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IAEA-TECDOC-1896

# Nuclear Forensics: Beyond the Science

*Summary of a Technical Meeting*

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# NUCLEAR FORENSICS: BEYOND THE SCIENCE

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IAEA-TECDOC-1896

# NUCLEAR FORENSICS: BEYOND THE SCIENCE

## SUMMARY OF A TECHNICAL MEETING

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2020

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## FOREWORD

In IAEA General Conference resolutions since 2005, Member States have acknowledged the IAEA's work in, and supported further development of, nuclear forensics. In a 2015 General Conference resolution, Member States recognized nuclear forensics as an important element of nuclear security; and since 2016, IAEA General Conference resolutions have encouraged the sharing of Member State experiences, knowledge and practice in nuclear forensics.

The IAEA programme of assistance in nuclear forensics science to prepare States to prevent and respond to a nuclear security event has grown considerably in the past decade. Through published guidance, applied training, coordinated research and technical advisory activities, the IAEA, working with its international partners, seeks to promote consistent practice of nuclear forensics science with all States that request assistance. In particular, in 2014, the IAEA organized the International Conference on Advances in Nuclear Forensics: Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control. This was the first international conference exclusively dedicated to the role of nuclear forensics science within a nuclear security infrastructure, and the outcomes emphasized the role of nuclear forensics science in countering the serious threat posed by continuing reports of nuclear and other radioactive material out of regulatory control.

Recent progress is reflected in the increased awareness and understanding of nuclear forensics globally, as well as the development of an array of scientific methods and techniques that can be used as part of nuclear forensics examination. However, there is a growing recognition of the need for nuclear forensics to go beyond the science to ensure that States can successfully implement comprehensive nuclear forensics programmes that meet nuclear security needs, including criminalizing unauthorized use or possession of nuclear and other radioactive materials. Therefore, the IAEA organized the Technical Meeting on Nuclear Forensics: Beyond the Science, held in Vienna from 1 to 4 April 2019. The technical meeting was attended by more than 150 participants from 80 Member States and 4 organizations.

The meeting's objectives were to provide a forum for the exchange of good practices among Member States that have established nuclear forensics science capabilities and Member States that are developing or considering developing such capabilities, and to highlight the role of nuclear forensics science in responding to incidents involving nuclear and other radioactive materials out of regulatory control.

The present publication contains the summaries and outcomes of the meeting sessions as well as a review of the broad themes of the meeting, with a focus on the consistent implementation of nuclear forensics globally. The supplementary files contain the submitted abstracts, the list of participants and the full conference programme. The publication provides information for States on recent developments to best implement nuclear forensics nationally as well as regionally.

The IAEA gratefully acknowledges the cooperation and support of the organizations and individuals involved in the technical meeting. The IAEA officers responsible for this publication were K.J. Montgomery and D.K. Smith of the Division of Nuclear Security.

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# 1. INTRODUCTION

Nuclear forensics science is an important nuclear security capability to prevent and respond to incidents involving nuclear and other radioactive material encountered out of regulatory control. The IAEA defines nuclear forensics as "a discipline of forensic science involving the examination of nuclear and other radioactive material, or of other evidence that is contaminated with radionuclides, in the context of legal proceedings" [1].

Since its conception in the 1990s, nuclear forensics has relied upon science to ensure confidence in findings and conclusions. As the field is maturing, there is a need to move beyond the science and into practice. To help Member States with that process, the IAEA held the Technical Meeting on Nuclear Forensics: Beyond the Science at the IAEA Headquarters from 1 to 4 April 2019.

The technical meeting follows two IAEA Ministerial Conferences on Nuclear Security (2013 and 2016) and an IAEA International Conference on Nuclear Forensics (2014). The IAEA Ministerial Conferences discussed the importance of physical protection in nuclear security, but also emphasized the important role that technical efforts including nuclear forensics and cybersecurity play in the nuclear security infrastructure [2, 3]. The 2014 IAEA International Conference on Nuclear Forensics reviewed the role of nuclear forensics science in a national nuclear security infrastructure, current practices and advances in analytical tools, ways to strengthen nuclear forensics science capabilities and capacities, and how to advance international and regional cooperation in nuclear forensics [4].

The IAEA Secretariat of the technical meeting worked with a Steering Committee of Member State experts to plan the format and agenda of the meeting, which focused on implementation processes, unique challenges facing nuclear forensics and potential solutions for those challenges. More than 150 participants from 80 Member States and four organizations, including nuclear forensics experts, law enforcement officials, judicial professionals, policy makers and national representatives who play an active role or have an interest in nuclear forensics attended the technical meeting to discuss how to advance nuclear forensics from the science into implementation. Additionally, the technical meeting was an opportunity for experts to highlight past accomplishments, share good practices, emphasize the role of nuclear forensics science in the response to incidents involving nuclear and other radioactive materials out of regulatory control, and showcase the important link between radiological crime scene management and nuclear forensics.

## 1.1.BACKGROUND

Nuclear forensics emerged in response to a number of high profile cases involving nuclear or other radioactive material out of regulatory control in the 1990s [5]. These cases led to affected States establishing nuclear forensics programmes. However, due to the urgency of the questions associated with trafficked nuclear and radioactive materials, to identify the material

and establish its origin and use, the focus of the nascent nuclear forensics programmes largely was on developing the knowledge, science, and technology to answer those questions. This resulted in a large number of scientific publications, new scientific methodologies and research tools for nuclear forensics, but did not always lead to the formation of comprehensive programmes that included a focus on implementation that applied nuclear forensics findings to support criminal prosecutions and nuclear security investigations resulting from these unauthorized acts.

### 1.1.1. IAEA activities related to nuclear forensics science

Over the past decade, the IAEA has increased its nuclear forensics science activities and currently its programme of assistance to States includes publications both within and external to the IAEA Nuclear Security Series, consistent outreach, training, residential assignments, expert missions, technical meetings and coordinated research projects.

*Published Guidance*

The IAEA develops guidance on nuclear security. The IAEA Nuclear Security Series No. 29-G states that "the State should establish a comprehensive system to prepare for and respond to a nuclear security event, including the development of capabilities for radiological crime scene management and ensuring the availability of capabilities for nuclear forensic analysis and interpretation (either by developing national capabilities or by entering into agreements with other States or relevant regional or international institutions)" [6]. In 2015, the IAEA published revised guidance on nuclear forensics in support of investigations examination that has been widely used by Member States [1]. More recently, in 2018, the IAEA released a publication on the development of a national nuclear forensics library (NNFL), which includes a description of how a Member State can use an NNFL in investigations of nuclear and other radioactive material out of regulatory control [7].

*Training*

The IAEA's training courses include an introductory course to nuclear forensics science that familiarizes participants with nuclear forensics science in the context of a national response plan; a practical introduction to nuclear forensics science, which provides applied instruction on analytical techniques pertinent to nuclear forensics examinations; and a training course on nuclear forensics science methodologies, which involves hands-on training on nuclear forensics analyses. All trainings mirror the IAEA's published guidance in the Nuclear Security Series. Along with the training courses and workshops, the IAEA established a Residential Assignment for Human Capacity Building in Nuclear Forensics Analytical Measurements. The programme recruits and places a technically qualified nuclear scientist at a leading nuclear forensics laboratory to work under the supervision of a distinguished nuclear forensics scientist for a period of approximately three months.

*Technical Advisory Activities*

The IAEA conducts expert missions and hosts technical meetings in nuclear forensics science. The IAEA also conducts expert missions in nuclear forensics science through the Integrated Nuclear Security Support Plan and has conducted missions in several nations including Burkina Faso, Lebanon, Malaysia, Argentina, Mexico and Thailand. The IAEA hosts seminars on nuclear forensics science in Member States, to include most recently in the Russian Federation in 2018 and 2019. In 2017, the IAEA held a Technical Meeting on Nuclear Forensics and Cooperation with African States, with the goal of promoting awareness and understanding throughout the region and highlighting the importance of nuclear forensics science in responding to nuclear security events involving nuclear and other radioactive material out of regulatory control.

*Collaborative Research*

The IAEA assists Member States to prepare to detect nuclear and other radioactive material out of regulatory control and respond to nuclear security events. In this context, the IAEA does not conduct nuclear forensics examinations and, as such, does not maintain its own nuclear forensics science laboratories. Working with its partner States, the IAEA has supported three coordinated research projects that bring together research institutions from its developing and developed States, and in 2016, the IAEA designated the Hungarian Academy of Sciences Centre for Energy Research as an IAEA Collaborating Centre for Nuclear Forensics.

## 1.2.OBJECTIVE

This publication is intended to summarize the discussions and outcomes of the technical meeting, with the goal of assisting Member States in using nuclear forensics science to meet their nuclear security responsibilities.

The technical meeting was organized in line with recent IAEA Resolutions from the General Conference that support further development of nuclear forensics among Member States, and to incorporate the outcomes from the 2014 IAEA International Conference on Nuclear Forensics.

The meeting was organized around four themes:

(a) Nuclear forensics capability building: initiation and sustainability;
(b) Nuclear forensics human resource development and sustainability;
(c) Nuclear forensics practice and experiences;
(d) Nuclear forensics science research and development: current status and future opportunities.

The outcomes of the meeting will inform the development of a road map of future activities for its nuclear forensics programme and inform the 2020 IAEA International Conference on

Nuclear Security: Sustaining and Strengthening Efforts, which will be held at IAEA Headquarters from 10 to 14 February 2020.

The publication is also intended to promote international cooperation among a diverse set of nuclear forensics stakeholders. This publication is intended for use by, but not limited to, nuclear and forensics scientists, nuclear security event responders, law enforcement officials, prosecutors, nuclear regulators, nuclear security specialists and officials supporting the development and implementation of national response plans for nuclear security events.

### 1.3.STRUCTURE

Section 2 of this publication summarizes the sessions of the technical meeting. Section 3 of this publication reviews the four broad themes and details conclusions and recommendations of the meeting. The supplementary material contains the papers presented at the meeting, the list of participants and the technical meeting's agenda.

## 2. SUMMARY OF THE MEETING SESSIONS

The meeting consisted of an Opening Session, one Keynote Presentation, eight Invited Presentations, three Panel Sessions, three Panel Discussions, ten Technical Sessions and a Poster Session that included ten posters. Additionally, the meeting featured an interactive exercise session involving all participants that demonstrated the necessary link between recovery of evidence contaminated by radionuclides and nuclear forensics analysis.

### 2.1.OPENING SESSION

Mr. Raja Raja Adnan, the Director of the Division of Nuclear Security in the Department of Nuclear Safety and Security at the IAEA stressed the role that nuclear forensics science plays in nuclear security by helping authorities determine the origin and history of seized materials. Although national authorities have the primary responsibility for ensuring nuclear and other radioactive material stays within regulatory control, the IAEA plays an important role assisting the Member States develop and sustain their national nuclear forensics science capabilities. He remarked on the significant progress that nuclear forensics science has made over the past decades including the increased number of Member States establishing nuclear forensics science programmes to significant international and regional cooperation in nuclear forensics science. However, with more than 3,000 reported incidents of nuclear and other radioactive material outside of regulatory control in the past 25 years, there is more work to do.

Director Raja Adnan remarked how this meeting provides an important forum for the IAEA Member States – ones with emerging or advanced nuclear forensics programmes – to share good practices. Since nuclear forensics science programmes span across nuclear science, law enforcement and criminal prosecution, this meeting will discuss ways to ensure effective

coordination and communication across the different areas as well. He stressed how this meeting will help the IAEA develop a road map of the IAEA's programme of assistance to Member States in nuclear forensics science for the next five years and will inform the IAEA International Conference on Nuclear Security in 2020.

Director Raja Adnan thanked everyone for their participation in the technical meeting. He concluded by highlighting that nuclear forensics science is only one piece of the nuclear security continuum and needs to be effectively coordinated with the other pieces, especially radiological crime scene management.

Mr. David Kenneth Smith of the Division of Nuclear Security, in the Department of Nuclear Safety and Security at the IAEA and the Scientific Secretary of the technical meeting welcomed the participants to Vienna and thanked them for their participation in the technical meeting. He highlighted the importance of a common definition of nuclear forensics to develop a shared understanding that nuclear forensics is the examination of nuclear or other radioactive materials, or evidence contaminated with radionuclides, in the context of legal proceedings under international or national law related to nuclear security. He stressed that although the IAEA does not conduct nuclear forensics examinations, the agency assists Member States develop and sustain their nuclear forensics science capabilities and helps address vulnerabilities in their nuclear security regime.

