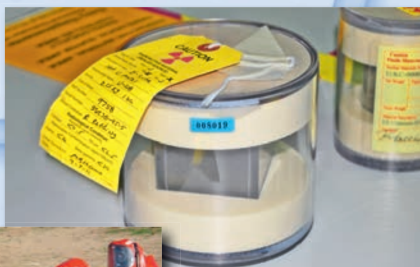
Advances in Nuclear Forensics:

Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control



Summary of an International Conference

Vienna, Austria
7–10 July 2014

IAEA
International Atomic Energy Agency

ADVANCES IN NUCLEAR FORENSICS: COUNTERING THE EVOLVING THREAT OF NUCLEAR AND OTHER RADIOACTIVE MATERIAL OUT OF REGULATORY CONTROL

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PROCEEDINGS SERIES

ADVANCES IN NUCLEAR FORENSICS: COUNTERING THE EVOLVING THREAT OF NUCLEAR AND OTHER RADIOACTIVE MATERIAL OUT OF REGULATORY CONTROL

SUMMARY OF AN INTERNATIONAL CONFERENCE
ORGANIZED BY THE
INTERNATIONAL ATOMIC ENERGY AGENCY
AND HELD IN VIENNA, 7–10 JULY 2014

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FOREWORD

The International Conference on Advances in Nuclear Forensics: Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control was organized by the IAEA and held in Vienna on 7–10 July 2014. The conference was organized in cooperation with the Nuclear Forensics International Technical Working Group (ITWG), the International Criminal Police Organization (INTERPOL) and the Global Initiative to Combat Nuclear Terrorism (GICNT). The conference was attended by 285 participants and observers from 76 Member States and 8 organizations.

The objective of the conference was to convene the first of its kind international conference solely dedicated to nuclear forensics; to review the role of nuclear forensics as an essential element of a nuclear security infrastructure; to present scientific achievements and to exchange experience and lessons learned on the implementation of nuclear forensics in support of law enforcement investigations and nuclear security vulnerability assessments; to review current practices in nuclear forensics and to identify advances in analytical tools; to discuss ways of strengthening nuclear forensic capabilities and capacity building in nuclear forensics to ensure sustainability; and to explore mechanisms to enhance international and regional cooperation in nuclear forensics as well as to best position the IAEA to provide assistance to States, upon request, in nuclear forensics.

This publication provides the President's summary and findings of the conference as well as summaries of all the sessions. The accompanying CD-ROM contains the full conference programme, the list of participants and the papers. The IAEA officers responsible for this publication were D.K. Smith and T. Bull of the Division of Nuclear Security.

EDITORIAL NOTE

CONTENTS

PRESIDENT'S SUMMARY OF THE CONFERENCE*

INTRODUCTION

The International Conference on Advances in Nuclear Forensics: Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control was organized by the IAEA and held in Vienna on 7–10 July 2014. The conference was attended by 285 participants from 76 Member States and 8 organizations, and included nuclear forensic experts, law enforcement officials, policy makers and national representatives who have interests or active roles in nuclear forensics.

The 2014 conference was the first international conference dedicated exclusively to the role of nuclear forensics within a nuclear security infrastructure. The objectives of the conference were:

(1) To review the role of nuclear forensics as an essential element of a national nuclear security infrastructure;
(2) To present recent scientific achievements and exchange experience and lessons learned related to the application of nuclear forensics;
(3) To review current practices in nuclear forensics and to identify advances in analytical tools;
(4) To discuss ways of strengthening nuclear forensic capabilities and capacity building in order to ensure the implementation and sustainability of national nuclear forensic programmes;
(5) To propose and discuss mechanisms for achieving further international and regional cooperation in the area of nuclear forensics;
(6) To enhance IAEA support to States that request assistance in developing nuclear forensic capabilities.

This year's conference followed the 2002 International Conference on Advances in Destructive and Non-Destructive Analysis for Environmental Monitoring and Nuclear Forensics, organized by the IAEA and held in Karlsruhe, Germany, 21–23 October. That three day conference, attended by experts and State officials from 37 Member States, the European Union and the European Police Office, discussed the role of nuclear forensics in the prevention of acts of

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* The views and recommendations expressed here are those of the President of the Conference and the participants and do not necessarily represent the views of the IAEA, its Member States or the other cooperating organizations.

nuclear terrorism and in combating illicit trafficking in nuclear material and other radioactive material.

Based on the outcomes of the 2002 conference and through continuous cooperation with Member States, the IAEA accelerated efforts to assist States in developing nuclear forensic capabilities that could support law enforcement investigations and nuclear security vulnerability assessments. In particular, from 2003 to 2012, the IAEA prepared a number of nuclear forensic guidance documents and outreach materials. In cooperation with the Nuclear Forensics International Technical Working Group (ITWG), the IAEA published technical guidance in 2006 entitled Nuclear Forensics Support, IAEA Nuclear Security Series No. 2. A revised publication, entitled Nuclear Forensics in Support of Investigations, IAEA Nuclear Security Series No. 2-G (Rev. 1), to be published in 2015 reflects Member States' recent experience in the conduct of a nuclear forensic examination. New technical guides in the area of nuclear forensics are also being prepared.

The importance of nuclear forensics as a tool to assist States in ensuring the security of nuclear material and other radioactive material for which they are responsible continues to grow. Resolutions on nuclear security adopted by the IAEA General Conference emphasize the importance of nuclear forensics as a component of a Member State's nuclear security infrastructure. Recent General Conference resolutions on nuclear security have noted the IAEA's work in developing and implementing training courses and providing guidance to assist States in the conduct of nuclear forensic examinations. Nuclear forensics was also featured in the President's Summary of the International Conference on Nuclear Security: Enhancing Global Efforts, organized by the IAEA in Vienna, Austria, from 1 to 5 July 2013. That conference included a technical session on nuclear forensics.

Furthermore, the IAEA Nuclear Security Plan 2014–2017 reflects the importance of nuclear forensics for the effectiveness and sustainability of national nuclear security measures. Recognizing the importance of international collaboration in nuclear forensics, the IAEA cooperates with the Global Initiative to Combat Nuclear Terrorism (GICNT), the International Criminal Police Organization (INTERPOL) and the ITWG to develop various forms of assistance, including enhancement of awareness, guidance and training. The international community increasingly recognizes the role of nuclear forensics as a preventive measure and as a tool to support the response to nuclear security events. Through this international conference on nuclear forensics, the IAEA seeks to facilitate a comprehensive exchange of information on relevant new technologies and techniques, as well as to showcase achievements in the application of nuclear forensics.

Among some of the themes included in the programme for the conference were:

- The history of nuclear forensics in response to the increased reports of illicit trafficking starting in the mid-1990s;
- The relevant legal instruments that pertain to nuclear forensics;
- The role of nuclear forensics in a nuclear security infrastructure;
- The integration of existing national resources into nuclear forensic capabilities;
- The state of practice of nuclear forensics to include scientific developments;
- Related nuclear forensic data interpretation tools, capacity building, international and regional cooperation, and policy implications.

The President's summary is intended to reflect the presentations and discussions at the conference, and to provide some observations derived from them. The summary is not intended to provide binding recommendations to the Secretariat or to Member States, but rather to help them in fulfilling their respective responsibilities in the realm of nuclear security.

OPENING STATEMENTS

HE Susan J. le Jeune d'Allegeershecque, President of the Conference and Resident Representative of the United Kingdom of Great Britain and Northern Ireland to the IAEA

The conference began with an address by the President of the Conference HE Susan J. le Jeune d'Allegeershecque, the Resident Representative of the United Kingdom of Great Britain and Northern Ireland to the IAEA. The Conference President stressed the ongoing threat posed by nuclear and other radioactive material out of regulatory control. She identified that through shared technical solutions — to include nuclear forensics — there is the ability to prevent and, as required, respond to this challenge. She further highlighted that the most significant challenge for nuclear forensics is to promote cooperation between nuclear scientists, law enforcement officers and criminal prosecutors that have not closely worked together in the past. The Conference President also underlined that the IAEA in collaboration with its Members States and international partners have convened the present conference to address this challenge and strengthen nuclear forensics.

The Conference President noted that the discipline of nuclear forensics has developed quickly since it emerged in the late 1990s with its successful application to high profile seizures of high enriched uranium (HEU).

The Conference President highlighted the importance of the cooperation between the IAEA, its Members States and its international partners to strengthen together the international nuclear security regime. To this end, she acknowledged the IAEA's effort to develop implementing guidance (i.e. Nuclear Forensics Support, IAEA Nuclear Security Series No. 2) in nuclear forensics and to provide training on using the generalized conduct of a nuclear forensics in support of investigations. The Conference President noted that the United Kingdom is dedicated to a comprehensive national response plan focused on real time solutions to ensure a successful criminal prosecution following unauthorized acts involving nuclear and other radioactive material out of regulatory control. Through participation in an international tabletop exercise conducted in 2014 under the auspices of the GICNT, nuclear forensics professionals from different institutions throughout the United Kingdom have started to work together. For their contributions to nuclear forensics, she also acknowledged several partners and international organizations — including the Nuclear Security Summit, the GICNT and the ITWG — and their efforts to promote integrated approaches to nuclear forensic examinations. She finally expressed that the objective of the present conference is an extensive sharing of information and experiences between participants from different countries and backgrounds, such as technical, legal and policy, to increase the security of nuclear material and other radioactive material.

IAEA Director General Yukiya Amano

IAEA Director General Yukiya Amano followed with his remarks. The Director General stressed the security of nuclear material and other radioactive material as an essential but elusive goal for Member States. From 1993 to 2013, the IAEA Incident and Trafficking Database (ITDB) compiled 2477 confirmed incidents of nuclear and other radioactive material out of regulatory control. Of these, 424 incidents involved unauthorized possession and related criminal activities. In the same period, 16 incidents involved the unauthorized possession of HEU and plutonium. Of heightened concern, incidents as recent as 2011 point to organized networks of illegal sellers and buyers for this nuclear material. Looking forward, the Director General noted that the international community needs to ensure harmonized approaches as the strongest possible basis for enabling effective nuclear forensic science. Through common approaches and consistent expectations, the international community benefits from robust and effective nuclear forensics. Through consistency of practice, the IAEA seeks to better establish the link between nuclear forensics and legal instruments as a way for States to fulfil their obligations under relevant international conventions. He reiterated that the 2005 Amendment to the Convention on the Physical Protection of Nuclear Material, yet to enter into force, is a key international instrument supporting nuclear security.

HE Grigory Berdennikov, Russian Federation, on behalf of the Global Initiative to Combat Nuclear Terrorism

HE Grigory Berdennikov of the Russian Federation spoke of how the GICNT most appreciates the important role of the IAEA in the maintenance of nuclear security and combating nuclear terrorism. He noted that GICNT activities are undertaken in support of, and with regard to, activities of the IAEA in coordinating States' efforts to ensure nuclear security. The partnership between the GICNT and the IAEA raises the awareness of the international policy community to the key challenges in implementing best practices at the political level and offers solutions to meet those challenges based on the experience of partner States. The GICNT believes that the role of this initiative is to support the activities of the relevant international organizations, notably the IAEA, through sharing experiences and conducting exercises and other practical activities, with a view to enhancing nuclear security. He expressed that the GICNT was looking forward to further active cooperation with the IAEA in all major areas of nuclear security.

Simon Limage, United States of America, on behalf of the Global Initiative to Combat Nuclear Terrorism

The United States of America thanked the IAEA for organizing and hosting the largest international nuclear forensics conference to date, as well as including the ITWG, INTERPOL and the GICNT as cooperating entities at the international conference. He emphasized that a theme of the week's conference is also a key element for the GICNT which seeks to bring together nuclear forensic experts with a range of policy, law enforcement, technical and related backgrounds to demonstrate the critical need for these experts to collaborate: policy makers informing the technical community of their needs and technical experts sharing with policy makers the capabilities of nuclear forensics. He remarked that presentations and discussions to be provided during the international conference represented a collective next step towards strengthening nuclear forensic capabilities, capacity building and international cooperation as part of a global nuclear security community. His remarks emphasized that ongoing work through the GICNT — in partnership with the IAEA, the ITWG and INTERPOL — as well as the outcomes from the international conference would help to sustain a robust and enduring international nuclear security architecture well into the future.

Alan King, on behalf of INTERPOL

Alan King of INTERPOL stressed that crime and terrorism require a coordinated approach involving collaboration and partnership working between different agencies to provide an effective and holistic response to the challenges many communities face as a result of criminal activity. For this reason, he stated that INTERPOL fully embraces the need for an international framework for law enforcement cooperation and sees the IAEA as its key partner in this regard. He noted that the IAEA and INTERPOL work together on a number of initiatives to include the sharing of information, the development of the IAEA's implementing guide Radiological Crime Scene Management, Nuclear Security Series No. 22-G, as well as the associated radiological crime scene management training in which INTERPOL provides the focus for the law enforcement activity. He reiterated that INTERPOL's ongoing close partnership with the IAEA, its collaborative work in training and preparing the law enforcement, scientific, health and other public sector communities, together with its long standing information sharing agreements, will go a long way to achieve the shared goals of these two international agencies in addressing the threat of nuclear terrorism.

Klaus Mayer, European Union, on behalf of the Nuclear Forensics International Technical Working Group

Klaus Mayer of the European Union explained that the ITWG is an informal group of nuclear forensic practitioners, including nuclear scientists, law enforcement and regulators, formed almost 20 years ago. He reflected that throughout these two decades, the ITWG has contributed to advancing nuclear forensics through its technical activities, including comparative material analysis exercises, tabletop exercises, technical guidelines and best practices conducted in task groups. He noted that the ITWG has been working in partnership with the IAEA and has supported many of its nuclear security related activities by providing expertise in the development of the science and technology supporting both law enforcement investigations and nuclear security vulnerability assessments.

Khammar Mrabit, Director of the IAEA Division of Nuclear Security

The Director of the IAEA Division of Nuclear Security, Khammar Mrabit, provided his perspective of the role of nuclear forensics as a component of the IAEA's portfolio of nuclear security cooperation with, and assistance upon request to, Member States. He stated that the IAEA is committed to positioning nuclear forensics as a key piece of nuclear security infrastructure. To do this, it is necessary to understand the bridge between nuclear science, law enforcement and criminal prosecution to ensure common understandings. The international security community also needs to be clear that nuclear forensics is neither expensive nor complicated, but that it is about using skills and technologies already in hand and applying them to the needs of nuclear security. In this vein, he observed that nuclear forensics can be included as part of the Integrated Nuclear Security Support Plan (INSSP) and International Nuclear Security Advisory Service (INSServ) peer reviews. The IAEA's central role in leading the coordination of international activities in nuclear security may be used to harmonize procedures and techniques through written guidance, training, pursuit of research as well as specialized assistance, upon request. Furthermore, developing analytical methods for a nuclear forensic examination, promoting quality and confidence in nuclear forensic findings, advancing the science of pathways or route identification and nuclear forensics as a preventive measure all strengthen nuclear security systems globally.

The opening session was followed by two plenary sessions, fifteen technical sessions, two poster sessions, two panel sessions and one round table discussion, where contextual, legal, scientific, and policy topics on nuclear forensics were explored in more detail.

SUMMARY OF PLENARY SESSIONS

Historical evolution of nuclear forensics (Plenary Session 1A)

Nuclear forensics arose in response to an increasing number of seizures of HEU and plutonium in Europe in the early 1990s. Using mass spectrometry and chemical techniques used in the manufacture of nuclear material as well as for the purposes of safeguards, these capabilities were applied to combat the illicit trafficking of nuclear material and other radioactive material. Initially, the concern was to determine the composition of these materials, the threat they posed and their likely origin. National laws that addressed illicit trafficking needed to be strengthened.

High profile seizures persisted with the indication of like material smuggled in separate incidents at different times. At the same time, nuclear forensic capabilities grew to also encompass examination of traditional forensic evidence to include DNA, fingerprints, hair and fibres that had been contaminated with radionuclides. National laws were enacted that increased the penalties for nuclear smuggling, while nuclear forensics was used to link materials to people, places and events. Nuclear forensic evidence was increasingly used by judicial systems to convict and sentence traffickers.

The IAEA has accelerated its efforts to provide implementing guidance, conduct introductory and advanced training, organize research as well as facilitate specialized nuclear forensic assistance to States, upon request. To promote capacity building, partnerships between the IAEA, the ITWG, the GICNT and the Nuclear Security Summits have raised the technical state of practice as well as awareness of nuclear forensics.

Nuclear forensic resources in the legal and nuclear security context (Plenary Session 1B)

An effective nuclear security infrastructure requires a comprehensive legislative and regulatory framework. Among other things, this framework should define offences or violations as those criminal or intentional unauthorized acts involving nuclear material, other radioactive material, associated facilities or associated activities. Through its ability to provide insight to the origin and the history of the radioactive material, nuclear forensics can play a key role in law enforcement investigations and prosecution of offences involving the unauthorized possession of these materials. The session highlighted issues related to the legal and regulatory framework, technical infrastructure and human capital. The session also featured means to achieve global awareness in nuclear forensics through capacity building and international cooperation projects. The international legal framework for strengthening nuclear security is comprised of both legally binding and non-binding international instruments and initiatives. The effectiveness of the international legal framework for nuclear security requires effective implementation at the national level, in particular the criminalization of offences in national law and the assignment of commensurate penalties.

The ITDB is the IAEA's information system that compiles confirmed incidents of illicit trafficking and other unauthorized activities and events involving nuclear and other radioactive material out of regulatory control. The ITDB facilitates the exchange of authoritative information involving these incidents among States. The scope of the ITDB information is broad and incorporates all reported incidents of nuclear and other radioactive material out of regulatory control. The nature of these events ranges from illegal possession, attempted sale and smuggling, to unauthorized disposal of material and discovery of lost radioactive sources. As of December 2013, a total of 2477 confirmed incidents had been reported to the ITDB by participating States and some non-participating States. The information reported demonstrates that the availability of unsecured nuclear material and other radioactive material persists. It also shows that effective border control measures help to detect illicit trafficking, although this control is not uniformly implemented at all international border points. Finally, the session concluded that individuals and groups are prepared to engage in the trafficking of this material.

Nuclear forensics has specifically been incorporated in relevant legislation within Hungary and its nuclear security regulatory system, with an emphasis on the national response plan to an illicit trafficking event regulated by a new governmental decree. The Hungarian national response plan is based on Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, IAEA Nuclear Security Series No. 15. The national response plan adopts a graded approach by applying different levels of response to a nuclear security event (e.g. at the strategic, tactical and operational levels).

SUMMARY OF TECHNICAL SESSIONS

The technical sessions were designed to explore the science of nuclear forensics and state of practice of implementation to support law enforcement and nuclear security. Technical sessions also included two poster sessions on 8 and 9 July. Topics included:

- Nuclear forensics as an element of a national response plan;
- Science of nuclear forensic signatures;
- Case studies;
- Laboratory based analytical techniques;
- Data interpretation tools and methods;
- Expressing confidence associated with nuclear forensic conclusions;
- Synergies with other disciplines;
- Radiochronometry (i.e. age dating);
- Raising awareness and enhancing education in nuclear forensics;
- International cooperation.

The following are brief summaries of the technical sessions:

(i) **Nuclear forensic capabilities as an element of a national response plan (Technical Session 2A)**: The session focused on the progress of Member States in using the nuclear forensics model action plan in support of investigations of nuclear and other radioactive material out of regulatory control. Participants shared national experience and lessons learned employing nuclear forensics in response to a nuclear security event. These will be used to complement the implementing guidance provided by the IAEA for the conduct of a nuclear forensic examination.

(ii) **Nuclear forensic science: Signatures of nuclear material (Technical Sessions 2B and 3A)**: The sessions highlighted the success of using analytical techniques to discern physical characteristics, chemical and elemental composition, and isotopic ratios that are incorporated into nuclear material and other radioactive material. These characteristics are introduced either geologically via feed stocks or from the nuclear fuel cycle manufacturing process and may provide information on the origin or history of these materials.

(iii) **Approaches to nuclear forensic examinations (Technical Session 2C)**: The session highlighted the importance of planning in advance an approach for responding to a nuclear security event. This approach involves means to protect the responders and the public as well as the integrity of the evidence. Validated methods and specialized facilities are required to analyse traditional forensic evidence (e.g. fingerprints, DNA, hair, fibres and digital evidence) contaminated with radionuclides. Strong ionizing radiation may also have an effect on the integrity of the evidence, which may necessitate either analysis in situ or decontamination.

(iv) **Data compilation tools for supporting nuclear forensic interpretation (Technical Sessions 2D and 3C)**: The sessions highlighted the advances made and the national experience of several Member States in the area of developing a national nuclear forensics library to support nuclear forensic interpretation. A national nuclear forensics library is one tool that may be used to compare characteristics of materials found outside of regulatory control. This will be useful to determine whether seized materials are consistent with materials used, produced or stored within a State. Accessing distributed data and subject matter expertise may assist States in ensuring the security of materials for which they are responsible. Difficulties associated with the use of a national nuclear forensics library include variations in the data characteristics for individual materials originating from a common facility. Alternatives to developing a national nuclear forensics library rely upon the experience of subject matter experts to provide information pertaining to the origin of seized materials.

(v) **Experiences in laboratory analyses and data interpretation (Technical Session 2E)**: Nuclear forensic capabilities need to be capable of analysing a wide range of samples of various sizes (typically from milligrams to grams) of uranium, plutonium and transuranics, as well as sealed and unsealed radioactive material. Both unirradiated and irradiated materials may be encountered. International cooperation can provide specialized techniques to allow measurements of bulk samples of uranium, plutonium and actinide microparticles. The application of multiple measurements in case studies has contributed in building confidence in the findings from a nuclear forensic examination.

(vi) **Exercises and cooperation (Technical Session 2F)**: The session focused on the requirement for personnel from multiple authorities to collaborate as a team to promote operational readiness in the context of a nuclear security event. First, cooperation is particularly required for the collection of evidence as well as for the formulation and implementation of a nuclear forensic examination plan that includes the use of a national nuclear forensics library. Second, exercises provide a means to ensure the reliability of nuclear forensics supporting a national response. This includes identifying appropriate roles and responsibilities of those involved in an investigation, the use of a chain of custody and the development of a comprehensive nuclear forensic examination plan, as well as documented procedures and methods for traditional and nuclear forensic analyses.

