ITWG Nuclear Forensics International Technical Working Group

ITWG NUCLEAR FORENSICS UPDATE

No. 21 December 2021

CHAIRPERSONS' ADDRESS

Welcome to the Nuclear Forensics International Technical Working Group newsletter, the ITWG Update. The past year has seen an evolution in the way the international community interacts and a concomitant change in ITWG activities. ITWG is still committed to identifying, developing and socializing best practices in nuclear forensic science, as evidenced by the recent launch of its seventh collaborative material exercise (CMX-7), but ITWG also initiated a new webinar series and held its first virtual annual meeting this past year. We are thankful for the active participation and strong technical content in both activities, and, likewise, we are thankful for the newsletter as a way to share updates among the community. This edition includes articles about updates to the Graded Decision Framework by Jeremy Gribble and Naomi Marks (page 1), about transporting evidence contaminated with radioactive material by Emily Alice Kroeger and Jens-Tarek Eisheh (page 3), and an update on the International Atomic Energy Agency (IAEA) nuclear forensics and radiological crime scene management activities by Gary Eppich (page 5). The pandemic continues to keep the world in suspense and in many countries around the globe restrictions are tightening up again. Nevertheless, we are optimistic and started making arrangements for an in-person annual meeting in June 2022. The first announcement will be issued soon; we hope to see you there. Finally, it is with deep sorrow that we note the passing of Dr Tamas Biro of the Centre for Energy Research, Budapest, Hungary (formerly the Institute of Isotopes). Dr Biro (Tamas) died in November 2021. Tamas was one of the original members of the ITWG Executive Committee (in the late 1990s and throughout the 2000s) and was unyielding in his advocacy for nuclear forensics and the work of the ITWG. Several of us now involved in the ITWG community counted Tamas as a mentor and great friend.

With our best wishes for a healthy holiday season,

Klaus Mayer and Michael Curry

EXPRESSING UNCERTAINTY IN PROVENANCE ASSESSMENTS: AN UPDATE ON THE GRADED DECISION FRAMEWORK

JEREMY GRIBBLE AND NAOMI MARKS

Assessing the origin of radioactive material

When radioactive material is discovered outside regulatory control, external stakeholders such as law enforcement agencies may commission nuclear forensics practitioners to assess the possible origin of the material. Various types of uncertainty make this assessment challenging as they constrain the approaches that can be used and potentially limit the scope of any findings. Random variability in nuclear forensics measurements (e.g. from sample to sample) means that statistical methods must be used to quantify uncertainty. The possibility of missing information (such as whether contamination might be present) must be given expert consideration. Finally, there may be insufficient comparator data or no data from the true origin of the unknown sample. These challenges place limitations on the language that can be used in the final assessment. The assessment should be tempered by subject matter expertise and take into account the quality of the evidence to arrive at an understanding of the overall uncertainty in the assessment. All this must be communicated clearly to the customers.

Clear communication is necessary to minimize the risk that inappropriate real-world actions are taken on account of the assessment. Communicating the uncertainty clearly is challenging because customers may not be familiar with the details of the scientific

