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Integration of Nuclear Safeguards and Security at the JRC

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Abstract
At political level, security and safeguards remain in separate hands. Safeguards are implemented by international and national authorities through an international treaty, while security is an important national responsibility.
At a technical level the synergies between safeguards and security lead to their integration allowing better optimization of the resources and important benefit from exchange of experience and expertise between the two systems.
In this paper, we will illustrate this integration process between nuclear security and safeguards. Many examples will be presented such as: non destructive assay (NDA) in nuclear safeguard /detection and identification of illicit nuclear and radioactive materials, destructive analysis (DA) and environmental sampling in nuclear safeguards/ nuclear forensic, use of seals in nuclear security for containers, combined camera and gamma/neutron source for source localisation in luggage, Open source information, export controls are also areas were the integration is possible.

1. Introduction

The JRC has now about 35 years experience in the implementation of nuclear safeguards in support to IAEA and even more in support to the Euratom inspectorate. It gained a significant experience in facing the challenge of safeguarding nuclear materials in huge and complex facilities, such as the European reprocessing plants. With the implementation of the Additional protocol, it looked at the overall picture of a countries nuclear activities with additional measurement activities (such as particles, swipes, etc.) and as well as at the suspicion of potential hidden activities, undeclared operations or inconsistent data. The JRC continues to contribute to the excellence of the EU situation concerning safeguards records and to IAEA activities world wide.
More recently, the Joint Research Centre was involved in the broad nuclear security. Although its activities in this field started in the nineties with the increasing number of seized nuclear materials inside the EU, the establishment of activities in this field of nuclear security as part of JRC Euratom work programme was confirmed in the recent few years. Actually since its adoption by the EU Council in 2003, the various Directorate General of the European Commission were deeply involved in the implementation of the EU security strategy. The JRC in providing technical and scientific support to these services and to EU Member States puts an important effort in the field of security in general and in the nuclear security area in particular.
Answering to new challenges, such as the detection of undeclared activities, the diversion of nuclear material or theft of radioactive sources associated with illicit trafficking of such material or sources, as well as other issues related to nuclear security; integration and enhanced coordination of safeguards and security activities was our answer to these challenges.
In this paper, we will illustrate this integration process between nuclear security and safeguards. Many examples will be presented such as: the integration of non destructive assay (NDA) in nuclear safeguard with detection and identification of illicit nuclear and radioactive materials, destructive analysis (DA) and environmental sampling in nuclear safeguards and nuclear forensic, use of seals in nuclear safeguards and security, combined camera and gamma/neutron source for source localisation, Open source information collection and analysis and export controls are also areas were the integration of safeguards and security is possible.

2. Some definitions

2.1. Nuclear Safeguards

In the Information Circular (INFCIRC)153 [1], the technical objective of International Nuclear Safeguards is defined as :"…the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by risk of early detection." . The safeguard is about deterrence of diversion.
The safeguards approach can include several different types of IAEA systems. These systems fall into several typical categories such as Tamper Indicating Devices (Seals), Containment and Surveillance, Radiation Monitors (Non-Destructive Analysis) that can be passive (receiving) or active (emitting), Very small nuclear materials sampling (Destructive Analysis), Swipe samples from the environment, Process Monitoring systems to watch the operating parameters of a chemical process, Information, export control / Trade analysis, Open source intelligence

2.2. Nuclear security

According to IAEA [2], the nuclear security is the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear or other radioactive substances or their associated facilities. Prevention includes issues like reliable inventories, Physical Security and Blending down HEU. The Detection concerns identifying possible signature, Monitor choke points, Monitor smuggling gaps, Nuclear detection programs and Response is mainly about the assess of dispersal of radioactive material, Collect samples for analysis, Identify from materials and design (Nuclear forensics).

2.3. The integration of Safeguards and security:

The table 1 summarises how we at the JRC have integrated the safeguards and security programmes. This matrix can be of course more developed in order to integrate more safeguard and security.