(vii) **Integration of existing national resources into nuclear forensic capabilities (Technical Session 2G and Panel Session 2H)**: The sessions highlighted that the prospect of a nuclear or radiological incident presents special challenges, as many States do not have designated nuclear forensic capabilities. In order to utilize existing capabilities to respond to nuclear or radiological incidents, it is important to identify facilities and capabilities that are equipped to analyse, handle and store radioactive material and evidence contaminated with radionuclides. Speakers and panellists noted the importance of States outlining the goals for nuclear forensics and then identifying ways to integrate their existing resources into a national nuclear forensic capability to meet these goals. One approach to begin integrating capabilities is to identify the personnel expertise existing within the State which can be used to help to categorize and then potentially to characterize material. Panellists also noted how States have forged relationships between the nuclear forensic experts and others in the State to build sustainability. For example, nuclear forensic experts may train first responders as well as assist in related aspects of an investigation of a nuclear security event.

(viii) **Nuclear forensic science: Synergies with other disciplines (Technical Sessions 3B and 3F)**: The sessions emphasized how technical services and analytical capabilities, initially developed for use in the nuclear industry, can be used for the analysis of nuclear material following a nuclear security event. The field of nuclear forensic science uses techniques, methods and tools that capitalize on over 100 years of achievements in the field of radiochemistry. New analytical instrumentation for spectrometry and spectroscopy allows for the exploitation of novel nuclear forensic signatures. Results of forensic medical evidence, drawing upon pathology studies with fatal and non-fatal outcomes, can provide crucial information regarding the details of a nuclear security event. Proven analytical techniques from other disciplines, such as radiochemistry and traditional forensics, are used to extract such information from seized materials or evidence. New approaches, applications and techniques enable reliable measurements that build confidence in nuclear forensic findings.

(ix) **Nuclear forensic science: Radiochronometry (Technical Session 3D)**: The session features the use of age dating to provide information important to nuclear forensics concerning the time of the last chemical purification of a sample of nuclear material or other radioactive material. The latest advances in highly accurate and high precision mass spectrometry and radiation counting techniques have enabled new radiochronometers to be exploited for nuclear forensic analysis. These novel radiochronometers are particularly useful for the characterization of HEU samples. The availability of new standards and isotopic spikes strengthens confidence in new age dating tools to include ^{235}U–^{231}Pa and ^{234}U–^{214}Bi isotope chronometers. The simultaneous application of several age dating pairs applied together on a common sample or set of samples improves the quality of age dating in nuclear forensics.

(x) **Confidence in nuclear forensic findings (Technical Session 3E)**: The session emphasized that conclusions are based on measurements of material characteristics and the interpretation of these results. The level of confidence in these findings depends on the quality assurance system and quality control procedures of the laboratory. This encompasses the use of validated methods, certified reference materials and adherence to demonstrated competencies. Some of the challenges include the validation of methods, the development of appropriate certified reference materials, maintaining relevant expertise and capabilities, and maintaining appropriate quality assurance management systems.

(xi) **Nuclear forensic awareness and education (Technical Session 3G)**: Nuclear forensic awareness and education comprise vital elements of a sustained nuclear forensic capability. By articulating the requirements for a nuclear forensic examination, roles and responsibilities can be identified, developers of the technical capability can be appropriately oriented, and common approaches can be used to increase confidence in nuclear forensic findings. Education and training is essential to ensure that evidence is collected and analysed appropriately in support of law enforcement investigations and nuclear security vulnerability assessments.

(xii) **International and regional cooperation in nuclear forensics (Technical Session 4A)**: The session recalled that reports to the IAEA of nuclear and other radioactive material out of regulatory control indicate that:

— Unsecured nuclear and other radioactive material remains available.
— Border control measures are effective in detecting illicit trafficking, although monitoring for nuclear material and other radioactive material is not uniformly implemented at all border control points.
— Individuals and groups are prepared to engage in the trafficking of these materials.

Harmonized and consistent awareness and understanding, regulation and state of practice strengthen the global nuclear security architecture. Regional approaches to include Nuclear Security Centres of Excellence are effective mechanisms to provide nuclear forensic solutions to prevent and respond to incidents of illicit trafficking. A key element in cooperative strategies is sharing experiences and lesson learned in establishing nuclear forensics as an effective component of nuclear security.

(xiii) **Poster Session I**: Within this session, information was presented across six general areas:

— Frameworks;
— National capabilities;
— Material out of regulatory control;
— Support to investigations;
— Exercises;
— Training.

Outcomes from this poster session emphasized that nuclear forensics is transitioning from an emerging to an established nuclear security discipline. The results from this session demonstrated that nuclear forensics is both designed into, and implemented as part of, States' national response plans. Nuclear forensics is sustained through both comprehensive exercises and training activities.

(xiv) **Poster Session II**: Results were presented in this session across three technical areas:

— Nuclear material and other radioactive material characterization;
— Radiochronometry;
— Data interpretation.

Outcomes from this poster session reinforced that research in nuclear forensics yields state of practice methods for nuclear and radioactive material characterization. These methods are useful to help to establish the scientific foundation for discriminating signatures to include radiochronometry. Mechanisms for data interpretation are contingent upon effective measures for organizing existing information to enable nuclear forensic comparisons.

PANEL SESSIONS AND ROUND TABLE DISCUSSION

Nuclear forensic capabilities within a national nuclear security infrastructure (Panel Session 1C)

The security of nuclear material and other radioactive material used, produced or stored is the State's responsibility. Specifically, each State has the obligation to provide for the security of nuclear material and other radioactive material as well as their associated facilities and activities. Each State also has the responsibility:

— To ensure the security of such material in use, storage or transport;
— To combat illicit trafficking and the inadvertent movement of such material;
— To be prepared to respond to a nuclear security event.

However, because terrorists and criminals work across international borders, a coordinated international response is crucial. States also recognize that nuclear security in one State may depend on the effectiveness of the nuclear security regimes in other States. Therefore, there is an increasing need for appropriate international cooperation to enhance nuclear security worldwide. In this respect, the IAEA plays a central role in leading the coordination of international cooperation in nuclear security and in helping States, upon request, to ensure that nuclear material and other radioactive material do not fall into the wrong hands.

It is also important to address the interfaces between nuclear forensics and all elements of an effective and sustainable nuclear security infrastructure for the prevention of, detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities. In this way, nuclear forensics is only one piece of the nuclear security continuum. States may need to ensure their national legislation allows for these interfaces as well as coordination on how information may be shared between relevant parties. In addition, ensuring that nuclear forensic evidence can be utilized in the courtroom is essential. This continuum is captured in Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, IAEA Nuclear Security Series No. 15, which refers to nuclear forensics as part of preventive measures, or deterrence, to enable response and to foster international cooperation to elevate the state of practice.

Nuclear forensics as part of a nuclear security infrastructure should provide information relevant to whether national legal statutes concerning unauthorized activities involving nuclear material and other radioactive material have been violated. It should also enable law enforcement to commence a nuclear forensic examination as well as conduct preliminary assessments about the characteristics of the seized nuclear material and other radioactive material. This will enable a path to conduct further examinations and the strengthening of nuclear security controls, and will allow the State to receive the full benefit of international assistance, as requested. The integration of nuclear forensics within a national response plan and nuclear security infrastructure is essential. Indeed, it is important to include on-scene categorization to identify the threat and to develop an appropriate nuclear forensic examination plan as well as to protect the public and responders at the scene of a nuclear security event.

Using nuclear forensics to verify that roles and responsibilities have been identified and implemented appropriately is essential — as is the provision of shared experience and lessons learned from the actual response to a nuclear security event.

Cooperation and coordination of all involved ministries, agencies and nuclear security event responders is essential to ensure that the appropriate subject matter experts are identified and fully represented in the conduct of a nuclear forensic examination.

Nuclear forensic science: The next five years (Panel Session 3H)

Nuclear forensics as a tool for law enforcement investigations and to support nuclear security vulnerability assessments requires continual innovation. As the threat associated with the continuing reports of nuclear and other radioactive material out of regulatory control persists, the science needs to advance as well. Nuclear forensic science ensures that new tools are always available to aid States in preventing and responding to a nuclear security event. Through peer review, nuclear forensic science allows new methods to be verified before they are used in support of an actual law enforcement investigation or potential criminal prosecution. Nuclear forensic science benefits from the widest intersection of all branches of science and engineering. Companion disciplines — including geochemistry, materials science, nuclear engineering and environmental science — exploit new frontiers of measurements and interpretation applicable to nuclear forensics as well as access to new subject matter experts to build confidence in nuclear forensic findings. By building in synergies with other fields of science and engineering, the effectiveness of nuclear forensics can be augmented for use in an examination. Using science at the intersection of individual disciplines, States can build a sustainable nuclear forensic capability through training the next generation of practitioners in the companion disciplines and educating them in the intersections with nuclear forensics. In addition, the international community should continue to share best practices and methods for nuclear forensics.

During the international conference, an interactive exercise involving all participants further demonstrated that States need to optimize the best use of existing resources and capabilities, while bridging to companion disciplines, to best advance nuclear forensics.

In the future, nuclear forensic science needs to provide the best answers to questions on the origin and history of nuclear and other radioactive material out of regulatory control, in support of law enforcement investigations and nuclear security vulnerability assessments. The panellists identified the following challenges for the next five years:

— Continued development of human resources;
— Advancement of new analytical tools and methods;
— Consideration of how to sustain technical nuclear forensic capabilities;
— Strategic international engagement.

Nuclear forensics: Where science meets policy (Round Table Session 4B)

Nuclear forensic science is a technical discipline supporting law enforcement investigations and nuclear security vulnerability assessments. However, nuclear forensics is not implemented in isolation. Understanding the requirements posed by the policy community is essential to ensure that nuclear forensics answers key questions of the nuclear security infrastructure. Effective implementation of nuclear forensic capabilities includes the coordination and management of policy makers and practitioners. It also requires international cooperation to advance and mature nuclear forensic capabilities as an element of nuclear security. Provisions are also required to enhance and evolve the technical foundations of nuclear forensics.

The needs of the policy community should also be clearly communicated to practitioners so that appropriate nuclear forensic capabilities can be developed and sustained, taking into account the national needs. Not all States need to have elaborate capabilities for nuclear forensics. Determining the scale and scope of nuclear forensic capabilities within the State involves coordination between the policy and technical communities. At the minimum, it is advisable that the policy community understands which capabilities currently exist within the State to support a nuclear forensic examination. These comprise national laws, a national response plan, coordination between law enforcement, and measurement and analysis laboratories. From the national perspective, establishing clearly understood roles and responsibilities to support a nuclear forensic examination and being fully prepared to implement them are two essential points.

Nuclear forensic awareness and understanding are crucial for policy makers. It is important for the policy community to understand what shapes confidence in nuclear forensic findings, such as demonstrated competencies, quality assurance and control, written procedures, and the use of calibrated equipment and standards. The most sophisticated instrumentation or nuclear forensic laboratories in the world are of little value if they are not used to return the most defensible scientific data in support of an investigation.

The development of nuclear forensics may require only modest investment and minor bureaucratic concessions. Existing capabilities already maintained by the State may be used for a nuclear forensic examination consistent with the generalized conduct of a nuclear forensic examination specified in Nuclear Forensics Support, IAEA Nuclear Security Series No. 2, published in 2006, and the revised publication, entitled Nuclear Forensics in Support of Investigations, IAEA Nuclear Security Series No. 2-G (Rev. 1), to be published in 2015. These existing capabilities for the analysis of nuclear material and other radioactive material may be found at nuclear research institutes and universities. Capabilities could also be maintained by nuclear operators or producers, or used by environmental monitors or regulators. The resulting strength of nuclear forensic findings not only depends on the instrumentation, but also on its use by subject matter experts.

Once developed, there is a need to foster and sustain the infrastructure supporting nuclear forensics. This involves regular exercises of all facets of a nuclear forensic examination — from evidence collection and analysis, to interpretation and reporting. Learning involving education and training needs to be in place to ensure an enduring nuclear forensic capability is implemented. This will also guarantee that the expertise is available from analytical science, nuclear engineering and forensic science disciplines. This will also ensure that the next generation of practitioners is properly prepared and that research can be sustained to enable innovation and advances. As its technical foundations mature through advances in technology and with improvements in methodologies, nuclear forensics also needs to evolve in parallel to ensure that credible findings most effectively support all facets of the investigation.

Systematic, comprehensive and harmonized approaches are critical and will enable the international community to rely on the strength of findings from a nuclear forensics examination. In this regard, the IAEA can play an important role through the development of technical guidance and its application, education and training, coordinated research projects, peer reviews and advisory services. Strategies for the IAEA to better assist Member States in nuclear forensics include harmonized guidance on relevant analytical measurements, assistance to nuclear forensic laboratories, regional approaches that use nuclear security support centres and assistance, upon request, through INSSPs.

CONFERENCE SUMMARY

CO-CHAIRS' SUMMARY OF PLENARY SESSION 1A*

HISTORICAL EVOLUTION OF NUCLEAR FORENSICS

M. Caspers
Germany

H. Yoo
Republic of Korea

INTRODUCTION

The co-chair **H. Yoo (Republic of Korea)** opened the session and welcomed the participants of the conference. In his introduction, he pointed out the importance of the topic of nuclear forensics. He welcomed the IAEA efforts in conducting this international conference, following its recognition by participants at the 2014 Nuclear Security Summit in The Hague.

The discipline of nuclear forensics was developed in response to a large number of seizures of plutonium and high enriched uranium (HEU) in Europe in the early 1990s. Using mass spectrometry and chemical techniques applied to the manufacture of nuclear material as well as for the purposes of safeguards, these capabilities were applied to combat the illicit trafficking of nuclear material and other radioactive material. Initially, the concern was to determine the composition of these materials, the threat they posed and their likely origin. National laws required strengthening to best address the threat posed by illicit trafficking. As high profile seizures persisted, with the indication of like material smuggled in separate incidents at different times, nuclear forensic capabilities grew to encompass traditional forensic evidence to include hair, fibres, DNA and fingerprints contaminated with radionuclides. National laws were enacted that increased the penalties for nuclear smuggling, and nuclear forensics was used to link materials to people, places and events. Nuclear forensic evidence was increasingly used by judicial systems to convict and sentence traffickers. To promote capacity building, partnerships between the IAEA and the Nuclear Forensics International Technical Working Group (ITWG), the Global Initiative to Combat Nuclear Terrorism (GICNT) as well as the three prior Nuclear Security

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Summits have raised the technical state of practice as well as political awareness of nuclear forensics.

PAPERS

S. Niemeyer (USA) and **L. Koch (Germany)** detailed the evolution of nuclear forensics since its beginning. They also described nuclear forensic applications to seized materials to determine material origin and history. The origin of nuclear forensics traces back to Member State reporting seizures of large quantities (grams to kilograms) of fissile materials in Europe in the mid-1990s. The emerging discipline of nuclear forensic science includes cooperative analytical exercises involving the measurement of nuclear material by self-identified nuclear forensic laboratories. To promote common solutions, the Nuclear Smuggling (now Nuclear Forensics) International Technical Working Group (ITWG) was formed in 1995. This informal group of nuclear forensic practitioners brought together scientists and law enforcement officials to design the ‘model action plan’, which covers the general conduct of a nuclear forensic examination. The model action plan was adopted by many States and was successfully implemented as part of a nuclear forensic examination of high profile seizures to include 4 g of HEU confiscated in Rousse, Bulgaria, in 1999. The model action plan, as part of a national response plan to address the illicit trafficking threat, was also an instrument to respond to other recently publicized seizures of HEU in the Caucasus region.

Nuclear forensics is an important nuclear security capability for the Russian Federation. **V. Kuchinov (Russian Federation)** discussed the development of capabilities within the Russian Federation. Different cases of nuclear forensic investigations undertaken by the Russian authorities were presented, highlighting the method used for analysis of the material, the structures for cooperation and the lessons learned during the process.

HE K. Nederlof (Netherlands) summarized the growing political recognition of the role of nuclear forensics as a tool to assist States in their nuclear security obligations in the context of law enforcement investigations. This presentation was focused on political perspectives that emphasized the importance of legal and regulatory provisions, which are necessary to enable effective prosecution of suspects and the admissibility of nuclear forensic evidence in a court of law. He highlighted the importance of United Nations Security Council resolution 1540, the International Convention for the Suppression of Acts of Nuclear Terrorism and the role in which nuclear forensics contributes to meeting the objectives set forth in these existing legal instruments.

K. Mayer (European Union) of the Joint Research Centre's Institute for Transuranium Elements (ITU) has assisted European States to analyse seized nuclear material since reports of illicit trafficking surfaced in the early 1990s. He described the role the ITU has played in applying bulk and particle analytical techniques to analyses of seized uranium fuels, mixed uranium and plutonium oxide as well as HEU and weapons grade plutonium. The ITU analyses were applied to determine the characteristics of these materials, as well as their intended use and likely origin. Accompanying this analytical work was a research portfolio to develop innovative techniques to determine the production history of nuclear material and other radioactive material, the age of samples since the time of last chemical purification and the use of trace elements — including the rare earth elements — to identify the geologic origin of uranium ores and ore concentrates. The ITU has also developed techniques for traditional forensic analysis (e.g. fingerprints, hair, fibres, DNA and explosive residues) of seized evidence contaminated by radionuclides that otherwise could not be measured in conventional crime laboratories. Through its technical capabilities to receive, handle and analyse nuclear material and other radioactive material, as well as the considerable experience of the scientific staff in case studies, the ITU remains an international leader in nuclear forensics.

OUTCOME

Nuclear forensics was recognized in the early 1990s as a tool to help combat illicit trafficking. By analysing seized nuclear material, nuclear forensics allowed determinations of what these materials were and provided information on their possible origin. Cooperation with law enforcement grew with the establishment of national laws that penalized the unauthorized possession of nuclear material and other radioactive material. The ITWG developed the model action plan, governing the conduct of a nuclear forensic examination; and further sustainability of the discipline was provided through the GICNT, as well as nuclear security summits, which have raised both the technical state of practice and the political awareness of nuclear forensics.

Questions by the audience focused on legal aspects of nuclear forensics, such as the applicability of the evidence obtained during nuclear security investigations in court. Discussion further focused upon developing nuclear forensics in those States which still do not have mature capabilities in this field and how common experience can best be shared.

CONCLUSIONS

In the closing statement, the co-chair **M. Caspers (Germany)** thanked the session speakers for their presentations and the audience for their contributions, and summarized the outcomes of the session. She expressed her appreciation to include this session within the conference, since sharing lessons already learned helps to improve nuclear security and to meet future challenges.

Nuclear forensics has emerged as an important component of a nuclear security infrastructure, supporting law enforcement investigations and nuclear security vulnerability assessments. Nuclear forensic examinations have successfully linked people to places, material and events. As a result, this capability is increasingly recognized as a means to promote the criminalization of incidents involving nuclear and other radioactive material out of regulatory control. For this reason, the ability of a nuclear forensic examination to support a prosecution requires the development of a nuclear forensic examination plan, appropriate laboratories, written procedures and trained examiners. By determining the likely origin and history, nuclear forensics can help States to make informed decisions on where to strengthen their nuclear security regime. Hence, it is important for States to be aware of nuclear forensics and how it supports a nuclear security infrastructure. International cooperation and collaboration have been essential in promoting awareness and understanding of this capability, improving the science, sharing lessons learned from implementation and sustaining the discipline through the best use of existing national capabilities. The IAEA has accelerated its efforts to provide implementing guidance, conduct introductory and advanced training, organize research and provide specialized nuclear forensic assistance to States, upon request.

CO-CHAIRS' SUMMARY OF PLENARY SESSION 1B*

NUCLEAR FORENSIC RESOURCES IN THE LEGAL AND NUCLEAR SECURITY CONTEXT

W.I. Zidan Mohamed
Egypt

A. Pavlenishvili
Georgia

INTRODUCTION

An effective nuclear security regime requires establishing a comprehensive legislative and regulatory framework that defines offences or violations as those criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities. In this regard, nuclear forensics plays a key role in the investigation and prosecution of such offences. Nuclear forensics supports the response by law enforcement investigators and prosecutors to determine the origin and history of detected nuclear material and other radioactive material. It is also important that States have effective mechanisms of cooperation and assistance to support nuclear forensic analyses.

PAPERS

The value of the recent discipline of nuclear forensics was recognized at a very high level during the 2010, 2012 and 2014 Nuclear Security Summits. Nuclear forensics can be an effective tool in determining the origin of detected nuclear material and other radioactive material and in providing evidence for the prosecution of acts of illicit trafficking and malicious use. **M. Wallenius (European Union)** provided a thorough introduction to the establishment of a nuclear forensic capability within a national framework. She emphasized the need for awareness of nuclear security and the role of nuclear forensics at all levels of

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government. She also presented the challenges that a State faces in developing a nuclear forensic capability: interagency cooperation, technical complexity, scientific expertise, national infrastructure and the legal basis (especially in relation to contacting foreign laboratories for forensic analysis) — all of which have to be taken into consideration in the development of a comprehensive national response plan.

This paper further provided an overview of the elements that have to be considered in the development of a nuclear forensic capability:

(a) The national framework: A State needs to assess the resources that already exist, a national response plan should be in place, collaborative agreements should be available, and a point of contact for the IAEA Incident and Trafficking Database (ITDB) should be designated.
(b) Evidence management: Challenges posed by radioactivity during the management of a radiological crime scene to include sampling collection, and storage and transport of traditional, nuclear and contaminated evidence.
(c) Material analysis and interpretation: Categorization and characterization of suspect material at the crime scene, comparison of data and advanced characterization where necessary.
(d) Human capital: The human resources that are needed for such a specialized field, including training and capacity development.

In order to illustrate these processes, the paper provided an overview of the experience of the Joint Research Centre’s Institute for Transuranium Elements in implementing the concept of nuclear forensics through various projects and programmes of the European Commission to include technical support, scientific collaboration and a comprehensive training programme.

I. Khripunov (USA) discussed the diversity and complexity of the international legal framework for nuclear security and the key role of nuclear forensics in the context of the international legal framework for strengthening nuclear security. He underlined that the global nature of nuclear security requires an international legal framework that is coordinated, consistent, sustainable and predictable. The international legal framework is comprised of a set of hard law (i.e. legally binding) and soft law (i.e. non-binding) international instruments and initiatives. He provided an overview of the hard law instruments under IAEA auspices (e.g. Convention on the Physical Protection of Nuclear Material and its Amendment, and Notification and Assistance conventions), under United Nations and other international organization auspices (e.g. International Convention for the Suppression of Terrorist Bombings, and International Convention for the Suppression of Acts of Nuclear Terrorism) and under the auspices of the United Nations Security Council (e.g. resolutions 1373 and 1540). He also discussed soft law instruments and initiatives (e.g. Code of Conduct on the Safety and Security of Radioactive Sources, Global Initiative to Combat Nuclear Terrorism, Proliferation Security Initiative, Nuclear Supplier's Group and Nuclear Security Summits) and their effectiveness as flexible tools that can be more quickly and easily implemented into the national framework. He emphasized that soft law instruments are complementary to hard law; soft law is able to fill gaps of hard law, and can later be used as the basis for hard law by the international community.