Mr. Smith reviewed the goals and objectives of the meeting, which include welcoming the new global partners in nuclear forensics, sharing good practices, innovating and sustaining the field as well as how to effectively prioritize nuclear forensics science leading up to the 2020 International Conference on Nuclear Security.

Although there is much work to be done, he reviewed the milestones and achievements that nuclear forensics has made. Notable milestones mentioned by Mr. Smith include four Nuclear Security Summits, 10 years of the Global Initiative to Combat Nuclear Terrorism (GICNT), over two decades of annual meetings of the Nuclear Forensics International Technical Working Group (ITWG), two IAEA Ministerial Conferences on Nuclear Security, the entry into force in 2016 of the Amendment to the Convention on the Physical Protection of Nuclear Material (A/CPPNM) [8], significant number of scientific publications, numerous training activities as well as several coordinated research projects focused on nuclear forensics and expert missions.

Mr. Smith stressed that this meeting will be vital for strengthening the relationship among nuclear forensics stakeholders including crime scene investigators, nuclear forensics researchers and prosecutors to ensure that there is an innovative and sustainable nuclear forensics community prepared to respond to an incident if it occurred.

Ms. Maria Wallenius a Research Scientist at the European Commission's Joint Research Centre and Co-Chair of the technical meeting, welcomed the delegates and thanked everyone involved with the planning and organizing of the technical meeting, especially the IAEA Secretariat and

the Steering Committee. Preparation for the meeting has been undergoing since March 2018 and was organized around four themes. Since nuclear forensics programmes need to be established and maintained, the meeting will have a focus on capacity development to ensure that nuclear forensics can continue to meet the needs of the international community

## 2.2.PANEL SESSIONS

### Progress and Potential: Nuclear Forensics in the Context of Nuclear Security

The meeting started with a panel on the progress and potential of nuclear forensics in the context of nuclear security. Invited panellists represented three countries and the European Commission and consisted of K. Heppell-Masys (Canada), K. Lützenkirchen (European Commission), M. Klimova (Russian Federation) and G. Ford (United States of America).

**K. Heppell-Masys (Canada)** reviewed the Canadian nuclear forensics programme. The Canadian Government appreciates the important role nuclear forensics plays in nuclear security and protecting Canadians. In its nuclear forensics programme, Canada recognizes the value of building up its national programme while supporting international nuclear forensics efforts. In her presentation, she stressed that there are no universal or one-size-fits-all solutions. Furthermore, since nuclear forensics spans multiple disciplines and agencies, Canada has taken a whole of government approach.

**M. Klimova (Russian Federation)** presented the Russian Federation nuclear forensics programme. The programme is based on national legislation and works with federal agencies to conduct investigations. In her presentation, she also reviewed how the Russian Federation has developed new methods for investigations.

**G. Ford (United States of America)** discussed the United States of America's nuclear forensics programme, which works across different departments and disciplines including scientific communities and law enforcement. Nuclear forensics is a priority for the United States of America to address national and international security issues and the United States of America is committed to strengthening its nuclear forensics capabilities for investigative purposes, to deter future incidents and to increase response capabilities. In his presentation, he specifically highlighted the work that the IAEA has done in the areas of training and publication of guidance documents. The United States of America is determined to work with the IAEA and other Member States on sharing best practices and working to further develop nuclear forensics capabilities across the globe. He praised the work that other countries and international organizations have done in nuclear forensics, including GICNT developing a new self-assessment tool and Member States showing their commitment to nuclear forensics by expressing support for IAEA Information Circular 917 (INFCIRC/917) [9].

**K. Lützenkirchen (European Commission)** presented the activities of the Joint Research Centre (JRC) in Karlsruhe, which is a multinational research centre for EU Member States, as

well as a national technical centre in Germany. The JRC started their nuclear forensics efforts in the 1990s when radioactive or other nuclear material was sent to them for analysis. In his presentation, he reviewed their training efforts, the importance of working with bilateral and multi-lateral partners and how the Joint Research Centre in Karlsruhe is open to non-EU partners for joint analysis. He remarked on the appropriate timing and objectives of the meeting to reflect on nuclear forensics and discuss how to move beyond the science of nuclear forensics into implementation.

*Outcome*

This session reviewed the national nuclear forensics programmes of several countries as well as of the European Commission. The session highlighted the efforts by international organizations and participating countries in developing and advancing nuclear forensics capabilities. Each State has to identify their own needs according to the threats and establish a national nuclear forensics programme that addresses these needs and priorities. The presentations highlighted the need for government support and the inclusion of strengthening the nuclear forensics capabilities in relevant government strategies.

The session stressed that since nuclear forensics fits into a much broader policy structure where no single agency or department can implement a comprehensive nuclear forensics programme, States may want to take a whole of government approach to coordinate and more effectively implement nuclear forensics activities. The presenters emphasised the important role for bilateral, regional and international cooperation in nuclear forensics especially in the areas of hands-on training. Additionally, the presentations highlighted ways for Member States to show their commitment to nuclear forensics, including working with international organizations to bolster national capabilities and expressing support for INFCIRC/917.

Questions from the delegates focused on developing national nuclear forensics plans, how incidents have increased in the past decade and the relationship between research and development and capacity building activities. The discussion focused on the need to have clear objectives before establishing a national nuclear forensics plan and the need to build and sustain cooperation among nuclear forensics stakeholders.

**International Perspectives on Nuclear Forensics**

A panel was organized on the international perspectives on nuclear forensics where the panellists emphasized the importance of building relationships with national nuclear forensics stakeholders. The panel consisted of J. Buchanan (INTERPOL), A. El-Jaby (Canada), K. Mayer (European Commission), T. Bull (Australia) and J. Davydov (IAEA).

**J. Buchanan (INTERPOL)** explained that INTERPOL works with law enforcement agencies as the coordinator for radiological nuclear terrorism. In his presentation, he stressed the need for scientific experts to understand the legal requirements for nuclear forensics and whether revised or additional legislation is needed to ensure effective prosecutions of incidents. It is

important to develop a strong working relationship between the scientific, law enforcement and legal communities early. These relationships can help increase engagement as well as the awareness of the risks and priorities of nuclear forensics within the law enforcement community. To help support these relationships, INTERPOL created workshops for investigators and prosecutors as a venue to share experiences and best practices.

**A. El-Jaby (Canada)** presented the work of the GICNT, which integrates scientists, policy makers and law enforcement in a nuclear forensics working group. In his presentation, he reviewed that GICNT works at the state level policies regarding nuclear forensics capacities and sustainability. For implementation of nuclear forensics, it is important to have effective legal instruments to correctly categorize illegal activities within the country's legal framework. He reviewed a new self-assessment tool developed by GICNT that facilitates structured dialogue between national stakeholders to identify solutions. Five countries have piloted the new tool.

**K. Mayer (European Commission)** gave an overview of the activities of the ITWG, an informal association of nuclear forensics practitioners. The ITWG identifies and shares best practices among scientists and law enforcement through international exercises and dedicated outreach. The contributions of ITWG include promoting a model action plan to guide the conduct of a nuclear forensics examination, the use of a national nuclear forensics library and publishing the quarterly ITWG newsletter.

**T. Bull (Australia)** discussed Australia's nuclear forensics programme. In her presentation, she stressed the need to build trust and develop relationships with law enforcement and the value of international nuclear forensics exercises to identify strengths and gaps in a nuclear forensics programme. She provided details on INFCIRC/917, submitted to the IAEA by the Australian Permanent Mission in 2017, which states the intent to advance nuclear forensics for nuclear security, a commitment to develop and sustain nuclear forensics expertise, a goal of establishing national plans and the objective of advancing national nuclear forensics programmes [9]. To date, over 30 Member States and international organizations have expressed support for INFCIRC/917. She encouraged other liked minded Member States express support for INFCIRC/917.

**J. Davydov (IAEA)** discussed that nuclear forensics involves multiple stakeholders, which cross disciplines and agencies. For example, nuclear forensics programmes work with technical experts on developing signatures and identifying materials; with policy makers to obtain appropriate resources and support; with law enforcement to investigate, and with legal stakeholders to prosecute any incidents. At their establishment, nuclear forensics programmes were focused on the science, which did not always result in incorporating all relevant stakeholders. As nuclear forensics matures, it is imperative to have all stakeholders working together to develop defined legal frameworks as well as roles and responsibilities to appropriately respond to nuclear security events. International organizations, such as the IAEA, INTERPOL, GICNT and ITWG can provide tools to help States develop and advance nuclear forensics programmes.

*Outcome*

The panel session stressed that since nuclear forensics has multiple stakeholders, it is important to incorporate, build trust and develop strong relationships with all stakeholders from the onset of developing a national nuclear forensics programme. To effectively support criminal investigations, nuclear forensics programmes ought to develop programmes jointly with law enforcement and legal stakeholders to ensure that the programme addresses law enforcement needs, has effective legal instruments to categorize illegal activities and that evidence can be used in legal proceedings. This may require revised or additional legislation. Furthermore, the IAEA, INTERPOL, GICNT, ITWG and other international collaborations will continue to provide tools that develop and advance nuclear forensics operational capabilities.

Questions from the delegates focused on the value of international cooperation of nuclear forensics and the new self-assessment tool developed by GICNT. The discussion centred on how physical protection and nuclear forensics serve as preventatives as well as the importance of having a platform to share best practices.

**Radiological Crime Scene and Nuclear Forensics Scenario**

The session consisted of an interactive session and a panel on radiological crime scene management and nuclear forensics analysis to support the investigation. The interactive session was presented by F. Wong (United States of America) and P. Burton (IAEA) and the panel consisted of J. Simm (United Kingdom), R. Kips (United States of America), T. Bull (Australia) and J. Buchanan (INTERPOL).

The session started with two videos and a discussion about crime scene management and nuclear forensics analysis to support the investigation presented by **F. Wong (United States of America) and P. Burton (IAEA)**. The scenarios and discussion that followed emphasized the importance of forensics procedures and custody chain as well as highlighting the essential roles of communication between scientists and law-enforcement and between nuclear forensics stakeholders and the public, including the value of having a designated point of communication for the public. The session finished with an interactive polling activity involving questions for participants on good practices, challenges and sustainability for nuclear forensics. Results from an interactive polling session indicated that participants thought there was a need for more training, sustained funding and increased communication between stakeholders and the public.

The interactive panel consisted of **J. Simm (United Kingdom)**, **R. Kips (United States of America)**, **T. Bull (Australia)** and **J. Buchanan (INTERPOL)** who engaged with the audience on questions focused on building relationships between technical and scientific nuclear forensics stakeholders, cybersecurity risks and managing communication during an incident. The discussion highlighted the value of building relationships and trust with stakeholders during the onset of establishing a nuclear forensics programme, the need for clear communication during a potential incident and having a liaison between science and law enforcement.

*Outcome*

The panel session illustrated the need for nuclear forensics technical experts to work with law enforcement before an incident occurred to establish procedures that will meet the needs of scientific, legal and law enforcement stakeholders. Further, since each State has a different legal system, the session highlighted the difficulty of sharing common protocols and how national nuclear forensics programmes need to ensure that their programmes are compatible with their court system.

The live polling and discussion demonstrated the difficulty of establishing priorities, for example how to balance health and safety of personnel while properly following the procedures for collecting materials and evidence, as well as the need for additional training, funding and communication efforts in nuclear forensics.

**Nuclear Forensics and Criminal Prosecution**

The panel session on nuclear forensics and criminal prosecution included a prosecutor's office, law enforcement, and the United Nations Office on Drugs and Crime and consisted of E. Dinu (Romania), N. Kovalenko (Russian Federation), J. Simm (United Kingdom) and M. Lorenzo Sobrado (United Nations Office on Drugs and Crime).

**E. Dinu (Romania)** stressed the role of nuclear forensics in criminal justice as a tool to find the links between people, materials and organizations that are involved in an incident of nuclear or other radioactive material out of regulatory control.

**N. Kovalenko (Russian Federation)** reviewed how nuclear forensics programmes need to follow the national legal system, which for the Russian Federation is a mixed system of civil and common law, to be an effective tool in a criminal proceeding and for nuclear forensics evidence to be admissible in court.

**J. Simm (United Kingdom)** discussed the United Kingdom's common law system; how it is valuable to develop relationships with law enforcement and prosecutors early; and the value of scientific experts understanding the legal processes, what constitutes evidence, and what might be expected from their testimony before they get involved in a court case.

**M. Lorenzo Sobrado (United Nations Office on Drugs and Crime)** presented relevant international conventions and amendments, which are binding for Member States who have signed onto them. However, she stressed that conventions are not national laws and instead are used as a framework for establishing national laws for prosecution. She noted that all States can use the conventions as a framework even if they have not signed onto them. Additionally, she highlighted that the United Nations Office on Drugs and Crime offers assistance to Member States who need help utilizing conventions when drafting national legislation.