Continued page 2

Expressing Uncertainty in Provenance Assessments *continued from page 1*

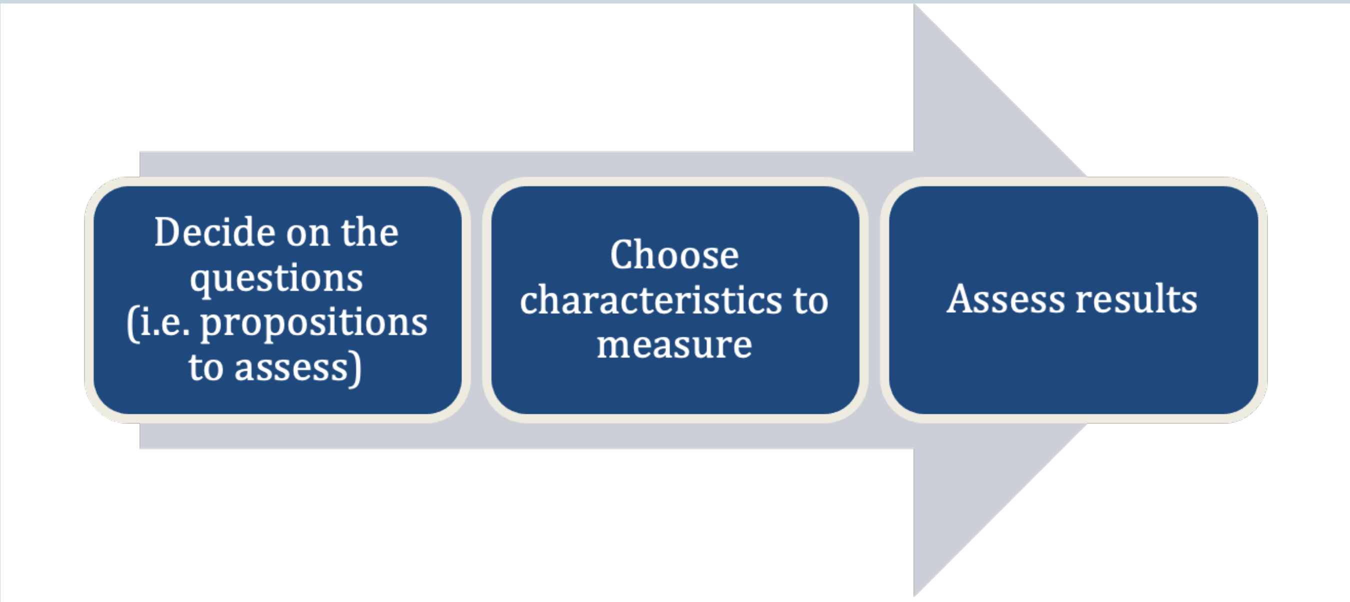


Figure 1. Schematic illustration of the graded decision framework process

analytical techniques used to examine the material, the statistical methods used to process the data or the language used to express the statistical results.

Graded decision framework

The graded decision framework (GDF) is a draft guidelines document prepared by the ITWG Guidelines Task Group which provides a statistically grounded framework to communicate confidence in findings to investigative authorities and other customers (see figure 1). It is intended to be accessible to nuclear forensics practitioners who are not themselves statistical specialists and do not have ready access to such expertise. Mainly intended for use in exercises, it is hoped that some of the ideas will be useful more generally. It aims to inform expert judgement but not replace it. The GDF is offered as *a* tool for the nuclear forensic practitioner's toolbox, but not *the* tool.

The GDF's statistical approach is based on the traditional view of statistical hypothesis testing. For example, given data for some characteristics (e.g. isotope ratios) of a sample of unknown material, how consistent is this data with the data for a sample with known origin A? If the differences between the two batches of data can plausibly be attributed to random variability, then the data for the unknown sample may be said to be consistent with origin A. If the difference between the measurement values for the two samples is bigger than can reasonably be explained solely by random variability, then it can be said that the unknown sample is inconsistent with origin A with a level of statistical confidence that reflects the discrepancy between data from the known and unknown samples. The magnitude of this discrepancy is quantified in terms of a number known to statisticians as the p-value. The *smaller* the p-value, the *bigger* the discrepancy between the two batches of data and the *greater* the degree of inconsistency between the two samples.

A process of elimination

The GDF method is essentially a process of elimination. For example, an unknown sample might be compared with a collection of samples of known origins A, B, C and so on. The origins which are inconsistent with the unknown sample can be eliminated. It may, however, be the case that the data for the unknown material is consistent with more than one possible origin. Does this mean that if all but one of the possible origins have been eliminated, then it can be asserted that the unknown sample necessarily has the same origin? Unfortunately, this is not the case due to a key difference between conventional and nuclear forensics.

The practitioner of conventional forensics considering the composition of a sample of glass from a crime scene may have access to a comprehensive database and have confidence that the true origin of the sample of glass is represented there. Due to the circumstances in which nuclear material is produced, the nuclear forensics practitioner probably has no such assurance. In the absence of complete confidence that the true origin of the material is represented within the comparison data, the best that can be done is to state whether or not the unknown material is consistent or inconsistent with the different batches of data of known origin.

Revisions to the graded decision framework

The original version of the GDF was produced by Rich Hanlen (Pacific Northwest National Laboratory) in 2009 and has evolved with input from various colleagues since then. The authors of this article have been collaborating since December 2020 to update the document in light of feedback on the previous version (version 2). A draft version 3 was produced in spring 2021. The revisions mainly concern the status of the GDF and the circumstances under which it should be used. They also improve the clarity of the explanation of some of the technical material; the technical content of the methods themselves remains the same as in version 2.