The international legal framework needs to be implemented at the national level in order to be effective, and the combination of hard and soft law can allow this to take place more effectively and efficiently. The criminalization of offences in national law, for which provisions are contained in all international instruments for nuclear security, should also be incorporated into national frameworks. In this context, nuclear forensics has a key role for the successful investigation and prosecution of offences. As a preventive measure, nuclear forensics yields clues to the origin of materials and their history and serves as a deterrent against potential perpetrators who would misuse materials. The diversity of the international legal framework makes it possible to successfully prosecute perpetrators as long as governments acknowledge that nuclear terrorism remains a global menace. It is also essential that governments collaborate and provide assistance to include nuclear forensics, as well as establish effective national laws and legal remedies.

M. Nicholas (IAEA) introduced the ITDB as the IAEA's information system on incidents of illicit trafficking and other unauthorized activities and events involving nuclear and other radioactive material out of regulatory control. The ITDB facilitates the exchange of authoritative information on incidents among States. The scope of ITDB information is broad and incorporates all incidents of nuclear and other radioactive material out of regulatory control, ranging from illegal possession, attempted sale and smuggling to unauthorized disposal of material and discovery of lost radioactive sources. As of December 2013, a total of 2477 confirmed incidents had been reported to the ITDB by participating States and some non-participating States. This paper provided an analysis of the incidents reported between 2007 and 2012, taking note that the information reported to the ITDB indicates:

(a) The availability of unsecured nuclear material and other radioactive material;
(b) The need for effective border control measures to help to detect illicit trafficking;
(c) Effective control is not uniformly implemented at all international border points;
(d) That individuals and groups are prepared to engage in trafficking this material.

To this end, the ITDB helps participating States and selected international organizations to combat illicit trafficking and strengthen nuclear security. In order to do so successfully, however, States have to be capable of determining the material that they have seized and its origin, including whether it came from another State or a facility within their territory. Accordingly, the establishment of a national nuclear forensics library or affiliated database may contribute to enhancing a State's nuclear forensic capabilities and can significantly enhance the quality and efficiency of the response to a nuclear security event.

Zs. Stefánka (Hungary) presented the role of nuclear forensics in the context of the relevant Hungarian legislation and the nuclear security regulatory system, with an emphasis on the Hungarian National Response Plan to an Illicit Trafficking Event regulated by a new governmental decree. The National Response Plan is based on Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, IAEA Nuclear Security Series No. 15, and adopts a graded approach by applying different levels of response to a nuclear security event with nuclear and other radioactive material out of regulatory control. Response also differs depending on the nature of the nuclear security event (i.e. if material is missing, detected, seized or confiscated). The main features of the relevant legislation and collected examples were presented as of October 2011. He also discussed the changes that Hungary will implement in order to improve its legal and regulatory framework for nuclear security, such as the enhancement of regulations to address orphan sources and national responsibilities.

OUTCOME

Awareness and understanding of nuclear forensics is crucial in order for policy makers to establish the basis for implementing nuclear forensic capabilities at the national level. Nuclear forensic capabilities support law enforcement investigations as well as strengthen nuclear security measures within the State. Illicit trafficking remains an ongoing threat, and nuclear forensics can provide technical information that may allow different cases to be compared. Having a viable nuclear forensic capability is in the State's interest to meet its security obligations.

CONCLUSIONS

States have demonstrated the viability of nuclear forensics to support national laws that criminalize the authorized possession of nuclear material and other radioactive material. Nuclear forensics does not operate in isolation but is an important component of a national response plan to a nuclear security event.

CO-CHAIRS’ SUMMARY OF PANEL SESSION 1C*

NUCLEAR FORENSIC CAPABILITIES WITHIN A NATIONAL NUCLEAR SECURITY INFRASTRUCTURE

G. Emi-Reynolds
Ghana

M. Senzaki
Japan

INTRODUCTION

Nuclear forensics is one piece of a comprehensive national nuclear security infrastructure. Nuclear Security Recommendations on Nuclear and Other Radioactive Material out of Regulatory Control, IAEA Nuclear Security Series No. 15, published in 2011, describes a State’s national response plan that includes capabilities to locate, identify and categorize nuclear material and other radioactive material as well as collect and analyse evidence associated with a nuclear security event. Nuclear forensics serves as an element of the response to identify the source, history and route of transfer of seized materials while taking into account the preservation of evidence. The recommendations also view nuclear forensics, with its ability to identify origin and link people to place materials and events, as a preventive measure. Furthermore, the development of a national nuclear forensics library is one way of determining whether seized samples are consistent with radioactive material used, produced or stored within the State.

PANEL DISCUSSION

Invited panellists represented Member States which are at differing stages of incorporating nuclear forensics as part of a national nuclear security infrastructure. The panel addressed the role of nuclear forensics and consisted of **R. Floyd (Australia)**, **S. Limage (USA)**, **K. Mrabit (IAEA)**, **L. Paredes Gutiérrez (Mexico)** and **J.E. de Souza Sarkis (Brazil)**. Each spoke of their own national

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experience developing and sustaining a nuclear forensic capability supporting law enforcement investigations and nuclear security vulnerability assessments to include the technical, legal and policy implications.

OUTCOME

Nuclear forensics is one part of a national response plan and a piece of a comprehensive nuclear security infrastructure. In particular, the panellists emphasized that nuclear forensics enables rapid and reliable categorization to identify seized material, supporting the conduct of an ensuing investigation. More specifically, nuclear forensics returns information necessary to help to design a nuclear forensic analytical plan guiding the subsequent nuclear forensic examination. Coordination and cooperation with law enforcement and response officials responsible for managing the radiological crime scene is vital to collect and document the forensic evidence and to establish a chain of custody. It is important to determine early whether national legal statutes have been violated and to establish the nature of the criminal investigation. In addition to these priorities, the nuclear forensic examination can provide decision makers with an assessment whether more nuclear material and other radioactive material — in addition to that seized — is out of regulatory control to better manage threat awareness. The panel noted that nuclear forensics not only needs to be implemented but it also needs to be sustained. Awareness and understanding of the role of nuclear forensics within a nuclear security infrastructure is essential and may be developed and sustained using expertise and technical resources already existing within the State.

CONCLUSIONS

An effective nuclear security regime requires:

(a) Information analysis on the type and amount of nuclear material and other radioactive material that is abandoned, stolen, smuggled or trafficked;
(b) An effective means of adjudicating information alerts and radiation alarms from detectors;
(c) Identification of roles and responsibilities that allow for the effective management of a nuclear security event;
(d) The collection and categorization of nuclear material and other radioactive material supporting a nuclear forensic examination.

Nuclear forensics provides information on the effectiveness of the nuclear security regime and where it needs to be strengthened. Indeed, nuclear forensics returns quantitative information supporting information analysis and optimal placement of radiation detectors. Nuclear forensics also provides information on the efficacy of material controls. Meeting the requirements posed for a State's nuclear security infrastructure can benefit from the information provided by nuclear forensics. Furthermore, by linking radioactive material to perpetrators, nuclear forensics can also help to deter unauthorized acts by individuals or groups with the intent to engage in malicious acts. Nuclear forensic conclusions are strongly dependent on the awareness of requirements guiding an examination. Therefore, a broad nuclear security regime (e.g. emergency management plan, transportation plan for nuclear material and other radioactive material, and national laws) needs to be in place to include the technology base as well as roles and responsibilities understood, concurrently with the development of a nuclear forensic capability. Accordingly, nuclear forensics might be included more prominently in IAEA nuclear security peer review services to include Integrated Nuclear Security Support Plans (INSSPs) and the International Nuclear Security Advisory Service (INSServ) as a means to elevate state of practice through independent and objective reviews of Member State capabilities.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2A*

NUCLEAR FORENSIC CAPABILITIES AS AN ELEMENT OF A NATIONAL RESPONSE PLAN

M. Kostor
Malaysia

I. Balan
Republic of Moldova

INTRODUCTION

Nuclear forensic state of practice has shown improvement in response to lessons learned from, and recent experience in, nuclear forensic applications within the context of a broader national response plan to a nuclear security event. Once adopted, a nuclear forensic programme reflects the State's experience with the nuclear fuel cycle and the threats posed by nuclear and other radioactive material out of regulatory control. The IAEA assists Member States through the development of implementing guidance to include recent revisions on nuclear forensics in support of investigations. Member States apply their own experience in nuclear forensic case studies within a national response plan to improve their own nuclear security infrastructure based on lessons learned and post-operational recommendations. Coordination and cooperation between law enforcement, forensic science and nuclear science is essential to ensure a viable national response plan.

PAPERS

F. Wong (USA) introduced a summary of the draft IAEA Nuclear Security Series publication Nuclear Forensics in Support of Investigations. This publication is the update of Nuclear Forensics Support, which was developed by the Nuclear Forensics International Technical Working Group and published in 2006 as IAEA Nuclear Security Series No. 2. It is the first revision within

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the Nuclear Security Series. The rationale for revising the original publication is based on advances in nuclear forensic science and lessons learned following practical applications and a number of cases involving illicitly trafficked nuclear material and other radioactive material to which nuclear forensic techniques have been applied. The revised publication, entitled Nuclear Forensics in Support of Investigations, IAEA Nuclear Security Series No. 2-G (Rev. 1), to be published in 2015, will serve as implementing guidance to provide context for nuclear forensics within a national nuclear security infrastructure as well as promote international cooperation.

R. Mogafe (South Africa) introduced South Africa's national multi-agency approach to nuclear forensic support of investigations, which allows significantly improved chain of custody while handling both nuclear forensics and traditional forensic evidence. This function is ensured through the joint support of the response operation by law enforcement agencies, regulatory body and the South African Nuclear Energy Corporation (Necsa). A set of recommendations and requirements were presented based upon South Africa's national experience with its development of a plan for a national capability in nuclear forensics.

M. Abuissa (Sudan) described a radiological incident involving an industrial radioactive sealed source stolen from the Moleta oil field location, in South Sudan. The source was stolen from a storage site for non-destructive testing, owing to a nuclear security breach. A mobile, expert support team responded to the event, and relevant measures to protect the public and the community were taken by national competent authorities. As a post-event lessons learned, important measures have been implemented to strengthen the national security regime, with a focus on enhanced physical protection at relevant locations, improved response capabilities and the development of human resources.

W. Daeng Beta (Indonesia) presented the status of developing nuclear forensic capabilities in Indonesia and also described upgrades to the capabilities that will be implemented by the national Nuclear Energy Regulatory Agency (BAPETEN).

OUTCOME

Existing capabilities within the State may be successfully used for a nuclear forensic examination consistent with the 'model action plan'. It is important to ensure that the roles and responsibilities of all entities involved in a nuclear security response understand how their actions can affect the outcome of a nuclear forensic examination. For this reason, it is imperative to have written procedures, calibrated instrumentation and trained personnel, in addition to regular response exercises and feedback from case investigations.

CONCLUSIONS

A national response plan should include nuclear forensics, and its overall effectiveness has to be regularly evaluated to ensure the plan reflects recent and relevant experience, addresses any technical or operational gaps, and capitalizes the expertise of both nuclear scientists and law enforcement officials.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2B*

NUCLEAR FORENSIC SCIENCE: SIGNATURES OF NUCLEAR MATERIAL I

J.E. de Souza Sarkis
Brazil

T. Hinton
Canada

INTRODUCTION

One of the most important tasks during the investigation of a nuclear security event consists of the analysis of chemical, physical and isotopic characteristics of the interdicted nuclear material and other radioactive material with the objective of identifying its nature, origin or past process history. The correlations obtained through this analysis constitute the nuclear forensic data characteristics (or signatures) of the material and are an important tool to support nuclear forensics and possible prosecution. As a consequence, there is much ongoing research into material signatures and the investigation of new signatures. This session focused on classical as well as new methodologies to identify useful signatures within uranium ore concentrates (UOCs).

PAPERS

Australia has large reserves of uranium ore. The Australian Nuclear Science and Technology Organisation is presently undertaking reflectance spectroscopy studies of the ore to distinguish different species and polymorphs of uranium. In addition, synchrotron X ray radiation is being applied to provide provenance characterization of uranium microparticles. **A. Wotherspoon (Australia)** identified that novel nuclear forensic signatures aid in determinations of the origin and processing history of nuclear material and other radioactive material.

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The analysis of UOCs using Raman spectroscopy involving the subsequent interpretation of datasets by principal component analysis shows promise. **D. Ho Mer Lin (Singapore)** also provided results from scanning electron microscopy (SEM) of particles and particle size distributions of UOCs.

Measurements of the isotope ratio of $^{143}Nd/^{144}Nd$ can be used to determine the geologic history of uranium bearing materials to include uranium ore, UOCs and high purity uranium oxides (UO_3 and UO_2). Despite challenges in sample preparation that involve a pre-concentration of rare earth elements (REEs) for accurate measurement from a uranium bearing material, **J. Krajko (European Union)** of the Joint Research Centre's Institute for Transuranium Elements (ITU) noted that correlations could be determined between the $^{143}Nd/^{144}Nd$ ratio, the Nd/Sm ratio and the deposit type of uranium.

A recent study evaluated the use of sulphur isotope ratios to determine whether these isotope ratios could provide a useful nuclear forensic signature bearing on the origin and history of UOCs investigated from around the world. **Z. Varga (European Union)** of the ITU reported that determination of the $^{34}S/^{32}S$ ratio in UOCs of worldwide origin showed significant differences between the samples, and these variations could be used to differentiate unique samples from disparate origins. These results are important to studies in nuclear forensics focusing on identifying front end nuclear feed materials.

OUTCOME

Considerable nuclear forensic research and development are focused on identifying high confidence nuclear forensic signatures of UOCs. These include reflectance and Raman spectroscopy, synchrotron X ray structural studies, particle size analysis using SEM, measurement of REEs as well as isotope ratio measurements of $^{143}Nd/^{144}Nd$ and $^{34}S/^{32}S$. Each has shown positive results in discriminating the unique geologic origin and processing history of uranium ore and UOCs collected and analysed from around the world.

CONCLUSIONS

Nuclear forensic signature science incorporates spectroscopy, trace element analysis and isotope ratio measures to establish the viability of new nuclear forensic signatures. As feed materials to the nuclear fuel cycle, uranium ore and UOCs have been widely analysed because they are less likely to reflect any proprietary or sensitive process information associated with the production of nuclear fuels. Research findings need to be peer reviewed and disseminated to accelerate international cooperation on the measurement and interpretation of new signatures in an array of samples.

CO-CHAIRS’ SUMMARY OF TECHNICAL SESSION 2C*

APPROACHES TO NUCLEAR FORENSIC EXAMINATIONS

V. Stebelkov
Russian Federation

H. Ramebäck
Sweden

INTRODUCTION

There are challenges in conducting traditional forensic examinations in the presence of nuclear material and other radioactive material. Conventional crime laboratories do not have the appropriate safety and security basis for the receipt of radioactive material that requires specialized handling and protections.

Following a nuclear security event, the analysis of traditional forensic evidence is complex and challenging. One of the two following strategies is often employed:

(1) The establishment of a forensic laboratory which is designated by a competent authority and equipped to handle radioactive material;
(2) Decontamination of evidence contaminated with radionuclides for subsequent analysis in a traditional forensic laboratory.

In addition, the effects of ionizing radiation may alter the crime scene and forensic evidence.

PAPERS

To ensure the safe, secure, effective and efficient conduct of operations at a radiological crime scene, a thorough awareness of all potential responders is essential. **C. Nogueira de Oliveira (IAEA)** discussed the guidance provided

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within Radiological Crime Scene Management, Nuclear Security Series No. 22-G, which was published in 2014. The proper procedures for evidence collection — to include a chain of custody and comprehensive documentation — at the radiological crime scene is essential for the success of the ensuing nuclear forensic examination.

Addressing the complexities of performing traditional forensic science studies in the presence of nuclear material and other radioactive material, **G. Graham (United Kingdom)** described ongoing method development and validation studies within the Conventional Forensics Analysis Capability laboratory at the Atomic Weapons Establishment. Although traditional forensic science techniques and methods are well established, performing such tasks in the presence of radiation creates unique challenges and difficulties, and often requires specialized equipment and processing. At this laboratory, traditional forensic scientists can be trained to work within the dedicated laboratory under the supervision of technical experts from the nuclear licensed site.

Demonstrating the absence of radionuclide contamination in crime scene evidence for release to a standard forensic laboratory is a great practical challenge. To further complicate matters, the legal limits for the unconditional release of items after decontamination may vary by State. **E. Hrnecek (European Union)** described efforts by the Joint Research Centre's Institute for Transuranium Elements to develop a methodology for decontaminating DNA samples for release to a standard forensic laboratory. Because direct assessment of the radioactivity present in the DNA eluate sample is often not feasible (owing to detection limits or destructive assessment methods), this approach utilized an indirect assessment of the DNA eluate. The radionuclide concentrations in the solutions from the lysis, washing and elution steps were determined. Decontamination factors were also established for radionuclides that are typically used in nuclear security scenarios. Demonstrating decontamination compliance of crime scene evidence can be achieved through the measurement of the radionuclide in the initial lysis solution and the decontamination factor for the investigated radionuclide.

The establishment of procedures for the safe handling of forensic evidence contaminated with radioactive material is paramount to an effective response to, and investigation of, a nuclear security event. **D. Hill (Australia)** provided an overview of the Australian experience in developing operational capabilities at the intersection of traditional and nuclear forensics. The approach is a collaborative one in which forensic scientists of the Australian Federal Police (AFP) conduct the examination of evidence in the Australian Nuclear Science and Technology Organisation's Nuclear Forensics Research Facility (NFRF). NFRF personnel are also part of the analytical team, often serving as a bridge between forensic science and nuclear science, as they have experience in both disciplines. To further promote this role, NFRF personnel are also included in AFP training to gain a better understanding of the specific needs of the police.

OUTCOME

Through an active collaboration between the police services and nuclear science institutes, evidence contaminated with radionuclides may be collected and successfully analysed using traditional forensic methods. Dedicated laboratories for these specialized analyses are being established in the United Kingdom and within the European Commission, as well as in Australia. A key point from the session is to ensure a comprehensive and working interface exists between forensic and radiation science to fully exploit available evidence within the appropriate safety and security authorization basis. This requirement may entail specialized education and training of all examiners. Additional guidance to include the implementing guide on Radiological Crime Scene Management, IAEA Nuclear Security Series No. 22-G, can assist institutes and agencies in the initiation of an investigation at a nuclear security event to protect the public, the environment and any associated nuclear forensic evidence.

CONCLUSIONS

A nuclear forensic examination needs to be prepared to exploit traditional evidence (e.g. fingerprints, DNA, hair and fibres) that has been contaminated with radionuclides. Specialized facilities and approaches to extract the evidence need to be employed. The session concluded that the most advanced methods and techniques for traditional forensic analysis of evidence contaminated by radionuclides need to be identified, owing to the importance of traditional forensic signatures to the outcome of a nuclear forensic examination. However, it is recognized that cases involving evidence contaminated with radionuclides occur infrequently and the resulting need for these investigations is quite rare. The resulting awareness of when and how to apply such methods is crucial.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2D*

DATA COMPILATION TOOLS FOR SUPPORTING NUCLEAR FORENSIC INTERPRETATION I

D. Dimitrov
Bulgaria

A. Singh Gill
India

INTRODUCTION

This session featured the advances several Member States have made in the area of developing a national nuclear forensics library to support a nuclear forensic interpretation. A national nuclear forensics library is one tool that may be used to potentially determine whether characteristics of materials found outside of regulatory control are consistent with nuclear material and other radioactive material used, produced or stored within a State.

PAPERS

The session began with a paper by **A. El-Jaby (Canada),** who described the rationale for developing the Canadian National Nuclear Forensics Capability Project (CNNFCP). The CNNFCP is an initiative of the Government to augment Canada's national capacity to respond to the threat of nuclear and other radioactive material out of regulatory control. As part of this initiative, the Canadian Nuclear Safety Commission was charged with the task of developing a national nuclear forensics library to catalogue Canada's nuclear material and other radioactive material holdings.

O. Gaidar (Ukraine) next described efforts at the Institute for Nuclear Research of the National Academy of Sciences of Ukraine (INR), which has been designated by the Ukrainian Government as the primary organization for the study and characterization of nuclear material and other radioactive material

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seized from illicit trafficking in Ukraine. In support of Ukraine's efforts, the INR is working to apply its expertise in the handling of nuclear material and other radioactive material as well as its expertise in database development to improve nuclear forensic capabilities in Ukraine. The presentation featured advantages of maintaining a national nuclear forensics library within Ukraine to complement the nuclear forensic analytical function.

J. Wacker (USA) described the historical evolution of the development of a national nuclear forensics library in the United States of America, including initial efforts to utilize existing nuclear material accountancy information, nuclear fuel fabrication data and other readily available datasets. The paper also included some of the logistics involved in identifying, gaining access to and reviewing the historical archives at several material production sites.

The session concluded with another paper from **M. Robel (USA)**, who detailed efforts to develop the Uranium Sourcing Database. This database contains material characteristics on thousands of samples of uranium ore concentrate (UOC) and related products. The database is part of a broader effort to characterize and document distinguishing properties of UOC. This will be used for the assessment of the probable source of sample of material lacking any packaging or identifying marks. While this presentation focused on UOC, the lessons learned are equally relevant to a wide range of nuclear and radiological materials. Overall, this session highlighted a number of efforts to capture nuclear material and other radioactive material characteristics as a resource to support nuclear forensic analyses.

OUTCOME

As part of a comprehensive approach to a nuclear forensic capability, many States are embarking on establishing a national nuclear forensics library commensurate with nuclear material and other radioactive material used, produced or stored within the State. A key theme of the reports in this session was the experience of States in locating datasets for inclusion in a national nuclear forensics library to cover nuclear material accountancy information and nuclear fuel fabrication data, as well as front end nuclear material, with a focus on UOC.

