LA-UR- 11-03999

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Title:	The Future of IAEA Safeguards: Challenges and Responses
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Intended for:	INMM Annual Meeting

Los Alamos
NATIONAL LABORATORY
EST. 1943

Form 836 (7/06)

The Future of IAEA Safeguards: Challenges and Responses

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Abstract

For nearly two decades, the International Atomic Energy Agency (IAEA) has been transforming its safeguards system to address the challenges posed by undeclared nuclear programs, the associated revelation of an extensive non-State nuclear procurement network and other issues, including past limits to its verification mandate and the burden of noncompliance issues. Implementing the new measures, including those in the Additional Protocol, and integrating new and old safeguards measures, remains a 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. As this process continues, new challenges are arising, including the demands of expanding nuclear power production worldwide, so-called safeguards by design for a new generation of facilities, the possible IAEA role in a fissile material cutoff treaty and other elements of the arms control and disarmament agenda, the possible role in "rollback" cases, etc. 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

When they were born as a result of President Eisenhower's Atoms-for-Peace proposal, the International Atomic Energy Agency (IAEA) and its safeguards system began a unique experiment in international security cooperation. For most of its history, the IAEA was acclaimed as a highly professional and competent technical organization, and was not a target of the criticism directed against many of the other organizations established under the auspices of the United Nations. Its safeguards pioneered on-site inspections and involved unprecedented, albeit limited, inroads into member states' sovereignty. These inspections have evolved over time to meet the challenges posed by new technologies, new international undertakings, and new threats. The IAEA's doors were always open to serious East-West security discussions during the chills and thaws of the Cold War.

While the end of the Cold War gave new authority to the United Nations, revelations about Iraq's nuclear-weapon program after the Gulf War threatened the IAEA and its mandate to administer international inspections of peaceful nuclear activities to help ensure that diversions to military programs were not occurring. In addition to the post-Gulf War Iraqi program, the terrorist attacks of 9/11, the discoveries of additional States under the NPT developing

[1] The views expressed are the authors' own and not those of the Los Alamos National Laboratory, the National Nuclear Security Administration, the Department of Energy or any other agency.

clandestine programs and the associated revelation of an extensive nonstate nuclear procurement network have presented new challenges to domestic and international safeguards. In the last decade and a half, the IAEA has been transforming its safeguards system to address these issues. For nearly two decades, the International Atomic Energy Agency has been transforming its safeguards system to address the challenges posed by undeclared nuclear programs, the associated revelation of an extensive non-State nuclear procurement network and other issues, including past limits to its verification mandate and the burden of noncompliance issues. Implementing the new measures, including those in the Additional Protocol, and integrating new and old safeguards measures, remains a 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. As this process continues, new challenges are arising, including the demands of expanding nuclear power production worldwide, so-called safeguards by design for a new generation of facilities, the possible IAEA role in a fissile material cutoff treaty and other elements of the arms control and disarmament agenda, the possible role in "rollback" cases, etc. 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.

Evolution of Safeguards

Pre-Gulf War

From the earliest safeguards to the Gulf War, innovations in procedures and technologies allowed IAEA safeguards to improve capabilities, to meet new challenges and to be utilized in additional areas. These improvements to safeguards have been made on a continuous basis and the agency has built up an unparalleled technical base in this area. A significant factor in the IAEA's continuing improvements in inspections effectiveness during this period was the system of support programs through which member states contribute to technology advances and other activities. It was under such programs that virtually all of the equipment used by inspectors was developed, that technical knowledge and training equipment was provided by cost-free experts and that lecturers and facilities were provided.

Innovations in nondestructive assay equipment provided inspectors with rapid *in situ* determinations of the concentration, enrichment, isotopics and masses of nuclear materials that would be expensive and time consuming and, in some cases, impractical by other means. These instruments include neutron coincidence counters for quantitative measurements of unirradiated plutonium in a variety of forms and gamma spectroscopy instruments for determining isotopics of plutonium and uranium. Advances in miniaturization of these instruments have provided inspectors with more portable measurement methods that are useful for both routine inspections in declared facilities and for in-field application during special inspections.

