IAEA Safeguards: The Role of Advanced Safeguards Technologies in Meeting Tomorrow's Challenges

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Abstract

As outstanding issues with Iran and North Korea and concerns about nuclear terrorism remind us, the International Atomic Energy Agency (IAEA) was created in a different time to deal with different threats. The pre-Gulf War Iraqi nuclear program, the terrorist attacks of 9/11, the discoveries of additional States under the Treaty on the Nonproliferation of Nuclear Weapons (NPT) developing clandestine programs and the associated revelation of an extensive non State nuclear procurement network have presented new challenges to international as well as domestic safeguards. For the last decade and a half, the IAEA has been transforming its safeguards system to address these and other issues, including past limits to its verification mandate and the burden of noncompliance issues. Central to the transformation is the Additional Protocol (AP), which is an important new tool and needs to be universally accepted as the basis for safeguards and as a condition for exports. Although most States with significant nuclear activities have now brought the Additional Protocol into force, there remain a large number of States that have not yet ratified the Additional Protocol. The Agency and Member States are trying to remedy this situation. Implementing the new measures in the Additional Protocol, as well integrating new and old safeguards measures, remains a

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work in progress. Implementation is complicated by factors including the limited technological tools that are available to address such issues as safeguarding bulk handling facilities, detection of undeclared facilities/activities, especially related to enrichment, etc. The Agency has confronted such challenges in the past, and safeguards have evolved over time to meet the challenges posed by new technologies, new international undertakings and new threats. There is no doubt safeguards will need to evolve in the future, as they have over the last decades. In order for the evolutionary path to proceed, there will *inter alia* be a need to identify technological gaps, especially with respect to undeclared facilities, and ensure they are filled by adapting old safeguards technologies, by developing and introducing new and novel safeguards technologies and/or by developing new procedures and protocols. Safeguards will also need to respond to anticipated emerging threats and to future, unanticipated threats. This will require strategic planning and cooperation among Member States and with the Agency. This paper will address challenges to IAEA safeguards and the technological possibilities and R&D strategies needed to meet those challenges in the context of the forty-year evolution of safeguards, including the ongoing transformation of safeguards by the Agency.

Introduction

As outstanding issues with Iran and North Korea and concerns about nuclear terrorism remind us, the International Atomic Energy Agency (IAEA) was created in a different time to deal with different threats. The pre-Gulf War Iraqi nuclear program, the terrorist attacks of 9/11, the discoveries of additional States under the Treaty on the Nonproliferation of Nuclear Weapons (NPT) developing clandestine programs and the

associated revelation of an extensive non State nuclear procurement network have presented new challenges to international safeguards, and to the entire nonproliferation regime. The Agency has confronted such challenges in the past, albeit perhaps not on this scale, and safeguards have evolved over time to meet the challenges posed by new threats and new international undertakings, and by the opportunities offered by new technologies,. Safeguards will need to evolve in the future, as they have over the last decades. In order for the evolutionary path to proceed, there will *inter alia* be a need to identify technological gaps, especially with respect to undeclared facilities, and ensure they are filled by adapting old safeguards technologies, introducing advanced safeguards technologies or developing new procedures and protocols. Safeguards will also need to respond to anticipated emerging threats and to future, unanticipated threats. This will require strategic planning and cooperation between the Agency and Member States. This paper will address challenges to IAEA safeguards and the technological possibilities and R&D strategies needed to meet those challenges in the context of the forty-year evolution of safeguards, including the ongoing transformation of safeguards by the Agency.

Transforming Safeguards

As it had in earlier decades, the IAEA has been transforming its safeguards system to address, in part, the limits of its verification mandate and the burden of noncompliance issues, which has raise questions in some quarters about the value and effectiveness of international safeguards. It is seeking to address emerging issues, many of which it was never designed to handle, as well as to deal with the expected dramatic growth in nuclear energy use as contemplated by the Global Nuclear Energy Partnership, or GNEP.

The IAEA is adopting a fundamentally new approach to implementing safeguards based on the strengthening measures developed in the 1990s and the lessons learned from South Africa, Iraq, Libya and elsewhere. The Additional Protocol (AP), which is an important new tool and needs to be universally accepted as the basis for safeguards and as a condition for exports, is central to the transformation. Although most States with significant nuclear activities have now brought the Additional Protocol into force, there remain a large number of States that have not yet ratified the Additional Protocol. The Agency and Member States are trying to remedy this situation, as well as the problem of the universality of comprehensive safeguards agreements.