Safeguards / Security	NDA (Non Destructive Assay)	DA (Destructive Assay)	Containment	Surveillance	Environmental Sampling	Export and import Control	Information
Prevention	**Remote monitoring** **Physical protection**		**Seals** **Security of containers**	**Satellite images** **Cameras, 3D Laser**		**Early warning**	**Open source information (early warning)**
Detection	**Passive and active detection** **Gamma and neutron alarms**			**3D laser Combined with Gamma/neutron for source localisation** **Satellite images**	**Particle analysis, detection of undeclared activities**	**Detection of Dual use Materials**	**Open source information (detection of undeclared activities)**
Response	**Identification and categorisation of Nuclear and radioactive materials**	**Nuclear Forensic: Isotopes, mass, impurities, age, geo-location,…**		**3D laser Combined with Gamma/neutron for mapping the dispersion of radioactivity**	**Nuclear Forensic: Isotopes, sizes, populations,…**		

3. Examples of Integration of Safeguards and security at the JRC

3.1. Reference Materials

Reference materials play an important role in analytical quality assurance. They are the essential pillar in establishing traceability and enabling comparability of measurement results, a key element in the process of safeguarding nuclear material. The basic purpose of their use is to validate the measurement process, and thus to provide a record of the analytical performance of a facility. Measurement laboratories benefit from the correct use of certified reference materials for calibration of instruments or measurement systems, method development and validation, and for quality control purposes. As chemical analytical methods often provide the basis for radiometric or non-destructive techniques, a link between the latter and reference materials for destructive analysis can be established, thus contributing to establish traceability of non-destructive measurements. Most quality assurance schemes (e.g. ISO 17025) also require laboratories to participate in interlaboratory comparisons to demonstrate and evaluate their measurement capabilities. In nuclear safeguards elemental reference materials, isotopic reference materials and spike reference materials are used for verification and accountancy of nuclear materials. Additionally, as the importance of actively verifying nuclear treaty compliance increases, new safeguards technologies and methods are being implemented that require new, more complex reference materials, including the need for reference materials for soils, for particles, reactor fuels of various forms/types, use of trace element compositions within nuclear material to determine origin or processing type, and materials in support of advanced power and recycling facilities. Particularly these kinds of reference materials are indispensible to provide reliable measurement results of high quality applying analytical procedures that give access to the complete (nuclear) fingerprint enabling to draw conclusions on origin, history, purpose and intended use of the material or sample under investigation [3-4]. This is of major importance towards the convergence of nuclear safeguards, nuclear forensics and nuclear security.

3.2. The Seals

The Seals and Identification Laboratory (SILab) developed ultrasonic bolt seals for years now, are applied in several countries throughout the world (UK, France, Romania, Pakistan & Canada) by the IAEA and by DG ENER / Euratom inspectors for Safeguards application, mainly underwater storage of nuclear spent fuel.
In parallel SILab also developed as a spinoff seals for the Supply Chain, which security shall be improved and achieved through tracing and tracking techniques to guarantee a controlled delivery of goods to the final distributor for the benefit of the citizen. The increased international awareness on security issues calls for improving, evaluating and making available best tracing technologies in order to reduce risks. Those seals are not anymore ultrasonic bolt seals but electronic passive or active seals, able to monitor openings or attempt of tampering and store the information (passive) and send the information to headquarters (active).
Recently, the Agency requested to adapt this type of “low cost” seals for surveillance of dry storage containers.
So it becomes clear that the same object, the seal, can be used for nuclear Safeguards (detection of diversion of nuclear material) and for nuclear Security (prevention and detection of theft, sabotage, … of nuclear substances). The seal just has to be adapted to the environmental conditions of exploitation and storage, but the aim remains the same : detect legal or illegal opening of a “container”.

3.3. Particle Analysis

In nuclear Safeguards one distinguish between traditional safeguards, which is mainly focused on nuclear material accountancy and strengthened Safeguards that is focused on verifying the absence of non-declared nuclear activities. In addition there is nuclear security with forensics analysis that is deployed as part of investigations to trace the origin of nuclear materials that has been diverted.

All three topics have however several common analytical needs and instruments like Thermal Ionisation Mass Spectrometry (TIMS) and Inductive Coupled Plasma Mass Spectrometry (ICPMS) are used for traditional Safeguards and nuclear forensics but can also be used for bulk swipe samples in strengthened Safeguards measures.

Scanning Electron Microscopes are often used both in nuclear forensics and in analysis of samples taken under strengthened Safeguards measures.