The revised version was presented at the ITWG virtual annual meeting in June 2021 and an online training session was delivered in July 2021. Version 3 has been submitted to the guidelines committee for formal review and it is anticipated that version 3 will be distributed to participants of the seventh collaborative material exercise (CMX-7). A recording of the training session is available on the closed ITWG website. •

TRANSPORTING EVIDENCE CONTAMINATED WITH RADIOLOGICAL AND NUCLEAR MATERIAL: CHALLENGES AND APPROACHES

EMILY ALICE KROEGER AND JENS-TAREK EISHEH

It is essential for nuclear forensics that evidence from a radioactively contaminated crime scene (RCS) is analysed at a suitable laboratory. However, this presents a challenge for radiological crime scene management (RCSM) and nuclear forensics practitioners (see IAEA Nuclear Security Series no. 22-G). The transportation of evidence contaminated with radiological and nuclear (RN) material from the RCS to the nuclear forensics laboratory, possibly via an interim storage site, is a complex topic. This article sets out the main considerations for the transport of evidence contaminated with RN material (or evidence that is itself RN material). In addition, the article shares the practical approach used in Germany.

Figure 1. Type A package used to transport a Cobalt-60 source from a storage site to Radiochemistry Munich for further examination. The German Federal Office for Radiation Protection organized the transport in 2020.

Laboratory restrictions

Before evidence from an RCS can be transported, it is important, on the one hand, to consider that most police laboratories cannot accept radioactive materials, and on the other hand, that nuclear forensics laboratories can typically not accept explosives or any biological or chemical hazardous material. Restrictions could be due to a lack of licence or safety measures or an excessively high risk of contamination to the laboratory. This leads to the following questions, which should be addressed before transport:

- Is the evidence contaminated with RN materials (or is it RN material)?
- Is the evidence free of explosives?
- Is the evidence free of biological and chemical hazards?

Evidence can be transported to a suitable nuclear forensics laboratory if it is contaminated with radioactive material, or is itself radioactive or nuclear material, but can be shown to be free of explosives

Continued page 4

Transporting Evidence Contaminated... *continued from page 3*

Figure 2. Type A packages, SAFPAK, designed as a reusable Type A package to the IAEA Regulations for the Safe Transport of Radioactive Materials. Credit: Dean Calma/IAEA

Figure 3. Type B packages, SAFKEG, designed as a reusable Type B package in accordance with the IAEA Regulations for the Safe Transport of Radioactive Materials. Credit: Dean Calma/IAEA

and of biological and chemical hazards at the RCS. Evidence can be transported to a laboratory or interim storage site that can accept this kind of evidence if it is contaminated with RN material and is not free of explosives or of biological and chemical hazards (and these cannot be separated at the RCS). Ideally, this site should be identified far in advance of any deployment. In any case, the chain of custody considerations should be agreed upon in advance, in particular whether the evidence can be examined without law enforcement present and whether the evidence can be stored in the laboratory or interim storage site in a suitable way.

To tackle some of these themes, the Radiochemistry Munich (RCM) extended the sixth collaborative material exercise (CMX-6)—an exercise series organized by the ITWG Exercise Task Group—in 2019; it was assumed that the exercise package arriving at the laboratory could contain explosives. This was not the case, but the assumption allowed the Bavarian State Criminal Police Office (BLKA) to engage at the beginning of CMX-6. The BLKA used their procedures for an RCS to show that the CMX-6 materials were free of explosive devices.

In general, the initial versions of the nuclear forensics examination plan and the nuclear forensics analytical plan (see IAEA Nuclear Security Series no. 2-G (Rev.1)) should be discussed before evidence is transported between an RSC and a laboratory. This is an iterative process: not all the nuclear forensics examinations that are possible are always necessary for a successful police investigation. This initial planning will inform law enforcement on which laboratory is most suitable for the analysis.

Packaging contaminated material

The evidence contaminated with radioactive material should be packaged for transport according to the legal requirements (see figures 1–3) and in a way that reduces the total dose rate and the surface contamination in accordance with the relevant transport regulations. Shielding materials that are suitable for transport should be kept on hand by radiation protection authorities or other RCSM experts for this eventuality.