CONCLUSIONS

A national capability in nuclear forensics often includes a national nuclear forensics library that reflects a State's current and past experience with nuclear material and other radioactive material used, produced or stored within the State. Several States have embarked on the establishment of a national nuclear forensics library; other States are contemplating development of the same. They see it as one possible tool to determine whether or not nuclear material or radioactive material encountered during a nuclear security event is consistent with their national experience using, producing or storing nuclear material and other radioactive material.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2E*

EXPERIENCES IN LABORATORY ANALYSES AND DATA INTERPRETATION

R. Chiappini
France

E. van Zalen
Netherlands

INTRODUCTION

Due the variety of nuclear material and other radioactive material encountered in the nuclear fuel cycle, a challenge for nuclear forensics is the need to potentially analyse milligram to gram sized quantities of uranium, plutonium and transuranics, as well as sealed and unsealed radioactive source materials.

Spent nuclear fuel can be analysed through reactor modelling codes to determine different types of candidate fuel and reactor. National laboratories in South Africa and the United States of America are collaborating on the analysis of a uranium rich sample recently seized in Durban, South Africa, in a coordinated operation. An aliquot of the seized material was transferred from South Africa to the Lawrence Livermore National Laboratory (LLNL), United States of America, following protocols and procedures outlined in Nuclear Forensics Support, IAEA Nuclear Security Series No. 2.

Investigation of actinide microparticles (micrometres in size) using nuclear forensic methods can provide examiners with very specific information about material characteristics. Material characteristics include the age of the material, homogeneity, as well as insight into the formation of the particles to potentially link perpetrators to unauthorized acts. The sizes, shapes and surface characteristics, as well as elemental composition (including impurities) of particles, the isotopic composition of uranium, plutonium and other radioactive elements, and a variety of isotope chronometers are all determined as part of the characterization of the particulate material using mass spectrometry, fission track detectors and secondary ion mass spectrometry.

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PAPERS

The ability to model the nuclear forensic signatures of spent nuclear fuel was presented by **G. Nikolaou (Greece)**. Using different feed enrichments, reactor configurations and simulated burnups, distinct spent fuel compositions were forecast through the use of three dimensional factor analysis computer models. Analytical data on uranium and plutonium compositions can be compared with the simulated cases for different reactor types to validate the accuracy of the model.

South African and US national laboratories described cooperation in joint nuclear forensic analyses of seized materials. **I. Hutcheon (USA)** described that a uranium bearing sample seized in South Africa was sent to LLNL for nuclear forensic analysis. The nuclear forensic examination plan for this sample included gamma ray spectroscopy, major and trace element composition, uranium assay by inductively coupled plasma mass spectrometry and mass spectrometry, isotope abundances for lead, oxygen, strontium and uranium, visible and near infrared spectroscopy, morphology and grain size, molecular structure and 'age' (time since the last chemical purification) to provide insights into the origin of the material.

The utility of nuclear forensic analyses of microparticles is important to exploit trace evidence, conduct pathways analysis of potential smuggling routes, provide specific indications of manufacture, and maintain a capability to analyse powdered samples. **V. Stebelkov (Russian Federation)** spoke of capabilities maintained by the Russian Federation for nuclear forensic analysis of individual microparticles (<0.2 μm). Microparticle analysis can provide law enforcement with information on the age of the material and processes likely involved in the formation of the particles. A range of measurements of these small samples can include measurements of the uranium and plutonium isotope ratios, elemental composition as well as radiochronometry (i.e. 'age dating'). Physical features also include the shape and sorting of particles for insight into the production history.

OUTCOME

Nuclear forensics is a capability to assist Member States to identify the origin and history of nuclear and other radioactive material out of regulatory control. While many seized samples consist of bulk, unirradiated materials, nuclear forensic analyses can also be applied to both irradiated materials as well as individual microparticles (micrometres in size). Multiple isotope measurements coupled with chemical analysis provide confidence in nuclear forensic conclusions. Cooperation between States in nuclear forensic case studies provides improved access to specialized facilities and methods to strengthen the course of a nuclear forensic examination.

CONCLUSIONS

A nuclear security infrastructure — to include nuclear forensics — may encounter a wide range of samples presenting various scales from milligrams to grams of uranium, plutonium in addition to sealed and unsealed radioactive materials that may require appropriate analysis. Both unirradiated and irradiated materials may be located. International cooperation can provide specialized and accurate techniques to allow efficient measurements of bulk samples of uranium, plutonium as well as actinide microparticles. The application of multiple measurements in case studies contributes to building confidence in the conclusions from a nuclear forensic examination.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2F*

EXERCISES AND COOPERATION

H. Le Quang
Viet Nam

J. Vaclav
Slovakia

INTRODUCTION

Nuclear forensic exercises ensure that a declared capability is able to meet the requirements set by the law enforcement and nuclear security infrastructure when needed by the State. Exercise scenarios employ data and hypothetical scenarios or use real world samples — all with realistic forensic investigation time constraints and reporting requirements. Through evaluations using anticipated reporting constraints and a realistic sequence of examination, exercises promote best practices in the field as well as evaluate and improve new technical capabilities, methods and techniques in order to promote nuclear forensic implementation.

Nuclear forensic exercises also build confidence in the forensic examination and are not necessarily proficiency based. Each stage, technique and method of a nuclear forensic examination which can affect the result is tested accordingly during an exercise. Comprehensive approaches to a nuclear forensic examination may require the contributions from a variety of subject matter experts.

PAPERS

H. Kroeger (Germany) emphasized that in cooperative exercises personnel from multiple authorities are needed to promote collaboration, team work and operational readiness. As part of this effort, he described ongoing radiological crime scene management exercises between the German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS), the Federal Criminal

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Police Office and the Federal Police. The exercises planned and executed under the framework of the Central Federal Support Group in Response to Serious Nuclear Threats typically focused on several distinctive elements, including:

— Practical procedures at the scene (e.g. decontamination procedures);
— Interoffice communication and coordination;
— Medical emergencies in a contaminated environment;
— General health and safety issues.

Based on the experience and best practices gained through these exercises, the BfS remains prepared to respond to a radiological emergency by defining roles and responsibilities by experience, actively training personnel to those predefined roles and responsibilities, and routinely exercising to foster coordination and teamwork.

J. Blankenship (USA) provided an overview of the technical activities of the Nuclear Forensics International Technical Working Group (ITWG) Evidence Working Group. The ITWG established the working group to address common issues with the collection, transport, analysis and reporting on evidence contaminated with, or consisting of, nuclear material and other radioactive material. Four tasks for the Evidence Working Group were established at the 2013 annual ITWG meeting in St. Petersburg, Russian Federation:

(1) To develop a document to discuss chain of custody and continuity of evidence;
(2) To develop a topical series of papers on the appropriate conduct of traditional forensic examinations of evidence contaminated by radionuclides;
(3) To develop a comprehensive, yet flexible, plan or framework for evidence collection;
(4) To develop an examination plan checklist to facilitate a stepwise path which ensures all essential points are identified and agreed upon by stakeholders.

Of these, tasks (1) and (2) will be prioritized.

J. Borgardt (USA) provided an overview of the Galaxy Serpent web based, tabletop exercise organized by the ITWG to promote the establishment of a national nuclear forensics library. The objective of this exercise was to promote best practices for developing and using a national nuclear forensics library. The exercise involved teams of scientists from various States and was conducted in two stages. In the first stage, each team used publically available spent fuel compositions to formulate their own national nuclear forensics. Then, in the second stage of the exercise, the teams were tasked with determining whether or not hypothetically seized spent nuclear fuel was consistent with their established national nuclear forensics library.

There were two notable observations and conclusions from the Galaxy Serpent exercise. First, many teams recognized the need to include additional areas of expertise, such as nuclear reactor engineers and nuclear fuel experts, in order to create a broader set of skills and expertise of the nuclear forensic community. Second, many teams noted that different technical approaches often yielded similar analytical conclusions.

The Galaxy Serpent exercise was very successful in demonstrating the utility of establishing a national nuclear forensics library. Further, some teams have used the experience gleaned from this exercise to inform their own national efforts to develop a national nuclear forensics library.

M.S. Zulkipli (Malaysia) provided a summary of the Tiger Reef regional workshop and nuclear forensic exercise held in Malaysia in February 2014. The Tiger Reef: Cross-Disciplinary Training and Tabletop Exercise, supported by Australia and New Zealand, focused on a safe, effective and efficient cooperative response to a crime scene involving nuclear material and other radioactive material. The workshop and exercise drew together more than 100 participants from 21 countries, primarily in South-East Asia and included the European Union and INTERPOL as official observers of the Global Initiative to Combat Nuclear Terrorism. Participants included experts from the crime scene management and the emergency response, health, and safety communities who worked to identify cross-disciplinary training opportunities and gaps for those communities. The event clearly illustrated the importance of training crime scene managers and response experts in each other’s fields to remove impediments to emergency response and to minimize the potential to compromise evidence. Tiger Reef ultimately reinforced the concept that a well trained and coordinated response will save lives and facilitate the identification of those responsible for perpetrating a nuclear security event. It identified key best practices of the participating partners in developing a national cross-disciplinary training programme.

The next steps include:

— Strengthening cross-organizational communication;
— Promoting a training programme (involving the IAEA and INTERPOL);
— Organizing other cross-disciplinary exercises in another region.

OUTCOME

Nuclear security exercises — including nuclear forensics — encompass a variety of operational scales, from an integrated broad respond to a radiological emergency, to a nuclear forensic collaborative material exercise, to bounded data interpretation exercises using a national nuclear forensics library. Identifying the roles and responsibilities of all those involved in a nuclear forensic examination is critical. The sessions highlighted that exercises provide an important diagnostic of readiness to reliably and rapidly apply nuclear forensics as part of a comprehensive response to a nuclear security event. International cooperation is an important condition to ensure the participation of States with limited resources in the full spectrum of nuclear forensic activities. The importance of conveying lessons learned after an exercise is imperative as well as the close cooperation between nuclear forensics and exercise elements as a part of fully integrated nuclear security infrastructure.

CONCLUSIONS

Regular exercises are crucial to evaluate the implementation and sustainability of nuclear forensics as a component of a comprehensive national response to a nuclear security event. Exercises build confidence in nuclear forensic solutions and are important to encourage the widest adoption by all States of nuclear forensics in support of law enforcement investigations and nuclear security vulnerability assessments.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 2G AND PANEL SESSION 2H*

INTEGRATION OF EXISTING NATIONAL RESOURCES INTO NUCLEAR FORENSIC CAPABILITIES

D. Hill
Australia

M. Sinaga
Indonesia

M. Curry
United States of America
(Moderator of Panel Session 2H)

INTRODUCTION

Nuclear forensics involves potential examinations of a range of nuclear material and other radioactive material representing the full spectrum of the nuclear fuel cycle as well as an array of radioactive sources used in medicine, industry and research.

In support of an investigation of an incident that involves nuclear material and other radioactive material nuclear forensic scientists may be requested to examine:

— A range of radioactive material that could represent the full spectrum of the nuclear fuel cycle;
— Radioactive sources normally used for medical, industrial or research purposes;
— Trace evidence associated with radioactive material.

Milligram to gram sized quantities of nuclear material and other radioactive material might constitute evidence at a nuclear security event and may have to be sampled as part of a nuclear forensic examination. For this reason, it is important

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for States to identify existing facilities, capabilities and experts that may be employed to receive and examine evidence in support of an investigation of a nuclear security event.

Having access to existing resources already maintained by the State that can be applied to nuclear forensics allows for an examination to quickly commence to determine what has been seized, associated threats and ensuing steps in the forensic investigation. Besides especially equipped nuclear science departments, non-destructive (e.g. gamma and X ray spectroscopy) and destructive equipment of analysis (e.g. alpha spectroscopy and inductively coupled plasma spectroscopy) maintained by emergency response organizations, nuclear operators, nuclear regulators or environmental monitors can be adapted for the purpose of nuclear forensics consistent with written procedures, trained personnel and calibrated equipment. Procedures for a nuclear forensic examination need to involve written procedures, and the use of standards and trained personnel.

Nuclear forensics is only one component of a national response plan. Harmonization with national laws that impose penalties for the unauthorized possession of nuclear material and other radioactive material is important to include forensic laboratories that can accept evidence contaminated with radionuclides.

The presentations in this session reported on the activities of Armenia, Canada, Japan and the Russian Federation to integrate nuclear science capabilities into national nuclear forensic capabilities. Following the technical session, a panel session was convened with **K. Pyuskyulyan (Armenia), F. Dimayuga (Canada)** and **N. Shinohara (Japan)** to discuss key themes of the presentations.

PAPERS

Canada recognized the importance of establishing a national nuclear forensic laboratory network following the 2010 Nuclear Security Summit. **F. Dimayuga (Canada)** described Canada’s formation of this network. This system consists of facilities for radioactive measurements, analytical chemistry (both isotopic and elemental compositions), physical characterization, optical and electronic microscopy, and surface and particle analysis, as well as having handling capabilities for nuclear material and other radioactive material. It is essential to involve law enforcement officials, forensic experts, scientists and policy makers throughout Canada in the establishment of the network.

The Russian Federation organizes forensics through its Ministry of Justice, Ministry of the Interior and Federal Security Service. Capabilities are wide ranging to include fingerprint analysis, biological matrices as well as anthropogenic microparticle analysis. **G. Kochev (Russian Federation)** stated that four organizations (Rosatom's Bochvar Institute, the V.G. Khlopin Radium Institute, the Federal Medical Biophysical Center and the Laboratory for Microparticle Analysis) provides specialized assistance in nuclear forensics. This includes measurement of isotopic, chemical and physical data characteristics — to include determinations of nuclear uptakes in the human body — that are required during a nuclear forensic examination. The combination of these specialized capabilities provides a comprehensive nuclear forensic capability at the national level.

N. Shinohara (Japan) described the development of nuclear forensic capabilities in Japan. The Japan Atomic Energy Agency has started a programme to support analytical measurements for nuclear forensics. This programme includes isotope ratio and trace element measurements, examination of microparticles, as well as uranium age dating. A prototype national nuclear forensics library is being created in parallel to the measurement capabilities. Japan recognizes the need for international cooperation to assist in these endeavours.

Armenia, in cooperation with international partners, has established a laboratory for technical and forensic analysis of nuclear material and other radioactive material. This initiative has been conducted in response to the threat from and potential for nuclear material and other radioactive material to be encountered outside of regulatory control. This new capability draws upon expertise available from the laboratory for radiation monitoring associated with the Armenian nuclear power plant. **K. Pyuskyulyan (Armenia)** noted that the laboratory is equipped with gamma spectroscopy and modest alpha spectrometry measurement capabilities. Incidents involving nuclear and other radioactive material out of regulatory control in Armenia are compiled in a newly established database. Additional activities include calibrated monitoring for illicit materials as well as orientation and the training of Armenian security service personnel and nuclear forensic examiners.

OUTCOME

Many States have well developed judicial systems with facilities capable of providing expert examination of trace evidence. However, the majority of these facilities do not have the required security or safety authorization basis that would allow for the examination of radioactive material or evidence contaminated by radionuclides. Similarly, States have laboratories that perform material characterization of nuclear material and other radioactive material, but the majority of such laboratories do not have methodologies that allow the appropriate examination of evidence for forensic purposes.

The development of an integrated, comprehensive and responsive national nuclear forensic capability uses a wide range of expertise across several diverse agencies and requires strong collaboration among law enforcement, policy makers, radiation scientists, forensic scientists and operational support teams. The process of building an integrated nuclear forensic capability has many steps, including, but not limited to:

- Identifying nuclear forensic capability requirements;
- Identifying and assigning national resources (laboratories, subject matter experts and radiation scientists);
- Developing action plans to address identified capability gaps;
- The development and delivery of course material for awareness raising, education and training of law enforcement personnel, policy makers and both nuclear and forensic scientists;
- The importance of regularly exercising the full national nuclear forensic capability through the planning and execution of operational activities and laboratory comparisons.

CONCLUSIONS

States are actively developing nuclear forensic capabilities in accordance with IAEA guidance as well as technical assistance from international partners that leverages existing resources in nuclear and radiation science. Using existing national nuclear science and forensic resources that were created and maintained for other purposes — but relevant for nuclear forensics consistent with written procedures, calibrated equipment, analytical standards and trained personnel — is an effective means to establish a national nuclear forensic capability. The presentations and ensuing panel session demonstrated that identifying and utilizing existing national nuclear science and forensic resources and other relevant resources is effective to develop and establish national capabilities in this field.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3A*

NUCLEAR FORENSIC SCIENCE: SIGNATURES OF NUCLEAR MATERIAL II

T. Fanghänel
European Union

S.B. Butt
Pakistan

INTRODUCTION

Nuclear forensics refers to the application of science — in particular nuclear science —within the forensic science field. It is no longer a concept but a working tool, although it is still regarded by some as an emerging discipline that connects nuclear science and forensic science. Nuclear forensics is currently used effectively and reliably to prevent and respond to nuclear security events which involve nuclear and other radioactive material out of regulatory control. Its applications are critical in nuclear security systems to determine the data characteristics (i.e. signatures) of nuclear material subject to law enforcement investigations. This session was dedicated to papers on nuclear material signatures that highlighted and presented current work and developments or future expectations demonstrating the potential of nuclear forensic science.

PAPERS

The evolution of nuclear forensics as a nuclear security capability has progressed since early reports to the IAEA of the seizure of high enriched uranium (HEU) and plutonium in the early 1990s. **S. LaMont (USA)** emphasized that the relationship between law enforcement and technical nuclear forensic communities has matured and become better coordinated in the last 20 years. Written procedures guiding nuclear forensic examination and the adoption of quality assurance protocols have become increasingly commonplace.

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While considerable attention has been focused in nuclear forensics on fresh nuclear fuels as well as reprocessed samples, less attention has been given to spent nuclear fuels. **É. Kovács-Széles (Hungary)** presented a means to correlate fission products and transuranic elements as well as use nuclear fuel burnup calculations to differentiate spent fuel originating from different reactors.

The study of uranium and plutonium microparticles using etched alpha track detectors is valuable for the identification of trace amounts of these actinides. **V. Stebelkov (Russian Federation)** described work underway that suggests the orientation and the shape of the alpha tracks can be used to determine the presence and identity of different uranium and plutonium microparticles at the scale of 2 μm for HEU and 0.2 μm for plutonium.

The reconstruction of a nuclear sample's process history provides insight into what and how data characteristics (signatures) become incorporated during manufacturing. Chemical processing history involves leaching and purification to extract uranium out of ore materials. **M. Wilkerson (USA)** investigated the morphology and chemical speciation of high purity uranium oxide powders (UO_2, U_3O_8 and UO_3) subject to different environmental temperatures and relative humidity in order to provide benchmark materials — with a known process history — that can be compared to real world samples.

OUTCOME

The effective use of signatures in nuclear forensic science has been driven by the acceptance by law enforcement of nuclear science as well as ongoing scientific advancements that enable microparticles and uranium oxides to be exploited to understand their process history. Advances in nuclear forensics support applied to law enforcement, the study of spent nuclear fuel samples to determine irradiation history, the measurement of uranium and plutonium in microparticles, identification of oxygen isotope signatures in uranium oxides and insight into the chemical history of processed uranium samples all provide new opportunities to extend the reach of a nuclear forensic examination to strengthen a nuclear security infrastructure.

CONCLUSIONS

Innovation drives nuclear forensic science. These advancements include measurements of actinide microparticles, correlation of fission products and other parameters in spent nuclear fuel, and reconstructions of the chemical processing history of uranium. Law enforcement officials could then apply these new methods and results to pursue criminal prosecutions in response to the unauthorized use of nuclear material and other radioactive material as well as to strengthen security throughout the entire nuclear fuel cycle.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3B*

NUCLEAR FORENSIC SCIENCE: SYNERGIES WITH OTHER DISCIPLINES I

M. Nizamska
Bulgaria

I. Roger
INTERPOL

INTRODUCTION

Scientific disciplines, including radiochemistry, provide a technical foundation for the science of nuclear forensics. In addition, analytical chemistry, pathology and nuclear material measurements all contribute to the technical spectrum encompassing a nuclear forensic capability. Subject matter experts versed in the former production of nuclear material may contribute to improved understanding of process streams of interest to a nuclear forensic examination.

PAPERS

Y. Panteleev (Russian Federation) of the V.G. Khlopin Radium Institute (KRI) reported how technical services and analytical capabilities, initially developed for use in the nuclear industry, can be leveraged for the assessment of nuclear material following a nuclear security event. Although first established in 1922, the KRI joined the IAEA Network of Analytical Laboratories in 1974. Therefore, the KRI has a long history of performing key nuclear industry tasks, including the development and application of highly sensitive, precision methods of nuclear material analysis and determination of radionuclide composition in material and environmental samples. The experience in analytical research and development, as well as the analytical methods and tools developed, allows the KRI to contribute to the assessment of nuclear forensic evidence from a nuclear

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security event and to provide an overview of methods available at KRI for obtaining analytical signatures of investigated nuclear material.

In the early 1990s, nuclear forensic science was borne out of the need to analyse nuclear material and other radioactive material to support the judicial process. The field of nuclear forensic science builds upon techniques, methods and tools in radiochemistry developed over 100 years. **P. Thompson (United Kingdom)** provided an overview of the history of radiochemistry in the century prior to 1990, and how these achievements were re-purposed and adapted to the new scientific discipline of nuclear forensics.

Mass spectrometry is an essential analytical technique for forensic analysis, as it can provide elemental and isotopic information of sample material. **K. Grabowski (USA)** described a novel hybrid analytical instrument system combining secondary ion mass spectrometry (SIMS) with accelerator mass spectrometry (AMS). This new system has been developed at the United States Naval Research Laboratory and improves the sensitivity and precision of measurements to determine isotopic distributions of actinides and lanthanides. The technology allows this instrument to overcome limitations that are encountered when these two techniques are performed separately. SIMS is often hampered by interference caused by molecular species, while AMS does not provide spatial information and requires the production and transmission of negative ions in the source (thereby limiting its sensitivity for nuclear forensics, since actinide and lanthanide elements preferentially generate positive ions). The hybrid SIMS–AMS system offers the potential to provide SIMS like particle analysis of nuclear material and other radioactive material without interference from other molecular species.

Raman spectroscopy is a fast and non-destructive technique that measures the vibrational spectrum of materials. The resulting spectra provide an indication of the chemical composition and symmetry, and can therefore assist in material identification. Micro Raman spectroscopy can be applied to the analysis of individual microscopic objects and offers better spatial resolution than other techniques, such as microinfrared spectroscopy and X ray microfluorescence. **F. Pointurier (France)** provided an overview of the nuclear forensic analyses that could be performed by micro Raman spectroscopy to include measurement of micrometric particles on container surfaces, bulk samples containing several compounds that require individual identification and trace evidence. In addition, he also discussed a new system that couples scanning electron microscope (SEM) imaging with micro Raman spectroscopy (SEM–MRS device) to obtain topographical, elemental composition and chemical information from the same location on a sample.

