Accelerating Safeguards Innovations

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Abstract

The spread of nuclear energy around the world requires devising new strategies for deterring proliferation of nuclear weapons. Some modern safeguards challenges are associated with new nuclear and related technologies as well as new reactor types (generation IV, small modular reactors, floating power plants). Meeting future safeguards challenges requires working on institutional and procedural enhancements in safeguards implementation to address the complications that stem from the nature of the International Atomic Energy Agency (IAEA) as an international institution. The IAEA has to continue to organize appropriate outreach to State representatives and operators to facilitate the understanding of modern approaches to and verification equipment for new types of reactors. The Departments of Nuclear Energy and Safeguards should continue to have as many cross-meetings as possible because such cooperation is desirable and crucial in meeting future challenges. Inspectors also have to have excellent knowledge of safeguards legal basis in order to make references to why they are, for example, entitled to use specific types of instrumentation. On top of that, increasing the visibility/accessibility of the existing formal equipment authorization process could help improve the Agency's efficiency. This calls for a more robust mechanism of collecting worldwide information on

safeguards-relevant R&D at one place and further developing a formal process of assessing the most user-needed entries in the database.

Introduction

The spread of nuclear energy around the world requires devising new strategies for deterring proliferation of nuclear weapons. Some modern safeguards challenges are associated with new nuclear and related technologies as well as new reactor types (generation IV, small modular reactors, floating power plants). Among them are institutional and procedural challenges in safeguards implementation, specifically – in the processes of developing safeguards approaches and authentication of safeguards equipment. As it turns out, these processes can take decades (even though some are now quicker with access to design information), whereas, for example, first new generation IV reactors can come online by 2030. With the increasing number of reactors and nuclear material under safeguards, growing number of facilities for decommissioning, and development of new technologies come concerns over the sufficiency of the IAEA resources. Certain innovations, like, for example, applying artificial intelligence to video surveillance analysis, could significantly reduce human-hours needed for safeguarding functions. However, how fast can new technologies be authorized for safeguards use by the Agency? The situation highlights the need to seek options to accelerate the processes mentioned. On top of that, enhancing communication among stakeholders involved in these processes, improving the procedures, and increasing their visibility/accessibility could help improve the Agency's efficiency. This, in turn, would allow for faster reactions to innovations and for employing cutting-edge technologies to deter proliferation.

Background

Safeguards are a set of technical measures established to verify that a State adheres to its international obligations to retain nuclear materials and technology in peaceful uses. There are two *technical objectives of IAEA safeguards*:

1. 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 the risk of early detection.
2. Detection of undeclared nuclear material and activities in a State.[1]

In order to meet its safeguards objectives, the IAEA employs *safeguards measures — methods* available to the IAEA under safeguards agreements and additional protocols.[2] The principal safeguards measures include nuclear materials measurement, sampling, analysis as well as containment and surveillance, which all depend on specific approved equipment.[3] New types of facilities require new types of safeguards equipment. For one, the inspectors' access to the material may be very limited (as with some small modular reactor (SMR) designs). Additionally, the use of coolants other than water (e.g. lead-bismuth, sodium) impedes traditional optical viewing of the fuel.[4,5]

However, before raising the question of authenticating new equipment, the IAEA has to identify if there is a need for it. The Agency can outline any additional needs after developing a safeguards approach. *Safeguards approach — a set of safeguards measures* chosen for the implementation of safeguards in a given situation in order to meet the applicable safeguards objectives[6] (i.e. they serve the technical objectives and are outlined for safeguards implementation in a particular setup). In other words, the

Agency chooses *a combination* of measures that could detect misuse of facilities and diversion of nuclear material for unauthorized, potentially military, purposes. The IAEA does it through first analyzing how a State can acquire, or a facility can divert nuclear material. Thus, there exists a State-level safeguards approach (SLA) and facility-specific approach to safeguards.

Current challenges

There are differences in perspectives on various aspects of equipment acquisition and authorization among the IAEA Secretariat, Member States, and other actors involved. We can outline the main sets of challenges.

