# Chapter 14
# Nuclear Safeguards Challenges from a JRC Perspective

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Nuclear Safeguards is a well-established activity which at the same time continues to be under constant evolution and challenges, both at world level by the International Atomic Energy Agency in Vienna and at regional level e.g. by the European Commission Nuclear Safeguards Directorate (Euratom). This paper presents some of the major challenges, both for the nuclear safeguards inspectors and for the inspection regime itself, and hints towards potential solutions, based on currently ongoing research and development and several in-field trials and validations.

Because the continued increase of nuclear fuel cycle facilities to be safeguarded and the amount of nuclear materials under international control cannot be matched with a proportional increase of human resources or even operational budget, a number of innovative solutions are required to support the nuclear inspectors in their job, and new approaches for the more efficient and effective implementation of safeguards need to be tested and validated [1, 2].

This paper describes first a series of challenges for the nuclear safeguards inspectors and then proposes a number of potential solutions. Also several challenges for the safeguards implementation are described including proposals how to address them.

When analyzing the required skill-set for a high quality nuclear safeguards inspector, based on the authors perspective, an impressive amount of requirements come together. Table 14.1 provides an overview of a number of characteristic requirements for a nuclear safeguards inspector.

Other challenges that can be identified for the inspectors are e.g.: the pressure on delivering high performance and deliver proof of the inspection findings, having to use multiple equipment types, being confronted with complex installations with many Material Balance Areas, different reporting standards, only limited analysis

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**Table 14.1** Characteristic requirements for a nuclear safeguards inspector: an author's perspective

| Skills set | Topics |
|---|---|
| Technical expertise | Nuclear Materials & Measurements<br>Nuclear fuel cycle installations/technologies<br>Controlled commodities & Knowledge |
| Legal expertise | NPT<br>Safeguards agreements<br>Additional Protocol |
| Safeguards instruments | Normal inspections<br>Complementary access<br>Short Notice/Unannounced inspections |
| Soft skills | Observation skills: situational awareness/spot anomalies<br>Synthetical mind: connect the dots<br>Negotiation capabilities: diplomacy and assertiveness |
| Cultural sensitivity | Language specificities<br>Habits & traditions<br>Power distance etc. |

tools and thus a major challenge for data integration and evaluation. In addition, the information dealt with is often confidential and can be highly sensitive.

The proper training, in-field assistance and constant wish for improvement of nuclear safeguards skill and competences are thus key features for an effective and efficient "inspector". Such capabilities do not come overnight and require a medium term investment in the gathering of experience, through dedicated training, in-field work and discussions and/or joint analysis with the safeguards analysts in the inspector head-quarters [3].

With respect to the technical expertise, both the knowledge of the available measurement and surveillance technologies and type of facilities in the nuclear fuel cycle, are typically quite well developed and covered in detail in the mandatory training courses. The same does not hold true necessarily w.r.t. the expertise on controlled commodities (i.e. technologies, know-how etc. as they are e.g. in the Nuclear Supplier Guidelines). Focused training and increased capabilities for the "standard" nuclear safeguards inspector to gain additional insight in these matters is thus highly recommended [4].

On the legal side, perhaps the most challenging part for the nuclear safeguards community is the verification on the required declarations under the additional protocol. Two examples are the declarations to be provided under article 2, (annex I and II) and how to verify completeness of a state declaration, and the obligatory export declarations. In this respect, a direct contact with industry could be efficient and effective, but this is practiced typically only at voluntary level, as the official/legal interlocutor is the State Authority for safeguards.

Another area where further improvements can be considered concerns the full use of the different safeguards instruments and the way of implementing them in the field. Specific training courses are e.g. provided to the nuclear safeguards inspectors, in dedicated facilities offering a variety of nuclear fuel cycle operations, on the way to implement complementary access.

The latter connects immediately to the requirements to continue developing further the soft skills of nuclear safeguards inspectors, while e.g. during a complementary access inspection, the inspector might have to negotiate a lot with the operator w.r.t. correctness of documents, access to specific locations, clarification of inconsistencies etc.