Another example is particle analysis typically made on sub-micron to micron sized uranium particles by

Secondary Ion Mass Spectrometry (SIMS) [5]. These analysis are typically refereed to as High Performance Trace Analysis (HPTA) used to analyse particles collected on swipe samples. These samples are taken as a routine measure to verify the declarations made by operators on European and international enrichment facilities. HPTA measurements can also be deployed to verify the absence of undeclared nuclear material handling at other types of facilities or sites. In nuclear forensics uranium particle analysis is also used, see Fig 1. One example of this is contaminated scrap materials that have been seen to carry mixtures of uranium materials with different composition. To determine the later particle analysis by SIMS are deployed.

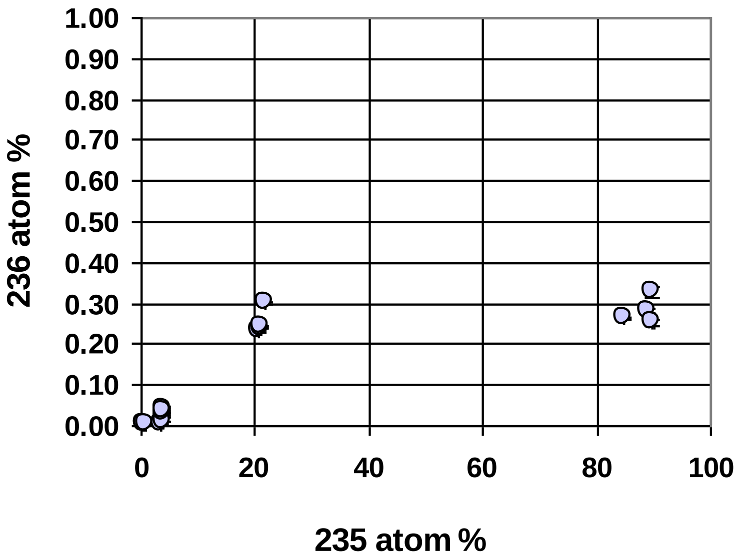

Fig 1. ^{236}U versus ^{235}U relationship on particles from a nuclear forensic sample analysed by SIMS. The SIMS particle analysis reveals that it is a mixture of different materials

3.4. Nuclear Forensics in nuclear Safeguards and security

The challenges associated with strengthened safeguards call for more investigative analytical methods. The verification of treaty compliance according to comprehensive safeguards agreements and according to the additional protocol are associated with a tremendous need for information. Part of the information required for the evaluation of the completeness of a state's declaration is inherent to the nuclear material. Advanced measurement methods need to be introduced in nuclear safeguards, methods that are very much of investigative character. Such methods have been applied in the area of nuclear forensics for almost two decades. Let us recall in this context two main prerequisites:

- The production and processing of nuclear material leaves (inevitably) traces in the environment. This is fundamental to environmental sampling. Depending on the cleanliness of the process and on the quality of the installations, the range of detectable traces can be rather narrow. The experience gained in many years of environmental sampling in general and of particle analysis in particular has demonstrated the power of this methodology.
- Every production process will leave characteristic patterns in the material. There are, however, a number of measurable parameters which may vary as a function of starting material, of process parameters, of reagents used, of storage conditions or of vessel materials. The complexity of the data and the interrelations between individual parameters require a careful step-by-step approach from measurement to data interpretation.

Chemical composition, impurities, isotopic composition of the nuclear material, isotopic composition of accompanying elements, particle size and microstructure are data which are accessible through measurements and which provide hints on the history of nuclear material. History, in this context may mean the age of the material (time elapsed since last chemical purification), the process by which the material was produced, the intended use of the material or the place of production. The instrumental techniques applied for measuring these parameters are well established; however the analytical methods have to be adapted to the specific needs of this type of investigative safeguards analysis. For developing such methods, we can benefit from experiences made in other fields of science: e.g. isotope geology, cosmochemistry, environmental chemistry or material science. Measurement techniques that are well established in modern nuclear safeguards, such as Inductively Coupled Plasma Mass Spectrometry, Secondary Ion Mass Spectrometry or Thermal Ionisation Mass Spectrometry may reveal information on the history of the material and thus serve also for nuclear forensics investigations [6-7]. The table 2 is a good example of the integration of the technical tools and methodolgies we used at the JRC for nuclear forensic and nuclear safeguards.

