential information about the R&D and technical support activities of the ESARDA Parties in the field of safeguards and nuclear material management.	The NDA WG reports the results from Intercomparison of Plutonium Isotopic Composition Measurements by X-Ray and Gamma-Ray Spectrometry: Results from the PIDIE Exercise, work involving seven of the ESARDA Parties, with additional US and IAEA participation.
1992	ESARDA publishes its Analysis of R&D Activities in the Field of Containment and Surveillance and Analysis of R&D Activities in the Field of NDA. The NDA WG begins similar studies on Target Values to those undertaken within the DA WG.	The NDA WG holds a Workshop on NDA Techniques Applicable to Safeguarding Nuclear Material in Waste, at Salamanca, Spain. The C/S WG holds a Workshop on C/S Safeguards Techniques Applicable to Intermediate and Long-Term Storage of Irradiated Fuel, leading to the first issue of a Compendium of C/S Devices.
1993	ESARDA publishes its Analysis of R&D Activities in the Field of Destructive Analysis. A Reflection Group on the Future of ESARDA in a Changing World is established.	ESARDA holds an International Workshop on Passive Neutron Coincidence Counting, at the JRC-Ispra. ESARDA publishes Performance Values for Non-Destructive Assay Techniques Applied to Safeguards: the 1993 Evaluation by the ESARDA NDA Working Group.
1994	The WKK, Germany, joins ESARDA. ESARDA celebrates its 25th anniversary during a closed Annual Meeting. The C/S and NDA WGs take the opportunity to hold their first joint meeting, identifying the importance of integrated systems. ESARDA is re-structured, including creation of an Executive Committee and a Scientific Council and Coordination Board. ESARDA institutes the position of ESARDA Honorary Member for people who have particularly worked towards the development of the Association and for the achievement of its goals. The work of the RIV WG is deemed to have been successfully completed.	Publication of the 1993 International Target Values for Uncertainty Components in Measurements of Amount of Nuclear Material for Safeguards Purposes. This document expanded upon the earlier ESARDA work, following a recommendation from SAGSI in 1988 and a Consultants Group Meeting in 1991, with incorporation of internationally agreed uncertainty components for both DA and NDA measurement techniques.

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1995	ESARDA publishes Report of the Reflection Group on the Future of ESARDA in a Changing World. ESARDA publishes its Analysis of R&D Activities in the Field of Fabrication Plants and Analysis of R&D Activities for Reprocessing Plant Safeguards. A new working group is created: Back-End of the Fuel Cycle (BFC).	The NDA WG publishes Scraps in the Nuclear Fuel Cycle: Aspects of Safeguards NDA Measurements. Further consideration of integrated systems leads to a Joint Meeting of ESARDA WGs (LEU, MOX, C/S, NDA) on Unattended/Integrated Safeguards Systems.
1996	The ESARDA Working Group on Reprocessing Input Verification issues a final report summarising the achievements of the WG over the 14 years of its activity. STUK, Finland, joins ESARDA.	ESARDA RIV WG publishes An International Collaboration Exercise on the Calibration of a Model Reprocessing Plant Accountancy (CALDEX) Tank Using a Lutetium Tracer. 138 participants attend a joint meeting of ESARDA and the UK Royal Society of Chemistry on the subject of Analytical Measurements and their Interpretation for Regulatory Purposes. A workshop on Science and Modern Technology for Safeguards is jointly organised by ESARDA and INMM and held in Arona, Italy.
1997	ESARDA proposes a joint seminar with the Russian Institute for Physics and Power Engineering. This subsequently develops into a Tripartite Seminar on Nuclear Material Accounting and Control at Radiochemical Plants, Obninsk, Russia, 1998, jointly organised by Minatom, the EC and USDoE. ENEA retires from the ESARDA Agreement.	ESARDA organises a workshop on The Status of Measurement Techniques for the Identification of Nuclear Signatures, held at the JRC-Geel. The NDA WG completes an experimental programme Plutonium Isotopic Determination by Gamma Spectrometry: Recommendations for the ^{242}Pu Content Evaluation using a new Algorithm.