The results of forensic medical evidence drawing upon pathology studies with fatal and non-fatal outcomes can provide crucial information regarding the details of an inadvertent radiation exposure. **E. Granovskaya (Russian Federation)** described how various intake pathways of internal radiation exposure (i.e. inhalation, ingestion and contact through skin), uniform and non-uniform external radiation exposure, exposure time and elapsed time can be reflected by different forensic biomarkers (e.g. location and severity of lesions). An assessment of such forensic biomarkers observed on the body of an exposed person may provide:

— The diagnostics of radiation injuries;
— The determination of the elapsed time from exposure to nuclear material and other radioactive material;
— Radiation characteristics;
— An assessment of the dose and exposure duration.

OUTCOME

Nuclear forensic science is accelerating the development and application of highly sensitive and precise methods for the analysis of nuclear material in a variety of matrices and in all ranges of concentration. Nuclear forensics comprises elements of radiochemistry, nuclear physics and analytical science to include microanalysis, medical physics and nuclear manufacture. Understanding the relevant forensic applications within each of these disparate disciplines augments a nuclear forensic capability.

CONCLUSIONS

States are adapting former capabilities to the requirements of nuclear forensics. The intersection of nuclear forensics with other disciplines and technologies to include forensics pathology, analytical mass spectrometry and spectroscopy in addition to technical services supporting the nuclear industry provides opportunities to exploit new signatures as part of a nuclear forensic examination.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3C*

DATA COMPILATION TOOLS FOR SUPPORTING NUCLEAR FORENSIC INTERPRETATION II

S. Biramontri
Thailand

J. Salas Kurte
Chile

INTRODUCTION

This session continued with presentations (following Technical Session 2D) focused on the application of national nuclear forensics libraries as a data compilation tool for nuclear forensic interpretation.

PAPERS

The session began with a paper from **S. LaMont (USA)** presenting the guidance that the United States of America is developing for a State to consider when organizing a national nuclear forensics library. The guidance takes into account the extensive production steps encountered throughout the nuclear fuel cycle and, therefore, frames the level of effort required to construct a functional national nuclear forensics library early in the process. The size and complexity of the national nuclear forensics library is commensurate with the history and inventory of nuclear material and other radioactive material used, produced or stored by the State. This approach incorporates a scoping study to identify the nuclear and radiological activities within a State and which data already exist that may be useful to the development of a national nuclear forensics library. When gaps have been identified, the approach seeks to develop a strategy to provide necessary information. The paper also notes the need to estimate the level of effort required to produce a functional national nuclear forensics library.

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Y. Kimura (Japan) detailed Japan's efforts to develop a prototype national nuclear forensics library based on data relating to nuclear material and other radioactive material maintained by the Japan Atomic Energy Agency (JAEA). A primary objective for the JAEA national nuclear forensics library project was to develop an evaluation methodology for interpretation enabling nuclear material attribution. A description of the prototype JAEA database includes its basic data handling capabilities.

D. Chamberlain (USA) presented the progress the United States of America has made in developing a database of radioactive sources and their signatures, which could be used to identify specific source manufacturers in the context of nuclear forensics. Some of the data captured in the database include the construction, dimensions and weld details of radioactive sources. In addition the database incorporates elemental composition and isotopic abundances of the radioactive material used in these sources to allow age dating to identify the time of production. Data collection includes open source information from vendor catalogues and web pages, discussions with source manufacturers (protected through non-disclosure agreements), and government registries such as the United States Nuclear Regulatory Commission's Sealed Source and Device Registry.

To conclude the session, **G. Kochev (Russian Federation)** detailed a number of concerns relating to the usefulness of a national nuclear forensics library and its ability to definitely attribute radioactive material out of regulatory control relative to its origin and history. Processes that are conducted within a nuclear facility introduce variations within original nuclear material and databases, which may not be captured in a national nuclear forensics library. Information sharing among unauthorized parties within a proposed national nuclear forensics library structure may pose a security risk. In addition, a national nuclear forensics library might only be used for purposes of excluding nuclear material and other radioactive material from further investigation that have data characteristics inconsistent with those contained within the library. The paper presented an alternative approach which focused on the involvement of subject matter experts to examine the characteristics of seized materials. These experts may be able to determine the possible origin for seized material using their familiarity with nuclear processing facility operations.

OUTCOME

A national nuclear forensics library is an organized collection of information designed to assist States to determine whether or not seized material is consistent with the materials used, produced or stored within the State. A national nuclear forensics library is one of several possible ways for States to make such comparisons; many States have now embarked on establishing such a library.

CONCLUSIONS

The experience of States that have developed a national nuclear forensics library is valuable to other States that are contemplating developing such a library as one possible means to assist in determining the origin and history of nuclear material and other radioactive material. Information relevant to a national nuclear forensics library may already exist within the States, having been collected at other times for other purposes. A national nuclear forensics library is one possible way for States to help ensure the security of nuclear material and other radioactive material for which they are responsible.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3D*

NUCLEAR FORENSIC SCIENCE: RADIOCHRONOMETRY

K. Peräjärvi
Finland

M.B.L. Ong
Singapore

INTRODUCTION

This session focused on the outcomes of recent investigations at institutes specialized in the nuclear forensic age dating of nuclear material and other radioactive material. These innovative findings underscore the importance placed on the accurate measurements of the age of nuclear material and other radioactive material — the time of last radiochemical purification — as a critical tool for understanding material origin and history.

PAPERS

R. Williams (USA), from the Lawrence Livermore National Laboratory, United States of America, presented research on the improved accuracy and precision of model dates bearing on the time of purification of nuclear material during its manufacture. Measurement of parent–daughter pairs ^{234}U–^{230}Th, ^{235}U–^{231}Pa, ^{241}Pu–^{241}Am, ^{137}Cs–^{137}Ba and ^{90}Sr–(^{90}Y)–^{90}Zr can be used to determine the model dates of nuclear material and other radioactive material important for nuclear forensics. Improvements in the determination of the model dates are possible through the analytical sensitivity and precision afforded mass spectrometric methods. The accuracy of mass spectrometry applied to nuclear forensic analysis requires the use of reference materials for calibration and spike materials used as part of an isotope dilution. The decay constant of the measured radionuclide also has to be accurate. Improvements to measurement precision

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require enhanced signal to noise ratios, incorporating instrumental methods and chemical purification of the sample. The United States of America is producing new certified reference materials for uranium–thorium and caesium–barium radiochronometers as well as analytical spikes (^{243}Am, ^{134}Ba, ^{236}Np, ^{229}Th and ^{233}U). This initiative is conducted in order to improve age dating as part of a nuclear forensic examination.

Analytical laboratories are maintained at the DAM Île-de-France of the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique, CEA/DIF) for bulk and particle analysis. These laboratories are now being used for nuclear forensic purposes. **A. Hubert (France)** reported that current priorities include age dating of uranium materials and the geolocation of uranium ore concentrates. For age dating micrograms of uranium, ^{234}U–^{230}Th and ^{235}U–^{231}Pa radioactive couples are used. Measurements of thorium and protactinium are performed using inductively coupled plasma mass spectrometry. Uranium is measured by thermal ionization mass spectrometry. Detection limits for ^{230}Th and ^{231}Pa are close to 1 femtogram (10^{-15} g). These detection limits also have implication for highly accurate and precise age measurements of particles.

The use of ^{231}Pa to date the age of last processing of nuclear material relies on the radioactive alpha decay of ^{235}U to ^{231}Pa. The Australian Nuclear Science and Technology Organisation (ANSTO) is developing a means to measure ^{231}Pa and apply this to nuclear forensics. **E. Keegan (Australia)** provided a description of technical procedures developed at ANSTO to produce ^{233}Pa spike for measurement of ^{231}Pa by mass spectrometry. This process enables this new chronometer to be used for nuclear forensic analysis.

L. Lakosi (Hungary) of the Centre for Energy Research of the Hungarian Academy of Sciences discussed the methods of uranium age dating using gamma spectroscopy based analysis of ^{214}Bi/^{234}U using direct measurements. This technique utilizes the direct measurement of count rates of ^{214}Bi and ^{234}U by low background gamma spectroscopy. The advantage of this technique is that it is non-destructive and does not require the use of any reference standard. This approach was tested using both uranium metal and oxide of enrichments from 4.4% to 90% ^{235}U enrichment. Challenges related to the analysis of low enriched or young aged uranium (with lower amounts of ^{214}Bi) were identified.

OUTCOME

Age dating provides information important to nuclear forensics. Indeed, age determination provides information on the time of the last chemical purification of a nuclear or radioactive sample. Research into using highly accurate mass spectrometry and counting techniques allows new radiochronometers to be exploited for nuclear forensic analysis — particularly for high enriched uranium. The availability of new standards and isotopic spikes strengthen the confidence in new age dating tools. This includes ^{235}U–^{231}Pa and ^{234}U–^{214}Bi chronometers. Confidence in the results of age dating is improved by using simultaneously several age dating pairs for the identification of a common sample or set of samples.

CONCLUSIONS

The session highlighted the importance of radiochronometry as a means for nuclear forensic examiners to understand the production and history of nuclear material and other radioactive material. New high abundance sensitivity instrumentation as well as novel analytical strategies and chemical processing of samples show promise to advance age dating of nuclear material measurements. This depends firstly on the decay characteristics of the parent and daughter radionuclides and secondly on the precision and accuracy desired by the nuclear forensic laboratory. Either mass spectrometry or gamma ray spectroscopy techniques may be successfully employed in age dating measurements.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3E*

CONFIDENCE IN NUCLEAR FORENSIC FINDINGS

R. Mogafe
South Africa

P. Chakrov
Kazakhstan

INTRODUCTION

Nuclear forensic findings reflect the confidence placed in the measurement of nuclear material and other radioactive material data characteristics (i.e. signatures) and the ensuing interpretation of these results. The level of confidence depends upon the quality assurance system and quality control procedures of the laboratory, including the use of validated methods, certified reference materials and demonstrated competencies. Ensuring these factors are in place allows for improved reliability and defensibility of the findings, which is essential because the findings may be used as evidence in a court or to identify nuclear security vulnerabilities.

In order to improve confidence in nuclear forensic findings, nuclear forensic scientists are validating methods, developing appropriate certified reference materials, and implementing appropriate quality assurance management systems. These efforts will improve both the defensibility of the findings as well as the sustainability of national nuclear forensic capabilities.

PAPERS

The need for standard reference materials to support a nuclear forensic examination is an important requirement to build confidence in conclusions originating from the measurement laboratory. **L. Tandon (USA)** described efforts to develop well characterized reference materials. These efforts contribute to ensuring the quality of analyses conducted in the nuclear forensic laboratory as well as to obtaining the accreditation of laboratory proficiency.

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Age dating is a powerful tool for the nuclear forensic scientist to determine when nuclear material was last chemically purified. In order to conduct defensible measurements, dedicated reference materials for age dating are required. **Z. Varga (European Union)** described the preparation and validation of an age dating standard based on the $^{230}Th/^{234}U$ chronometer. Measurement of the standard by independent laboratories is required to establish the applicability of these methods to include preparation of this uranium age dating standard.

C. Venchiarutti (European Union) presented work on uranium age dating standards based on the $^{230}Th/^{234}U$ chronometer. Important in the production of this standard was the elimination of any thorium from the sample to subsequently allow for the ingrowth of the daughter products from the decay of the uranium parent alone. After laboratory intercomparison, this standard will be available to interested nuclear forensic laboratories.

Independent quality assurance accreditation, a laboratory information management system and qualification as part of the IAEA Network of Analytical Laboratories help Canadian analytical laboratories meet the criteria to join a national nuclear forensic laboratory network. **M. Totland (Canada)** described the efforts of Atomic Energy of Canada Limited to satisfy national technical expectations for networked nuclear forensic laboratories.

OUTCOME

Nuclear forensics requires the highest confidence in conclusions, since it supports law enforcement investigations leading to a potential criminal prosecution as well as consequential nuclear security vulnerability assessments within the State as well as, in some cases, internationally. The use of standard reference materials, laboratory information management systems as well as external proficiency based laboratory quality accreditation provides assurances that the nuclear forensic laboratory is performing reliably.

CONCLUSIONS

Quality assurance systems and quality control procedures within the nuclear forensic laboratory need to be both initiated and sustained to ensure full confidence in the findings from nuclear forensic examination. A national nuclear security infrastructure reflects, in part, the strength of conclusions from a nuclear forensic examination since determinations of courts of law and policy makers are predicated on knowledge of the level of confidence that accompanies these findings.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3F*

NUCLEAR FORENSIC SCIENCE: SYNERGIES WITH OTHER DISCIPLINES II

I. Mirsaidov
Tajikistan

A. Álvarez García
Spain

INTRODUCTION

Nuclear forensic science is a relatively new discipline but may be traced to many older and established branches of science and technology. The aim of nuclear forensics is to categorize and characterize seized nuclear material and other radioactive material, to determine the origins and intended use of the materials, and to provide evidence for a potential criminal prosecution. Often existing and proven analytical techniques from other disciplines, such as radiochemistry and traditional forensics, are used to extract such information from the seized radioactive material or evidence contaminated with radionuclides. In addition, new approaches, applications and techniques may be developed to improve nuclear forensic conclusions.

The session first summarized recent work using nanoscale morphology and sample impurities as nuclear forensic signatures. The session continued with a report on the use of laser ionization time of flight mass spectrometry to acquire rapid uranium isotope ratios. The session concluded with the presentation of the results and progress of two IAEA coordinated research projects, aimed at the application of nuclear forensics in combating illicit trafficking of nuclear material and other radioactive material.

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PAPERS

G. Eiden (USA) explained that high abundance sensitivity measurements of actinide ratios are essential to the nuclear forensic analysis of nuclear material. A new generation of inductively coupled plasma mass spectrometers features a multi detector array specifically designed and dedicated to the measurement of isotope abundances of actinides. These new instruments allow for precise measurements of ^{234}U and ^{236}U even on small abundance samples. In addition to conventional solution based on the introduction of samples, these instruments can also enable laser ablation sample introduction methods as a novel means to measure the isotopic abundance of surfaces and small particles.

The Nuclear Forensics International Technical Working Group has conducted collaborative material exercises involving analysis of nuclear material as a means to promote technical collaboration among official nuclear forensic practitioners with an emphasis on the nuclear forensic laboratory. These exercises are designed to be learning experiences rather than performance based tests. Three collaborative material exercises have been completed over the past 15 years and a fourth is now planned. **J. Schwantes (USA)** described the preparations for the fourth collaborative material exercise that will involve the ability to rapidly and accurately categorize low enriched uranium, exploit material characteristics in addition to isotopes, and apply the forensic results to identify a likely facility of origin. The objective of this latest exercise is to improve international analytical methodologies, cooperation and communication centred on nuclear forensic analysis.

Advancements in the field of nuclear forensics rely upon the consistent implementation of existing analytical techniques in concert with the development and validation of novel methodologies. To further enhance nuclear forensics and its application in combating illicit trafficking of nuclear material and other radioactive material, the IAEA promotes innovative research and development related to nuclear security through coordinated research projects (CRPs). **T. Bull (IAEA)** provided an overview of two CRPs in the field of nuclear forensics. The first CRP (conducted 2008–2012) focused on the requirements for measurement of seized materials, as well as techniques to collect and preserve forensic evidence. It also concentrated on the improvements to interpretive capacities for law enforcement response in the context of nuclear security. The second CRP (commenced in 2013 and currently in progress) is focused on data that may be used in the development of a national nuclear forensics library or associated databases. This second CRP also supports the promotion of research into novel signatures indicative of material production processing and explores how these signatures are imparted, persist or modified throughout the nuclear fuel cycle.

OUTCOME

Common themes on the role of science to enable nuclear forensics:

(a) Nuclear forensic science is built on the established disciplines of nuclear chemistry, radiochemistry and traditional forensics.
(b) There are benefits from the advancements in many related disciplines, such as nuclear chemistry, radiochemistry and spectrometry techniques.
(c) Research and innovation drives the advancement of nuclear forensics. New instrumentation enables reliable measurement of data characteristics reflecting the origin and history of nuclear material and other radioactive material.
(d) Nuclear forensic analysis invites international scientific collaboration and cooperation.

CONCLUSIONS

The discipline of nuclear forensic science is built on and borrows from the established disciplines of nuclear chemistry, radiochemistry and traditional forensics. Nuclear forensics continues to benefit from developments in these and other fields of science and technology. In particular, analytical science represents a ‘common language’ among States to further international scientific collaboration and cooperation in nuclear forensics.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 3G*

NUCLEAR FORENSIC AWARENESS AND EDUCATION

A. Farhane
Morocco

F. Dimayuga
Canada

INTRODUCTION

Awareness and education are important elements of a sustained nuclear forensic capability. By clearly articulating the requirements for an effective nuclear forensic examination, roles and responsibilities can be identified. Developers of the technical capability can be then oriented appropriately and common approaches can be utilized to increase confidence in nuclear forensic conclusions. Education and training is essential to ensure that the nuclear forensic evidence is collected and analysed to support law enforcement investigations and nuclear security vulnerability assessments.

PAPERS

I. Hutcheon (USA) described the creation of the Confidence Building Measures Program, within the Office of Nonproliferation and International Security of the United States Department of Energy's National Nuclear Security Administration. This programme will foster efforts in international engagement to develop and enhance indigenous capabilities in nuclear forensics. The paper focused on development of the nuclear forensic capabilities in the South Africa to include:

(a) The signing of a memorandum of understanding between the South African Nuclear Energy Corporation (Necsa) and the Lawrence Livermore National Laboratory, United States of America;

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(b) The creation of a regional centre of excellence;
(c) Human resource capacity building;
(d) Establishing the dedicated cleanroom facility;
(e) Nuclear forensic database development.

G. Moore (USA) highlighted the impact of numerous nuclear forensic awareness training organized in different States. These trainings targeted different audiences: decision makers, scientists, diplomats and law enforcement officials. Nuclear forensics training is usually aimed at the technical community. Therefore, the critical challenge is to present the specialized topic of nuclear forensics to students without a scientific education or technical experience.

S. Connelly (USA) reported that the National Nuclear Forensics Expertise Development Program serves across the US Government to educate and sustain the qualified technical expertise required to execute the State's nuclear forensic mission. Through its fellowship, scholarship, junior faculty and education development initiatives, the programme links next generation scientists with technical experts at laboratories. This programme aims at facilitating critical knowledge transfer and at establishing a seamless pipeline from academia into an attractive career in nuclear forensics through practical research experience and individual mentoring.

Australia provided results from its participation in the Nuclear Forensics International Technical Working Group Galaxy Serpent national nuclear forensics library tabletop exercise. This exercise contributed important lessons and experience useful to the establishment of a national nuclear forensics library. **K. Smith (Australia)** described that a national nuclear forensics library may be supported by common spreadsheet software tools. She then stated that multivariate analysis can augment the interpretative capabilities of the software packages. She also emphasized that the use of common SI units aids in the dissemination of the results within the technical community. Finally, she noted that assumptions introduced to aid participants in the design of the exercise may not reflect circumstances encountered during the response to a nuclear security event.

OUTCOME

Awareness and understanding of nuclear forensics by specialists and non-specialists alike is essential. Having informed and trained personnel ensures the highest confidence in nuclear forensic conclusions. Nuclear science research and collaboration relevant to nuclear forensics between universities and nuclear science institutes and laboratories ensures that the next generation of experts can maintain nuclear forensics within a nuclear security infrastructure. Exercises help in promoting a comprehensive national capability by assembling diverse subject matter experts to work together on nuclear forensic analysis and interpretation using available national capabilities.

CONCLUSIONS

Due to its multidisciplinary nature, nuclear forensics is a multifaceted science that combines elements of both law enforcement and nuclear science. Therefore, education and training of those participating in a nuclear forensic examination is imperative. Training provides specialized guidance in nuclear forensic implementation, while education advances the state of practice through the development of novel concepts and inventive methods. Practical arrangements, centres of excellence and exercises that include nuclear forensics can facilitate the provision of advanced methods tailored to specific nuclear security needs within a State or a region.

CO-CHAIRS' SUMMARY OF PANEL SESSION 3H*

NUCLEAR FORENSIC SCIENCE: THE NEXT FIVE YEARS

W. Huang
China

S. Clark
United States of America

INTRODUCTION

A nuclear forensic examination exploits measurements of physical characteristics, chemical and elemental composition and isotopic ratios (i.e. data characteristics or signatures) from nuclear material and other radioactive material. These measurements provide information on the origin and history of these materials in the context of law enforcement investigations and nuclear security vulnerability assessments. The ability to provide information on material origin and history is dependent on the ability to make accurate bulk and microscale analytical measurements. These insights also depend upon the capacity to correctly interpret these results relative to the incorporation and persistence of these signatures into the materials during manufacture or transport. Useful nuclear forensic signatures are predicated on the science that enables accurate and precise analysis as well as the means to interpret measured variations and profiles.

The focus of this panel session was discussion of priorities to support the advancement of nuclear forensic science for the next five years. Panellists identified the following challenges for the next five years:

(a) Continued development of human resources;
(b) Advancement of new analytical tools and methods;
(c) Consideration of how to sustain technical nuclear forensic capabilities;
(d) Strategic international engagement.

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These efforts should be focused on the identification of new signatures, validation of new analytical methods, and continued support for the establishment of domestic libraries to aid in nuclear forensic interpretation.

PANEL DISCUSSION

Invited panellists comprised senior nuclear forensic scientists representing leading institutes from around the world. The panel consisted of **T. Fanghänel (European Union)**, **K. Smith (Australia)**, **V. Stebelkov (Russian Federation)**, **R. Mogafe (South Africa)**, **P. Thompson (United Kingdom)** and **D.K. Smith (IAEA)**. Brief comments were made by the panellists followed by a moderated discussion with the delegates. In addition, the Scientific Secretary, D.K. Smith, introduced an interactive exercise to explore the science base supporting nuclear forensics and to identify nuclear forensic priorities going forward from the international conference.