Category of Parameters	Technique	Information/Purpose	Safeguards
Physical Characterization	**Visual Inspection**		
	Radiography		
	Photography	**Documentation**	
	Weighing	**Mass of sample**	**X**
	Length measurements	**Dimensions**	
	Optical Microscopy	**Toolmarks**	
	Density		
	SEM/EDX	**Microstructure, Elemental Comp.**	
	TEM		
Traditional Forensic Analysis	**Fingerprints**	**Identification of individuals**	
	DNA	**Identification of individuals**	
Isotope Analysis	**Radiochem. Separations**		**X**
	γ-spectroscopy	**Nuclide identification**	**X**
	α-spectroscopy	**Nuclide identification**	**X**
	SIMS	**Isot. comp. of particles**	**X**
	TIMS	**Isotopic composition**	**X**
	MC-ICP-MS	**Isotopic composition**	**X**
Elemental/ Chemical	**Titration**	**Element assay**	**X**
	IDMS	**Element assay**	**X**
	ICP-MS	**Metallic impurities**	**X**
	GC/MS	**Organic impurities**	
	XRF	**Chemical impurities**	

Table 2: integration of the technical tools and methodologies used at the JRC for nuclear forensic and nuclear safeguards.

(SEM/EDX= Scanning Electron Microanalysis with Energy Dispersive X-ray fluorescence, TEM= Transmission Electron Microscopy, SIMS= Secondary Ion Mass Spectrometry, TIMS= Thermal Ionization Mass Spectrometry, ICP-MS= Inductively Coupled Plasma Mass Spectrometry, MC-ICP-MS= Multi-Collector Inductively Coupled Plasma Mass Spectrometry, XRF= X-ray Fluorescence, Analysis, IDMS= Isotope Dilution Mass Spectrometry, GC/MS= Gas Chromatography / Mass Spectrometry)

3.5. Non-destructive Assay (NDA)

The NDA techniques nowadays applied in nuclear safeguards have been originally developed and introduced with the goal to create and to provide measurement capabilities for verification measurements on nuclear materials contained in bulk items (e. g. process equipment, storage containers, finished unirradiated products, fresh and spent fuel elements etc.) through a true non-destructive assay. The NDA techniques developed and used at the JRC for this purpose include Passive Techniques, measuring self-radiation produced in the natural radioactive decay of actinides, and Active Techniques.

The JRC NDA experience gained from safeguards as well as the dedicated facilities and laboratories (e.g. the Performance laboratory at IPSC-ISPRA) are now also used by the JRC in the area of combating the illicit trafficking of nuclear and radioactive materials. As example of the JRC activities in this area of security is the implementation on behalf of the European Commission (HOME Directorate General) of the ITRAP+10 project. (Illicit trafficking radiation assessment program) [8-9]. The project is about an evaluation and comparison of the performance of available radiation detection equipment relevant to nuclear security (figure 1). The results will provide an independent assessment of the available radiation detection equipment on the market which will serve as a reference for regulatory and other Member State authorities to identify equipment and or families of equipment to address their particular needs, and help to ensure common standards at a European level. The manufacturer will get recommendations to improve performance, reliability and user-friendliness of the equipment.

Fig 2*: Performance testing of hand held identifiers devices (HH). HH are used by nuclear safeguard inspectors and front line officers.*

JRC has also invested in active methods in the nuclear safeguards by building the PUNITA facility (the Pulsed Neutron Interrogation Test Assembly*)*. PUNITA aims at direct measurement of the fissile content of the sample. To achieve this aim, intense bursts of thermal neutrons, produced by a neutron generator, induce fission in the fissile isotopes of the sample. The detection of fission neutrons and gammas are used for the sample analysis. In the nuclear safeguards, the method is particularly effective for small amounts of fissile material independent of their chemical or physical form and applications are expected to be diverse including nuclear waste.
In the area of nuclear security the instrument is ideal for testing quantitatively the efficiency of techniques for detection of fissile material and current applications are focussed on detection of special nuclear materials in shielded containment.