*Outcome*
In this session, the panellists emphasized the importance of scientific experts and law enforcement working together and developing an effective bridge between science and law through utilizing and understanding the same terminology. It is advisable that the collaboration between scientific experts and law enforcement begins at the onset of a national nuclear forensics programme. Additionally, the session highlighted relevant international frameworks that are available, which can be customized and incorporated into national legislation.

Questions from the delegates focused on how nuclear forensics can be used to prevent future crimes, why so few cases are prosecuted and the difficulty with establishing uniformity across countries. The discussion concentrated on how establishing national laws can serve as a preventive measure and how some cases need to be prosecuted as a lesser crime due to the lack of fuller evidence.

**Nuclear Forensics Human Resource Development: Residential Assignment**

The session discussed the IAEA Residential Assignment for Human Capacity Building in Nuclear Forensics Analytical Measurements, which places fellows in leading nuclear forensics laboratories for up to three months and consisted of É. Kovacs-Széles (Hungary), M. Larisa Ganea (Romania), K. Mayer (European Commission), A. Apostol (Romania), K. Treinen (United States of America) and M. Bavio (Argentina). Participants and mentors described their experiences in the programme, which ranged from participating in a nuclear forensics scenario to obtaining advanced training on nuclear forensics techniques and analytical methods.

*Outcome*
The session stressed the value of a residential based human resource capacity development programme for developing domestic nuclear forensics capabilities and building a network of nuclear forensics practitioners.

Questions from the delegates focused on the technical skills needed to participate in the programme and about the duration of the programme. The discussion centred on how the programme has significant flexibility to allow for different experiences, provides an opportunity to enhance nuclear forensics capabilities and is a mechanism to establish regional and global networks of nuclear forensics experts.

**Nuclear Forensics Workforce Development and Sustainability**

The panellists discussed challenges on attracting, retaining and sustaining a capable workforce for nuclear forensics. The panel consisted of T. Bull (Australia), R. Kips (United States of America), A. El-Jaby (Canada), R. Awbery (United Kingdom), A. Goodsell (United States of America) and A. E. Serban (Romania).

The session's moderator **C. Hobbs (United Kingdom)** stressed the role for universities in developing and sustaining a nuclear forensics workforce. One challenge for universities trying to establish nuclear forensics programmes is that academia is often organized into disciplines and nuclear forensics is at the intersection of science, technology, policy and security. He reviewed Kings College London's efforts to introduce students to this area, which involves multiple stakeholders and connecting the topic to real world situations. He reviewed the IAEA International Nuclear Security Educational Network that includes modules and curriculum and detailed how it had grown from a few universities to now including over 100 institutions.

**T. Bull (Australia)** discussed her experience assembling a nuclear forensics team where she learned to effectively use the unique skills of her team members, to utilize various recruitment processes including secondments and short-term assignments and the difficulty of sustaining technical capabilities when cases and examinations are infrequent. Additionally, she discussed the challenge of attracting and retaining scientific staff since nuclear forensics research is focused on mostly case work and the development of methods, which may result in fewer published papers than in traditional academia.

**R. Kips (United States of America)** reviewed her career in nuclear security, which started in nuclear safeguards before moving to nuclear forensics where she now works on international partnerships. In her presentation, she discussed how a significant number of nuclear forensics experts begin their nuclear forensics career at the postdoctoral level. Due to this, nuclear forensics experts come to the discipline with a wide range of experiences and backgrounds, which need to be considered by national nuclear forensics programmes.

**A. El-Jaby (Canada)** reviewed the strategy in Canada for nuclear forensics human resources development. In his presentation, he reviewed some of the challenges, including how the national nuclear forensics programme spans multiple agencies that need different skills. Further, in any workforce development strategy, it is important to focus on the continuity of operations, build in redundancies and ensure training and professional development of the future experts and leaders of nuclear forensics.

**R. Awbery (United Kingdom)** focused on sustaining nuclear forensics capabilities in the United Kingdom. A major challenge in sustaining capabilities is that nuclear forensics is often not the expert's primary or fulltime responsibility, but rather, experts are brought in to participate in nuclear forensics exercises and only when they are needed. Another challenge is that nuclear forensics experts are ageing so it is critical to focus on developing the next generation of experts. In his presentation, he discussed a United Kingdom programme that offers inducements to place experts in nuclear security technical positions if they agree to contribute as a nuclear forensics expert when needed, and how the United Kingdom is looking beyond the traditional fields, like the nuclear industry, to find people with relevant skills for nuclear forensics.

**A. Goodsell (United States of America)** discussed her experience in nuclear security and her current role working on a NNFL. In her presentation, she highlighted key lessons she learned

from her experiences, including working with an NNFL, which include that programme and stakeholder needs are different and how it is imperative to have good communication between different experts and programmes.

**A. E. Serban (Romania)** reviewed, from the perspective of a younger nuclear forensics examiner, how nuclear forensics brings people with different technical backgrounds working in diverse fields together for a common purpose. In her presentation, she stressed the important role that the international community plays in nuclear forensics workforce development, especially in organizing and implementing international exercises and meetings.

*Outcome*

In this panel session, presenters described their own career pathways and experiences in managing nuclear forensics teams and reviewed the significant accomplishments that nuclear forensics has made in the area of workforce development, which include launching university programmes, establishing peer-reviewed journals and creating an international educational network. The session stressed how multidisciplinary approaches can play a crucial role in developing a workforce for nuclear forensics and highlighted the value of engaging with academia and having a government mandate to successfully develop and sustain a qualified nuclear forensics workforce. However, workforce challenges remain and include the diverse backgrounds of team members, that nuclear forensics is often not a primary responsibility and sustaining nuclear forensics with an ageing workforce.

Questions from the delegates included balancing internal and external capabilities, the challenge of salary levels on recruitment and sustaining capabilities between incidents. Discussion focused on ideas on how to attract team members, including recruiting from non-traditional fields with similar expertise, how to sustain capabilities through exercises and meetings and the need to increase awareness for nuclear forensics for both support and resources.

**Nuclear Forensics 2025: A Strategic Vision**

The panellists discussed the history and future of nuclear forensics and consisted of T. Bieda (Argentina), B. Warner (United States of America) and R. Howsley (World Institute for Nuclear Security).

**T. Bieda (Argentina)** discussed how the threat of nuclear or other radioactive material out of regulatory control is real and that nuclear forensics is a key to combat that threat. In his presentation, he stressed the value of regional workshops for developing a regional nuclear forensics community, which could help if a regional incident occurred. He highlighted how nuclear forensics programmes can use existing laboratories while learning new techniques, which can make developing national nuclear forensics programmes less expensive. For establishing and maintaining nuclear forensics capabilities, he stressed the importance of having support from all decision makers and the government, and how participating in

exercises can shed light on gaps, strengths and test protocols in national nuclear forensics programmes.

**B. Warner (United States of America)** remarked on the progress nuclear forensics has made, especially in the area of nuclear forensics science. In his presentation, he stressed that the scientific development needs to be followed by standard references, standard operating procedures and standards for experts as well as further developing international collaborations, increasing trainings and more effectively incorporating stakeholders such as law enforcement into national nuclear forensics programmes. He concluded by discussing the need for nuclear forensics to focus on recruiting the next generation of nuclear forensics experts, engaging stakeholders and the value of training programmes, especially residential assignment programmes, on increasing nuclear forensics capabilities and developing nuclear forensics networks.

**R. Howsley (World Institute for Nuclear Security)** discussed the potential of developing professional certifications and credentials for nuclear forensics examiners as well as establishing an international nuclear forensics association. Additionally, in his presentation, he stressed the need to more effectively promote nuclear forensics and increase the awareness of nuclear forensics.

*Outcome*

The panel session illustrated the substantial progress nuclear forensics has made since its beginning, including the development of nuclear forensics capabilities across the globe and the implementation of training programmes and international exercises. However, the session stressed the need to recruit and retain the next generation of the nuclear forensics workforce, engage broad academic fields, further develop and sustain international collaborations, build strong partnerships within the broad nuclear forensics community and strengthen regional and global networks of professionals in nuclear forensics. Additionally, the panellists remarked on the value of more effectively connecting nuclear forensics and traditional forensics, the need to support communication efforts around nuclear forensics science and the potential value of developing nuclear forensics associations and certifications. Finally, they highlighted the need for outreach efforts to increase the awareness and support for nuclear forensics.

The presentations included a call to action for the future of nuclear forensics to communicate the value of nuclear forensics more broadly to increase support and awareness, grow international collaborations, more effectively connect traditional and nuclear forensics, train the next generation of nuclear forensics experts and stakeholders, consider establishing professional standards and credentials for nuclear forensics and the need to develop comprehensive national nuclear forensics programmes that effectively work together as a community – from scientists to law enforcement to prosecutors.

## 2.3.INVITED PRESENTATIONS AND KEYNOTES

### Nuclear Forensics Special Topics: Nuclear Forensics and Criminal Prosecution

**A. Apostol (Romania)** detailed the process of implementing a nuclear forensics programme working with law enforcement and prosecutors in Romania. He described the different legal systems (e.g., civil or common) around the world and that a national nuclear forensics programme needs to be compliant with its national legal framework. The legal framework dictates what acts can be prosecuted, the rules to be followed in a criminal process and the extent and manner in which the nuclear forensics programme can function.

He detailed the process for involving the opening of criminal cases in Romania and the roles of the different stakeholders – police, prosecutor and scientific experts – in the proceedings. Although every seizure of material outside of regulatory control could lead to a criminal case, no criminal cases in Romania had been investigated. However in 2018, four criminal cases were opened and five nuclear forensics reports have been provided to judicial authorities in Romania. The reason for the increase in judicial cases is the Romanian nuclear forensics programme started working with legal stakeholders and asking investigative questions at the onset of each case.

He concluded his presentation by stressing the importance of prosecuting incidents of material found out of regulatory control for justice and prevention reasons. Further, he suggested that to increase the awareness in the nuclear forensics community about the procedures involved in a criminal investigation, a judicial section could be added to the GICNT exercises.

He stressed that before establishing a national nuclear forensic programme, it is important to consider the national legal framework and its implications since the national legal framework dictates what acts can be prosecuted, the rules to be followed in a criminal process and the extent and manner in which the nuclear forensics programme can function. Additionally, he highlighted how prosecuting incidents of material found out of regulatory control can serve as preventive measure.

*Outcome*
The invited presentation highlighted that since nuclear forensics programmes are typically established with agencies that are closely aligned with the topic, such as nuclear regulatory bodies, there is often a lack of involvement with other relevant stakeholders, including the legal system. This lack of involvement of legal and judicial stakeholders can impede conducting proper investigations and can result in the failure to open criminal cases. To address this, it is essential for nuclear forensics programmes to be compliant with the national legal framework and to include broad stakeholders in the development of national nuclear forensics programmes from the beginning.

Questions from the delegates focused on how every seizure of illicit trafficking of material out of regulatory control could lead to a criminal investigation as well as outreach activities to

support and educate people without a technical background about nuclear forensics. The discussion focused on how the involvement of the public and other relevant stakeholders are critical and how those relationships may be developed at the onset of the national nuclear forensics programme.

**Nuclear Forensics Special Topics: Nuclear Forensics International Technical Working Group**

**K. Mayer (European Commission)** presented the work and history of the ITWG. The ITWG is an informal association to advance the scientific discipline of nuclear forensics, provide a common approach and develop effective technical solutions. Participation in the ITWG is open to recognized participants from countries with an established or a desire to establish nuclear forensics capabilities.

An executive committee oversees the ITWG's activities, which activities include annual meetings, special exercises, participation with international intergovernmental organizations and professional development seminars. Additionally, the ITWG has several task groups, including outreach and training, which is responsible for the ITWG websites and newsletters; evidence and testimony, which develops guidelines for evidence collection; technical exercises, which oversees the collaborative laboratory-based exercises; guidelines, which is responsible for the development and adoption of best practice guidelines; and national nuclear forensics libraries, which addresses the need for databases and archives.

The ITWG is a unique forum for developing and promoting best practices in nuclear forensics, advancing nuclear forensics science and actively collaborating with nuclear forensics related activities with international organizations such as the IAEA, the GICNT and the INTERPOL.

*Outcome*
This presentation highlighted the important role that the ITWG, which has included a broad range of participants, including scientists and law enforcement from the beginning, has played in developing and promoting the field of nuclear forensics.