1. *Technical.* The IAEA needs to develop or acquire equipment for safeguarding new reactor types (molten-salt, pebble-bed, high-temperature gas cooled, and others). There is a potential need for specialized or different types of safeguards equipment because their fuel and other technical characteristics can impede traditional safeguards implementation. However, more fundamentally, safeguards approaches for those types of reactors have yet to be developed. Historically, the IAEA installed safeguards equipment after plant construction ended. The first safeguards approaches were developed after many facilities had already begun operation. At the same time, it meant retrofitting instrumentation, which sometimes required making changes to the facility itself and significantly increased the costs. In order to reduce safeguards impact on the operational facility to the minimum and to avoid additional financial burden and complications related to redesigning facilities, the Agency has embraced a *safeguards by design* (SBD) approach. SBD is the process “of including international safeguards considerations throughout all phases of a nuclear facility life cycle; from the initial

conceptual design to facility construction and into operations, including modifications and decommissioning."[7] At the same time, the process of creating such an approach can be very protracted. For example, the IAEA started a forum for discussing safeguards for geological repositories in 1988. The advisory group working on the project included Belgium, Canada, Finland, France, Hungary, Sweden, the UK, and the U.S., plus Germany as an observer.[8] An approach based on the specific facility design and the SLA for Finland was developed in detail only in 2002.[9] The provisional application started only in 2017 at a Finnish facility at Olkiluoto.[10]

Even though using SBD approach seems logical, there are complications with applying it. For example, a lot of new reactor technologies come from nuclear weapons countries, like China's pebble-bed reactor. China does not have an obligation to safeguard it because the State has only a Voluntary Offer Agreement with the Agency, which means that the choice of the facilities offered for the IAEA inspections is left to its sole discretion. However, when PRC started to contemplate exporting such reactors, it realized that the reactors must be safeguardable. It meant that it benefitted China to engage the Agency to look at their facility in Shidaowan, Shandong province, to create a safeguards approach. As the reactor is already constructed, the only way to apply safeguards is retrofitting.[11] This is a complicated situation for the Agency as, for example, the extensive wiring for cameras needs to cut through the walls. Moreover, the IAEA also has to take cyber risks into consideration and ensure the absence of tampering with the information as it goes to the IAEA, which would be easier to do during the construction phase because then the wiring would be hidden inside.[12] Similar challenges can arise, for example, with Russian floating nuclear power plants. Now the idea even expanded to the concept of “transportable” nuclear power plants, not only floating, and Russia contemplates exporting such units.[13]

A challenge is that operators may not always understand the reason for some safeguards measures. Some of the operators see own work as practical and down to earth, whereas they refer to what the Agency does as probabilistic and question the necessity of allocating vast financial resources for such preemptive activities. For example, with the IAEA already working on a safeguards approach for a Chinese pebble-bed reactor, some call such work futile unless there already exists an exact export contract signed. What they mean is that unless the technology for sure will leave the official nuclear weapons state, there is no sense in creating such a safeguards approach: China does not have an obligation to safeguard all of its facilities and can just make voluntary offers.[14] There is no clear understanding of the benefits of SBD or, rather, there is one on paper, but there is no shared view on when it is reasonable to start creating a safeguards approach for new types of facilities. At the same time, the IAEA has limited resources and can only focus on a certain amount of activities at a time. Sometimes, there is a way to overcome such constraints when States themselves offer donations or extrabudgetary funds for developing model approaches and equipment. For example, a lot of unique instrumentation was developed for Rokkasho reprocessing plant by the US and Japan, which required extensive financial input from both. When the Agency works on creating approaches and equipment itself, it has to identify a type of facility closest to deployment in order to avoid criticism (e.g. of being probabilistic as mentioned above). Such identification is often hard to assess due to 1) proprietary information and thus the lack of willingness to share it on the part of a state and 2) the insufficient coordination of departments within IAEA. If there was better communication among the departments, for example, more official information exchange through regular dedicated channels like meetings or newsletters, it could let the Department of Safeguards (SG) be aware of the facilities (new designs) actually being closest to deployment. Without this, the development of appropriate safeguards equipment can be delayed.

There are four ways in which the Agency can acquire instrumentation:

1. "*Off the shelf*" – conventional equipment like HM-5 radiation detectors (hardware). Something that everyone around the world knows and uses.
2. The *IAEA can develop* or customize instrumentation itself in Austria.
3. Equipment can also be *created in Member States through Member State Support Programmes (MSSP) or national laboratories* in cooperation with the IAEA.
4. *Private entities and laboratories* can also come up with new or enhanced equipment.