3.6. The 3D Laser Technology:

In the frame work of the EC support programme to IAEA, JRC has developed a laser based system for Design Information Verification (DIV) system aimed at enhancing IAEA's Safeguards verification capabilities. The 3D-DIV system is capable of creating an accurate geometric model (millimeter accuracy) of a complex facility "as-built"; detecting changes in the facility and integrating Safeguards data and measurements for easy presentation and interpretation. Following routine use experience the IAEA has now many of DIV systems. The technique would be also used for self-authentication or unique identification by using the native unique 3D surface structure of the UF6 cylinders to recognize and authenticate them.
In view of enhanced nuclear security, this technology can be envisaged also for urban radiation modelling, to create the baseline of radiation sources in large vulnerable areas, such as urban environments. The JRC participates to the EU project on-Integrated Mobile Security Kit (IMSK) that will combine technologies for area surveillance; checkpoint control; CBRNE (Chemical, Biological, Radiological, Nuclear and Explosives) detection and support for VIP protection into a mobile system for rapid deployment at venues and sites which temporarily need enhanced security. The laser technologies, to acquire 3D models (indoors and outdoors) will be used for i) change detection (offline and real-time); ii) integrate information from multiple sensors; iii) help sensor

deployment; and iv) situation awareness. This includes both local and wide areas (e.g. ground and aerial segments).

3.7. Open source information

Open source information is a key component of nuclear non-proliferation analysis. Open source information can shed light on a number of safeguards related matters such as research into sensitive technologies, details about nuclear material production, imports and exports of nuclear technology and information relevant to a State's development of its nuclear fuel cycle. In some cases, open source analysis can provide the first clue that a state might be pursuing a nuclear weapons programme counter to its treaty obligations.
JRC IPSC developed Europe Media Monitor (EMM) [10] news aggregator monitors more than 2,500 news sites – with multi lingual, world wide coverage– in near-real-time (some sites every five minutes) and collects more than 40,000 new items each day. EMM automatically analyzes the full-text articles and all news articles talking about the same event or subject are grouped into clusters and displayed by cluster size. The content is further categorized into over 750 customer orientated subject categories and themes. EMM offers additional analysis tools to deal with information overflow including e.g. detection of breaking news, entity extraction, duplicate detection and trend analysis.

JRC is currently working to further increase the benefit of using EMM for nuclear security information collection and analysis by starting the development of a *Nuclear Security Media Monitor* (NSMM). The NSMM will additionally monitor news sources reporting on nuclear security specific issues. Over 100 nuclear-specific sources have already been identified to be monitored by the NSMM. In addition to standard news sites, the NSMM will also monitor other types of web sites, for example .gov, Blogs or sites providing relevant scientific or technical information. The NSMM will also introduce more categories, which can filter the news according to relevant nuclear security themes and therefore allowing a structured organization of the retrieved news. In this way, the NSMM could support specific nuclear security programs such as e.g.:
- Combating illicit trafficking of nuclear and radioactive material through the timely detection of newly reported trafficking incidents in the news or
- Combating illicit exports of nuclear material, equipment and technology, by the monitoring the reported violations of export control regimes with respect to the exports of controlled equipments material and technologies

The systematic storage of the related information will constitute a data base of events for further exploitation and analysis.

3.8 Training

Over more than three decades the JRC has built up significant experience in measuring and controlling nuclear material through its involvement in the safeguards area. This long-standing expertise and competencies in the field has been made available for nuclear security training. For many years training courses in the areas of nuclear security have been carried out, focusing on the response to illicit incidents involving nuclear materials. Customs and police officers, regulators and measurement experts from EU member states, from the CIS countries and from western Balkan countries participated in these sessions.
The increasing demands from EU-MS authorities has been taken into account by the recently approved EU CBRN action plan and consequently the Joint Research Centre has been tasked by the EC (DG HOME) to work on the establishment of a European security training centre(EUSECTRA) for staff of authorities involved in the field of radiological and nuclear security. The program should encompass both detection and response to nuclear security events including nuclear forensics and build on the technical expertise, infrastructure and experience of Institute for the Protection and Security of the Citizen (IPSC – Ispra, Italy) and the Institute for Transuranium Elements (ITU – Karlsruhe, Germany). The feasibility study of the establishment of the EUSECTRA has been approved and the JRC and the next step would be its construction.

4. Conclusion:

At political level, security and safeguards remain in separate hands. Safeguards are implemented by international and national authorities through an international treaty, while security is an important national responsibility. At a technical level the synergies between safeguards and security lead to their integration allowing better optimization of the resources and important benefit from exchange of experience and expertise between the two systems.

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