Questions from the delegates focused on the structure of ITWG activities and about guidelines for validating nuclear forensics analytical methods. The discussion was focused on how the informal nature of the ITWG offers flexibility and the possibility to promote an open exchange of technical views.

**Nuclear Forensics Special Topics: Perspectives from Russian Federation I**

**V. Maltsev (Russian Federation)** reviewed the nuclear forensics system in the Russian Federation where federal authorities are in charge of the control, physical protection, state supervision and nuclear facilities and there are bilateral agreements between federal authorities with standard procedures. The national nuclear forensics programme includes several key

laboratories and nuclear forensics capabilities are sustained through training, courses and participation in exercises.

The investigation of a criminal case is within the framework of national legislation, which defines the roles and responsibilities of the participants, who can be scientific experts in legal proceedings. Nuclear forensics investigations rely on nuclear forensics methods as well as traditional forensics and investigative tools. Research laboratories must submit their reports to authorities and need to follow state legislation. To improve their nuclear forensics capabilities, the nuclear forensics programme is focusing on improving stakeholder interactions, developing new investigative methods and improving their detection technology.

*Outcome*
This invited presentation highlighted the Russian Federation's nuclear forensics programme. The session stressed that national nuclear forensics programmes are established according to their legal framework and procedures as well as the value of co-developing national nuclear forensics programmes with legal and judicial stakeholders from the beginning.

Questions from the audience focused on the decision making system for nuclear forensics investigations – whether it was more centralized or distributed. The discussion centred on how the Russian Federation has entered into bilateral agreements with authorities and specific research laboratories.

**Nuclear Forensics Research and Development: Current Status and Future Needs**

**K. Mayer (European Commission)** reviewed the development, status and future needs of nuclear forensics research and development (R&D). Nuclear forensics examinations were successively applied to address the incidents of smuggling and illicit trafficking of nuclear or other radioactive materials in the 1990s. Initially, nuclear forensics was focused on the science of nuclear forensics taking many of the analytical techniques from the nuclear fuel cycle and nuclear safeguards fields. The topics and subjects that have been covered comprehensively include spent fuel, morphology, stable isotopes, measurement techniques and age-dating of uranium. However, there is less work on trace elements, morphology and statistical methods. Topics that may need more attention include organics, traditional forensics, luminescence dosimetry, sample inhomogeneity, post-dispersion, further development of signatures using micro-analytical techniques and the use of new technologies like artificial intelligence and block chain.

He remarked on the impetus to continue developing nuclear forensics research and development includes the persistent threat of incidents, the excitement of a new scientific field and the ability to transfer and expand scientific knowledge to real cases. The expansion of nuclear forensics research and development can be seen by the relevant scientific publications, which have increased over the years.

In his presentation, he discussed that along with the development of analytical methods and techniques, there is a need for subject matter experts in the nuclear fuel cycle and industrial processes as well as experts with experience in hands-on casework. Finally, to meet the future needs of nuclear forensics, it is important to encourage and foster the next generation of individuals to pursue education and training in nuclear forensics.

*Outcome*

This invited keynote presentation reviewed the development, current status and future needs of nuclear forensics research and development. Since it is an emerging field, the R&D of nuclear forensics is still developing. Some of the research topics are well covered, such as spent fuel; whereas, some topics, such as trace elements and morphology need further development. The future of nuclear forensics R&D could include research areas such as morphology techniques and the exploration of block chain and artificial intelligence in nuclear forensics. Finally, there is a need to ensure the competencies of the next generation of nuclear forensics experts.

Questions from the delegates focused on inhomogeneity of samples, biological measurements and training. The discussion centred on the efforts by international organizations, like the IAEA, on developing nuclear forensics R&D capabilities as well as need to further develop nuclear forensics science so it is able to provide necessary evidence for potential criminal prosecution of incidents of nuclear and other radioactive material out of regulatory control.

**Nuclear Forensics Special Topics: NuFor2019**

**R. Awbery (United Kingdom)** presented the concepts and plans for NuFor 2019 Nuclear Forensics Conference, which will be held at the University of Bristol, United Kingdom in July. NuFor 2019 is a conference that will include experts from academia, industry and government. The aims of the conference are to increase awareness of nuclear forensics, showcase the work of leading nuclear forensics researchers and examiners, highlight potential career pathways in nuclear forensics, build a sustainable pipeline for the future of nuclear forensics, and provide a networking opportunity. The sessions will focus on materials and processing, radiochemistry, analytical techniques, environmental science, data analysis and statistics, and modelling and simulation.

**Nuclear Forensics Special Topics: Perspectives from the United States of America**

**T. Black (United States of America)** presented the nuclear forensics programme in the United States of America. Nuclear forensics is a priority in the United States of America where multiple agencies with scientific expertise and capabilities work in partnership together. Nuclear forensics enables investigations and prosecutions, disrupts smuggling networks and deters potential perpetrators. In its role, the United States National Nuclear Security Administration covers nuclear forensics from evidence collection, collection of post-detonation debris, laboratory measurements of pre-detonation materials, developing new signatures and methodologies and establishing and implementing international partnerships. He stressed how

clear communication is necessary when explaining scientific analysis to other stakeholders such as law enforcement and for fostering successful interagency and international partnerships.

Although the United States of America has a developed national nuclear forensics programme, it is working on strengthening its capabilities, including developing more accurate, faster and more robust methods for analysis and interpretation; and new signatures and methodologies, as well as participating in training and exercises and forging strong partnerships among domestic and international nuclear forensics stakeholders.

*Outcome*
This session reviewed the United States of America's nuclear forensics programme, which incorporates nuclear security and nuclear forensics partnerships. For partnerships to be effective, it is important to involve all the essential stakeholders, including nuclear forensics scientists, law enforcement, policy makers and regulators from the onset. The United States of America is focused on improving its nuclear forensics capabilities, developing the next generation of nuclear forensics experts and further strengthening its bilateral, regional and international partnerships.

Questions from the delegates focused on whether all nuclear security and nuclear forensics programmes in the United States of America were at the federal level. Discussion centred on the structure of nuclear forensics activities in the United States of America.

**Nuclear Forensics Special Topics: Perspectives from Russian Federation II**

**M. Klimova (Russian Federation)** discussed the nuclear forensics capabilities in the Russian Federation where the investigation into criminal conduct including illicit trafficking and illegal possession of nuclear or other radioactive material out of regulatory control is the responsibility of the state and the roles and responsibilities of the investigation are prescribed through national legislation. Nuclear forensics evidence is often combined with other traditional investigative procedures, including traditional forensics examinations and interrogations. A judge determines who is recognized as a nuclear forensics expert and what nuclear forensics evidence can be used in a criminal proceeding.

For future development of its nuclear forensics program, the Russian Federation is working to improve radiation detection technology, the quality of interaction between crime scene and operational personnel, developing new methods in investigations and better utilization of knowledge of crime connected with nuclear materials.

*Outcome*
The Russian Federation has a developed national nuclear forensics programme that is based on national legislation. There are significant nuclear forensics capabilities, but in the future, the Russian Federation is focusing on developing better coordination between stakeholders and new methods of investigation.

Questions from the delegates were focused on the relationships between nuclear forensics and the police and whether nuclear forensics scientists need to be certified to be an expert witness. The discussion centred on how experts were housed in laboratories and can be endorsed as well as the relationships between stakeholders in the nuclear forensics programme.

**Nuclear Forensics Special Topics: Perspectives from Tajikistan**

**I. Mirsaidov (Tajikistan)** reviewed the development of the nuclear forensics capabilities of Tajikistan, which is strategically positioned in Central Asia. Tajikistan's nuclear forensics developed around a legal framework for nuclear forensics, which started with a 2003 Radiation Safety Law and has continued with the passage of a 2018 law that details procedures for interagency cooperation, including the interface between law enforcement with regulatory bodies and technical staff.

In 2017, Tajikistan opened a regional centre for non-proliferation, which is used for nuclear forensics and training law enforcement in Tajikistan and the Central Asian region. The laboratory has significant technical facilities, including for physical measurements, gamma spectrometry and dosimetry.

In his presentation, he reviewed how Tajikistan is enhancing their national nuclear forensics capabilities through national, bilateral and international cooperation activities. There is a government decree to maintain and update databases and they have a mobile expert support team. In collaboration with regional partners, they have successfully analysed an abandoned source and concluded that it was not radioactive. For future capabilities, there is a need for mass spectrometry capabilities at the laboratory.

*Outcome*
Tajikistan has developed a nuclear forensics programme built upon a legal framework, but it is in need for additional equipment and capabilities. They have established a regional centre for training for the Central Asian region. This session highlighted the need to establish a technical basis for nuclear forensics at the onset of developing a nuclear forensics programme as well as the value of attracting experts from different areas of nuclear forensics, working across agencies and departments and adapting existing techniques.

Discussion centred on the important role bilateral, regional and international collaborations play to help build up domestic nuclear forensics capabilities.

**Nuclear Forensics Special Topics: Perspectives from Sweden**

**L. van Dassen (Sweden)** reviewed how in a relatively short-time, nuclear forensics has gone from a nascent field to developing into a more mature field with analytical methods and techniques. This development has been strengthened by the increasing number of national nuclear forensics programmes being established across the globe. International collaborations, which include exercises and guidance, have helped States advance their national nuclear

forensics programmes, including developing model action plans. Additionally, international cooperation has led to significant efforts in the workforce development through trainings and residential programmes.

In his presentation, he reviewed that after these impressive technical advances in nuclear forensics, it is time to move to establishing comprehensive nuclear forensics programmes that include multiple stakeholders from different disciplines. Further, it is important for nuclear forensics programmes to connect the scientific and legal side more effectively. One reason for the lack of prosecutions and convictions in nuclear forensics cases may be a deficiency in communication between the technical and legal stakeholders.

He reviewed the institutional and structural changes that have impacted nuclear forensics. He classified them in three generations: generation one – pre-1991; generation two - the early 1990s, which had a significant number of cases of illicit trafficking of materials that resulted in world leaders calling for the technical development of nuclear forensics as well as strong international cooperation working to prevent and stop illicit trafficking events; and generation three – the future, which could involve global institutions being connected together both regionally and globally to effectively combat illicit trafficking.

*Outcome*
Since its establishment in the early 1990s, nuclear forensics programmes have largely been focused on technical development and the science of nuclear forensics. As the field is maturing, there is a need to take in account other disciplines from criminology to sociology and psychology in order to understand fully the motivations of people's actions and develop comprehensive national nuclear forensics programmes that could connect the technical and legal side more effectively.

Questions from the delegates focused on how to gain support and increase awareness of nuclear forensics as well as the impact of terminology used in nuclear forensics. Discussion centred on the importance of terminology, the value of international collaborations, how to improve communication among stakeholders including policy makers and the need for increased awareness about nuclear forensics among the press and the general public.

## 2.4.TECHNICAL SESSIONS

### Nuclear Forensics Practices and Experiences: National and International Perspectives I

The session focused on the practices and experiences taking a national and international perspective and consisted of M. Wallenius (European Commission), J. Simm (United Kingdom), J. Schwantes (United States of America) and P. Lobanov (Kazakhstan).

**M. Wallenius (European Commission)** presented the evolution of nuclear forensics as a field, which began in the early 1990s when several cases of radioactive material were found out of regulatory control. Nuclear forensics started by using mostly modified analytical methods developed from nuclear safeguards. Over the decades, nuclear forensics science has established its own tool-box, accepted techniques and methods. As nuclear forensics matures, there needs to be a focus on how best to sustain nuclear forensics capabilities due to the infrequency of cases and how to foster better relationships with law enforcement to ensure effective prosecution of incidents when they do occur.

**J. Simm (United Kingdom)** presented how the United Kingdom's law enforcement responds to a nuclear security event, including the procedures for managing a scene contaminated with radioactive material. He detailed a system to enable the safe transfer of evidence from a scene to the laboratory, in-scene exhibit management and forensics capabilities, and how they are developing additional capability support for crime scene forensics examinations, including how to integrate procedures into the policy response. In his presentation, he stressed the need for developing procedures that satisfy national legal requirements.

**J. Schwantes (United States of America)** reviewed the five analytical ITWG collaborative materials exercises in which almost 30 countries and organizations participated. The exercises use real world nuclear material samples for scenario based exercises that have realistic reporting times of a preliminary report at 24 hours, a second report at one week and a final report at two months. Participating laboratories conduct analyses on the samples from visual inspection, basic categorization, to more advanced methods including spectrometry. These exercises are an important mechanism to enhance international nuclear forensic capabilities.