Continuous unattended monitoring of activities in nuclear facilities has improved the efficiency of inspections by reducing the time spent by inspectors at facilities. Examples of this technology are video surveillance devices that monitor spent fuel ponds at reactors, core discharge monitors that monitor fuel movements in on-load reactors, and electronic seals that record the time of application. All of these devices have been important in providing assurances of material integrity during an inspector's absence by recording surveillance data for periodic review.

Further gains in efficiency were provided by automated review stations. In addition, the agency developed technology for remote transmission of these data that would further reduce the need for inspector presence in facilities.

In addition to technology advances, the agency made innovations in procedures that enhance effectiveness and efficiency in this period. Examples include new ways of working with regional safeguards systems such as the Joint Partnership Agreement with EURATOM, where the agency saved significant numbers of inspection days through randomly deciding to accompany the EURATOM inspectors; 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. The agency also looked to later agreements with on-site inspections, such as those found in the CWC, and sought to incorporate certain features into its own safeguards where appropriate and acceptable.

Due in large part to the capabilities it evolved over these critical decades, the IAEA was able to act in a rapid and flexible manner to handle unprecedented situations in South Africa, Argentina and Brazil, the former Soviet Union, Iraq, North Korea, Libya and Iran. The South African situation is notable. President De Klerk revealed the existence and destruction of a South African nuclear-weapon program in March 1993. The next day IAEA inspectors visited the newly revealed laboratories where the bombs were built. A dedicated nuclear-weapon inspection team arrived three weeks later. They visited all the facilities designated by South Africa and several indicated by intelligence supplied to the agency.

The South Africans cooperated with the IAEA and enabled the teams to complete their work in three visits. The accomplishments of the inspections included:

- visits to all relevant facilities, whether implicated in the weapon program or not;
- mapping of the entire nuclear weapons program structure;
- understanding of the South African implosion weapons development program;
- reconciliation of the inventory of highly-enriched uranium (HEU) produced in the Helikon enrichment plant;
- inspection of remaining records of the given assembled nuclear weapons and a judgment that they were dismantled; and
- destruction of the underground nuclear tests shafts in the Kalahari Desert.

Although absolute certainty is impossible in such a case, the IAEA was able to technically certify to a high degree of certainty that all aspects of the South African nuclear-weapon program are understood and that the program is dead.

Beyond South Africa, the Agency's role in carrying out UN Security Council Resolutions in Iraq, and confronting the unique challenges posed by Libya's decision to give up its nuclear program has been widely acclaimed. However, the discoveries of additional States under the NPT developing clandestine programs, including Iran, North Korea, Syria and possibly Myanmar; the associated revelation of an extensive non-state nuclear procurement network; and the terrorist attacks of 9/11 have presented new challenges to international safeguards, and to the entire nonproliferation regime.

Developments after Iraq

In the two decades, the IAEA has been transforming its safeguards system to address, in part, the limits of its verification mandate, the burden of noncompliance issues and other challenges to the value and effectiveness of international safeguards. In this context, 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 Iraq, the DPRK, Libya and Iran. 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. "Completenes" as well as "ccorrectness" was critical.

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 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, and the problem of the universality of comprehensive safeguards agreements as well.

Implementing the new measures in the Additional Protocol, as well integrating 153 and 540 safeguards, remains a work in progress. 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 just each of its declared nuclear facilities.

The new IAEA 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 risk. As the Agency moves towards an information-driven safeguards system, efficiencies will be required and could be improved through greater utilization of information and communication technologies for the collection, analysis and processing of safeguards-related information, greater use of remote monitoring coupled with secure information technologies, etc. However, such efficiencies may not be sufficient.