Year	Developments within ESARDA	Technical Highlights
1998	ANPA, Italy, joins ESARDA. Within the framework of its annual meeting, ESARDA holds a seminar on Modern Verification Regimes: Synergies, Differences and Challenges.	Following the event in 1996, a second workshop on Science and Modern Technology for Safeguards is jointly organised by ESARDA and INMM and held in Albuquerque, USA. The C/S WG publishes a Compendium of Containment and Surveillance Products. The NDA WG holds a workshop Quality Requirements for NDA in Safeguards.
1999	SKI, Sweden, joins ESARDA.	The BFC WG publishes Installations for the Storage of Spent Fuel, outlining European trends, current safeguards requirements and recommendations for the optimisation and implementation of safeguards approaches within conditioning facilities and geological repositories. The NDA WG manages a programme to develop a set of standard waste drums for calibrating waste assay.
2000	The ESARDA Reflection Group 2000 reports its findings, subsequently published within the 2002 ESARDA Bulletin. The ESARDA Working Group on Integrated Safeguards (IS WG) is established as a forum for exchange on the Additional Protocol and Integrated Safeguards.	Following the event in 1996 and 1998, the third workshop on Science and Modern Technology for Safeguards is jointly organised by ESARDA and INMM and held in Tokyo, Japan. Joint symposia continue at regular intervals. The ESARDA NDA and DA WGs collaborate with the IAEA, INMM, ABACC and ISO in preparation of International Target Values 2000 for Measurement Uncertainties in Safeguarding Nuclear Materials.
2001	The LEU WG is considered to have completed its work and is discontinued.	The NDA WG completes a benchmark exercise for the evaluation of different techniques for the prediction of the REALS count rate.

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2002	ESARDA's Verification Technologies and Methodologies Working Group (VTM WG) is established. Following its closure, ESARDA publishes a summary report on the LEU WG describing achievements over the 13 years of its activity. ESARDA launches its own website, hosted by the JRC.	The DA WG publishes Sample Analysis Methods for Accountancy and Verification: A Compendium of Currently Applied Analytical Methods. The ESARDA MOX WG publishes a description of how work in progress and, in particular, material holdup, is controlled, measured and accounted for: Control of Nuclear Material Holdup in MOX Fuel Fabrication Plants in Europe. The NDA WG participates in and co-authors Results from the International Evaluation Pu-2000 Exercise for Plutonium Isotopic Composition.
2003	IRSN, France, joins ESARDA ESARDA's Training and Knowledge Management Working Group (TKM WG) is established. VTM WG and the INMM commence a series of joint symposia dealing with legal and technical non-proliferation issues (2003, Italy; 2005, USA; 2008, Japan; 2011, France, and 2015 USA).	The DA WG completes a survey of available certified reference materials suitable for accountancy and verification in nuclear safeguards. The NDA WG completes a Monte Carlo "Simple Case" Benchmark Exercise. The DA WG holds a dedicated meeting Striving for Quality in Nuclear Analytical Laboratories
2004	Following development of its website, ESARDA begins to develop a safeguards glossary, technical sheets and course modules intended to provide the public with authenticated, accurate and respected sources of information.	The NDA WG publishes a major review: Performance Values for NDA Techniques Applied to Safeguards: The 2002 Evaluation by the ESARDA NDA Working Group. The IS WG publishes Aspects of Unannounced Inspections – a View of the ESARDA WG on Integrated Safeguards.
2005	HAEA, Hungary, IKI, Hungary, and VATESI, Lithuania, join ESARDA. ESARDA is re-structured, with the Editorial Committee taking on some of the responsibilities of the former Scientific Council and Coordination Board. In addition, a new "ESARDA Agreement" is drawn up and signed by the Parties. TKM WG begins the preparation of course modules for a prototype three-day nuclear safeguards course.	The C/S and NDA WGs complete Guidelines for Developing Unattended and Remote Monitoring and Measurement Systems. Preparation for implementation of the Additional Protocol within the EU had included activities within the framework of the IS Working Group, with discussions between Members States, the IAEA and the European Commission. Beyond 30th April 2004, the first feedback experiences (declarations, questions, CA etc) shared between participants of the Working Group were also very useful to facilitate and improve the implementation of the AP, leading eventually to integrated safeguards in EU NNWS.