Evidence contaminated with radioactive material must be transported in accordance with local, national and, where applicable, international laws. A local or national radiation protection authority, a specialized company or an international partner could carry out the transport depending on the capabilities available, the urgency and other considerations. Military transport could also be considered depending on which state is concerned and other factors. Relevant information about the evidence should be forwarded to the laboratory that will take the material, in particular the initial characterization of the RN material. Law enforcement may travel with the transport depending on chain of custody considerations.

It can be useful after transport if there is a separate laboratory for unknown (not fully characterized) samples, ideally on the laboratory site with a separate entrance, which can receive evidence contaminated with RN material. The German Federal Office for Radiation Protection (BfS), for example, has a laboratory that can receive material with higher activities than the main laboratory. The BfS laboratory for unknown samples was used during the initial nuclear forensic examination of evidence contaminated with Iodine-125 (found in Berlin/ Brandenburg in 2014–17).

German approaches to transport of RN material

Within Germany, there are, broadly, two possible alternatives for transporting evidence contaminated with radioactive materials. The first is emergency transport by the police for immediate hazard prevention. This does not require a transportation permit and can be carried out directly by the police. The second approach is transport under a normal permit from the relevant authorities for the transportation of radioactive materials. This can be organized, typically within 48 hours, by the radiation protection authorities working together with law enforcement as part of RSCM. Further options are also possible, but typically a transport under a normal permit is used.

International regulations, for example, the Agreement of 30 September 1957 Concerning the International Carriage of Dangerous Goods by Road (ADR) should be applied for transport between states.

Regardless of the exact approach to the transport of evidence contaminated with radioactive material, the relevant competent authorities and the nuclear forensics laboratory should test and refine the approach through tabletop and/or practical exercises. This process is undergoing constant optimization in Germany. The main lesson learned is that a community of RCSM and nuclear forensics practitioners who know each other and can contact each other easily is essential to overcome transport challenges quickly. •

FROM THE RADIOLOGICAL CRIME SCENE TO THE NUCLEAR FORENSIC LABORATORY: CURRENT PERSPECTIVES AND FUTURE DIRECTION AT THE IAEA

GARY R. EPPICH

Investigating nuclear smuggling incidents

The threat of nuclear or other radioactive materials falling out of regulatory control and into the hands of those that might cause harm continues to evolve in unexpected ways. In response, the IAEA continues to explore ways to better assist IAEA member states to thoroughly investigate nuclear smuggling and trafficking incidents. Nuclear forensics remains, of course, a cornerstone of any member state's response to a nuclear security event involving material out of regulatory control. However, the IAEA recognizes that more must be done to ensure that the outcomes of nuclear forensic examinations can be utilized by the competent authority in each member state, resulting in successful investigations, prosecutions and convictions of criminal smugglers and traffickers.

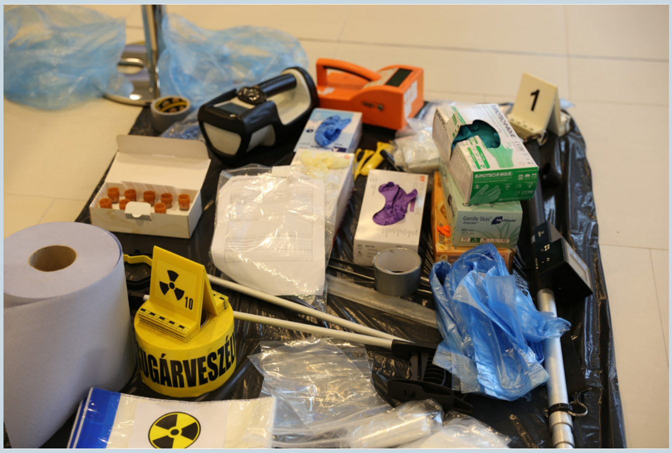
Nuclear Security Plan 2022–25 approved

The IAEA Nuclear Security Plan 2022–25 was recently approved by member states at the 65th IAEA General Conference. It highlights the importance of assisting states in radiological crime scene management (RCSM) and nuclear forensics, and emphasizes the alignment of these two key areas. To this end, the IAEA assists member states to strengthen their capabilities in RCSM in a variety of areas. These include in-field categorization analysis through gamma-ray spectrometry and neutron detection