Any state-of-the-art equipment needs to be validated in different environments: e.g. very warm, very humid, very low temperatures. These tests can take up to ten years. For example, one of the latest technologies, authorized in 2017 was Passive Gamma Emission Tomography (PGET). PGET development timeline included design, manufacturing, and testing between 2004-2014 and authorization process between 2015-2017.[15,16]

2. *Procedural.* An additional complication is that if the procedures were written ten years ago, they may not be usable because of obsolescence, thus, it is important to keep

them up to date. But first of all, it is crucial to make sure that all the employees are aware of them and can easily identify and access the relevant document – Safeguards Instrument Authorization Process – where the procedures and processes are outlined. In general, the process includes the following phases:

- Assessing user need (who is going to use the equipment);
- User requirements;
- Option analysis (what are other equipment options addressing the same need);
- Addressing user need (preparing a separate document per each user requirement explaining how the instrumentation addresses it);
- Evaluating data security;
- Explaining overall usability (how easy it is to use);
- Field evaluation (testing of the equipment at the IAEA and in the field);
- Consulting with SG operations (to get their opinion on the equipment and how convenient it is for them to use);
- Preparing a development report;
- Undergoing Scientific and Technical Panel (STP) and Technical and Scientific Coordination Sub-Committee (STS) approval.

As can be seen, operations, who actually use the equipment, are formally consulted pretty late in authorization process. Thus, it is left on the discretion of the officer responsible for the process to hold informal consultations in advance. If this is not done properly, then there is a risk of running into a situation where an extensive amount of effort and resources is put into something that is not usable by operations.

The authorization process itself can take not so long, like around two years spent on the next generation of Cerenkov Viewing Device (XCVD). The longest phases of the process are addressing user needs and field testing, which usually happens through MSSP, requires negotiating with the Member State and particular facilities not to interfere with their operation, and thus can be lengthy. On top of that, at this stage, the IAEA has to consider and try to refute potential objections to the equipment's use within a sate. However, before the authorization process is initiated, the development processes are pretty ad hoc, can be lengthy, and depend on one of the four ways in which the Agency can acquire instrumentation mentioned above. In order to have the greatest efficiency in meeting the new technological challenges, the Agency has to be aware of the most modern of them at all times and seek cooperation with developers even outside traditional MSSPs. One of the already existing ways is holding Emerging Technology Workshops. At the same time, after the workshops are conducted, it is important to keep the focus and have a single place where the most relevant ideas can be collected and further developed. It will help avoid the situation when an event remains "just a talk." Nowadays, with many new reactor types in various stages of development, safeguards-relevant R&D happening all over the world, and thus the abundance of information flow, one cannot overestimate the importance of highlighting the most relevant instances for the attention of SG. Professionals with deep knowledge of certain aspects are not only based in SGTS but also different SG and the Department of Nuclear Energy (NE) divisions, and even in other traditional and non-traditional partnering entities. Thus, there should exist a mechanism, sort of a drop box, where professionals could bring most SG-relevant R&D to the Agency's attention. It could be a good starting point to assess the user need for any equipment and check in with relevant stakeholders (in particular, SG operations) early in the day.

3. *Political*. Another challenge is that it is hard to accelerate the aforementioned processes because the external research community barely knows about the issue and in many cases lacks access to the information necessary for solving it. The IAEA develops State-level safeguards acquisition paths to understand what can be misused or diverted in a particular State, bearing in mind the existing safeguards agreement. The question of safeguards application is a matter that is addressed exclusively at the State-Agency level within the framework of close cooperation. Member States are not obliged to share their safeguards experience. The application of safeguards is a mutually agreed process; thus, it only allows the activities that a country agreed to (as spelled out in the country's safeguards agreement and subsidiary arrangements).

The use of required safeguards equipment, as well as the equipment installation locations, are discussed jointly by State experts (including, in some cases, operators) and the IAEA. No equipment is installed without the country's knowledge. If the equipment is portable, sometimes it takes diplomatic effort on the part of inspectors themselves. At the same time, the issue of applying IAEA safeguards in a country is a legally defined process, enshrined in the Agreement for the Application of Safeguards between a particular State and the IAEA. One of the reasons is that even though there is a procedure to approve the IAEA equipment, there is no universal mechanism to ensure its use worldwide: operators can disagree to inspectors' use of particular equipment, e.g. 360 cameras, referring to proprietary information or security aspects.[17] This is possible because model agreements, which are standard, do not stipulate specific safeguards technologies to be used, which is logical because the technologies develop with time and it would be very complicated if the IAEA had to re-negotiate the whole agreement anytime new safeguards equipment is introduced. Any related information can be included in subsidiary arrangements, which are negotiable.