Year	Developments within ESARDA	Technical Highlights
2006	As CIEMAT reduces its safeguards-related activity, MITyC, Spain, joins ESARDA. ESARDA establishes the Nuclear Material Accountancy/Control and Audit Focus Working Group (NMACAF WG), in response to a report to Euratom proposing an audit-focussed control. The first four Technical Sheets are published in the ESARDA Bulletin: Statistical Methods in Nuclear Material Accountancy and Auditing; Electronic Safeguards Seals; Monte Carlo Simulation Applied to NDA Techniques and Gamma Spectrometry for U and Pu Isotopic Determination. Further Technical Sheets follow in subsequent years.	The first ESARDA Course 2006 on Nuclear Safeguards and Non-Proliferation is held at JRC-Ispra, with 47 participants from 12 European countries. A special edition of the ESARDA Bulletin provides ESARDA Multiplicity Benchmark Exercise – Final Report. The VTM WG holds a seminar on Export Control of Dual-Use Items at the JRC-Ispra. The DA WG holds a workshop on Uncertainties in Nuclear Measurements at the JRC-Geel
2007	CNCAN, Romania, NRPA, Norway, SFOE, Switzerland, and Sellafield, UK, join ESARDA. Following feedback from the 2006 course, the ESARDA TKM WG extends its second offering of the "Safeguards Course" over a five day period, March 2007. The course attracts 61 participants and becomes a regular event. Two selected essays from the students of the course are published within the ESARDA Bulletin. The VTM WG creates three sub-groups, dealing with Environmental Monitoring; Satellite Imagery; and Novel technologies and Approaches for IAEA Safeguards. The NDA WG proposes an international Working Group on Gamma Spectrometry Techniques for U/Pu Isotopics.	The NMACAF WG provides the results of its work on an audit approach to safeguards within three reports, delivered within its one-year mandate. EC DG TREN (now DG ENER) used the results when drafting the recommendations related to the audit part of a new document "Implementing Euratom Treaty Safeguards". The C/S WG publishes the first paper in a suite dedicated to bridging RF technologies with safeguards monitoring applications: Wireless Communications for Monitoring Nuclear Material Processes, Part I: Context and Technologies.

Year	Developments within ESARDA	Technical Highlights
2008	ATI, Austria, joins ESARDA. SSM, Sweden, become a Party to ESARDA, replacing SKI. A special edition of the ESARDA Bulletin deals with Proliferation resistance.	The C/S WG publishes Wireless Communications for Monitoring Nuclear Material Processes, Part II: Wireless In-Plant Data Transmission. The DA WG holds a dedicated workshop on the subject of Measurements of Minor Isotopes in Uranium in bulk and Particle samples at JRC-Geel INMM and the ESARDA NDA WG co-host the International Workshop on Gamma Spectrometry Analysis Codes for U and Pu Isotopics, ORNL, USA.
2009	Springfields Fuels Ltd, UK, joins ESARDA. A new ESARDA NMAC Audit Working Group (NMACA WG) is established, to review the applicability under real operating conditions of audit criteria expressed in the Commission recommendation of February 2009 on the implementation of NMAC.	ESARDA publishes Assessment of the Performance of Containment and Surveillance Equipment, Part I: Methodology and Part II: Trial Application. The DA WG holds a dedicated workshop on the subject of Impurity Measurements in Uranium Samples at JRC-ITU (now JRC-Karlsruhe). The NDA WG publishes ESARDA Multiplicity Benchmark exercises – Phases III and IV. The NDA WG prepares and publishes A Good Practice Guide for the use of Modelling Codes in Non-Destructive Assay of Nuclear Materials.
2010	NRI, Czech Republic, PAA, Poland, and UBA-GmbH, Germany, join ESARDA. ESARDA launches Reflection Group 2010. From an earlier sub-group of VTM, ESARDA establishes a dedicated Novel Approaches/Novel Technologies Working Group (NA/NT WG)., which holds its first meeting in Vienna later that year. Following the introduction of integrated safeguards in all relevant EU Member States, the existing IS WG is renamed the Implementation of safeguards Working Group (IS WG), enlarging the area of activities of the working group to incorporate continued activities that would previously have been conducted under the NMACA and FFP working groups.	The NMACA WG completes its activity with publication of three reports: Applicability and Interpretation of Audit NMAC Criteria; Establishment of the Role of NMAC Audit in the Context of the Safeguards Cooperation between European Commission and the IAEA; and Final Report of the ESARDA NMAC Audit Group. The DA and NDA WGs contribute to the latest edition of International Target Values through dedicated ESARDA workshops and contributions to an IAEA Consultants' Group Meeting. International Target Values 2010 for Measurement Uncertainties in Safeguarding Nuclear Materials is subsequently published by the IAEA and reproduced by ESARDA and INMM. The NDA and C/S WGs hold a joint meeting on the subject of nuclear security.