Finally, it is deemed very beneficial if the safeguards inspector, taking into account the variety of the above listed challenges, has the required cultural sensitivity, starting of course from some (basic) knowledge of the language and safeguards vocabulary [5], the way of behavior (incl. role of hierarchy) in a country etc. This aspect is not always recognized to the full extent and it is thus recommended to assure at least a minimum exposure and awareness rising of nuclear safeguards inspectors to these issues. This could possibly be integrated in the tools and approaches for the improved preparation of future inspection missions, which is covered in the next chapter.

A number of tools have been either recently developed or in the process of being validated in the R&D facilities supporting safeguards.

Before physically visiting a site, new technologies that are currently under investigation can facilitate the inspection preparation phase, when studying the site from the office, e.g. by relying upon the wealth of information that can be provided by open source information, review of the history of the site, looking at the trends of previous inspections and studying "typical anomalies" that can occur in such facilities. One example is the geotagging of social media activity of a particular site to distinguish between open and closed buildings. Also the use of virtual reality and 3D Vision to familiarize with all features of the site-interior can make the inspector much more confident about where to go, what to observe, which barriers to face etc. An illustration is provided in Fig. 14.1 below. To upfront be aware of the changes in between two inspections, satellite imagery, aerial monitoring and use of specialized software to spot the changes can be very useful.

When an inspector goes on site, his or her work could be supported and enhanced by the use of several different sensors (nuclear measurements, laser monitoring, volume and density, ultrasonics, particle collectors/analysers etc.). Automatic reconstruction and intercomparison with the 3D model of the facility visited earlier should become the standard. Similarly, the opportunities offered by augmented reality and ambient intelligence during the physical inspections should be fully exploited. When these multiple signals can then in real-time be compared to the "expected operations" based on a realistic model of the plant processes and operational practices, this can immediately lead to the almost real time registration of anomalies, which might then be able to be addressed on the spot. To allow the testing and validation of such approaches, dedicated laboratories are required, such as the one set-up by JRC in Ispra, called Advanced Safeguards Measurement, Monitoring and Modelling Laboratory [6, 7].

From both physical inspections and from the gathering of open source data, a vast amount of data is accumulated in the inspection head-quarters. The analysis

**Fig. 14.1** Illustration of use of 3D model vision, reconstructed based on laser measurements

and exploitation of this valuable set of data could benefit from the use of advanced technologies like those developed in the area of Big-data and Data-analytics tools, both for enhanced visualization of the data and enhanced analysis (including finding issues, based on these data, which one is not necessarily a priori looking for). Multiple approaches like pattern recognition, neural networks, machine learning etc. and be deployed in this field including the analysis of variations/trends etc. over time and location and also the influence of the human element in the chain.

There are aspects that might potentially prevent the full exploitation of the inspectors skills and capabilities. Some of these aspects could be prevented and/or mitigated via solutions aiming at:

- Preventing stove-pipe thinking based on preconceived opinions
- Confronting all-information sources to seek for inconsistencies/signals
- Exploiting full information as allowed in the Safeguards Agreement (incl AP)
- Using of physical model or other guidance tools to structure information
- Enhancing collaborative platforms and assure regular updating of files
- Optimizing the open source data gathering process and tailor to specific needs

Both because of human resources constraints and because of the experience and potential in remote controlling and operating very sophisticated equipment and tools, it is proposed to also consider a paradigm shift in nuclear safeguards inspections, from the limited (de facto) independent safeguards verifications, to a monitoring of the full processes of a nuclear fuel cycle facility to guarantee its proper operation. While independent verification is crucial and at the core of safeguards verification activities, the possibility to complement it via a broader process monitoring could be beneficial in gaining a better and more consistent characterization of the big picture of the state's nuclear fuel cycle activities.

This proposal is based first of all upon a number of shortcomings of the current in-field inspections and the full exploitation of its results i.e.

- For the independent control it is difficult to work in "partnership" with operators and/or states
- Independently measured data are prone to inherent differences with operator
- There is a limited number of measurement points/sample taking opportunities
- Individual measurements do not show full picture
- There is a lack of full/complete insight in the installation
- Often there are no real-time warning/control in case of deviations
- It is difficult to quantify the overall contribution of a finding to "satisfactory" confidence.