**P. Lobanov (Kazakhstan)** presented the nuclear forensics programme in Kazakhstan for interacting with law enforcement authorities to combat illicit trafficking of nuclear materials/radioactive substances, which includes meetings and training for law enforcement, customs and border personnel. The training is comprehensive and focuses on the identification of material, training on transport and storage of material and the organization of a nuclear forensics investigation.

*Outcome*

This technical session reviewed how nuclear forensics has grown from an inital ad-hoc activity to a comprehensive, mature discipline with developed tools, communities and ways to practice capabilities through global exercises. The development of the field has shown the importance of retaining expertise in conventional methods and developing expertise in new methods as well as the need to work with law enforcement at the onset to ensure that a nuclear forensics investigation could lead to a successful prosecution and the value of a national strategy for nuclear forensics. Additionally, nuclear forensics programmes have the challenge of sustaining capabilities since incidents of material out of regulatory control are infrequent. The presentations reviewed how government support is critical sustaining national nuclear forensics capabilities by providing the proper resources, oversight and support for activities such as hands-on training and international exercises.

Questions from the delegates focused on the development of signatures for materials, the reporting timeframes used for the international exercises and the need for laboratory standards to avoid contamination when conducting analyses.

**Nuclear Forensics Practices and Experiences: Case Studies**

The session focused on four case studies and had presentations from four countries that were given by E.A. Kroeger (Germany), A.E. Serban (Romania), E. Elish (Israel) and E. Nzambimana (Burundi).

**E. A. Kroeger (Germany)** presented a 2014 case of contaminated playing cards found in Germany. The 2014 case involved manipulated gambling using playing cards with $^{125}I$, which is a low-energy gamma emitter that has many uses in the medical field. For manipulated gambling, people mark playing cards with $^{125}I$ and then use a hidden detector to distinguish marked cards to know whether the cards are facing up or down. The marked playing cards were detected at an incinerator plant and the evidence was collected and transported for analysis. This case highlighted how the playing cards can cause secondary contamination, which could lead to investigators and other unwitting persons coming into contact with contaminated materials, and how the low-energy gamma of $^{125}I$ can be difficult to measure. Although this case was in Germany, there have been other reported cases of contaminated playing cards elsewhere.

**A. E. Serban (Romania)** discussed the analytical methods conducted by the Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering nuclear forensics laboratory. The analyses consisted of initial observations of physical signatures, isotopic and gamma spectrometry and a comparative analysis using the institute's safeguards depository. Additionally, in her presentation, she reviewed the analytical techniques developed to determine relevant signatures of depleted uranium containers used in industry. This research has been published, contributed to the national nuclear forensics library and was used by judicial stakeholders in the case of an investigation of a uranium based sample.

**E. Elish (Israel)** presented a 2013 case when a scrap metal container triggered a radiation alarm when it was scanned at the Haifa seaport in Israel. The first responders to the scene were from the Israeli Ministry of Environmental Protection and a detector was used to locate the source of radiation. Although not a malicious act, it was treated as an incident with initial characterization and then the material was shipped to the laboratories for characterization. The material was determined to be Am-Be. He presented a second case study regarding a suspicious package where an onsite inspection identified the presence of $^{232}Th$. After laboratory analysis, it was identified with certainty as $^{232}Th$. Along with identification, traditional forensics including examination of fingerprints was done on the package.

**E. Nzambimana (Burundi)** reviewed the current nuclear forensics programme in Burundi, which was established by several pieces of legislation. In Burundi, the sources of nuclear and

radioactive materials are from the agriculture and environment sectors. Burundi has a national authority as well as several government institutions with responsibilities for nuclear forensics from coordination, establishment of standards, analysis, response, investigations, regulatory control and legislation. There are no laboratories in Burundi that are specialized in nuclear forensic analysis, but they have supporting laboratories. In his presentation, he reviewed the challenges facing Burundi, which include insufficient laboratory equipment, lack of mobile laboratories, insufficient technical staff and lack of clear legislation regarding nuclear forensics.

*Outcome*
The technical session presented several cases from different countries and highlighted the need for developed and standard scene management procedures, analytical methods, investigation and response. The session highlighted the need to sustain nuclear forensics capabilities even when the cases are infrequent and the challenges of developing national nuclear forensics capabilities.

Questions from the delegates focused on whether the cases led to successful investigations, how monitors detected the material, on destructive versus non-destructive techniques, using robots to avoid contamination and plans for analyses. The discussion centred on the value of having plans before a case occurs, the need to conduct non-destructive before destruction analyses and the value of innovative approaches to respond to a nuclear security event.

**Nuclear Forensics Initiation and Sustainability: National Considerations I**

The session was focused on the development and sustainability of national nuclear forensics programmes in four countries with presentations given by É. Kovacs-Széles (Hungary), H. Angeyo Kalambuka (Kenya), P. Lobanov (Kazakhstan) and V. Stebelkov (Russian Federation).

**É. Kovacs-Széles (Hungary)** presented the nuclear forensics capabilities in Hungary, which started in the 1970s, and then were utilized in the 1990s with over 20 cases of illicit trafficking of nuclear materials through the Hungarian borders. Since the 1990s, Hungary has established a delegated research institute, developed further techniques and capabilities, conducted national field exercises, established an on-site operating procedure for radiological crime scene investigation working with the Hungarian Police, conducted numerous training programmes and participated in international exercises in nuclear forensics. Additionally, Hungary has partnered closely with the IAEA over the past two decades, which includes having a designated IAEA Collaborating Centre for nuclear forensics.

**H. Angeyo Kalambuka (Kenya)** reviewed the nuclear forensics capabilities in Kenya, which are being developed. In his presentation, he discussed how they are working with the University of Nairobi to improve nuclear security and nuclear forensics capabilities through developing courses and research opportunities. Further efforts include hosting nuclear security training

courses, developing a national plan, signing onto international conventions and developing experimental facilities for nuclear forensics. Additionally, Kenya is working on national legislation that would include a comprehensive regulatory framework for nuclear security.

**P. Lobanov (Kazakhstan)** reviewed the nuclear forensics capabilities of Kazakhstan, which is currently a non-nuclear power State with a history of nuclear testing prior to independence, as well as current threats of illicit trafficking of materials out of regulatory control. In his presentation, he reviewed how they have developed analytical techniques and standard procedures for nuclear forensics examinations. He discussed how Kazakhstan has benefited from significant international cooperation and how they have participated in training courses, workshops, conferences and international exercises.

**V. Stebelkov (Russian Federation)** discussed how international recommendations help develop and maintain nuclear forensics capabilities. He stressed how nuclear forensics is in the field of forensics and national laws need to be followed and actions be compliant with the legal statutes.

*Outcome*

The technical session highlighted the importance of national nuclear forensics science capabilities in several States. The session showcased the differences in maturity level of nuclear forensics programmes – ranging from programmes that have been fully developed to programmes that are still building up technical capabilities. The session stressed the need to develop relevant academic programmes and participate in exercises to build and maintain human resource capabilities in nuclear forensics.

The presentations emphasized the importance of working with the relevant stakeholders in nuclear forensics, the value of government support for nuclear forensics programmes and the potential need for States to amend or pass new relevant legislation. Additionally, the session highlighted the need for developing standard procedures for use of laboratories and experts and the importance of developing end-to-end capabilities, including a national nuclear forensics library to aid in a nuclear forensics examination.

**Nuclear Forensics Human Resource Development: Residential Assignment**

The session focused on the IAEA's Residential Assignment for Human Capacity Building in Nuclear Forensics Analytical Measurements, which places a nuclear forensics scientist in a leading nuclear forensics laboratory for career development. Three participants of the programme, I. Ivanov (Bulgaria), M. Bavio (Argentina) and A. Rueanngoen (Thailand) presented their experience at nuclear forensics laboratories in Hungary and the United States of America.

**I. Ivanov (Bulgaria)** discussed his experience participating in the residential assignment programme in Hungary, which provides scientists an opportunity to participate in a nuclear forensics investigation following a hypothetical seizure of material. The team discussed the

steps of a nuclear forensics investigation, planned the analytical methods, conducted in-field categorization through laboratory and use of the NNFL and provided the findings of the investigation following the reporting guidelines. In his presentation, he described how through participating in this programme, he gained experience in developing an investigative plan, collecting evidence, analytical methods and working with an NNFL. Additionally, he stressed how the programme provides an excellent networking opportunity to expand the nuclear forensics community.

**M. Bavio (Argentina)** described her time participating in the programme at the Lawrence Livermore National Laboratory in the United States of America. Her participation was part of a larger collaborative programme between Argentina and the United States of America. In her presentation, she reviewed her experience in the programme and how they had developed a research plan on the analysis of nuclear fuel before she arrived that focused on developing her skills in nuclear forensics analytical techniques that could be adapted to methods used in Argentina. She stressed the value of the programme for developing nuclear forensics capabilities at a host laboratory which can be taken back and utilized in the home laboratory.

**A. Rueanngoen (Thailand)** reviewed her experiences in the residential assignment programme in Hungary. In her presentation, she stressed how this programme is the most intensive of the IAEA capacity development programmes in nuclear forensics. She highlighted the value of all the training programmes in raising awareness in nuclear forensics, passing along knowledge and experience, understanding the role of nuclear forensics in investigations and sharing experiences and best practices. However, she stressed that the residential assignment programme, in particular, provides countries establishing their nuclear forensics capabilities with an opportunity to develop skills in nuclear forensics in a host laboratory and bring them back to their home country. She reviewed how Thailand has utilized all the IAEA capacity development programmes to develop their national nuclear forensics capabilities and establish a nuclear forensics network.

*Outcome*

This technical session reviewed the IAEA Residential Assignment for Human Capacity Building in Nuclear Forensics Analytical Measurements that provides an opportunity for individuals to spend up to three months in a leading nuclear forensics laboratory. The presentations showcased participants' experiences in the programme and highlighted how the programme is flexible to meet applicants' needs and allows hosting laboratories to develop their own programme. The session highlighted the value of this residential assignment programme for developing skills in nuclear forensics, enhancing national nuclear forensics programmes with new capabilities and developing nuclear forensics networks.

The discussion centred on how this programme provides a unique opportunity for participants to develop nuclear forensics analytical skills that can be brought back to their home country as well as establishing and sustaining a nuclear forensics network.

**Nuclear Forensics Research and Development: National Research and Development Efforts**

The session reviewed the national R&D efforts of the United States of America, Japan and the Russian Federation and included presentations from T.A. Wellington (United States of America), Y. Kimura (Japan) and K. Zhizhin (Russian Federation).

**T.A. Wellington (United States of America)** reviewed the nuclear forensics R&D efforts at the Oak Ridge National Laboratory. In her presentation, she reviewed Oak Ridge's facilities and capabilities, which include an Ultra-Trace Forensics Science Centre; methods to conduct traditional environmental sampling; meteorological sensors and test beds; and expertise in nuclear processing operations, analytical capabilities, and modelling and simulation. Additionally, the nuclear forensics programme at Oak Ridge National Laboratory is developing new programmes and working to establish new capabilities.

**Y. Kimura (Japan)** discussed the nuclear forensics capabilities in Japan. In 2011, Japan established the Integrated Support Centre for Nuclear Non-proliferation and Nuclear Security in the Japan Atomic Energy Agency, which conducts advanced nuclear forensics technology development, data analysis methodology and procedure development for nuclear forensics. In his presentation, he discussed a recent international cooperation project on collaborative exercises with the United States Department of Energy and the European Commission Joint Research Centre. Future work will focus on nuclear forensics technology for post-dispersion events and innovative nuclear forensics technology.

**K. Zhizhin (Russian Federation)** discussed the nuclear forensics capabilities in the Russian Federation. In his presentation, he discussed the investigative strategies and plans for the analysis of material out of regulatory control and how to characterize the material, determine whether the material is dangerous and decide whether the incident could be a criminal case. Additionally, he reviewed different non-destructive and destructive analytical techniques utilized in the national nuclear forensics programme.

*Outcome*

The technical session highlighted the national nuclear forensics programmes in the United States of America, Japan and the Russian Federation. The presentations illustrated the advanced facilities used for nuclear forensics across the globe and provided examples of current national nuclear forensics programmes that are improving existing techniques, developing new methods and focusing on the complete spectrum of nuclear forensics.

The session highlighted the facilities and basic and applied technologies available at the different laboratories as well as stressing the need for collaborating with domestic, regional and international stakeholders for sustaining and further developing nuclear forensics R&D efforts.

**Nuclear Forensics Research and Development: Destructive Analysis**

The session focused on destructive analysis techniques and included presentations from J. Denton (United States of America), Z. Varga (European Commission) and E. Pili (France).