Implementing the new measures in the Additional Protocol, as well integrating traditional NPT safeguards measures (INFCIRC/153) with the new AP safeguards measures (INFCIRC/540), remains a work in progress. It is recognized that an effective, strengthened international safeguards system, with a strong focus on searching for undeclared nuclear materials and activities, is essential to provide confidence that shared nuclear technologies and expertise, as well as nuclear materials themselves, are not being diverted to weapon programs. “Completeness” as well as “correctness” has become critical.

Fundamental to the new approach to IAEA safeguards is information acquisition, evaluation and analysis along with inspections. The new approach is designed to provide

an evaluation of the nuclear program of a State as a whole and not only of its declared nuclear facilities.

The new IAEA safeguards system that is emerging is more flexible, and should be better suited than the old to allocating scarce resources to where they are needed most in countering proliferation risks. To deal with the growth in nuclear energy use, it is essential that this transformational international safeguards system be both credible and efficient.

However, there are limits based on the authorities themselves, e.g., limited off-site access far short of “anytime, anyplace” that is often put forward; by their implementation, including integration and residual cultural issues; by technological gaps, e.g., wide-area environmental sampling (WAES); and by cost issues.

The effectiveness of the new and integrated measures remains to be fully demonstrated in the field. If they are being oversold, the risks to the Agency could be great. The limits of the AP measures are exacerbated by the fact that the Agency does not fully use all of its existing authorities, especially special inspections. And we have limited technological tools at present to address emerging threats, which could raise questions about the responsiveness of safeguards to current and identified emerging threats and to future, unanticipated threats.

Safeguards Challenges

While the transformation of safeguards begun by the Agency in response to a changing world is vital, further changes in safeguards will be necessary to meet tomorrow's challenges. There are safeguards challenges we can anticipate because of existing facilities and operations as well as known proliferation threats. Among the key anticipated challenges for safeguards are the following:

- detecting undeclared facilities/activities involving enrichment and reprocessing, including characterizing operations at clandestine enrichment facilities that have been revealed and enhancing detection of undeclared misuse of hot-cells;
- detecting trace elements for enhanced forensics and source attribution, and possibly for other safeguards purposes;
- increasing the accuracy of measurements at large, increasingly complex new facilities, with high material throughputs where improvements in current technology alone cannot meet detection goals;
- increasing the accuracy of nondestructive analysis and other measurements of difficult-to-measure materials, including spent fuel;
- taking measurements in harsh environments with high dose rates and temperatures;
- measuring new isotopes and combinations of isotopes, including for example, separations outputs of the UREX+ suite and pyroprocessing;
- measuring both continuous flows of nuclear materials and of nonnuclear process parameters (temperature, density, flow rate, etc.); and
- improving containment of unattended and remotely-monitored systems.

History suggests there will be many proliferation challenges we do not anticipate.

Addressing these challenges—both anticipated and unanticipated—will require the development of new technologies and procedures as was the case in the past. Over the last forty years, we witnessed technological innovations that dramatically improved the Agency's ability to implement safeguards. For example, the development and miniaturization of nondestructive assay equipment provided inspectors with rapid *in situ* determinations of the concentration, enrichment, isotopics and masses of nuclear materials that would otherwise have taken a great deal of time or not have been practicable; and the use of video surveillance devices, core discharge monitors, electronic seals and other technologies allowed continuous unattended monitoring of activities in nuclear facilities and improved the efficiency of inspections by reducing the time spent by inspectors at facilities. In addition to technology advances, the Agency made innovations in procedures that enhanced effectiveness and efficiency in this period, including application of randomized inspections to verify the material flows at low-enriched uranium fuel fabrication plants; expanded reporting requirements for States, especially in the area of imports and exports of nuclear technology; and earlier reporting requirements for design information relating to new facilities.

In meeting today's and tomorrow's challenges, a combination of new technologies and procedures is necessary to provide an enhanced defense-in-depth approach that includes:

- state-of-the-art instrumentation and methodologies for materials measurement, accounting and tracking, including

    - next-generation neutron and gamma ray detectors,
    - systems for process monitoring, in-line measurements and item tracking,
    - integration of data from multiple sensor platforms and
    - automated means to detect anomalies;
- enhanced containment and surveillance, including portal and area radiation monitoring;
- integration of access denial and transparency elements of physical protection and safeguards; and
- integration of traditional process monitoring with nontraditional indicators, such as detection of unexpected signals (i.e., in locations where there should be no corresponding activity), questionable movement of equipment and people, etc.