For all of the above reasons, and some additional potential benefits to be identified still in the approach, it is proposed to move toward and/or complement the current approach with a full process monitoring of the facility. The benefits are manifold:

- Have a proper model of the "normal"/authorized operation of the plant
- Integrate maximum amount of process control parameters in the monitoring
- Combine COTS equipment with specific "safeguards grade" tools [8]
- Remote data transfer in (near) real time (respecting security and commercial sensitivity concerns without undue restrictions: WIN-WIN with the operator)
- Analyse (in)consistencies between signals/detect anomalies etc. [9].
- Optimize statistical data treatment to focus on data reduction/filtering
- Define intervention/alert levels based on multiple signals (risk based) (mixed hierarchy and intervention levels (unannounced inspections/direct halt of certain paths/need for a posteriori verification of certain steps etc.).

In Fig. 14.2, a set of different levels of challenges and focus points for current safeguards R&D are listed, starting from issues with the direct measurement of the nuclear materials (e.g. in spent fuel) which continues to pose challenges and requires adequate tools, training and experience [10]. At the next level comes the understanding and monitoring of the processes where these nuclear materials are used, idem at the level of the facilities to finally address challenges at the level of the state as a whole. Clearly, at the interface between these different levels, there are a number of issues also which can be addressed with the approaches, schematically referred to in Fig. 14.2 such as:

- fingerprinting of nuclear materials, i.e. uniquely identifying them based on the content (isotopic composition, impurities, microscopic structure etc.) also depending upon their production process

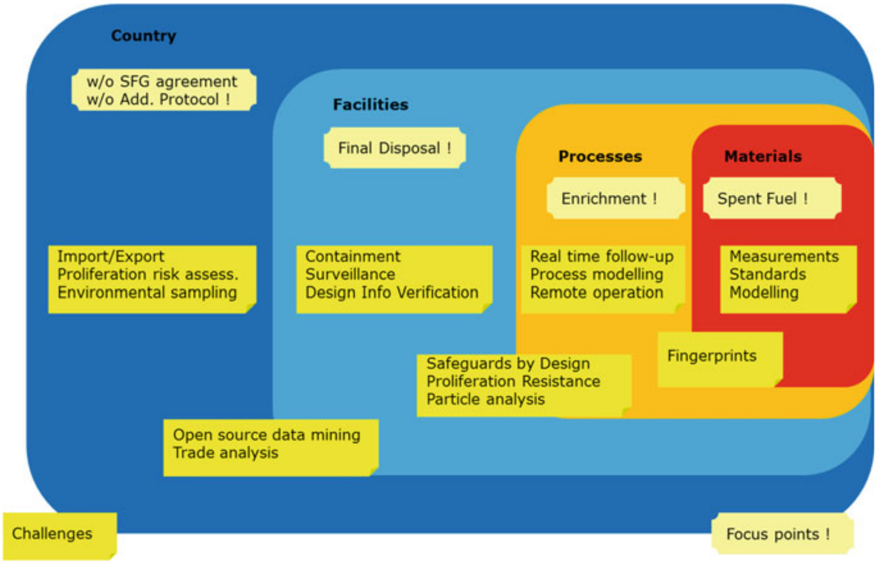


**Fig. 14.2** Schematic overview of nuclear safeguards & non-proliferation challenges and focus points

- analysis of proliferation resistance, which apart from the materials themselves, also depends on the processes used and of course on the design of the facility and its safeguardability
- trade analysis as a tool to verify or identify specific commodities being traded which might refer to existing and declared nuclear fuel cycle technologies in a country but could also serve as indicator for clandestine activities [11, 12].

A large variety of challenges remain in the area of nuclear safeguards, both from the human perspective (inspector/analyst) and from the technology side. This short paper provides a succinct overview of a number of these challenges and refers to the potential of research and development to contribute in addressing these. Two key messages are that continued investment is needed in the development of the multi-disciplinary skills of the inspectors and that innovation, new sensors and data handling tools can significantly enhance nuclear safeguards efficiency and effectiveness in the future.

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