Figures 1 and 2. A side event of the 65th IAEA General Conference demonstrates the key elements of radiological crime scene management and its connection to nuclear forensics. Credit: S.H. Bolt/IAEA

Continued page 6

From the Radiological Crime Scene... *continued from page 5*



Figures 3 and 4. Radiological Crime Scene Management and Nuclear Forensics Side Event, 22 September 2021. Credit: Fiorda Llukmani/IAEA

equipment, as well as training on best practices in operating in a crime scene where nuclear or other radioactive materials are known to be or are suspected to be present. These activities, combined with other on-scene activities and the laboratory-based methods that form the basis of nuclear forensic science, are necessary for the successful investigation of nuclear or other radioactive materials encountered out of regulatory control.

A highlight of the 65th IAEA General Conference, held this year in September, was a side event (see figures 1–4) involving a demonstration of best practices in RCSM, conducted by a team of Hungarian law enforcement and nuclear forensic experts. The event simulated a scenario in which a combined team of law enforcement and scientists equipped with the appropriate personal protective equipment investigated a crime scene contaminated with radionuclides. Participants were shown the types of procedures often used in this challenging working environment and were able to witness the application of various types of field-deployable gamma-ray spectrometry and neutron detection equipment. The demonstration team re-enacted the techniques used in the proper collection and documentation of specific types of evidence, such as hardware (in this case a cell phone) contaminated with radionuclides, as well as the radioactive material itself. The demonstration highlighted other key RCSM concepts, including the need for personnel assigned with specific tasks (such as evidence collection, photography, team leader and radiation protection), the use of different detection equipment to allow for safe ingress and egress at the crime scene (e.g. telescopic dose meters, surface

NOTABLE PUBLICATIONS ABOUT THE WORK OF THE ITWG, NUCLEAR FORENSICS AND RELATED DISCIPLINES

- Glennon, K. J. et al., 'Nuclear forensics methodology identifies legacy plutonium from the Manhattan Project', *Journal of Radioanalytical and Nuclear Chemistry*, vol. 330 (October 2021), pp. 57–65.
- Schwantes J. M., Corbey, J. F. and Marsden, O., *Exercise Celestial Skónis: 6th Collaborative Materials Exercise After Action Report, PNNL-32028* (Pacific Northwest National Laboratory: Richland, WA, 2021).
- Burdeinyi, D. et al., 'Application of HRGS for forensic characterization of uranium oxides, pure uranium metals and uranium alloys', *Applied Radiation and Isotopes*, vol. 177 (November 2021), 109910.
- Brandis, M. et al., 'Morphological and chemical characterization of uranium and cerium nuclear forensics samples', *Journal of Nuclear Materials*, vol. 555 (November 2021), 153109.
- Vesterlund, A. et al., 'National nuclear forensics libraries: A case study on benefits and possibilities for identification of sealed radioactive sources', *Journal of Radioanalytical and Nuclear Chemistry*, (December 2021), pp. 1–5.

contamination monitors and radioisotope identifiers), and the critical need to preserve continuity of evidence and prevent cross-contamination of evidence.

Successful crime scene management

Successful management of a radiological crime scene ensures that nuclear and other radioactive materials collected at the scene are properly handled as evidence and can be analysed by the nuclear forensic laboratory in a manner useful in legal proceedings and to further the investigation.

The need to coordinate and synchronize activities in RCSM and nuclear forensics is also reflected in a current IAEA Coordinated Research Project (CRP), 'Applying Nuclear Forensic Science to Respond to a Nuclear Security Event'. The CRP is funding fifteen research and development projects, run by IAEA member states, that aim to further the community's understanding of the types of analyses and approaches that can lead to the successful investigation and prosecution of criminal smugglers and traffickers through RCSM and nuclear forensics. Many projects within this CRP utilize gamma-ray spectrometry and other non-destructive analytical instrumentation, often focusing on the types of nuclear or other radioactive materials that have been encountered most frequently. The technical document that will be published as a result of the innovative work will assist all member states in furthering their goals and objectives in RCSM and nuclear forensics. Another CRP, currently at the planning stage, will continue to seek member state ideas on how to improve approaches and scientific support to RCSM, and to better connect RCSM and nuclear forensics.