The political consequence of this is that the Agency aims to remain unbiased and does not want to give a leg-up to any one particular safeguards equipment design as it can be seen as giving a vendor an undue advantage. Thus, even though the vendors bring exhibits to events, trying to arrange meetings with IAEA staff, it often cannot result in cooperation.[18] The authentication (approval for use) of such equipment lies on the Deputy Director General of Safeguards, as the only items needing the Board of Governors approval are the Safeguards Implementation Reports and the yet unused measure of Wide-Area Environmental Sampling from the Additional Protocol. However, a facility owner can "veto" any equipment use, referring, for example, to undue intervention into its operation or to safety impediments.

4. *Cultural.* One of the reasons why it is hard to address the challenges mentioned above is the difference in the cultures of two mainly involved departments: NE and SG. NE has a mission of fostering sustainable nuclear energy development by supporting existing and new nuclear programs around the world. Its approach is *sharing* experience and knowledge in relevant spheres in order to build indigenous capabilities. Whereas SG's culture is *secrecy*, they are constrained by confidentiality obligations. At the same time, State representatives at meetings often think that if an SG person is present, they are trying to record what has not been reported in State declarations, to find inconsistencies. The analogy could be "having a cop in the room."[19] It is necessary

for SG to be present at NE technical meetings, such as the ones talking about new developments in reactors or other facilities. The closest possible cooperation between the two departments is crucial for understanding of each other's needs and developments.

Conclusion

Meeting future safeguards challenges requires working on institutional and procedural enhancements in safeguards implementation to address the complications that stem from the nature of the Agency as an international institution.

The safeguards by design approach can help simplify verification and overcome the issues related to the post-construction installation of safeguards instrumentation. It is ever so crucial for the IAEA and the State to avoid retrofitting to avoid unnecessary additional expenses. Thus, the Agency needs to continue to provide compelling argumentation for promoting SBD approach. Even more importantly, it has to continue to organize appropriate outreach to State representatives and operators to facilitate the understanding of creating approaches to and verification equipment for new types of reactors. The IAEA also needs to search for additional ways of achieving close cooperation from the very beginning with the States that are in the process of creating new reactors. It is especially important for nuclear weapons states, because unlike others, they do not have an obligation to put all their nuclear-related developments under safeguards and do so only voluntarily.

Whereas devising safeguards measures requires international approval in model agreements, equipment is authorized by the Deputy Director General for Safeguards (meaning that Member States are not directly involved). For that reason, the inspectors also have to have excellent knowledge of the legal basis in order to make references to why they are entitled to use specific types of instrumentation. In attempts to stay independent, the IAEA sometimes misses cooperation opportunities with manufacturers, while new equipment acquisition before the official authorization process is initiated has a fairly sporadic nature. On top of that increasing the visibility/accessibility of the existing formal authorization process could help improve the Agency's efficiency. This calls for a more robust mechanism of collecting worldwide information on safeguards-relevant R&D at one place and further developing a formal process of assessing the most user-needed entries in the database. In other words, there should be a guidance/process document where it is outlined who you talk to in order to initiate acquisition of or development of (including cooperative development outside established MSSPs) a particular piece of equipment if you are a safeguards professional and found something very relevant in the database of safeguards-related R&D. This should also include formal consultations with operations early in the process. Safeguards Instrument Authorization Process document should be also available in the database and easily accessible. One of the criticisms that the Agency tries to avoid is that its representatives meet with vendors selectively giving undue preferences. A good way to approach this issue is to outline some type of tendering process in a potential guiding document. At the same time, an essential consideration for the IAEA to keep in mind is that vendors are competing and they do not want to share all the proprietary information. In any case, a guiding document would give potential instrumentation producers the idea of what they have to take in consideration from the very beginning.

Even bearing in mind differences in cultures, the NE and SG departments should continue to have as many cross-meetings as possible because such cooperation is desirable and crucial in meeting future challenges. SG benefits greatly from such coordination as it gives them a better understanding of what is on the way to deployment or export in the nearest time and focus on developing specific approaches and equipment. SG's presence is beneficial, as it would allow NE and States to know more about safeguards needs and requirements for new types of facilities and make the startup or export dates sooner.

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Keywords

IAEA, safeguards, safeguards equipment, authorization, procedures, R&D.