In her presentation, **J. Denton (United States of America)** discussed an international collaboration testing global radiochronometry capabilities to measure certified reference materials. She presented promising laboratory results on age prediction from the United States of America and international laboratories, and reviewed future plans for the project that include working with additional international partners to validate age measurements of certified reference materials and to identify reasons why radiochronometers do not produce the same measurements.

**Z. Varga (European Commission)** discussed how the Joint Research Centre - Karlsruhe developed a rapid, reliable and precise measurement of age-dating of uranium materials. In the study, they measured four certified reference materials with either known age or known material. He reviewed the advantages of the new method, which include speed and lower uncertainty. However, one limitation of the method is that the analysis has to be conducted in a glove box.

**E. Pili (France)** detailed the development of new techniques for conducting more reliable, precise, and accurate isotopic analyses by mass spectrometry. In his presentation, he showed results for developing specific isotope signatures in uranium oxides relate to their origins and transformations.

*Outcome*
The presentations on destructive analytical techniques highlighted the need for equipped laboratories, highly trained staff and quality control standards. Further, the technical session showcased the value of international collaborations to develop and confirm new analytical methods.

**Nuclear Forensics Initiation and Sustainability: National Consideration II**
The session focused on initiation and sustainability of national nuclear forensics programmes in Moldova, Myanmar, Azerbaijan and Japan with presentations from A. Nitrean (Moldova), M. Mar Oo (Myanmar), R. Pashayev (Azerbaijan) and H. Tomikawa (Japan).

**A. Nitrean (Moldova)** discussed the nuclear forensics programme in Moldova, which counters risks, threats and vulnerabilities associated with nuclear and radioactive material out of regulatory control as well as to respond to a history of trafficking incidents. In 2013, Moldova opened a Forensics and Legal Expertise Centre that conducts traditional forensics and specific examinations. In her presentation, she reviewed how Moldova has participated in several ITWG international exercises, which demonstrated the need for increased resources, more effective cooperation between traditional and nuclear forensics, and for interagency

cooperation as well as how Moldova has piloted the GICNT nuclear forensics self-assessment tool.

**M. Mar Oo (Myanmar)** presented the current status of nuclear forensics in Myanmar, which is centred under the Division of Atomic Energy. The major radioactive sources in Myanmar are in the healthcare, industrial, agricultural and livestock sectors. In her presentation, she reviewed how Myanmar is drafting a national nuclear law and is increasing cooperation among the relevant departments. Further, Myanmar is working with the IAEA and the United States Department of Energy to implement physical protection systems. Future plans for nuclear forensics in Myanmar include increasing capabilities, awareness and engagement in nuclear forensics.

**R. Pashayev (Azerbaijan)** discussed the nuclear forensics programme in the Republic of Azerbaijan, where they have established a single regulatory authority for nuclear and radiation safety. In Azerbaijan, the nuclear materials include medical equipment and sources for the oil and gas industry. In his presentation, he reviewed the work of the Nuclear Spectroscopy and Radiochemistry Department in the National Nuclear Research Centre, which analyses and tests nuclear and radioactive substances.

**H. Tomikawa (Japan)** discussed the Japan Atomic Energy Agency's efforts to establish the regional nuclear forensics capabilities. Along with building up their domestic nuclear forensics capabilities, Japan surveyed countries in the region and found that they had challenges in developing a national framework, establishing nuclear forensics laboratories and in nuclear forensics interpretation and findings. To address these challenges, the Japan Atomic Energy Agency developed a regional training course involving lectures and a scenario-based discussion on crime scene management and investigation and conducted the course with 16 participations from 12 countries in the region. Due to the success of the training, they are planning a hands-on exercise involving nuclear forensics analysis in Thailand with its Office of Atoms for Peace.

*Outcome*

The technical session reviewed the process for developing a domestic nuclear forensics capability and establishing a national legislative and regulatory framework for nuclear forensics. Presenters from Moldova, Myanmar, Azerbaijan and Japan described their country's history with nuclear forensics and how their nuclear forensics programmes were established. The presentations illustrated the value of government support in establishing programmes, need for coordination across departments and agencies, significance in bilateral agreements and international cooperation and the value of regional nuclear forensics training courses for strengthening regional nuclear forensics capabilities and networks.

Questions from the delegates focused on working with international partners for nuclear forensics analysis. Discussion centred on mechanisms, such as bilateral agreements, to effectively work with bilateral and regional partners in nuclear forensics.

**Nuclear Forensics Human Resource Development: Training**

The session focused on nuclear forensics training as an important component for nuclear forensics human resources development and consisted of presentations from S. Lamont (United States of America), J. Schwantes (United States of America) and L. Dallas (United States of America).

**S. Lamont (United States of America)** detailed a training curriculum for applying alpha spectrometry to nuclear forensics examinations. The benefits of alpha spectrometry include its relatively low cost and its robustness as an analytical method without cooling needs typical of gamma spectroscopy. In his presentation, he reviewed a bilateral cooperation between the United States of America and Armenia to develop alpha spectrometry capabilities. The cooperation involved site visits, assistance with installation of gamma-ray spectrometry and alpha spectrometry instruments in Armenia and training. The collaboration has been a successful way to provide training and increase domestic nuclear forensics capabilities.

**J. Schwantes (United States of America)** presented the 5$^{th}$ IAEA International Training Course on Nuclear Forensics Methodologies held at the Pacific Northwest National Laboratory, USA, in cooperation with the United States National Nuclear Security Administration and with technical support from the European Commission's Joint Research Centre. The methodologies course involved both training modules and scenario based exercises. The fifth offering of the course included training in developing an analytical plan, basic physical measurements, high-resolution gamma spectroscopy, high-resolution alpha spectroscopy and advanced analytical methods of nuclear and radiological sources utilized for the training under controlled conditions handed by experts. As part of the training course, participants took part in a scenario-based exercise where they assisted in a simulated nuclear forensics investigation. Together, the five IAEA training courses have trained 120 participants from 40 Member States. In his presentation, he reviewed the changes to the course since the initial offering, which include lengthening the course, increased hands-on instruction, more involvement by law enforcement and additional international instructors.

**L. Dallas (United States of America)** presented the Nuclear Forensics Scenario Exercise, a table top cooperative simulation nuclear forensics exercise that was developed by the U.S. Department of Energy and the European Commission – Joint Research Centre (EC-JRC). In her presentation, she reviewed an exercise hosted by the EC-JRC in May 2017 that included 15 participants from Georgia, Ukraine, Azerbaijan and Moldova. The exercise involved assigning participants to teams with responsibility for custom and border patrol, nuclear regulation, mobile expert support and nuclear forensics. The participants interacted with the other teams through email and with a master team that asked the teams questions and sent them datasets. The exercise saw high commitment from participants and can be an effective way to deliver hands-on learning.

*Outcome*

This technical session presented several training programmes that increased nuclear forensics technological and human capabilities. A bilateral cooperation programme between Armenia and the United States of America developed alpha spectrometry capabilities for Armenia. The IAEA applied Nuclear Forensics Methodologies training has attracted over 100 practitioners from 40 countries. Finally, a table top cooperation simulation exercise programme allows multiple teams to interact with each other on coinciding scenarios. The session highlighted the importance of hands-on exercises to develop and sustain nuclear forensics capabilities.

Questions from the delegates focused on the timing of exercises and the preparation needed to conduct the exercises. Discussion centred on how training, especially hands-on training, is important for developing and sustaining nuclear forensics capabilities since nuclear forensics events are infrequent.

**Nuclear Forensics Research and Development: Non-Destructive Analysis**

The session focused on non-destructive analytical techniques in nuclear forensics R&D and had presentations from H. Dikmen (Turkey), M. Larisa Ganea (Romania), A. Sumaryanto (Indonesia) and R. Marginean (Romania).

**H. Dikmen (Turkey)** presented analyses of a uranium sample using gamma spectrometry, a common non-destructive analytical technique that can be used as an initial tool for categorizing material enabling further investigations. In his presentation, he discussed the study as well as Turkey's national nuclear forensics programme and its national authorities related to nuclear activities.

**M. Larisa Ganea (Romania)** discussed a nuclear forensics case in Romania regarding radioactive material found in a scrap yard. Initial findings concluded that the seized sample contained a radioactive source and was likely from an aircraft. For the analysis, they used a beta spectrometer assembled in the laboratory and measured spectra of known samples to verify the results. In her presentation, she discussed how the new detection system could characterize radioactive sources in a short-time frame and in a non-destructive manner. Future plans include testing the detector by measuring the seized sample and other radioactive sources.

**A. Sumaryanto (Indonesia)** discussed the nuclear forensics programme in Indonesia, which is positioned to counter potential threats of transferring and smuggling nuclear materials. These threats are manifested by the Indonesian archipelago which include five large islands and 17,000 small islands. Indonesia's nuclear forensics programme contains field, laboratory and nuclear library teams. The Indonesian national nuclear forensics programme is developing standard operating procedures, strengthening capabilities and increasing cooperation with relevant domestic and regional institutions. In his presentation, he reviewed how non-destructive analytical methods are important to keep nuclear forensics evidence intact, avoid

potential contamination, limit spread of contamination and reduce the danger of radiation exposure to the public and others.

**R. Marginean (Romania)** reviewed the experimental infrastructure at the Horia Hulubei National Institute of Physics and Nuclear Engineering that includes tandem accelerators, cyclotrons, gamma detectors, gamma spectrometry and mass spectrometry. In her presentation, she reviewed a study using the Romanian detection array for spectroscopy in heavy ion reactions, which uses multiple arrays that can host up to 25 detectors and can work in two different configurations to do gamma spectroscopy measurements in coincidence. The study looked for signatures of reprocessed uranium and were able to answer the question of whether there was an excess $^{232}U$ present in the sample quickly and reliably.

*Outcome*

The technical session on non-destructive methods reviewed the nuclear forensics capabilities in Indonesia, Romania and Turkey, and presented research projects using non-destructive techniques. The research projects developed a new detection system to characterize radioactive sources and a new method to assess signatures of reprocessed uranium. The session highlighted the value of working with comprehensive teams when developing new analytical methods.

Questions from the delegates focused on the utilization of the new non-destructive analytical techniques. Discussion centred on technical explanations about the methods as well as the importance of meetings and hands-on exercises for motivating and developing the next generation of technical nuclear forensics experts.

**Nuclear Forensics Research and Development: National Nuclear Forensics Library**

The session featured the development and application of a national nuclear forensics library (NNFL) and consisted of R. Kips (United States of America), J. Canaday (United States of America), D. Podlesak (United States of America), V. Gladyrev (Russian Federation), J. Davydov (IAEA) and J. Borgardt (United States of America).

**R. Kips (United States of America)** detailed a partnership with Kazakhstan that has included projects, scenario-based workshops, data review meetings and hands-on training. One project involved three laboratories from the United States of America, Kazakhstan and Japan where the laboratories found very similar results regarding analysis on uranium ore concentrates. Another project focused on contributing to the nuclear forensics database in Kazakhstan and is using six uranium samples (five known and one unknown sample). Additionally, in September 2018, a NNFL workshop was held in Kazakhstan that demonstrated the purpose and functionality of an NNFL, developed a strategy for NNFL implementation and support for international library exercises. In her presentation, she reviewed how this partnership has laid the foundation for further scientific exchanges and highlighted the need for standard operating procedures shared among laboratories.

**D. McLain (United States of America)** reviewed how the NNFL can be used in an investigation of illicit trafficking or material found out of regulatory control to provide potential leads by comparing the seized sample to known datasets. In his presentation, he discussed that when establishing an NNFL, organizers need to keep flexibility and scalability in mind as well as considering things such as level of detail needed, which platform to use, and which organization will be hosting the library. Further, it is important to understand what signatures will be collected and where the data would come from (manufacturers, scientific literature, incident reports, etc.). Organizers may need data agreements or Memoranda of Understanding with manufacturers, regulatory and other partners. Additionally, he stressed that organizers of the NNFL need to maintain the data and provide access to subject matter experts, who interpret the data and are vital to the establishment and sustainability of the NNFL.

**A. Stratz (United States of America)** reviewed the process of querying the United States of America's NNFL to identify materials out of regulatory control that have been used, produced or stored within the United States of America. There are three ways to submit a query – contact the United States of America's Embassy in the country, contact a country's embassy in Washington DC or submit a query via email. The query process is the following: (1) the query goes through the United States Department of State, (2) the query is sent to the United States Department of Energy, (3) the United States Department of Energy processes the query through the United States of America's NNFL, (4) the query results are conveyed to the United States Department of State and (5) the United States of America's Embassy notifies the requesting State of the results. In his presentation, he presented an example of a query and reviewed the benefits of the query system, which include assisting with material determination, bilateral information sharing and bolstering international efforts.