As the international community continues to manage the effects of the Covid-19 pandemic, the IAEA remains available to assist member states in the development of RCSM and nuclear forensics capabilities in support of nuclear security. At the upcoming IAEA Technical Meeting, 'Nuclear Forensics: From National Foundations to Global Impact', one full day will be devoted to RCSM and will highlight the many connections between activities that occur at the crime scene and those that occur at the laboratory. Other topics related to nuclear forensics will be discussed in Davos-style panels, and participants will be able to take part in other interactive sessions and demonstrations. Member states will also have the opportunity to present recent developments in nuclear forensics and related areas in technical sessions, sharing their innovations with the global nuclear forensic community. •

UPCOMING TRAINING COURSES AND MEETINGS*

- ITWG Webinar, Virtual, 14 December 2021
- European Commission's Joint Research Centre (JRC), National Workshop on Response to Nuclear Security Events, Virtual, 14–16 December 2021
- 12th International Conference on Methods and Applications of Radioanalytical Chemistry (MARC XII), Kailua-Kona, Hawaii, United States, 3–8 April 2022
- IAEA Technical Meeting on RCSM and Nuclear Forensics, Vienna, Austria, 11–14 April 2022
- French Alternative Energies and Atomic Energy Commission (CEA) ,Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) Research and Innovation Conference, Lille, France, 2–5 May 2022
- ITWG Annual Meeting, San Francisco, California, United States, TBD June 2022
- Science and Technology Center in Ukraine (STCU), Nuclear Forensics Summer School, Kiev, Ukraine, 5–9 September 2022
- Japan Atomic Energy Agency (JAEA), 7th Asia-Pacific Symposium on Radiochemistry 2022 (APSORC22), Fukushima, Japan, 11–16 September 2022

*Please check directly with the event organizer on the status and dates for implementation of the individual events listed above.

Dates and locations of IAEA training courses and meetings will be officially confirmed with host member states; participation in IAEA training courses and meetings is by nomination and in accordance with established IAEA procedures.

CONTENTS

NUCLEAR FORENSICS

Nuclear forensics is an essential component of national and international nuclear security response plans to events involving radioactive materials diverted outside of regulatory control. The ability to collect and preserve radiological and associated evidence as material is interdicted and to conduct nuclear forensics analysis provides insights to the history and origin of nuclear material, the point of diversion, and the identity of the perpetrators.

THE NUCLEAR FORENSICS INTERNATIONAL TECHNICAL WORKING GROUP

Since its inception in 1995, the Nuclear Forensics International Technical Working Group (ITWG) has been focused on nuclear forensic best practice through the development of techniques and methods for forensic analysis of nuclear, other radioactive, and radiologically contaminated materials. The objective of the ITWG is to advance the scientific discipline of nuclear forensics and to provide a common approach and effective technical solutions to competent national or international authorities that request assistance.

ITWG PRIORITIES AND ACTIVITIES

As a technical working group, the priorities for the ITWG include identifying requirements for nuclear forensic applications, evaluating present nuclear forensic capabilities, and recommending cooperative measures that ensure all states can respond to acts involving illicit trafficking and unauthorized possession of nuclear or other radioactive materials. An objective of the working group is to encourage technical peer-review of the nuclear forensic discipline. These goals are met through annual meetings, exercises, and informal and formal publications.

Outreach is a primary goal of the ITWG. The working group disseminates recent progress in nuclear forensic analysis and interpretation with the broader community of technical and security professionals who can benefit from these advancements. Affiliated international partner organizations include the International Atomic Energy Agency (IAEA), the European Commission, the European Police Office (EUROPOL), the International Criminal Police Organization (INTERPOL), the Global Initiative to Combat Nuclear Terrorism (GICNT) and the United Nations Interregional Crime and Justice Research Institute (UNICRI).

ITWG MEMBERSHIP

Nuclear forensics is both a technical capability as well as an investigatory process. For this reason the ITWG is a working group of experts including scientists, law enforcement officers, first responders, and nuclear regulators assigned by competent national authorities, affiliated contractors, and international organizations. The ITWG is open to all states interested in nuclear forensics.

ITWG participating states and organizations recognize that radiological crimes deserve thorough investigation and, when warranted, criminal prosecution. The ITWG encourages all states to possess the basic capability to categorize nuclear or other radioactive materials to assess their threat. As an international group, the ITWG shares its expertise through its membership to advance the science of nuclear forensics as well as its application to nuclear security objectives.

http://www.nf-itwg.org/

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