Year	Developments within ESARDA	Technical Highlights
2011	Urenco joins ESARDA. Growing interest in the ESARDA Course results in two deliveries of the course in 2011, at JRC-Ispra and Uppsala University, Sweden. ESARDA and INMM sign a letter of intent for cooperation in the field of nuclear safeguards.	The NA/NT and NDA WGs hold a joint workshop on Stand-off Detection Technologies, establishing sub-groups to work on optical stand-off detection methods; stand-off detection of antineutrinos; and novel methods for the verification of future arms control and disarmament treaties. The sub-groups go on to hold dedicated meetings on their respective interests. The TKM WG and INMM collaborate to establish NuSaSET (Nuclear Safeguards and Security Education and Training) with a web portal offering global support to professionals. The DA WG organises a dedicated workshop on Uncertainties in Nuclear Measurements, hosted by the IAEA Safeguards Analytical Services, Seibersdorf, Austria. The DA WG organises in collaboration with the Hungarian Atomic Energy Authority (HAEA) a dedicated workshop on Direct Analysis of Solid Samples Using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) in Budapest, Hungary
2012	NNL, UK, joins ESARDA. The IS WG commenced the collection of information on the history of and experiences during the implementation phases of the IAEA's Integrated Safeguards. A new ESARDA Export Control Working Group is established.	The C/S WG publishes Guidelines for the Development of Sealing Systems. The NDA WG publishes Performance Values for Non-destructive Assay Techniques Applied to Wastes, providing the first dedicated review of performance values for waste assay since 1993.
2013	Uppsala University, Sweden, joins ESARDA. University of Hamburg joins ESARDA. University of Liege joins ESARDA.	The NA/NT, DA and NDA WGs hold a joint workshop on Reference Material needs and Evaluation of Measurement Uncertainties in Destructive and Non-Destructive Analysis, . As a result of this WS the IAEA initiates their biannually International Technical Meeting on Statistical Methodologies for Safeguards. The ESARDA DA WG is represented in these IAEA TM. The IS, VTM and Export Control WGs of ESARDA hold a joint meeting with the IAEA, Euratom and other interested parties to review and discuss the State-Level Concept in the context of the Additional Protocol. The IS WG presents a paper on the history of and experiences with the development and implementation of new concepts in safeguards.

Year	Developments within ESARDA	Technical Highlights
2014	ONR, UK, joins ESARDA. SUJB, Czech Republic, joins ESARDA. The TKM WG commences an approach to foster capacity building within universities for teaching the topics contained within the ESARDA course.	With funding provided by the EC's DG DEVCO for the Asian region, an ESARDA safeguards course is held in Bangkok, attracting 41 participants from 11 countries of South-East Asia. DG ENER organised in collaboration with the DA, NDA and NA/NT WGs the Joint Workshop on Applied Metrology & Material Balance Evaluation, Luxembourg. As an outcome of this workshop the first joint IAEA, ENER, ESARDA DA WG paper on IAEA Safeguards and GUM-based Measurement Uncertainty Estimation: a Reconciliation was presented at the Symposium on International Safeguards, Vienna, Austria
2015	NRG, Netherlands, joins ESARDA. ESARDA and the Asia Pacific Safeguards Network (ASPN) sign a MoU for cooperation in safeguards.	The VTM working group focusses on new verification techniques for treaty verification, taking a broad view (i.e. beyond pure safeguards concerns) and integrating multidisciplinary approaches.
2016	SIEPS France joins ESARDA as Party.	IAEA Technical Meeting on the Production of Working Standards for Safeguards held in 2016, Seibersdorf, Austria with lecturers facilitators and participants from ESARDA WGs
2017	Back-end fuel cycle addressed at joint NDA, IS, C/S and VTM WG meetings in Ispra 2015- 2017	Special ESARDA Bulletin 56 (2018) on disposal of spent nuclear fuel in geological repositories.
2018	JAEA joined ESARDA as Associated Member, the first one from an Asian country ONR also signed the accession letter as ESARDA Party	The ESARDA Course on Nuclear Safeguards and Non-Proliferation is held for the first time in Africa (in South Africa for 13 countries of the region and in Algeria for 8 countries of Northern Africa and Sahel)
2019	ESARDA publishes the outcome of the 2019 ESARDA Reflection Group including short term, medium term and organisations actions and a Roadmap for implementation	ESARDA 50thAnniversary Symposium includes some new tools (like outreach to European School, World Cafe on the outcome of the Reflection Group and History speech looking back on 50 years of successes).


ESARDA
European Safeguards Research & Development Association