**V. Gladyrev (Russian Federation)** reviewed the process for identification of materials, which are carried out in accordance with national legislation. In his presentation, he expressed concerns about how developing an NNFL could be time-consuming and resource-intensive. Additionally, he noted that information in an NNFL may not be the only source of information that a country can use in an investigation involving nuclear or other radioactive material out of regulatory control.

**J. Davydov (IAEA)** provided an overview of the 2018 IAEA publication, "Development of a National Nuclear Forensics Library: A National System for the Identification for Nuclear or Other Radioactive Material out of Regulatory Control", which introduces the IAEA concept of an NNFL, describes the characteristics of an NNFL and how an NNFL could be used to support a nuclear forensics examination [7]. The process for developing an NNFL includes establishing a mandate to develop an NNFL; coordinating with subject matter experts, regulators, and law enforcement; evaluating necessary characteristics; comparing those characteristics against existing data; identifying and addressing gaps; and continuously supporting the NNFL. An NNFL can support nuclear forensics examinations in several ways from initial material characterization, to developing of a nuclear forensics analytical plan and to comparative

analysis to identify possible material origins and possible histories. Further, an NNFL can promote and foster international collaborations supporting an investigation.

**J. Borgardt (United States of America)** presented the Galaxy Serpent exercises, which were developed by the ITWG Libraries Task Group to advance capabilities in developing and utilizing a NNFL in support of an investigation involving material out of regulatory control. The Galaxy Serpent exercises focus on the transfer of information and involve teams organizing an NNFL around a specific material and then utilizing their model library to respond to questions. There have been three versions of the exercise with the latest version focused on uranium ore concentrate that had an incomplete dataset where teams had to decide what to do with the missing data. The use of multiple analytical methodologies resulted in similar findings and showed that NNFLs can play a vital role in investigations. Version 4 is being developed with a timeline of starting in the fall of 2019.

*Outcome*

The technical session reviewed the concept and use of an NNFL as part of a nuclear forensics examination. Presentations explained how to establish an NNFL, how they can be used in bilateral research projects, how an NNFL can provide information to international partners and how NNFL exercises encourages the wider use of NNFLs. The session highlighted considerations when developing an NNFL, including the needed flexibility and scale; identifying the country's data owners and data users; and ways to build in sustainability within the NNFL.

Questions from the delegates focused on flexibility on the timeframe of reporting, computer security and how subject matter experts state the confidence in their findings. Discussion centred on the importance of working with a variety of stakeholders when establishing and using an NNFL, how there is no one-size fits all methodology for developing an NNFL and the important role of subject matter experts in implementing and sustaining an NNFL.

## 2.5.NUCLEAR FORENSICS POSTER SESSION

Topics presented in the poster session included the following.

**C. Cáceres Rivero (Peru)** presented Peru's testing capabilities for uranium analysis using existing laboratory facilities and nuclear forensics equipment.

**D. Dwianna Lestiani (Indonesia)** presented Indonesia's efforts on developing laboratory nuclear analytical techniques and building up their capabilities through training and workshops.

**M. Fernández (Spain)** presented on developing field exercises designed for training law enforcement agents on detection and characterization of nuclear material.

**A. Hubert (France)** presented on the validation of determining the age of nuclear material using different methods such as radiochronometry and mass spectrometry.

**J. John (Czech Republic)** presented a new Ph.D. programme in nuclear safety, security, and forensics.

**S. Jovanovic (Montenegro)** presented utilizing ANGLE software for advanced gamma spectrometry and its applicability to nuclear forensics.

**S. Lamont (United States of America)** presented the efforts of the ITWG to organize practical exercises that demonstrate technical aspects of NNFLs.

**H. Mungpayaban (Thailand)** presented Thailand's efforts to develop a standard operating procedure for nuclear forensics to strengthen prevention.

**J. Park (Republic of Korea)** presented a study focused on the correction for gamma-spectroscopy on swipe samples from the environment and nuclear facilities.

**A. Rueanngoen (Thailand)** presented an analytical method for determination of uranium and thorium particles in nuclear forensics investigations.

## 2.6.CLOSING SESSION

Mr. Daming Liu, Head of the Nuclear Security of Materials Outside of Regulatory Control Section in the Division of Nuclear Security in the Department of Nuclear Safety and Security at the IAEA thanked the Co-Chairs of the meeting, the Steering Meeting members, and all the participants. This meeting was crucial for moving nuclear forensics from focusing on the science to the implementation and highlighted the need for sustainability of nuclear forensics science and the value of international cooperation. The IAEA, working with regional and international partners, will help Member States develop and sustain comprehensive nuclear forensics programmes that include scientists, law enforcement, first responders and decision makers to ensure states fulfil their obligations to protect and respond to material out of regulatory control.

Mr. Liu stated that this technical meeting demonstrated not only a common interest and understanding in nuclear forensics, but also the need to work together, more effectively engage with diverse stakeholders and develop national response plans and legislation. The IAEA will document the outcomes of this meeting, which will be used to develop a road map of future services and activities in nuclear forensics science that can be offered by the IAEA. Mr. Liu concluded his remarks by encouraging participation in the 2020 IAEA Ministerial Conference on Nuclear Security that will be held at the IAEA from 10 to 14 February 2020.

Mr. Frank Wong, a Senior Scientist at the Lawrence Livermore National Laboratory in the United States of America and Co-Chair of the technical meeting, thanked all the organizers of the meeting as well as the participants for contributing to a successful technical meeting and concluded the meeting with an interactive session regarding lessons learned and areas needing

further attention. The interactive session found that participants increased their awareness of several topics including the need to have closer coordination among stakeholders (scientists, investigators/prosecutors and policy makers), the value of international R&D efforts to advance nuclear forensics and the importance of using established procedures and standards. Participants thought exercises and training, human resources and recruitment and how nuclear forensics has been used in real cases could benefit from further international attention.

# 3. CONCLUSIONS AND RECOMMENDATIONS OF THE TECHNICAL MEETING

## 3.1.CONCLUSIONS OF THE TECHNICAL MEETING

The technical meeting highlighted the recent successes and achievements in nuclear forensics, which included the growth of national nuclear forensics programmes and the development of new analytical methods for nuclear forensics. The meeting demonstrated that nuclear forensics is a national responsibility, but national nuclear forensics programmes can be enhanced and strengthened through regional and international collaborative efforts. Thus, the meeting called attention to the value of having distributed regional hubs, working in close collaboration with the IAEA, supporting aligned nuclear forensics activities.

Along with the key messages and four broad themes, outcomes from the meeting identified the need for increased awareness and outreach activities in nuclear forensics. The IAEA will utilize these key messages, themes and outcomes that arose from the technical meeting as an informational foundation when it works with its regional and international partners to develop and implement its future nuclear forensics science programme. Additionally, this technical meeting will inform the 2020 IAEA International Conference on Nuclear Security: Sustaining and Strengthening Efforts. This conference will include sessions highlighting the role that nuclear forensics plays in nuclear security, its achievements, its plan to ensure the sustainability of nuclear forensics and its ability to be implemented in a criminal case of nuclear or other radioactive materials out of regulatory control as well as providing crucial input to the next IAEA Nuclear Security Plan 2022 – 2025.

### 3.1.1. Capability building: initiation and sustainability

The meeting included a number of presentations and discussions around initiating and sustaining capabilities in nuclear forensics from developing national nuclear forensics programmes to the role that international and regional efforts play in advancing nuclear forensics.

Participants from States discussed their national nuclear forensics programmes. For example, Hungary presented the development of their nuclear forensics programme that included the delegation of a research institute via a government decree, participation in inter-laboratory exercises, hosting international meetings and developing a close cooperation with the IAEA with participation in training courses, the residential assignment programme, and Hungary's

progress to be recognized as an IAEA Collaborating Centre for Nuclear Forensics. Kenya reviewed their development efforts, which included drafting nuclear regulatory legislation, obtaining government support, developing experimental facilities, working with the academic sector to build up capabilities and developing an NNFL. Kazakhstan highlighted the development of analytical techniques, methods and standard procedures as well as the role of international cooperation, including workshops, in the development of their nuclear forensics programme.

The presentations featuring the initiation of a nuclear forensics programme demonstrated the differences in the maturity level in these programmes – ranging from fully developed programmes to programmes that are still promoting technical capabilities. The presentations emphasized the importance of working with the relevant stakeholders in nuclear forensics, the potential need to amend or pass new legislation, the necessity for clear procedures for use by laboratories and experts and the importance of developing capabilities for experts when developing a national nuclear forensics programme. Further, the discussion stressed the value of government support in establishing national nuclear forensics programmes, the need for coordination across departments and agencies, the significance in bilateral agreements and international cooperation and the importance of working with neighbouring countries to build up regional capabilities in nuclear forensics. Finally, the discussion highlighted the need to develop nuclear forensics capabilities and national nuclear forensics programmes before an incident occurs.

The meeting included presentations and productive discussions on the role of bilateral, regional and international efforts in the nuclear forensics. The ITWG co-chair described how they assist countries and organizations establish and sustain their nuclear forensics capabilities by developing guidelines, conducting international exercises, conducting trainings and outreach and developing the concept of national nuclear forensics libraries. Experts encouraged Member States to express support for INFCIRC/917 to show their commitment to nuclear forensics and to work with international organizations and affiliated working groups such as ITWG and GICNT.

Although bilateral, regional and international cooperation can be important resources for States when developing their national nuclear forensics programmes, each State faces a unique threat from nuclear and radioactive material out of regulatory control and have to make their own choices when developing a national response plan. There is no one size fits all approach. Further, several States stressed that no single government agency or ministry can achieve the goals of a comprehensive nuclear forensics programme and thus, States may need a whole of government approach.

*Future Directions*

Since the establishment of nuclear forensics, national nuclear forensics programmes have developed mostly within the European Union, Russian Federation and the United States of America. However, this meeting highlighted how several countries in Asia, Africa, Latin America and South America have developed or are in the process of developing national

nuclear forensics programmes. The establishment and expansion of nuclear forensics programmes throughout the world, in particular in the developing world, is essential for the global success of nuclear forensics.

Although nuclear forensics science is a State responsibility, a theme of the meeting was the value of regional and international cooperation in initiating and sustaining national nuclear forensics science capabilities. Thus, the meeting highlighted the value for supporting international organizations, such as INTERPOL and ITWG, and their activities, particularly international exercises that help sustain nuclear forensics capabilities.

### 3.1.2. Human resource development and sustainability

Since incidents involving nuclear and other radioactive materials out of regulatory control occur infrequently, nuclear forensics faces the unique challenge of how to develop and sustain the necessary human resources capabilities that can be fully utilized when needed. The technical meeting provided an opportunity for States to discuss that challenge, potential ways to develop and sustain human resource capabilities and the role of bilateral and international cooperation in addressing human resource development and sustainability challenges.

Several States discussed their efforts in human resource capacity building that included launching multi-disciplinary university programmes, establishing peer-reviewed journals and participating in the IAEA's international educational network. Several presenters described their own career pathways and experiences in managing nuclear forensics teams. Workforce challenges discussed included the diverse backgrounds of team members, that nuclear forensics is often not a primary responsibility for the employee and an ageing workforce. Discussion included ideas on how to attract team members, including recruiting from non-traditional fields with relevant expertise and how to sustain capabilities through nuclear forensics exercises and meetings.

The technical meeting highlighted several bilateral and international cooperation programmes in nuclear forensics workforce development. A bilateral cooperation programme between Armenia and the United States of America developed alpha spectrometry capabilities for Armenia. A bilateral cooperation between the United States of America and the European Commission's Joint Research Centre (JRC) in Karlsruhe developed a table top simulation exercise that allows multiple teams to work together on overlapping scenarios. An IAEA international training course, a collaboration between the IAEA, ITWG, GICNT and JRC, on nuclear forensics methodologies that involves both training modules and scenario-based exercises, has trained over 100 people from 40 Member States. A presentation on ITWG's six collaborative materials exercises that almost 30 countries and organizations have participated, demonstrated global nuclear forensics capabilities, the need to incorporate traditional forensics more deeply in nuclear forensics and the use of different technologies over time.