OUTCOME

An interactive exercise involved anonymous survey responses to questions posed by the conference Scientific Secretary, D.K. Smith, to all the conference delegates. The survey intended to explore the nature of the science and technology base that supports nuclear forensics. It also enquired into technical priorities and suggestions for synergies with other scientific fields relevant to nuclear forensics. For the science and technology base supporting nuclear forensics, the response from the conference delegation suggests that traditional forensic laboratory and environmental laboratory capabilities are generally well developed. This is also true for nuclear science research and development. On the contrary, understanding and study of the nuclear fuel cycle in the context of nuclear forensics is an area for which few States have identified technical capabilities. Therefore, this latest element represents an important scientific opportunity in the upcoming five years. The conference delegation identified the following topics with equal priority going forward:

(a) Education and training;
(b) Nuclear forensic exercises;
(c) Nuclear forensic research and development;
(d) Optimization of laboratory resources.

These areas are mutually complementary — for example, exercises can inform education and training needs while research and development can support laboratory optimization. Additional technical areas relevant to nuclear forensics identified by conference delegates include geology and geochemistry, materials science, nuclear engineering and environmental science related to radioactive waste disposal. It was further noted that scientific peer review serves the valuable purpose of building scientific credibility in nuclear forensic science methods and techniques. Scientific acceptance is important, since nuclear forensics results need to be accepted by a court of law within the context of a law enforcement investigation involving a criminal prosecution.

CONCLUSIONS

An additional area for discussion in this session was the distinction between nuclear forensics and nuclear safeguards. From the perspective of the IAEA, the two programmatic capabilities are separate, since safeguards and nuclear security each have a different and unique international legal foundation. The commonality between the two areas resides with the analytical tools and methods applied to measurements of the nuclear fuel cycle. If managed effectively, this synergy can strengthen the technical foundations for both areas. The panel also focused on the importance of validation of new and existing analytical tools and methods. Since nuclear forensics services law enforcement, the technical information supporting legal evidence and crime scene investigations has to be admissible in a court of law. Finally, the session undertook to clarify the roles of agencies such as the IAEA and organizations such as the Nuclear Forensics International Technical Working Group relative to the provision of nuclear forensic technical assistance. For example, the IAEA reiterated that it does not conduct nuclear forensic examinations. Instead, however, the IAEA supports the Member States in their efforts to develop their own national capabilities using existing technical and human resources.

CO-CHAIRS' SUMMARY OF TECHNICAL SESSION 4A*

INTERNATIONAL AND REGIONAL COOPERATION IN NUCLEAR FORENSICS

S.-C. Kim
Republic of Korea

É. Kovács-Széles
Hungary

INTRODUCTION

Reports to the IAEA of nuclear and other radioactive material out of regulatory control indicate that:

(a) Unsecured nuclear material and other radioactive material remain available.
(b) Border control measures are effective in detecting illicit trafficking, although border monitoring is not uniformly implemented.
(c) Individuals and groups are prepared to engage in trafficking these materials.

Because illicit trafficking persists as a transboundary concern, international and regional cooperation is essential. Harmonized and consistent awareness and understanding, regulation and state of practice strengthen the global nuclear security regime. Regional approaches to include nuclear security centres of excellence are effective mechanisms that will provide nuclear forensic solutions to prevent and respond to incidents of illicit trafficking.

PAPERS

The European Commission's chemical, biological, radiological or nuclear (CBRN) Action Plan and CBRN Risk Mitigation Centres of Excellence bring cross-border cooperation and consistent approaches to the conduct of a nuclear forensic examination within a response plan both in Europe and with

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international partners. **Z. Pajalova (European Union)** presented the European Commission's priorities for the implementation of nuclear forensic activities. These priorities include training, research, and systemic guidelines on best practices for implementation through the EU CBRN Action Plan and Centres of Excellence projects.

H. Dion (USA) of the Confidence Building Measures Program of the National Nuclear Security Administration (NNSA), United States Department of Energy, spoke of the cooperation between the United States of America and the IAEA. She also described the NNSA programme of engagement with individual States to bring the appreciable technical strengths and science of the US national laboratories to improve the nuclear forensic state of practice. Scientific collaboration enables regional cooperation. As an example of a successful area of technical cooperation using science as a tool for engagement, radiochronometry (i.e. age dating) studies of uranium bearing materials facilitates international technical exchange and collaboration.

Regional approaches to implement nuclear forensics have proved successful in South-East Asia. The Association of Southeast Asian Nations (ASEAN) Regional Forum provided an engagement platform for a collaborative programme involving the Joint Research Centre and the NNSA. **J. Galy (European Union)** described the current focus on nuclear forensic awareness, the introduction of a national response plan, fundamentals of nuclear forensics in support of an investigation, and opportunities for further regional and international cooperation.

OUTCOME

The session highlighted the effectiveness of regional cooperation to improve the nuclear forensic state of practice through shared experience and confidence building. Examples from the session highlighted successful approaches in the Caucasus and South-East Asia. Nuclear forensics combines elements of analytical methodologies, forensic science and nuclear science. This multidisciplinary aspect of nuclear forensics contributes to foster regional and international collaborations. Centres of excellence are well positioned as a bridge to provide regional nuclear forensic solutions.

Working with States using existing technical capabilities and infrastructure, a key element in cooperative strategies is sharing experiences in establishing nuclear forensics to combat incidents of nuclear material and other radioactive material being diverted out of regulatory control. A regional focus in the Caucasus and South-East Asia has proved successful by ensuring that partners can work peer to peer. In these particular cases, necessary capabilities and, training, exercises, techniques and research activities were shared. This has contributed to confidence in implementing nuclear forensics as part of a nuclear security infrastructure.

Presenters reminded the audience that there are many resources available internationally and regionally to develop nuclear forensic capabilities.

CONCLUSIONS

Combating illicit trafficking of nuclear material and other radioactive material is a global problem that benefits from effective national, regional and international cooperation. This cooperation enables nuclear forensics to support criminal prosecution as well as to improve the nuclear security regime. Confidence building requires shared experiences and harmonized guidance to develop and maintain a nuclear forensic capability. Regional cooperation enables peer to peer exchanges incorporating tailored nuclear forensic solutions that result in real improvements to nuclear security. Nuclear forensics can also be built in as States contemplate a civilian nuclear energy programme.

Like any scientific discipline, nuclear forensics requires practitioners to share best practices and lessons learned, and one of the best ways to do this is through international partnerships and collaborations. The session also discussed how regions can work together to help to build nuclear forensic capabilities that can be used to support the whole region. This means of cooperation can help with sustainability, since it is likely that no single State in a particular region will need to implement nuclear forensics on a regular basis. However, regional cooperation will still allow for the capability to be available for the States whenever support to nuclear security objectives is required.

CHAIRS' SUMMARY OF ROUND TABLE SESSION 4B*

NUCLEAR FORENSICS: WHERE SCIENCE MEETS POLICY

K. Mrabit
IAEA

INTRODUCTION

Nuclear forensic awareness and understanding are crucial for both policy makers and technical experts. It is vitally important for the policy community to understand what shapes confidence in nuclear forensic conclusions. This includes demonstrated competencies, good quality management, written procedures, and the use of calibrated equipment and standards. Advancements in technology have made the science much more robust and increased the ability of nuclear forensics to identify nuclear and other radioactive material out of regulatory control. It is essential that policy makers understand how to use these advancements to meet policy goals. Similarly, policy makers should understand the inherent limits of technology and science to avoid overestimating the effect of techniques within overall nuclear security practice.

It is also urgent that technical experts understand the policy and security needs for nuclear forensics in order to adapt their research and development efforts to policy objectives. It is not only the instrumentation, but rather how it is used that determines the contribution of a nuclear forensic examination towards deterring or responding to a nuclear security event. The most sophisticated instrumentation or nuclear forensic laboratory is of little value for the purposes on law enforcement investigation of nuclear security vulnerability assessments if it is not used to formulate defensible scientific data as part of a nuclear forensic examination.

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ROUND TABLE DISCUSSION

Invited members of the round table consisted of senior policy makers that have relied upon nuclear forensics to make informed decision in support of law enforcement investigations, improvements to nuclear security and as a mechanism for regional and international cooperation in nuclear security. **W. Huang (China)**, **HE G. Berdennikov (Russian Federation)**, **HE G. de Salazar Serantes (Spain)**, **A. Harrington (USA)** and **J.M. Palma López (AMERIPOL)** all recognized nuclear forensics as a critical component of a State's nuclear security infrastructure. Indeed, nuclear forensics may deter malicious acts involving the unauthorized use of nuclear material and other radioactive material. Furthermore, nuclear forensics assists States to strengthen nuclear security measures.

OUTCOME AND CONCLUSIONS

The participants recognized that there are substantial challenges at the national and international levels for the coordination and cooperation of effective nuclear forensic implementation. Owing to the multidisciplinary and technical nature of nuclear forensics, States should consider ensuring coordination, cooperation, and awareness among policy makers, law enforcement, and technical experts in order to develop and sustain nuclear forensics within a nuclear security infrastructure. Political commitment is essential: there is a need for policy makers to support and maintain technical expertise as well as communicate policy needs to the technical community. In return, it is essential that law enforcement and technical experts regularly report to the policy making community on the capability situation. National policies supporting nuclear forensics are also essential and can be as complex as the science itself.

The participants took note that nuclear forensic capabilities require neither expensive investments nor an extensive bureaucracy. Existing capabilities already implemented and maintained by the State in other disciplines and institutions may be used for nuclear forensic examinations as described in Nuclear Forensics Support, IAEA Nuclear Security Series No. 2, published in 2006, and the revised publication, entitled Nuclear Forensics in Support of Investigations, IAEA Nuclear Security Series No. 2-G (Rev. 1), to be published in 2015. These existing capabilities for the analysis of nuclear material and other radioactive material may be found in nuclear research institutes, technical support organizations and universities. Finally, nuclear operators or producers and environmental monitors or regulators can also provide capabilities.

Once developed, a security infrastructure to include nuclear forensics needs to be sustained. This involves regular exercises of all facets of the examination process — from evidence collection and analysis, to interpretation and reporting. Establishing programmes in education and training is essential to ensure logical progression of building nuclear forensic expertise. This expertise particularly needs to be developed within the realms of analytical science, nuclear engineering to forensic science. This will ensure that the next generation of experts have a solid foundation and their ensuing research is the key to enable the science of signatures.

The work plan and communiqué developed during the 2010, 2012 and 2014 Nuclear Security Summits and statements from the IAEA International Conference on Nuclear Security: Enhancing Global Efforts convened in 2013 emphasized the increasing commitment of States in developing nuclear forensic capabilities. However, nuclear forensic capabilities exist primarily with developed States. There is a need for developed States and the international community to support developing States in obtaining appropriate nuclear forensic capabilities as well. International initiatives, such as the Global Initiative to Combat Nuclear Terrorism, and international organizations, such as the IAEA, have the capacity to assist in diversifying this effort.

Systematic, comprehensive and harmonized approaches are critical and will support the international community in the development of consistent nuclear forensic examinations. In this regard, the IAEA has a strong track record of developing appropriate and harmonized guidance. The IAEA has also a wealth of experience in education and training, coordinated research projects, peer reviews and advisory services useful for the implementation of nuclear forensics into national programmes.

A path forward is necessary to set strategic priorities for nuclear forensics. A future conference, or other international forum, may be beneficial to encourage the widest possible implementation of IAEA and related international guidance in nuclear forensics. Exercises, meetings, and technical exchanges should continue to be supported to promote the state of nuclear forensics globally. The policy, technical, and law enforcement communities should consider addressing challenges on how to share sensitive law enforcement and technical information. Nuclear forensics should be emphasized as an important capability to assist States in meeting their nuclear security responsibilities. Nuclear forensics has now emerged as a global nuclear security imperative.

SUMMARY OF POSTERS*

POSTER SESSION I

INTRODUCTION

The posters presented in Poster Session I were organized into four topical areas: nuclear forensic frameworks, national capabilities, material out of regulatory control, support to investigations, exercises and training.

POSTERS

Nuclear forensic frameworks

Currently, there are several multilateral efforts that are intended to engage nuclear forensics as a key component of nuclear security. **A. Farhane (Morocco)** reviewed the effectiveness of the multilateral efforts in enhancing the role of nuclear forensics in nuclear security and explored new strategic orientation and future implementation of these efforts to strengthen nuclear forensics in the context of an international nuclear security regime.

National capabilities

In Slovakia, **J. Vaclav (Slovakia)** reviewed the history of developing nuclear forensic capability, including a partnership with the Joint Research Centre's Institute for Transuranium Elements, using the context of several seizures natural uranium and uranium fuel pellets.

The Egyptian framework for nuclear forensics was described by **A. Ahmed Tawfik (Egypt)**, who presented an approach based on nuclear material control and accountability and implemented by the Nuclear and Radiological Regulatory Authority.

D. Apriliani (Indonesia) described the Indonesian approach of identifying existing capabilities for nuclear forensics within Indonesia. He also portrayed how Indonesia is re-purposing these capabilities for nuclear security in line

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with IAEA recommendations and guidance. The presentation also included a description of the Indonesia Center of Excellence on Nuclear Security and Emergency Preparedness.

R. Reyes (Philippines) presented the development of the Philippine Nuclear Security Plan (PNSP). He also exposed the PNSP direction for the development of a nuclear forensic capability supporting law enforcement authorities. The poster highlighted engagements with international partners that have enhanced existing capabilities.

A. El-Jaby (Canada) provided an overview of the process that the Government of Canada has undertaken to identify the gaps in its current nuclear forensic capacity to respond to radiological and nuclear threats. He also exposed the objectives and scope of the Canadian National Nuclear Forensics Capability Project, including the development of a national dedicated laboratory network for comprehensive nuclear forensic analysis and a national nuclear forensics library.

Regarding the collaboration between the United States of America and Ukraine in nuclear forensics, **K. Knight (USA)** discussed the process, current status and successes. This included new research initiatives, infrastructure improvements, the development of country specific and regional training, and progress in development of a national nuclear forensics library in Ukraine. Her poster provided insights gained in the course of forging these relationships and how such engagements can positively impact nuclear security not only within a country, but also beyond national borders.

Material out of regulatory control

U. de Silva (Sri Lanka) described the Sri Lankan experience to address the illicit trafficking of radioactive sources using a portal monitoring system deployed with assistance from the United States of America that detects both gamma radiation and neutrons in 11 gates at the Colombo port. Using this system, two incidents were reported involving scrap metal contaminated with ^{137}Cs as well as copper electrical grounding rods contaminated with ^{60}Co.

Egypt has benefited from the coordination and cooperation of the national agencies to counter the threat from smuggling of nuclear material and other radioactive material. Nuclear forensics is an important capability that is recognized by Egypt to help to categorize and characterize radioactive material as part of a national response plan. **M. Elbarody (Egypt)** described training and awareness activities to orient law enforcement in Egypt to the threat from illicit trafficking with an emerging emphasis on nuclear forensics.

L. Chelidze (Georgia) noted that development of nuclear forensic capabilities has helped national response in Georgia to the threat of residual nuclear material and other radioactive material that persists from the time of the former Union of Soviet Socialist Republics.

In Greece, progress in identifying radioactive material in scrap metal has been enabled by the installation of radiation portal monitors at the entrances of three steel industries. **M. Nikolaki (Greece)** presented case studies involving the detection of ^{137}Cs, ^{226}Ra and ^{90}Sr associated with radioactive sources and natural uranium ore that emphasize the need to use care in the examination of acquired spectra as well as inherent limitations in the radiation detection instrumentation.

Lithuania has established a national response capability to include a laboratory to identify abandoned radioactive sources as well as trafficked nuclear material and other radioactive material. **J. Ziliukas (Lithuania)** described the national efforts to search for and categorize abandoned radioactive sources. He also mentioned that interviews of individuals with a knowledge of the history of these materials are also beneficial.

Abandoned radioactive sources in Egypt pose a threat to the local population. These abandoned radioactive sources also pose a serious terrorist threat. **M. Abdel-Geleel (Egypt)** described a nationally integrated management programme for sealed radioactive sources to track these radioactive sources throughout the country.

C. Boyd (Jamaica) noted that Jamaica is cooperating with the IAEA through the IAEA Incident and Trafficking Database to address nuclear and other radioactive material out of regulatory control and has completed an Integrated Nuclear Security Support Plan to include development of legal and regulatory instruments to address materials out of regulatory control. In Jamaica, the deployment of radiation portal monitors at ports in support of customs enforcement detected four incidents of unauthorized activities involving radioactive material.

Support to investigations

D. Orlokh (Mongolia) described an investigation of ^{125}I doped dice used for gambling and seized in Mongolia. Radioactively doped dice were interdicted at the international airport and characterized for constituent radionuclides. A comprehensive radiation monitoring system in Mongolia enabled this seizure.

Exercises

The Australian Nuclear Science and Technology Organisation's National Security Research Program participated in the recent Nuclear Forensics International Technical Working Group Galaxy Serpent national nuclear forensics library tabletop exercise. In this regard, **K. Smith (Australia)** reported that a national nuclear forensics library can be created using a commonly available spreadsheet software application. Furthermore, she mentioned that multivariate analysis can be applied, and that use of common SI units aids in nuclear forensic interpretation. Using nuclear reactor isotope data sets provided in the exercise, it was possible to identify a likely reactor origin.

I. Smith (United Kingdom) spoke on outcomes of the January 2014 Nuclear Forensics Workshop and Exercise Blue Beagle hosted by various ministries of the United Kingdom under the sponsorship of the Global Initiative to Combat Nuclear Terrorism. The exercise demonstrated the importance of maintaining the chain of custody for evidence throughout a nuclear forensic examination. It also showed the importance of provision of assistance to partner nations taking into account national or regional capabilities to support a nuclear forensic examination.

Training

The European Nuclear Security Training Centre (EUSECTRA) is located at the Joint Research Centre's Institute for Transuranium Elements in Karlsruhe, Germany. EUSECTRA is unique, since it allows participants access to realistic scenarios using actual special nuclear material. In particular, EUSECTRA is one on a limited number of training venues in the world where a wide range of samples of plutonium and uranium of different isotopic compositions can be used for training in nuclear security detection, categorization and characterization. **E. Hrnecek (European Union)** noted the training centre provides courses for front line officers, trainers and experts on how to detect and respond to illicit trafficking of a range of nuclear material and other radioactive material.

In South Africa, the Centre for Applied Radiation Science and Technology (CARST) has been established to support research and human capital sustainability for the national nuclear industry. **M. Mathuthu (South Africa)** noted that CARST is now offering a PhD degree in applied radiation science to complement MSc programmes in South Africa to educate the necessary cadre of future nuclear security experts.

OUTCOME AND CONCLUSIONS

The posters in Poster Session I were organized in the following themes in the context of nuclear forensics as part of nuclear security infrastructure:

— Framework;
— National capabilities;
— Material out of regulatory control;
— Support to investigations;
— Exercises;
— Training.

Nuclear forensics is transitioning from an emerging to an established nuclear security discipline. The results from this sessions demonstrated that nuclear forensics is both designed into, and implemented as part of, States' national response plans. Nuclear forensic sustainability is enabled through comprehensive exercises and training activities.

SUMMARY OF POSTERS*

POSTER SESSION II

INTRODUCTION

The posters presented in Poster Session II are arranged into four topical areas: nuclear forensic categorization, nuclear forensic characterization methods, radiochronometry and nuclear forensic interpretation.

POSTERS

Nuclear forensic categorization

Nuclear forensic categorization requires information provided by handheld instruments to determine the nature of nuclear and other radioactive material out of regulatory control and any threat it may pose to the public, the environment or nuclear security event responders. In particular, fast neutrons with kinetic emission energies in excess of 1 MeV can have deleterious consequences to the human body. **K. Tsuchiya (Japan)** described the evaluation results of the response of personal semiconductor based dosimeters to real time thermal and fast neutrons exposures.

To address the radiotoxicity of alpha emitting particles as well as the short range of alpha particles in air that complicates a field survey, **K. Peräjärvi (Finland)** described a novel screening technique involving the thermalization of alpha particles in air. The resulting excited gaseous molecules in the atmosphere produce ultraviolet (UV) light which can be detected over longer distances. The UV light from this process can also penetrate plastic, which makes it ideal for the categorization of alpha emitters held in plastic sample bags. Research is ongoing to improved measurements with tolerance to external lighting. This technique holds promise to advance screening of alpha particle emissions for nuclear forensics.

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Nuclear forensic characterization methods

The presence of organic traces in nuclear material has yet to be routinely measured as part of a nuclear forensic examination. These signatures may be important owing to the presence of high abundances of organic compounds used in the production of materials throughout the nuclear fuel cycle. **Z. Varga (European Union)** reported on the feasibility of using gas chromatograph–mass spectrometry to assess the origin of unknown uranium ore concentrates.

K. Ünlü (USA) described studies to accelerate processing of radiochemical samples for nuclear forensics using polymer ligand film for the extraction of plutonium and uranium. Extracted samples can be subsequently counted directly using radiometric techniques.

Analysis of micrometre sized uranium particles has important implications for nuclear forensic studies in support of law enforcement or nuclear security. **X. Liu (China)** described a technique for a fission track detector to be directly applied to a surface containing uranium particles as a film and then irradiated in a nuclear reactor and etched to expose the fission tracks.

The combination of machine learning and laser based spectroscopy as well as imaging techniques is being investigated to noninvasively determine the trace elemental and uranium isotopic composition of nuclear material. **H. Kalambuka (Kenya)** notes that laser based spectroscopy tools allow for an improved signal and resulting confidence in the spectral and imaging analysis of nuclear forensics.

J. Su (China) reported on research into fission product xenon, including ^{131m}Xe, ^{133m}Xe, ^{133}Xe and ^{135}Xe that are fissile products of ^{235}U and ^{239}Pu, with implications for post detonation nuclear forensics. The potential for analysis of xenon isotope ratios (e.g. $^{135}Xe/^{133}Xe$ for uranium and $^{135}Xe/^{133}Xe$ for plutonium), within the short half-life for these isotopes, enables the potential identification of fissile nuclear material origins.

The use of gadolinium shows promise for nuclear forensic applications owing to its use throughout various stages of the nuclear fuel cycle and its high neutron cross section (i.e. probability to capture a thermal neutron to include ^{155}Gd and ^{157}Gd isotopes). **G. Brennecka (USA)** noted that promising research is being conducted on the chemical separation and high precision measurement of gadolinium isotopes within various nuclear material.

Studies into the analysis of the gamma ray spectra of strong ^{241}Am sources provides insight into their composition. **A. Vesterlund (Sweden)** described research results that indicate that gamma ray source signatures including age and impurities can be used as unique identifiers of the origin of a ^{241}Am source.