As a consequence, there is a move to shift safeguard resources away from countries with large nuclear power programs such as Japan, Canada and Germany to states of concern. Based on the Additional Protocol and other new authorities, the use of a state-level approach would be in theory differentiate but not discriminate among states. Yet, this approach will require balance. If it were to go too far, it will necessarily be seen as discriminatory. Moreover, if the resources devoted to large nuclear power programs were cut so deeply that these programs were not properly monitored, the IAEA may lose the ability to make independent judgments on them. If this were to occur, the system could breakdown or, more likely, erode. This could undermine global nonproliferation efforts, especially at a time when the interest in deep cuts and the goal of zero is high. These objectives depend on watertight, not relaxed nonproliferation efforts.

Continuing and Emerging Challenges to Safeguards

Safeguards evolved to meet the challenges posed by new technologies, new international undertakings and new threats. In the changed and changing world of today, it will be necessary to keep efforts to strengthen safeguards on track. However, as safeguards are strengthened, there are a host of critical continuing and emerging challenges confronting the Agency and its safeguards system, including the prospect of new technologies and fuel cycles in the context of nuclear power growth; the Agency's continuing role in addressing noncompliance; and possible new or expanding roles for the Agency and its safeguards system to safety and security, weaponization, rollback operations and arms control and disarmament..

Nuclear Power Growth, New Technologies and Fuel Cycles

Before Fukushima, the prospect of global nuclear expansion--in the view of some, a nuclear renaissance--appeared to be defining the future nuclear landscape. While there prospects for a renaissance may have been overstated, virtually all analyses recognized some level of nuclear power growth both within states with existing nuclear power programs and in new states. Moreover, this growth it was held would involve new technologies and fuel cycles. To date, Fukushima has not significantly affected global interest in nuclear power, and most states with nuclear players have not cancelled them. This could change, but whether or not it does, even incremental growth of nuclear power and new fuel cycles will raise proliferation concerns and increasingly put strains on IAEA safeguards.

To deal with the growth in nuclear energy use in a constrained budget environment, it is essential that today's transformational international safeguards system be both credible and efficient. Beyond the critical resource issue, a fundamental challenge is posed by the prospect of new, challenging fuel cycle technologies.

On the basis of current plans and other factors, the IAEA will be inspecting third and fourth generation nuclear reactors, enrichment plants using new technologies, pyroprocessing plants and other new fuel cycle facilities will require more inspection resources and the development of new safeguards approaches, techniques and technologies. Moreover, regardless of growth, increasingly old plants will be decommissioned; and growing stocks of plutonium and spent fuel (including excess defense material stocks of nuclear weapon states) will have to be safeguarded. Safeguards by design will be critical to meeting the challenges of new fuel cycles.

The greater inspection responsibilities, especially if nuclear energy expands, and the introduction of new technologies and fuel cycles, will require the Agency to ensure that it is capable of meeting the technical and human resources to meet the challenges it confronts. Efforts ensure safeguards R&D, development of inspectors and analysts, and maintaining and improving infrastructure are beginning to be pursued by the Agency and Member States and will need a renewed commitment.

Continuing Noncompliance Concerns

The IAEA needs to come to grips with noncompliance with safeguards. The Obama Administration has highlighted the importance of compliance with nonproliferation treaties and agreements and ensuring that the IAEA has all the tools it needs to fulfill its essential mandate and support the Additional Protocol. In his landmark Prague speech in April 2009, President Obama stated: "We need real and immediate consequences for countries caught breaking the rules or trying to leave the treaty without cause." Discussing the need to develop a new framework for peaceful nuclear cooperation, he stated:

> ...we go forward with no illusions. Some countries will break the rules. That's why we need a structure in place that ensures when any nation does, they will face consequences.
>
> ...Rules must be binding. Violations must be punished. Words must mean something. The world must stand together to prevent the spread of these weapons. Now is the time for a strong international response -- now is the time for a strong international response, and North Korea must know that the path to security and respect will never come through threats and illegal weapons. All nations must come together to build a stronger, global regime. And that's why we must stand shoulder to shoulder to pressure the North Koreans to change course.
>
> Iran has yet to build a nuclear weapon. My administration will seek engagement with Iran based on mutual interests and mutual respect. We believe in dialogue. But in that dialogue we will present a clear choice. We want Iran to take its rightful place in the community of nations, politically and economically. We will support Iran's right to peaceful nuclear energy with rigorous inspections. That's a path that the Islamic Republic can take. Or the government can choose increased isolation, international pressure, and a potential nuclear arms race in the region that will increase insecurity for all.