To support such an approach, the Agency and Member States will need *inter alia* to:

- determine the best near-term measurement technologies and analytical methods for development, while exploring long-term possibilities in areas such as artificial intelligence and nanotechnology;
- develop new and novel approaches for detecting undeclared facilities and for safeguarding gas centrifuge enrichment plants, reprocessing plants and other fuel cycle facilities, as well as for new reactor types that pose problems for current safeguards;
- develop and deploy multifunctional equipment for use in inspections that allow inspectors to make rapid and accurate measurements and to prescreen environmental samples in the field;

- develop integrated facility designs to enable advanced safeguards, to minimize proliferation risks and to provide intrinsic transparency in facility operations;
- develop enhanced information management capabilities to address massive amounts of disparate data and begin a transition to knowledge-based systems; and
- provide support and assessment capability to the facility design process to evaluate design tradeoffs between facility operations, safeguards effectiveness and cost.

If this vision is to be realized, it will be necessary to develop a robust, flexible and adaptive international technology base for advanced safeguards through cooperation among Member States and with the Agency.

Other Challenges to Safeguards

Beyond efforts to ensure that IAEA safeguards are in a position to evolve to meet new challenges in the future, as they had in the past, there are a host of critical issues confronting the Agency that could affect the future of safeguards, including its ability to address noncompliance in an appropriate manner; and its role in dealing with weaponization, nuclear security, illicit nuclear trafficking and rollback operations. The Agency's weaponization and rollback roles are particularly important.

The IAEA is facing the issue of deciding on the path it will take on addressing weaponization. The IAEA currently considers weaponization, among other factors, in its State evaluations. It is apparently looking to expand the effort. While the Agency is

proceeding down the path toward greater attention to weaponization in its safeguards, the issues raised are serious, involving the capabilities and focus of Agency safeguards and, if not done carefully, could involve spreading classified/sensitive information, worsening the proliferation problem and possibly raising other issues. How well can the Agency assess weaponization? In addition to the current efforts to detect clandestine weaponization activities, should the Agency determine the status of a State's weapon program? Can the IAEA under any circumstances be expected to make independent judgments on a State's weaponization? What are the legal authorities on which these activities are based? Are there other legal authorities that would support or raise questions on this activity?

These are difficult and complex issues and need to be better understood by the Agency and Member States. It may be that the existing level of activity is all the Agency can be expected to do. If, in the end, the Agency does not or cannot pursue detection, assessment or determination of weaponization, should another international organization assume an overt role in such detection? Should or could the five permanent members of the UN Security Council—who are also the five recognized nuclear-weapon States under the NPT—do so informally? What are the implications for perceptions of discrimination?

What role should Agency safeguards have in rollback activities? There are clearly issues of both the IAEA's capability and its mandate on complex rollback operations, despite its positive roles in South Africa and Libya. There is also the issue of whether it *should* play a role in rollback. The IAEA probably should play a role in verifying rollback, where its

capabilities are unique and its contributions are beneficial. However, this role will need to be augmented by capabilities to detect clandestine facilities and activities, and the need to greatly improve key elements of verifying both declared and undeclared enrichment. Beyond verification, there are classification and proliferation issues similar to those raised with the Agency's role in weaponization, especially for a State with weapons and an extensive weapon infrastructure. Any role with respect to rolling back weaponization should probably be off the table.

Not only does defining the proper roles for the Agency in these areas raise issues concerning the IAEA's mandate and the capabilities, but they might compete with safeguards for the attention and resources of the Agency.

Conclusions

Given these challenges, it is clear that IAEA safeguards will need to continue to evolve in the future as they have over the last four decades. There is an increased need for capabilities to detect undeclared nuclear facilities, a need for continuing improvements in safeguards at increasingly large and complex declared fuel cycle facilities and a desire for a more intensive involvement in applying safeguards in new roles. There will also be a need to identify technological gaps, especially with respect to enrichment, and ensure they are filled to the extent possible. This will require strategic planning and cooperation among Member States and with the Agency. For the United States, it will mean revitalizing its safeguards R&D effort. The Agency will also need to begin using all its authorities, e.g., special inspections, and to continue and strengthen efforts to change the

culture. It is not too early to begin thinking about future authorities and the technologies that will be needed to fill them.