Radiochronometry

The importance of inductively coupled plasma mass spectrometry (ICP-MS), including quadrupole based instruments, to nuclear forensic measurement of $^{230}Th/^{234}U$ isotope ratios for age dating of uranium samples should not be underestimated. **M. Fernández (Spain)** discussed results of the development of an analytical procedure for the precise measurement of ^{230}Th and ^{234}U in uranium samples. This procedure uses a quadrupole equipped ICP-MS which allows measurement of ^{230}Th at environmental levels.

C. Venchiarutti (European Union) reported that the Joint Research Centre's Institute for Reference Materials and Measurements (IRMM) and the Institute for Transuranium Elements have partnered to develop a unique uranium reference material (IRMM-1000) certified for the date of last chemical separation. Certified reference materials are essential to the validation of measurement procedures in determinations of the 'age' of uranium samples. The IRMM-1000 reference material will be made available in early 2015. Prior to the release of IRMM-1000, the IRMM, in cooperation with the Nuclear Forensics International Technical Working Group and laboratories in the field, launched a new Regular European Interlaboratory Measurement Evaluation Programme (REIMEP-22). This programme is based on this reference material and aims at evaluating the results of participating laboratories against an independent external certified reference value (i.e. the certified production date) with demonstrated traceability and uncertainty and consistent with international guidelines.

A round robin exercise between the United States Department of Energy national laboratories, the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique) and the Japan Atomic Energy Agency focused on the consistency of ^{229}Th and ^{233}U isotope dilution standards used for reliable and consistent radiochronometry measurements of ^{230}Th and ^{234}U. **R. Steiner (USA)** spoke on the resulting comparisons of approaches and data associated with these collaborative measurements.

Nuclear forensic interpretation

J. Wacker (USA) presented a history of the development of the United States Nuclear Materials Characteristics Data Dictionary, which supports the effort of the United States of America to establish a national nuclear forensics library. The data dictionary provides the foundation for the definition of specific data that needs to be used for the development of a national nuclear forensics library. By design, the data dictionary is comprehensive to capture information from a wide variety of nuclear material and other radioactive material residing in the civilian and military nuclear fuel cycles.

The categorization as depleted uranium, natural uranium, low enriched uranium and high enriched uranium is essential to supporting a nuclear forensic examination to provide insight into its origin, use and history. **P. Thompson (United Kingdom)** used examples from the open literature containing information on uranium reference materials, data from prior nuclear forensic case studies and nuclear industry operating practices to further subdivide uranium into these categories for the purposes of a nuclear forensic examination.

To enhance its national capability in nuclear forensics, the United Kingdom has refurbished a number of scientific laboratories to address the analytical requirements associated with the measurement of a variety of nuclear material and other radioactive material. An advanced nuclear forensic laboratory capability has been established at the Atomic Weapons Establishment to include the installation of latest generation mass spectrometers. **C. Watt (United Kingdom)** noted that in addition to these facility and equipment upgrades, statistical techniques to support interpretation of the data from a nuclear forensic examination is also underway, including the involvement of a variety of subject matter experts.

OUTCOME AND CONCLUSIONS

Important to a nuclear forensic examination is nuclear material categorization and characterization. Nuclear forensic categorization and characterization requires application of validated methods and techniques for both non-destructive analysis (NDA) and destructive analysis (DA). At the scene of a nuclear security event, NDA techniques or methods are utilized by the response teams for the safety of responders and also for the identification of, and preliminary information about, the material at the scene. However, any information derived from the scene through the use of NDA techniques or methods has to be subsequently fully confirmed in the nuclear forensic laboratory through the application of DA methods and techniques (e.g. the use of mass spectrometry and radiochemistry) involving comprehensive material characterization. This poster session was dedicated to papers that highlighted developments that will help advance nuclear forensics as an important tool within the national and international nuclear security framework.

CLOSING SESSION

PRESIDENT'S FINDINGS*

HE S.J. le Jeune d'Allegeershecque
President of the Conference and Resident Representative
of the United Kingdom of Great Britain and Northern Ireland to the IAEA

The International Conference on Advances in Nuclear Forensics: Countering the Evolving Threat of Nuclear and Other Radioactive Material out of Regulatory Control was held at the IAEA Headquarters, in Vienna, 7–10 July 2014. The conference was attended by 285 participants from 76 Member States and 8 organizations, and included nuclear forensic experts, law enforcement officials, policy makers and national representatives who have interests or active roles in nuclear forensics. The 2014 conference was the first international conference dedicated exclusively to the role of nuclear forensics within a nuclear security infrastructure. The President's findings are intended to reflect the presentations and discussions at the conference and provide some observations derived from them. The President's findings are not intended to provide binding recommendations to the Secretariat or to Member States, but rather to assist Member States in fulfilling their respective responsibilities.

Recognizing the importance of international collaboration in nuclear forensics, the cooperating entities for this conference were the Global Initiative to Combat Nuclear Terrorism (GICNT), the International Criminal Police Organization (INTERPOL) and the Nuclear Forensics International Technical Working Group (ITWG). The IAEA collaborates with the GICNT, INTERPOL and the ITWG to develop and continuously improve various forms of cooperation, including enhancement of awareness, guidance, training and coordinated research. The international community increasingly recognizes the role of nuclear forensics as a deterrent and as a tool to support the response to nuclear security events. Through this international conference on nuclear forensics, the IAEA sought to facilitate a comprehensive exchange of information on relevant new technologies and techniques, as well as to highlight achievements in the application of nuclear forensics.

The cooperating entities for the conference and the IAEA affirmed their vision of continued collaboration to advance nuclear forensics as a keystone of a nuclear security infrastructure. The co-chairs of the GICNT, the Russian Federation and the United States of America, noted that the role of the GICNT

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is to support the activities of the relevant international organizations, notably the IAEA, through sharing experiences and conducting exercises and other practical activities, which will help to sustain a robust and enduring international nuclear security framework well into the future. INTERPOL's ongoing close partnership with the IAEA, its collaborative work in training and preparing the law enforcement, scientific, health and other public sector communities, together with its long standing information sharing agreements, will go a long way to achieve the shared goals of these two international agencies in addressing the threat of nuclear terrorism. The ITWG has been working in partnership with the IAEA and has strengthened many of its nuclear security related activities by providing expertise in the development of the science and technology supporting law enforcement investigations and nuclear security vulnerability assessments.

Among some of the areas examined at this conference were:

— The history of nuclear forensics in response to the increased reports of illicit trafficking in the mid-1990s;
— The relevant international legal instruments that pertain to nuclear forensics;
— The role of nuclear forensics in a nuclear security infrastructure;
— The current state of nuclear forensics, including scientific developments;
— Related topics such as interpretation tools for nuclear forensic data, capacity building, international and regional cooperation and policy implications.

The opening plenary session was followed by 15 technical sessions, three panel sessions and one round table discussion, where contextual, legal, scientific and policy topics on nuclear forensics were explored in more detail.

The technical sessions were highly interactive and explored the science of nuclear forensics and the state of implementation to support law enforcement and nuclear security. Technical sessions also included two poster sessions. The key topics included:

— Nuclear forensics as an element of a national response plan;
— Science of nuclear forensic signatures;
— Case studies;
— Laboratory analysis techniques;
— Data interpretation tools and methods;
— Expressing confidence associated with nuclear forensic conclusions;
— Synergies with other disciplines;
— Radiochronometry (i.e. age dating);
— Raising awareness and enhancing education in nuclear forensics;
— International cooperation.

Findings included identifying the important role of nuclear forensics within a national response plan. The sessions highlighted the need to build trust among law enforcement, policy makers and nuclear forensic scientists in the conduct of an effective nuclear security investigation. Many States have embarked on national efforts to establish nuclear forensics as an effective tool to support an investigation of a nuclear security event involving nuclear and other radioactive material out of regulatory control. An outcome of the conference is that nuclear forensics is no longer emerging but is now a recognized tool to address nuclear security needs. Organizing a national nuclear forensics library or database, which may consist of an administrative association of existing databases, is viewed as an effective knowledge framework to help to determine whether or not seized material is consistent with a State's material holdings. The conference also recognized that training, education and international cooperation are practical measures that can help to sustain nuclear forensic capabilities.

Nuclear forensics as a tool for law enforcement investigations and to support nuclear security vulnerability assessments requires continual innovation. As the threat associated with the continuing reports of nuclear and other radioactive material out of regulatory control persists, the science needs to advance as well. Nuclear forensic science ensures that new tools are always available to aid States in preventing and responding to a nuclear security event. Through peer review, nuclear forensic science allows new methods to be validated before they are used in support of an actual law enforcement investigation or potential criminal prosecution. Nuclear forensic science benefits from the widest intersection of all branches of science and engineering. Companion disciplines — to include geochemistry, materials science, nuclear engineering and environmental science — exploit new frontiers of nuclear forensic signatures and interpretation as well as access additional subject matter experts to build confidence in nuclear forensic conclusions. This week's interactive exercise further demonstrated that we need to optimize the use of existing resources and capabilities, while bridging companion disciplines, to best advance nuclear forensics. A unique aspect of this conference was a round table session addressing the intersection where science meets policy in the context of the IAEA's role in providing guidance and training to enable nuclear forensics as a critical component of nuclear security.

Nuclear forensic science is not implemented in isolation. The needs of the policy community have to be clearly articulated to practitioners so that appropriate nuclear forensic capabilities can be developed and sustained relative to national needs. Determining the scale and scope of nuclear forensic capabilities within a State involves coordination between the policy and the technical community.

Nuclear forensic awareness and understanding are crucial for policy makers. It is important for the policy community to understand what shapes confidence in nuclear forensic findings.

During the development of a nuclear forensic capability, measures to sustain these capabilities also need to be considered. Programmes in education need to be in place to ensure that expertise is available into the future — from analytical science, nuclear engineering and forensic science disciplines — to guarantee the next generation of practitioners is properly prepared and that research can foster innovation and advances in nuclear forensic science. Also, training and regular exercise of all facets of a nuclear forensic examination are valuable in building confidence in the capability. Trainings and exercises are also important to ensure nuclear forensics has an enduring role as part of a State's nuclear security infrastructure.

From the national perspective, establishing clearly understood roles and responsibilities to support a nuclear forensic examination and being fully prepared to implement them is essential.

I am pleased to inform you that a draft of the President's findings will be available in hardcopy at the Information Desk as you leave here today. Next week, a finalized version will be made available to participants, along with the presentations approved for release, on the IAEA Nuclear Security Information Portal.

CLOSING REMARKS

D. Flory
Deputy Director General
IAEA Department of Nuclear Safety and Security

Excellencies, Ladies and Gentlemen,

During the past three and half days, we have heard from you regarding the crucial role nuclear forensics plays within a nuclear security infrastructure supporting both law enforcement investigations and nuclear security vulnerability assessments. This conference assembled 285 participants from 76 Member States and 8 organizations to Vienna to share experience and to set priorities for advancing nuclear forensic state of practice.

As we have seen this week, nuclear forensics gathers a community of scientists, law enforcement officials, responders and policy makers who share a common commitment to nuclear forensics. This common commitment encompasses the capability for States to fulfil their nuclear security obligations to secure all nuclear material and other radioactive material that are used, produced or stored. Nuclear forensics requires international cooperation, since the threat of nuclear terrorism affects us all. Effective solutions to address this serious threat rely upon our confidence in nuclear forensics as an effective tool to prevent and respond to these threats.

Let us also leave this international conference as a community. Let us take the common understanding we have gained this week, the lessons learned affecting nuclear forensic implementation, the advancements in the science, national efforts to build nuclear forensics into a national response plan and link policy requirements to strengthen national efforts in nuclear forensics going forward. Through common solutions, regular exchanges of information and consensus practices adopted after this conference, we have the greatest expectation that nuclear forensics will continue to flourish as a crucial nuclear security capability over the next ten years as much as it has in the past ten.

With the results from the international conference this week, we are better positioned to continue our efforts. I thank you for many and important contributions, particularly as they relate to best positioning the IAEA to provide nuclear forensic assistance, upon request, to the Member States. We are committed to continue our cooperation with our international partners and continue serving our Member States through, inter alia, the development of international guidance within the Nuclear Security Series, and to help States, upon request, to provide for their application through education and training, peer review and advisory services, coordinated research projects and specialized technical assistance.

I wish you all the best success in the important and continuing the work you do to ensure the peaceful uses of nuclear science and technology globally.

Have a safe and secure travel back home. The conference is adjourned.

ABBREVIATIONS

GICNT	Global Initiative to Combat Nuclear Terrorism
HEU	high enriched uranium
INSSP	Integrated Nuclear Security Support Plan
INTERPOL	International Criminal Police Organization
ITDB	Incident and Trafficking Database
ITU	Institute for Transuranium Elements
ITWG	Nuclear Forensics International Technical Working Group
LLNL	Lawrence Livermore National Laboratory
NFRF	Nuclear Forensics Research Facility
REE	rare earth element
SEM	scanning electron microscopy
SIMS	secondary ion mass spectrometry
UOC	uranium ore concentrate

Appendix I

OUTLINE CONFERENCE PROGRAMME

OUTLINE CONFERENCE PROGRAMME

Monday, 7 July 2014

08:00	Registration	
10:00–12:00	Opening Session (Board Room A)	
12:00–13:30	Lunch break	
13:30–15:00	Plenary Session 1A (Board Room A)	Historical Evolution of Nuclear Forensics
15:00–15:30	Hosted coffee break	
15:30–16:50	Plenary Session 1B (Board Room A)	Nuclear Forensic Resources in the Legal and Nuclear Security Context
16:50–17:10	Information Session (Board Room A)	
17:10–18:00	Panel Session 1C (Board Room A)	Nuclear Forensic Capabilities within a National Nuclear Security Infrastructure
18:00–20:00	Welcome reception (M Ground Floor)	

Tuesday, 8 July 2014

09:00–10:40	Technical Session 2A (Parallel Session) (Board Room A)	Nuclear Forensic Capabilities as an Element of a National Response Plan
09:00–10:40	Technical Session 2B (Parallel Session) (Room M3)	Nuclear Forensic Science: Signatures of Nuclear Material I
10:40–11:10	Hosted coffee break	
11:10–12:30	Technical Session 2C (Parallel Session) (Board Room A)	Approaches to Nuclear Forensic Examinations
11:10–12:30	Technical Session 2D (Parallel Session) (Room M3)	Data Compilation Tools for Supporting Nuclear forensic Interpretation I
12:30–14:00	Lunch break	Poster Session I
14:00–15:20	Technical Session 2E (Parallel Session) (Board Room A)	Experiences in Laboratory Analyses and Data Interpretation
14:00–15:20	Technical Session 2F (Parallel Session) (Room M3)	Exercises and Cooperation
15:20–15:50	Hosted coffee break	
15:50–17:10	Technical Session 2G (Board Room A)	Integration of Existing National Resources into Nuclear Forensic Capabilities
17:10–18:00	Panel Session 2H (Board Room A)	Discussion on Integration of Existing National Resources into Nuclear Forensic Capabilities

Wednesday, 9 July 2014

09:00–10:40	Technical Session 3A (Parallel Session) (Board Room A)	Nuclear Forensic Science: Signatures of Nuclear Material II
09:00–10:40	Technical Session 3B (Parallel Session) (Room M3)	Nuclear Forensic Science: Synergies with Other Disciplines I
10:40–11:10	Hosted coffee break	
11:10–12:30	Technical Session 3C (Parallel Session) (Board Room A)	Data Compilation Tools for Supporting Nuclear Forensic Interpretation II
11:10–12:30	Technical Session 3D (Parallel Session) (Room M3)	Nuclear Forensic Science: Radiochronometry
12:30–14:00	Lunch break	Poster Session II
14:00–15:20	Technical Session 3E (Parallel Session) (Board Room A)	Confidence in Nuclear Forensic Findings
14:00–15:20	Technical Session 3F (Parallel Session) (Room M3)	Nuclear Forensic Science: Synergies with Other Disciplines II
15:20–15:50	Hosted coffee break	
15:50–17:10	Technical Session 3G (Board Room A)	Nuclear Forensic Awareness and Education
17:10–18:00	Panel Session 3H (Board Room A)	Nuclear Forensic Science: The Next Five Years

Thursday, 10 July 2014

09:00–10:20	Technical Session 4A (Board Room A)	International and Regional Cooperation in Nuclear Forensics
10:20–10:50	Hosted coffee break	
10:50–12:00	Round Table Session 4B (Board Room A)	Nuclear Forensics: Where Science Meets Policy
12:00–12:30	Closing Session (Board Room A)	

Appendix II

LIST OF CONFERENCE PAPERS AND PANEL MEMBERS

LIST OF CONFERENCE PAPERS AND PANEL MEMBERS

PLENARY SESSION 1A: HISTORICAL EVOLUTION OF
NUCLEAR FORENSICS

Chairpersons: **M. Caspers** (Germany)
H. Yoo (Republic of Korea)

The historical evolution of nuclear forensics: A technical viewpoint[*]
(IAEA-CN-218/117)
S. Niemeyer (USA), L. Koch
Development of nuclear forensics in Russia[*]
(IAEA-CN-218/118)
V.P. Kuchinov (Russian Federation)
Historical evolution — Nuclear forensics: A political viewpoint[*]
(IAEA-CN-218/119)
HE K. Nederlof (Netherlands)
20 years of nuclear forensics at ITU: Between R&D and case work
(IAEA-CN-218/044)
T. Fanghänel (European Union), K. Mayer, Z. Varga, M. Wallenius, T. Wiss

PLENARY SESSION 1B: NUCLEAR FORENSIC RESOURCES IN
THE LEGAL AND NUCLEAR SECURITY CONTEXT

Chairpersons: **W.I. Zidan Mohamed** (Egypt)
A. Pavlenishvili (Georgia)

Nuclear forensics awareness and understanding[*]
(IAEA-CN-218/072)
M. Wallenius (European Union), K. Mayer
International legal framework for strengthening nuclear security[*]
(IAEA-CN-218/120)
I. Khripunov (USA)

[*] Invited paper.

Analysis of incidents reported during 2007–2012 to the IAEA Incident and Trafficking Database[*+]
(IAEA-CN-218/121)
M. Nicholas (IAEA)
Nuclear security legislation in Hungary: Overview of the national response plan to events with nuclear and other radioactive material out of regulatory control
(IAEA-CN-218/060)
Zs. Stefánka (Hungary), Á. Vincze, K. Horváth

PANEL SESSION 1C: NUCLEAR FORENSIC CAPABILITIES WITHIN A NATIONAL NUCLEAR SECURITY INFRASTRUCTURE

Chairpersons: **G. Emi-Reynolds** (Ghana)
M. Senzaki (Japan)

Panel members

R. Floyd (Australia), J.E. de Souza Sarkis (Brazil), L. Paredes Gutiérrez (Mexico), S. Limage (USA), K. Mrabit (IAEA).

TECHNICAL SESSION 2A: NUCLEAR FORENSIC CAPABILITIES AS AN ELEMENT OF A NATIONAL RESPONSE PLAN

Chairpersons: **M. Kostor** (Malaysia)
I. Balan (Republic of Moldova)

Overview of nuclear forensics in support of investigations
(IAEA-CN-218/048)
F.M.G. Wong (USA), T. Hinton, D.K. Smith
South Africa's nuclear forensics response plan step 1: In support of nuclear security investigations
(IAEA-CN-218/084)
P.R. Mogafe (South Africa), B.L. Kokwane, P. Tshidada, A.L. Matshiga

[*] Invited paper.
[+] Paper not made available for CD-ROM.

Lessons learned from Moleta incident
(IAEA-CN-218/030)
M. Abuissa (Sudan), M. Osman, M. Yossif, I. Abdalla, S. Karma
Opportunity and challenge of nuclear forensics in Indonesia
(IAEA-CN-218/038)
W.P. Daeng Beta (Indonesia)

TECHNICAL SESSION 2B: NUCLEAR FORENSIC SCIENCE: SIGNATURES OF NUCLEAR MATERIAL I

Chairpersons: **J.E. de Souza Sarkis** (Brazil)
T. Hinton (Canada)

Investigating macro- and micro-scale material provenancing signatures in uranium ore concentrates/yellowcake
(IAEA-CN-218/010)
A. Wotherspoon (Australia), L. Vance, J. Davis, J. Hester, D. Gregg, G. Griffiths, I. Karatchevtseva, Y. Zhang, T. Palmer, E. Keegan, N. Blagojevic, E. Loi, D. Hill, M. Reinhard
Exploring spectroscopic and morphological data as new signatures for uranium ore concentrates
(IAEA-CN-218/077)
D. Ho Mer Lin (Singapore), D. Manara, Z. Varga, L. Fongaro, A. Nicholl, M. Ernstberger, A. Berlizov, P. Lindqvist, T. Fanghänel, K. Mayer
^{143}Nd/^{144}Nd ratio: A powerful signature for origin assessment of natural uranium products
(IAEA-CN-218/045)
J. Krajko (European Union), Z. Varga, M. Wallenius, K. Mayer
Measurement of sulphur isotopic ratio for the nuclear forensic investigation of uranium ore concentrates (yellow cakes)
(IAEA-CN-218/053)
Z. Varga (European Union), S.-H. Han, J. Krajko, M. Wallenius, K. Song, K. Mayer

TECHNICAL SESSION 2C: APPROACHES TO NUCLEAR FORENSIC EXAMINATIONS

Chairpersons: **V. Stebelkov** (Russian Federation)
H. Ramebäck (Sweden)

Radiological crime scene management[*+]
(IAEA-CN-218/122)
C. Nogueira de Oliveira (IAEA), R. Hlavacka
Developing traditional forensic science exploitation of contaminated exhibits recovered from a nuclear security event
(IAEA-CN-218/036)
G.A. Graham (United Kingdom), S.E. McOmish, K. Rayment, R. Robson, R. Baldwin
Strategies for DNA analysis from contaminated forensic samples
(IAEA-CN-218/023)
E. Hrnecek (European Union), J. Krajko, G. Rasmussen, A. Nicholl, K. Mayer
Translating research findings into operational capabilities in nuclear forensics: The Australian experience
(IAEA-CN-218/008)
D. Hill (Australia), K. Toole, T. Evans, E. Young, A. Goodman-Jones, C. Chang, P. Roffey, M. Reinhard

TECHNICAL SESSION 2D: DATA COMPILATION TOOLS FOR SUPPORTING NUCLEAR FORENSIC INTERPRETATION I

Chairpersons: **D. Dimitrov** (Bulgaria)
A. Singh Gill (India)

Overview of Canada's national nuclear forensics library development programme
(IAEA-CN-218/067)
A. El-Jaby (Canada), T. Hinton, F.R. Doucet, S. Jovanovic
Developing a nuclear forensics library in Ukraine: The pilot project stage[+]
(IAEA-CN-218/028)
O. Gaidar (Ukraine), V. Tryshyn, V. Kushka, S. Lopatin, K.B. Knight, T.M. Kayzar, M. Robel

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[*] Invited paper.
[+] Paper not made available for CD-ROM.