There is a widespread sense that negotiations and sanctions are not working. The Obama Administration's engagement policy has not succeeded. While sanctions have been a leading instrument, they have been undermined by smuggling and trade with the UAE and other neighbors of Iran and have not produced the desired results. In Prague, the President stated: "We need more resources and authority to strengthen international inspections." Is this the key? Are there other ways in which the Agency can move forward on this critical issue?

Possible New and Expanding Roles

Safety and Security. The IAEA has had a longstanding role in safety and security, which has been evolving in response to global challenges--the accidents at Chernobyl and more recently, Fukushima, and the increasing concerns about radiological and nuclear terrorism followingthe attacks of September 11, 2001. The Agency's role in both areas involves peer reviews, training and the development of international standards. While these areas remain national responsibilities, the Agency's role is increasingly seen as critical and likely to grow. To the extent this occurs, there will be opportunities to increasingly integrate safety, security and safeguards systems from design through life cycle operations. This could increase effectiveness

and efficiency. There are resources and other challenges to these growing roles, and some institutional risks associated with greater Agency involvement in areas where national responsibilities remain central.

Weaponization. The IAEA is also 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 about 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?

Rollback. If the DPRK or any other proliferation states were to disarm, the verification issues could be difficult and complex--far more so than those encountered in Libya or South Africa. If this is the case, what role should Agency safeguards have in future 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, Iraq 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 its 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.

The IAEA and Arms Control and Disarmament. A key challenge that raises many of the issues of institutional capabilities, resources and attention raised by a role in weaponization and rollback will involve the role of the IAEA in arms control and disarmament efforts. Although envisioned in the Atoms for Peace speech that embodied the vision of the IAEA, and intermittently pursued in recent decades, this issue has not been at the forefront of thinking about the IAEA's future. The FMCT and growing interest in disarmament could change this situation.

Although negotiations of an FMCT are stalemated in the CD, there is interest in finding ways to begin negotiations, including discussions of a new venue, from P-5 talks to negotiations in the UN General Assembly. Even if negotiations begin, they are unlikely to proceed quickly, as the issues that have led the CD breakdown will complicate any negotiations that may be undertaken. However, one critical issue will be verification, and although many issues will need to be worked through, there is considerable interest in using the IAEA and its safeguards system to verify FMCT. At one end of the spectrum, this will bring a small number of production facilities in the P-5 or the eight states with nuclear weapons into IAEA safeguards. At the other end, the FMCT could bring all facilities in their states under safeguards and could overwhelm IAEA capabilities.

The case for an IAEA role centers on the fact that the IAEA has the human and technical capabilities to be the inspectorate for an FMCT. If the IAEA was not the inspectorate, it could adversely affect the IAEA and its safeguards. Moreover, creating a new inspectorate could be costly and be seen as a duplication of effort. Arguments against an Agency role include the politicization of the Agency (especially the Board) on compliance issues over Iran, which could worse with responsibilities for FMCT verification. There is also a concern that IAEA inspections of weapon states could unintentionally release weapon design information or other sensitive or classified information. Moreover, Russia and other key players may not accept the IAEA in a verification role. These are difficult issues and there are no easy answers.

In addition to the FMCT, the Agency's role in addressing excess defense material will certainly be raised. Indeed, the Trilateral Initiative was an effort in the late 1990s to explore the technical, financial and other modalities of IAEA involvement in inspecting the storage and disposition of US and Russian excess defense material. There has been some discussion of reviving this effort. Moreover, the IAEA has been requested to assist in the independent verification of the US-Russian Plutonium Management and Disposition Agreement (PMDA) and is working on the legal agreement with the parties to allow this to occur. There are difficult and complex technical and resource issues that remain elusive.