Along with bilateral cooperation programmes, training courses and exercises, presentations highlighted the IAEA Residential Assignment for Human Capacity Building in Nuclear

Forensics Analytical Measurements. This programme is the most advanced training programme offered by the IAEA in nuclear forensics, and it provides an opportunity for nuclear forensics examiners to spend a period of approximately three months in a leading nuclear forensics laboratory. The programme is flexible to meet applicants' needs and allows hosting laboratories to develop their own programme – example projects range from participating in a real world nuclear forensics scenario from the crime scene to the court system to an individual nuclear forensics research project. The participants and mentors discussed the programme, how it enhances nuclear forensics capabilities and strengthens the global network of nuclear forensics experts.

Throughout the discussion on sustaining nuclear forensics capabilities, participants stressed the value of training, especially hands-on training and exercises since incidents involving response are infrequent; the potential for more effectively utilizing people from non-traditional nuclear fields with applicable skills; the need to recruit the next generation of nuclear forensics workforce; and the importance of sustaining capabilities across the nuclear forensics platform – from first responders, technicians, and senior researchers to implementers, including prosecutors and judges.

*Future Directions*

The meeting discussed the challenge of nuclear forensics human resource development and sustainability and potential solutions, which included expanding human resource activities and the potential of incorporating non-traditional experts that have transferrable skills.

The meeting highlighted how the IAEA Residential Assignment for Human Capacity Building in Nuclear Forensics Analytical Measurements programme provides opportunities for nuclear forensics scientists to develop their nuclear forensics capabilities, bring those advanced capabilities back to their States and increase the number of regional nuclear forensics champions. This programme fosters stronger regional partnerships, an increased number of regional networks of nuclear forensics experts and promotes a more distributed model of qualified regional partners working in collaboration with the IAEA on nuclear forensics programmes and activities.

The IAEA continues its efforts in training, expert missions, and workshops, which can be an important mechanism for training the next generation of nuclear forensics experts, including non-traditional nuclear forensics personnel with relevant skills. In addition, the IAEA supports international exercises, including those by ITWG that help nuclear forensics experts sustain their skills between cases.

### 3.1.3. Case studies and practical experiences

The meeting included a number of presentations about case studies, practical experiences and tools to help with implementation in the context of legal proceedings.

Germany presented a case of playing cards contaminated with iodine-125, Romania discussed the analytical techniques developed to determine relevant signatures of depleted uranium containers used in industry and Israel discussed the recovery of orphan sources in a port station. Romania reviewed how they have worked with law enforcement to ensure that their national nuclear forensics programme follows proper criminal procedures and that prosecutors can use nuclear forensics evidence. These presentations highlighted the need to work with law enforcement when developing national nuclear forensics programmes, how those programmes need to be implemented in accordance with national legal framework (for example, common or civil law) and that potential legislative changes may be necessary to ensure prosecution.

INTERPOL presented how they have developed workshops for investigators and prosecutors as well as a platform for law enforcement to share experiences across regions. INTERPOL holds the workshops with the goal of increasing awareness of nuclear forensics in the law enforcement community; building trust and strong relationships between investigators and law enforcement; and explaining that although the likelihood of an incident involving nuclear and other radioactive material out of regulatory control is low, the risk and priority of an incident – would it occur – is high.

A session highlighted the concept of an NNFL and how it can be used in practice. The session explained how to establish an NNFL, how to use an NNFL in bilateral research projects, how an NNFL can provide information to international partners and how NNFL exercises can develop capabilities. The session illustrated the importance of working with a variety of stakeholders when establishing and using an NNFL, how there is no one-size fits all methodology for development and the important role of subject matter experts in implementing and sustaining an NNFL.

Throughout the discussion around case studies and practical experiences, participants stressed the important role nuclear forensics plays in helping prosecutors make the links between the people, material and intended use of the material; the need to build trust and work with the law enforcement community from the beginning; and the importance of understanding the national legal framework and whether new or changes to legislation is required. Additionally, participants highlighted the value of co-developing plans and procedures with law enforcement and an NNFL to help in implementing effective national nuclear forensics programmes.

*Future Directions*

The meeting provided a forum to elevate a number of successful programmes by States that have collaborated with law enforcement on activities ranging from prosecuting incidents to developing standard operating procedures. However, the meeting demonstrated the need for a stronger coupling between law enforcement and nuclear forensics experts to work together and co-develop programmes to ensure the possibility of effective prosecutions of illicit incidents.

To address the need for a stronger bridge between science and law enforcement, the meeting highlighted the value of activities that include detection and response experts, activities that are focused on understanding national legal frameworks and how they apply to national nuclear

forensics programmes, activities that incorporate traditional forensics into nuclear forensics, and activities that focus on implementing standard procedures that meet the legal requirements. In addition, this meeting highlights the value of working with States and regional and international partners, such as INTERPOL, to identify potential liaisons between science and law enforcement and provide them with a venue to share experiences and work together to establish a more effective bridge between science and law enforcement.

Further, the IAEA continues its activities in the areas of guidance and documents that foster implementation consistent with the recent IAEA publication that provides the rationale for the development of an NFFL.

### 3.1.4. Research and development: current status and future opportunities

Because nuclear forensics was formulated around the "science of signatures" and their measurements, this meeting provided a good opportunity to reflect on the achievements and to highlight future opportunities and needs in this area.

A keynote address by K. Mayer (European Commission) focused on the status and future needs in the science of nuclear forensics. The presentation highlighted that some topics, including spent fuel, stable isotopes, measurement techniques, age-dating of uranium and reference materials, have been well developed. However, there is less development in areas such as trace elements, morphology and statistical methods. Further, areas such as traditional forensics and sample inhomogeneity are underdeveloped. The presentation highlighted potential growth areas in nuclear forensics science such as inhomogeneity of bulk samples, post-dispersion of samples and the use of block chain technology.

Additional presentations reviewed several research projects on destructive and non-destructive techniques including projects on radiochronometry, uranium determination by alpha spectrometry, using gamma ray spectrometry to determine the level of uranium enrichment, validating age-dating methods of nuclear material, the use of software for advanced quantitative gamma-spectrometry, using microanalysis techniques for determination of uranium and thorium, and a multiple array that can host up to 25 radiation detectors and two different configurations to look for the signatures of reprocessed uranium. The projects highlighted the need to develop new methods and the value of working with international partners.

A multi-national collaboration project focused on confirming global radiochronometry capabilities and worked with international laboratories to obtain reproducible/consensus ages for certified reference materials. The collaboration, which involved Australia, Canada, China, France, Israel, Japan, the United Kingdom and the United States of America showed early promise for establishing consensus values and demonstrated the need to work with international partners to validate scientific methods and results.

Throughout the discussion on the science of nuclear forensics, participants reviewed the successful developments of several methods and techniques, stressed the gaps in research and development and highlighted potential growth areas. Additionally, the discussion focused on the importance of communicating technical information to non-technical officials to increase awareness as well as for obtaining and sustaining public and government support and resources for nuclear forensics.

*Future Directions*
The meeting highlighted the significant process made in the development of the science of nuclear forensics. However, there is a need to further develop the science of nuclear forensics, including developing new analytical methods and utilizing new technologies in nuclear forensics.

To help address this, the IAEA strongly supports activities in these areas. The IAEA has completed two Coordinated Research Projects focused on nuclear forensics science [10, 11] and has now embarked on a third. The current Coordinated Research Project entitled, "Applying Nuclear Forensics Science to Respond to a Nuclear Security Event" runs from 2019 to 2023. Additionally, the meeting highlighted the value of IAEA collaborating centres on nuclear forensics. Designating multiple collaborating centres in nuclear forensics science could support a more distributed model of qualified regional partners working in collaboration with the IAEA on nuclear forensics programmes and activities.

### 3.1.5. Awareness and outreach

Along with the main four themes of the meeting, the need for increased awareness and outreach was a cross-cutting theme. A number of States and participants commented on the value of engaging with the public and policy makers on nuclear forensics.

This meeting called for the further support of the design, development and implementation of nuclear forensics awareness and outreach activities. These activities could be targeted to different stakeholders as well as broad awareness and outreach activities targeted to the general public and could focus on what nuclear forensics is, how it can be used by law enforcement and governments and why it is important to support in the context of nuclear security.

## 3.2.RECOMMENDATIONS OF THE TECHNICAL MEETING

The field of nuclear forensics was established in response to cases involving nuclear or other radioactive material encountered out of regulatory control in the 1990s. Over the past decades, nuclear forensics has developed from a nascent field focused on developing methods and techniques to answer immediate questions about the nature and intended use of the found material to a mature one with national strategies focused on implementing nuclear forensics science to support criminal prosecutions and nuclear security investigations. In addition, national nuclear forensics programmes have been initiated across the globe – first being

developed mostly within the European Union, Russian Federation and the United States of America to now including countries across Asia, Africa, Latin America and South America.

Although significant progress and growth has occurred, nuclear forensics faces significant challenges moving towards comprehensive national programmes that incorporate all relevant stakeholders at the onset, work successfully across agencies and departments and ensure effective communication across the programme and with the public. In order to address those challenges, below are some recommendations from the technical meeting for implementing nuclear forensics programmes to meet national nuclear security responsibilities.

### 3.2.1. Nuclear forensics on the national level

The experts stressed the need to establish and conduct national nuclear forensics programmes in accordance with national laws and international legal instruments, such as A/CPPNM. To successfully implement national nuclear forensics programmes, it is important to have strong links between the scientific, law enforcement, response and prosecutorial communities. These links could be developed at the onset and be utilized to co-develop the programme, policies and procedures. Since national nuclear forensics programmes involve a wide range of stakeholders, programmes will cross traditional boundaries of individual department or agencies. Thus, national nuclear forensics programmes may need to take a whole of government approach to ensure effective coordination across departments and agencies. Finally, it is vital for Member States to reorganize their nuclear security possibilities and to take strong ownership of their national nuclear forensics programme.

Although national, nuclear forensics programmes are supported by strong regional and international collaborations. Those efforts could be enhanced by shifting away from the model of the IAEA as the centre for nuclear forensics science activities to a more distributed model with regional hubs working in close cooperation with the IAEA and its regional and international partners.

### 3.2.2. Nuclear forensics programs need a workforce with diverse capabilities

Nuclear forensics faces unique workforce challenges because incidents involving an examination are infrequent, which results in a workforce primarily focusing on other tasks. In addition, national nuclear forensics programmes need a team of qualified individuals with a broad range of capabilities – from scientific analysis to incident response to criminal investigation and prosecution – to effectively respond when cases do occur.

The technical meeting suggested that to sustain capabilities and gain confidence in nuclear forensics, hands-on training through direct experience in nuclear forensics laboratories and/or in participation to scenario based and collaborative material exercises is essential. Further, national nuclear forensics programmes may want to consider including individuals with relevant skills from non-traditional backgrounds as team members as well as focusing on recruiting and retaining the next generation of the nuclear forensics workforce.

### 3.2.3. Nuclear forensics science needs to meet the needs of implementation

Nuclear forensics was founded on analytical science. Nevertheless, in order to ensure that nuclear forensics science yields the strongest evidence for nuclear forensics implementation, there are topics and areas of nuclear forensics science that call for further development. National nuclear forensics programmes, working in close cooperation with the IAEA and its regional and international partners, may consider focusing their research efforts on developing new methodologies, addressing the research gaps and utilizing new tools. Further, those new methodologies and new analytical tools need to go beyond the laboratory and have effective links to incident response and the needs of law enforcement.

### 3.2.4. Nuclear forensics requires increased awareness

Along with strong government ownership of national nuclear forensic programmes, public engagement is valuable. Thus, it is important for national nuclear forensics programmes to communicate technical information about nuclear forensics to a broad audience. Outreach efforts could help increase awareness of the role of nuclear forensics in nuclear security and potential legal proceedings, sustain necessary government resources for nuclear forensics activities and obtain public support for implementing and sustaining a national nuclear forensics programme.

## ABBREVIATIONS

| | |
|---|---|
| A/CPPNM | Amendment to the Convention on the Physical Protection of Nuclear Material |
| CPPNM | Convention on the Physical Protection of Nuclear Material |
| GICNT | Global Initiative to Combat Nuclear Terrorism |
| INFCIRC | IAEA Information Circular |
| INTERPOL | International Criminal Police Organization |
| ITWG | Nuclear Forensics International Technical Working Group |
| JRC | European Commission's Joint Research Centre |
| NNFL | national nuclear forensics library |
| R&D | research and development |

# APPENDIX

## STEERING COMMITTEE

| | |
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## SECRETARIAT OF THE TECHNICAL MEETING

| | |
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| K.J. MONTGOMERY | Scientific Support |
| T. TSVETKOV | Scientific Support |
| N. VORHOFER | Administrative Support |
| M. RIEDER | Administrative Support |

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