Populating a national nuclear forensics library: Lessons learned+
(IAEA-CN-218/016)
J. Wacker (USA), A.C. Misner, J. Watts, J.D. Olivas
The Uranium Sourcing Database project: Practical insights into the establishment and application of a national nuclear forensics library
(IAEA-CN-218/025)
M. Robel (USA), N. Marks, I. Hutcheon, R. Lindvall, M. Kristo

TECHNICAL SESSION 2E: EXPERIENCES IN LABORATORY ANALYSES AND DATA INTERPRETATION

Chairpersons: **R. Chiappini** (France)
E. van Zalen (Netherlands)

Identification of unknown nuclear material
(IAEA-CN-218/005)
G. Nicolaou (Greece), G. Melanofthalmidou, I. Lantzos
Analysis of a uranium ore concentrate sample interdicted in Durban, South Africa (FSC 14-1-1)
(IAEA-CN-218/082)
I.D. Hutcheon (USA), L.E. Borg, Z. Dai, G.R. Eppich, B.K. Esser, A.M. Gaffney, V.G. Genetti, P.M. Grant, J.J. Hancke, T.M. Kayzar, G.L. Klunder, K.B. Knight, M.J. Kristo, R.E. Lindvall, N.E. Marks, R. Mogafe, K.J. Moody, A. Nelwamondo, C.E. Ramon, M. Robel, S.K. Roberts, K.C. Schorzman, M.A. Sharp, M.J. Singleton, R.W. Williams
Informativeness of microparticle analysis for nuclear forensics
(IAEA-CN-218/062)
V. Stebelkov (Russian Federation)
Characterization of US plutonium: Understanding our data+
(IAEA-CN-218/017)
J. Wacker (USA), A.C. Misner, J. Watts, J.D. Olivas

+ Paper not made available for CD-ROM.

TECHNICAL SESSION 2F: EXERCISES AND COOPERATION

Chairpersons: **H. Le Quang** (Viet Nam)
J. Vaclav (Slovakia)

Periodical radiological crime scene management exercises in Germany
(IAEA-CN-218/098)
H. Kroeger (Germany), J.-T. Eisheh
The Nuclear Forensics International Technical Working Group (ITWG): The Evidence Working Group
(IAEA-CN-218/086)
J.F. Blankenship (USA), É. Kovács-Széles
Galaxy Serpent: A web based tabletop exercise for national nuclear forensics libraries
(IAEA-CN-218/047)
J.D. Borgardt (USA), F.M.G. Wong
Tiger Reef: Cross-disciplinary training workshop and tabletop exercise, 4–7 February 2014, Kuala Lumpur, Malaysia[*]
(IAEA-CN-218/124)
M.S. Zulkipli (Malaysia)

TECHNICAL SESSION 2G: INTEGRATION OF EXISTING NATIONAL RESOURCES INTO NUCLEAR FORENSIC CAPABILITIES

Chairpersons: **D.M. Hill** (Australia)
M. Sinaga (Indonesia)

Establishing Canada's national nuclear forensics laboratory network
(IAEA-CN-218/081)
I. Dimayuga (Canada), E. Inrig
The network of Russian analytical laboratories for support of nuclear forensics
(IAEA-CN-218/091)
G. Kochev (Russian Federation), A. Kuchkin, V. Stebelkov
Development of nuclear forensics capabilities in Japan
(IAEA-CN-218/026)
N. Shinohara (Japan), Y. Kimura, K. Sato, N. Toda, Y. Shinoda, Y. Funatake, M. Watahiki, Y. Kuno

[*] Invited paper

Armenian nuclear forensic lab
(IAEA-CN-218/063)
K. Pyuskyulyan (Armenia), V. Atoyan

PANEL SESSION 2H: DISCUSSION ON INTEGRATION OF EXISTING NATIONAL RESOURCES INTO NUCLEAR FORENSIC CAPABILITIES

Chairpersons: **D.M. Hill** (Australia)
M. Sinaga (Indonesia)
Moderator: **M. Curry** (USA)

Panel members

K. Pyuskyulyan (Armenia), F. Dimayuga (Canada), N. Shinohara (Japan).

TECHNICAL SESSION 3A: NUCLEAR FORENSIC SCIENCE: SIGNATURES OF NUCLEAR MATERIAL II

Chairpersons: **T. Fanghänel** (European Union)
S.B. Butt (Pakistan)

Nuclear forensic science: An emerging discipline[*+]
(IAEA-CN-218/125)
S. LaMont (USA)
Identification of high confidence nuclear forensic signatures by analysis of spent fuel samples and other nuclear materials[+]
(IAEA-CN-218/031)
É. Kovács-Széles (Hungary), T.C. Nguyen, S. Szabo, K. Talos, L. Lakosi
Detection and distinguishing of uranium particles and plutonium particles by using alpha autoradiography
(IAEA-CN-218/061)
V. Stebelkov (Russian Federation), A. Kuchkin, S. Arkhipov, M. Lomakin

[*] Invited paper.
[+] Paper not made available for CD-ROM.

Probing forensic signatures of nuclear materials
(IAEA-CN-218/055)
M. Wilkerson (USA), W.S. Kinman, S.A. Kozimor, A.L. Pugmire, B.L. Scott, A.L. Tamasi, G.L. Wagner, J.R. Walensky

TECHNICAL SESSION 3B: NUCLEAR FORENSIC SCIENCE: SYNERGIES WITH OTHER DISCIPLINES I

Chairpersons: **M. Nizamska** (Bulgaria)
I. Roger (INTERPOL)

Analytical capabilities of the V.G. Khlopin Radium Institute in view of nuclear forensics challenges
(IAEA-CN-218/011)
Y. Panteleev (Russian Federation)
i2®©: Investigative and interpretive radiochemistry — The precursor to nuclear forensics
(IAEA-CN-218/088)
P. Thompson (United Kingdom)
Capabilities of hybrid SIMS–SSAMS system for nuclear forensics applications
(IAEA-CN-218/015)
K.S. Grabowski (USA), K.C. Fazel, D.L. Knies
Use of micro-Raman spectrometry for nuclear forensics
(IAEA-CN-218/080)
F. Pointurier (France), O. Marie
Forensic and medical aspects of radiation accidents investigation
(IAEA-CN-218/085)
E.O. Granovskaya (Russian Federation), K.V. Kotenko, Y.E. Kvacheva, B.A. Kukhta

TECHNICAL SESSION 3C: DATA COMPILATION TOOLS FOR SUPPORTING NUCLEAR FORENSIC INTERPRETATION II

Chairpersons: **S. Biramontri** (Thailand)
J. Salas Kurte (Chile)

Strategies and considerations for developing a national nuclear forensic library[+]
(IAEA-CN-218/057)
S. LaMont (USA), M. Brisson, H. Dion, E. Fei, S. Fendrich
National nuclear forensics library at Japan Atomic Energy Agency
(IAEA-CN-218/027)
Y. Kimura (Japan), N. Shinohara, Y. Funatake, M. Watahiki, Y. Kuno
Resources and forensics signatures to help determine the origin of sealed radiological sources
(IAEA-CN-218/064)
D. Chamberlain (USA), J. Canaday, Y. Tang, J. Morman, J. Steeb, S. Naik, Y. Tsai, V. Sullivan, K. Carney, M. Finck, D. Cummings, J. Gigilio, J. Summers
Mechanism of interpretation of seized materials without creation of nuclear forensics library
(IAEA-CN-218/090)
G. Kochev (Russian Federation), V. Kryuchenkov, A. Kuchkin, V. Stebelkov

TECHNICAL SESSION 3D: NUCLEAR FORENSIC SCIENCE: RADIOCHRONOMETRY

Chairpersons: **K. Peräjärvi** (Finland)
M.B.L. Ong (Singapore)

Radiochronometry by mass spectrometry: Improving the precision and accuracy of age dating for nuclear forensics
(IAEA-CN-218/014)
R. Williams (USA), I. Hutcheon, M. Kristo, A. Gaffney, G. Eppich, S. Goldberg, J. Morrison, R. Essex
Advances in nuclear forensics analysis at CEA/DIF: Radiochronology studies
(IAEA-CN-218/078)
A. Hubert (France), M. Mendes, J. Aupiais, F. Pointurier
Protactinium-231 (^{231}Pa) measurement for isotope chronometry in nuclear forensics
(IAEA-CN-218/012)
E. Keegan (Australia), A. Stopic, G. Griffiths
Uranium age dating by gamma spectrometry
(IAEA-CN-218/013)
L. Lakosi (Hungary), C.T. Nguyen, J. Zsigrai

[+] Paper not made available for CD-ROM.

TECHNICAL SESSION 3E: CONFIDENCE IN NUCLEAR FORENSIC FINDINGS

Chairpersons: **P.R. Mogafe** (South Africa)
P. Chakrov (Kazakhstan)

Challenges in bulk nuclear forensics sample analysis
(IAEA-CN-218/049)
L. Tandon (USA), L. Colletti, L. Ortega, K. Haynes, P. Mason, R. Essex, K. Kuhn
Proof of principle for the preparation and validation of a uranium age dating reference material
(IAEA-CN-218/051)
Z. Varga (European Union), K. Mayer, A. Hubert, I. Hutcheon, W. Kinman, M. Kristo, F. Pointurier, K. Spencer, F. Stanley, R. Steiner, L. Tandon, R. Williams
First certified uranium reference material for the production date in nuclear forensics
(IAEA-CN-218/029)
C. Venchiarutti (European Union), Z. Varga, A. Nicholl, S. Richter, J. Krajko, R. Jakopic, K. Mayer, Y. Aregbe
Atomic Energy of Canada Limited prepares for nuclear forensic analyses
(IAEA-CN-218/070)
M. Totland (Canada), I. Dimayuga, A.-M. Fillmore, S. Thomson, T. Shultz, R. Turgeon, S. Howett

TECHNICAL SESSION 3F: NUCLEAR FORENSIC SCIENCE: SYNERGIES WITH OTHER DISCIPLINES II

Chairpersons: **I. Mirsaidov** (Tajikistan)
A. Álvarez García (Spain)

High precision isotopic analysis of actinide bearing materials: Performance of a new generation of purpose built actinide multi-collector ICPMS instruments
(IAEA-CN-218/134)
G.C. Eiden (USA), A.M. Duffin, M. Liezers, J.D. Ward, J.W. Robinson, G.L. Hart, S.H. Pratt, K.W. Springer, A.J. Carman, D.C. Duckworth

Announcing the 4th collaborative materials exercise (CMX-4) of the Nuclear Forensics International Technical Working Group (ITWG)+
(IAEA-CN-218/136)
J.M. Schwantes (USA), O. Marsden
*IAEA Coordinated Research Project: Application of nuclear forensics in combating illicit trafficking of nuclear and other radioactive material**
(IAEA-CN-218/131)
T. Bull (IAEA), D.K. Smith

TECHNICAL SESSION 3G: NUCLEAR FORENSIC AWARENESS AND EDUCATION

Chairpersons: **A. Farhane** (Morocco)
F. Dimayuga (Canada)

Building a nuclear forensic analysis capability in South Africa
(IAEA-CN-218/019)
I.D. Hutcheon (USA), L.E. Borg, K. Hancke, M.J. Kristo, W.S. Kinman, R.E. Lindvall, R.P. Mogafe, A.N. Nelwamondo, E.C. Ramon, L.R. Riciputi, R. Steiner
Educating policy students in nuclear forensics
(IAEA-CN-218/009)
G.M. Moore (USA)
Nuclear forensics expertise development: Transferring knowledge to the next generation
(IAEA-CN-218/021)
S.K. Connelly (USA), W.B. Daitch
Australia's experience in the ITWG Galaxy Serpent NNFL tabletop exercise+
(IAEA-CN-218/100)
K.L. Smith (Australia), G.J. Griffiths, E.H. Loi, D. Boardman, M. Reinhard, D.M. Hill

* Invited paper.
+ Paper not made available for CD-ROM.

PANEL SESSION 3H: NUCLEAR FORENSIC SCIENCE: THE NEXT FIVE YEARS

Chairpersons: **W. Huang** (China)
S. Clark (USA)

Panel members

K.L. Smith (Australia), J.E. de Souza Sarkis (Brazil), V. Stebelkov (Russian Federation), P.R. Mogafe (South Africa), O. Marsden (United Kingdom), T. Fanghänel (European Union), D.K. Smith (IAEA).

TECHNICAL SESSION 4A: INTERNATIONAL AND REGIONAL COOPERATION IN NUCLEAR FORENSICS

Chairpersons: **S.-C. Kim** (Republic of Korea)
É. Kovács-Széles (Hungary)

Nuclear forensics activities supported by the EU CBRN Action Plan and EU CBRN Risk Mitigation Centres of Excellence (CoE) initiative[*]
(IAEA-CN-218/127)
Z. Pajalova (European Union), S. Abousahl

International cooperation to advance global nuclear forensics capabilities[+]
(IAEA-CN-218/056)
H. Dion (USA), E. Fei

From awareness raising to capacity building in nuclear forensics in South-East Asia
(IAEA-CN-218/043)
J. Galy (European Union), K. Mayer, P. Alfonso, A. Winterfield, D. Smith, H. Dion, E. Fei, W. Mei

[*] Invited paper.
[+] Paper not made available for CD-ROM.

ROUND TABLE SESSION 4B: NUCLEAR FORENSICS:
WHERE SCIENCE MEETS POLICY

Moderator: **K. Mrabit** (IAEA)

Panel members

W. Huang (China), HE G. Berdennikov (Russian Federation), HE G. de Salazar Serantes (Spain), A. Harrington (USA), J.M. Palma López (AMERIPOL).

POSTER SESSION I

European Nuclear Security Training Centre (EUSECTRA)
(IAEA-CN-218/024)
E. Hrnecek (European Union), V. Berthou, C. Carrapico, V. Forcina, J. Galy, L. Holzleitner, I. Krevica, K. Mayer, A. Nicholl, P. Peerani, F. Rosas, A. Rozite, H. Tagziria, M. Toma, A. Tomanin, Z. Varga, M. Wallenius, T. Wiss, J. Zsigrai
Establishing of a nuclear forensics capacity in Republic of Moldova
(IAEA-CN-218/020)
I. Balan (Republic of Moldova)
Sri Lankan experience on control of illicit trafficking of radioactive sources+
(IAEA-CN-218/050)
U.W.K.H. de Silva (Sri Lanka), H.L.A. Ranjith
Role of nuclear forensics in supporting national organizations in combating against smuggling of nuclear materials+
(IAEA-CN-218/007)
M. Elbarody (Egypt)
National security system to combat nuclear and radiation threats in Georgia
(IAEA-CN-218/108)
L. Chelidze (Georgia), G. Nabakhtiani
The use of the radioactive isotopes for cheating in gambling: An interaction between different authorities
(IAEA-CN-218/109)
D. Orlokh (Mongolia)

+ Paper not made available for CD-ROM.

Australia's experience in the Galaxy Serpent tabletop exercise
(IAEA-CN-218/100)
K. Smith (Australia), G.J. Griffiths, E. Loi, D. Boardman, D. Hill
Exercise Blue Beagle and information security+
(IAEA-CN-218/107)
I. Smith (United Kingdom)
Nuclear security capacity building at the Centre for Applied Radiation Science and Technology (CARST)
(IAEA-CN-218/039)
M. Mathuthu (South Africa), R.Y. Olobatoke
Challenges in identifying radioactive material in scrap metal
(IAEA-CN-218/033)
M. Nikolaki (Greece), G. Takoudis, S. Seferlis, A. Clouvas, S. Xanthos, C. Potiriadis
Countering the evolving threat of nuclear and other radioactive material out of regulatory control: Jamaica's experience
(IAEA-CN-218/035)
C.O. Boyd (Jamaica)
Search and investigation of orphan sources in Lithuania
(IAEA-CN-218/034)
J. Ziliukas (Lithuania), R. Ladygienė, R. Kievinas, L. Pilkytė
Egyptian framework for implementing nuclear forensics capabilities+
(IAEA-CN-218/065)
A. Ahmed Tawfik (Egypt)
Threat of radioactive materials out of regulatory control in Egypt: Orphan sources+
(IAEA-CN-218/066)
M. Abdel-Geleel (Egypt)
Increasing role of nuclear forensics to support nuclear security events investigation in Indonesia
(IAEA-CN-218/068)
D. Apriliani (Indonesia), Suharyanta, R. Alamsyah
Nuclear forensics: An integral part of the Philippines' national response plan for a nuclear security event
(IAEA-CN-218/006)
R.Y. Reyes (Philippines), W.G. Lim, E.U. Tabora, J.E. Seguis

+ Paper not made available for CD-ROM.

Overview of the Canadian National Nuclear Forensics Capability Project
(IAEA-CN-218/092)
E. Inrig (Canada), N. Yanofsky, A. El-Jaby, T. Hinton, F. Dimayuga, J. Whitlock

Strengthening nuclear forensic capabilities and partnership through collaborative science in Ukraine+
(IAEA-CN-218/040)
K.B. Knight (USA), E.S. Vergino, T.M. Kayzar, M. Robel, V. Tryshyn, D.V. Kutniy, O. Gaidar, I.A. Malyuk

Nuclear forensics activities in the Slovak Republic
(IAEA-CN-218/087)
J. Vaclav (Slovakia)

The contribution of international initiatives on non-proliferation to the enhancement of the nuclear forensics as a fundamental component of the international nuclear architecture+
(IAEA-CN-218/071)
A. Farhane (Morocco)

Investigative police of Chile: Implementation of an action plan to confront of radiological threats+
(IAEA-CN-218/079)
I. Trostel (Chile), L. Paiva, P. Saez, F. Torres, L. Bustamante

International workshop on basic nuclear forensic methodologies for practitioners+
(IAEA-CN-218/137)
J.M. Schwantes (USA), T. Morales, E. Ashbaker, J. Blankenship, T. Bull, A. Casella, H. Dion, M. Douglas, G. Eiden, O. Farmer, E. Fei, B. Garrett, S. Gregory, R. Hanlen, D.M. Hill, T. Hogg, T. Hubler, P. Karpius, K.B. Knight, L. Laverentiev, N.E. Marks, D. Meier, L. Minnema, A. Mitroshkov, S. Morley, M. Miner, K. Olsen, R. Pierso, M. Robe, P. Santi, D.K. Smith, P. Thompson, M. Wallenius, D. Vo

Nuclear forensics role and capabilities in the Romanian nuclear security infrastructure+
(IAEA-CN-218/138)
S. Repanovici (Romania), D. Dragusin

+ Paper not made available for CD-ROM.

POSTER SESSION II

Mass spectrometry in nuclear forensics
(IAEA-CN-218/133)
S.K. Aggarwal (India)
Origins of ^{137}Cs and ^{133}Xe in soils from two campuses in University of Douala-Cameroon+
(IAEA-CN-218/132)
M.M. Ndontchueng (Cameroon), C.J.S. Gembou, E.J.M. Nguelem, A. Simo
Characterization of strong ^{241}Am sources
(IAEA-CN-218/041)
A. Vesterlund (Sweden), D. Chernikova, P. Cartemo, K. Axell, A. Nordlund, G. Skarnemark, C. Ekberg, H. Ramebäck
REIMEP-22: Interlaboratory comparison on U age dating
(IAEA-CN-218/022)
C. Venchiarutti (European Union), S. Richter, Z. Varga, R. Jakopic, K. Mayer, Y. Aregbe
The US nuclear material characteristics data dictionary: History and development+
(IAEA-CN-218/059)
J. Wacker (USA), A. Luksic, M. Brisson, S. LaMont
^{230}Th–^{234}U thorium radiochronometry method comparison: A trilateral round-robin exercise+
(IAEA-CN-218/054)
R. Steiner (USA), W.S. Kinman, R. Williams, A. Gaffney, K. Schorzman, F. Pointurier, A. Hubert, M. Magara, A. Okubo
Measurement of organic residues of uranium ore concentrates (yellow cakes) for nuclear forensics
(IAEA-CN-218/052)
Z. Varga (European Union), D. Ho Mer Lin, M. Novak, Z. Eke, Z. Bodai, A. Nicholl, K. Mayer
Nuclear families: An extension to is it DU, NU, LEU or HEU
(IAEA-CN-218/089)
P. Thompson (United Kingdom)
Neutron-dose control of first responders under sampling and categorization
(IAEA-CN-218/083)
K. Tsuchiya (Japan), J.M. Schwantes, R.M. Pierson, R.K. Piper
Novel method for rapid extract of radionuclides using polymer ligand film for nuclear forensics applications
(IAEA-CN-218/032)
K. Ünlü (USA), J. Rim, D. Peterson, E. Gonzales, C. Armenta

Determination of the uranium containing particles from swipe samples by a fission track method+
(IAEA-CN-218/037)
X. Liu (China)

Nuclear forensics via machine learning laser based spectral analysis and imaging
(IAEA-CN-218/069)
H.A. Kalambuka (Kenya), B. Bhatt, A. Dehayem-Massop

Contaminants of the bismuth phosphate process as signifiers of nuclear reprocessing history+
(IAEA-CN-218/135)
L.E. Sweet (USA), D.G. Abrecht, D.D. Reilly, J.M. Schwantes

In-field detection and analysis of α radiation
(IAEA-CN-218/093)
K. Peräjärvi (Finland), S. Ihantola, J. Sand, H. Toivonen, J. Toivonen

The feasibility analysis of the materials of the nuclear explosion with the fission product xenon
(IAEA-CN-218/096)
J. Su (China)

Gadolinium isotopic signatures in nuclear material+
(IAEA-CN-218/018)
G.A. Brennecka (USA), L.E. Borg, M.J. Kristo, I.D. Hutcheon

A technical nuclear forensics capability to support the analyses of illicit radiological and nuclear materials
(IAEA-CN-218/042)
C. Watt (United Kingdom), P. Turner, G. Graham, D. Thomas

Potential and limitations of ICP-QMS technique for the measurement of ^{230}Th
(IAEA-CN-218/073)
M. Fernández (Spain), N. Navarro, E. Conde, A. Álvarez, A. Quejido, V. Esteban, J. Quiñones

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This publication provides the President's summary and findings of the conference as well as summaries of all the sessions. The accompanying CD-ROM contains the full conference programme, the list of participants and the papers.

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