Other arms control roles for the IAEA and its safeguards system have been put forward as well, including a direct role in verifying the reduction or elimination of warheads. If the IAEA plays an increasing role in arms control and disarmament, it will have to overcome issues relating to the possible inadvertent spread of classified or proliferation sensitive information and other issues. There will be concerns about is ability to obtain the resources and to pursue this new mission without undermining its traditional nonproliferation mission.

Responding to Challenges

Ensuring that IAEA safeguards are in a position to evolve to meet these and other challenges in the future as they had in the past goes far beyond technical issues. Statesmanship at the Agency and among key Member States will be necessary. However, if the Agency is to be able to address challenges now and in the future, there are technical and issues that will have to be addressed.

Improving the IAEA's capabilities to meet current safeguard requirements will continue to be necessary both because of the need to enhance efficiencies and to better address requirements that are not optimized, including;

- the time, cost and limited capacity to analyze environmental samples;
- in-line NDA to monitor and verify the flows, enrichment levels, etc., at enrichment plants;
- monitoring holdup and waste containers at reprocessing plants; and
- novel technologies for long-range, wide-area detection of undeclared facilities.

Beyond current challenges, there are future proliferation challenges we can anticipate, including:

- large, increasingly complex new facilities, with high material throughputs;
- difficult-to-measure materials;
- harsh environments with high dose rates and temperatures;
- measurement of new isotopes and combinations of isotopes; and
- possible diversions without physical change to plant.

History shows there will be many safeguards challenges we do not anticipate.

Addressing these challenges—both anticipated and unanticipated—will require a defense-in-depth approach that includes:

- state-of-the-art instrumentation and methodologies for materials measurement, accounting and tracking, including sensor platform integration;
- enhanced containment and surveillance, including portal and area radiation monitoring, and measures to assure the absence of materials or radiation signals;
- integration of access denial and transparency elements of physical protection and safeguards; and
- integration of traditional process monitoring with non-traditional indicators, such as detection of radiation signals where they should not be, questionable movement of equipment and people, etc.

To support such an approach, it is necessary to begin a robust, flexible and adaptive technology base for advanced safeguards. A technology R&D program should investigate next generation technologies including:

- integrated facility design to enable advanced safeguards and eliminate/minimize proliferant facility designs;
- intrinsic transparency in facility operations; and
- more robust integration of physical protection and safeguardability.

The safeguards program will also need to:

- provide support and assessment capability to design process;
- model facility safeguards design to assess detection paths and sensitivity to detect;
- determine best near term measurement technologies for development; and
- determine best near term analytical methods to draw rapid safeguards conclusions.

Finally, there is also a need to utilize systems analysis to evaluate design tradeoffs between facility operations, safeguards effectiveness and cost, as well as to assess the effectiveness of an integrated safeguards system as a whole.

Conclusions

It is clear that IAEA safeguards will need to evolve in the future as they have evolved over the last four decades. At a time when nuclear activities are increasing throughout the world, IAEA safeguards faces several new challenges. These include an increased need for capabilities to detect undeclared nuclear facilities, the need for improvements in conventional safeguards and the desire for a more intensive involvement in applying safeguards in new roles.

As the Agency and Member States look to address these challenges, a sound technical base will provide the necessary foundation for addressing difficult and divisive political issues, As suggested above, a key requirement is the development of a defense-in-depth safeguards/security approach that needs to be fully responsive to emerging threats, which requires cutting-edge threat assessment and other capabilities, and the R&D base to realize this approach. While the Agency will need to fully use all existing authorities, it is not too early to begin thinking about future safeguards authorities and institutional reform. A victim of oversell in the past, the agency along with key member states must avoid creating unduly high expectations as improvements are made, because there will always be theoretical and practical limits to the pursuit of this and other forms of verification.