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Nuclear Safeguards and the Security of Nuclear Materials

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Introduction

Nuclear technology is Janus-headed; it is a dual-use technology with both peaceful and military applications. Concerns about the misuse of peaceful applications of nuclear energy were at first focused on states seeking nuclear weapons. The first concepts for restricting nuclear energy to peaceful purposes were proposed in the context of a broad international agreement under the auspices of the newly formed United Nations. The term *safeguards* in relation to peaceful uses referred to institutional, legal, and technical mechanisms to prevent the misuse of nuclear technologies and nuclear materials for military applications. Domestic security measures employed by states developing nuclear technologies were designed to counter commercial or military espionage or theft of materials by agents of other countries. The increase in concern about threats from nonstate groups and terrorists began to significantly impact the nuclear industry in the early 1970s as the specter of international terrorism grew, from the attacks at the 1972 Munich Olympics to the attacks on the World Trade Center and the Pentagon on September 11, 2001. This chapter deals with the history of measures to counter the proliferation of nuclear weapons by states and nonstate groups or terrorists.

International Control or Secrecy and Denial: From 1945 to Atoms for Peace

Even before the end of the Second World War, the scientists and political leaders who knew the secret of the U.S. Manhattan Project to build a nuclear weapon debated how to control the technology they had created and at the same time to realize its civilian benefits.[1] In a major political commitment, the President of the United States and the Prime Ministers of the United Kingdom and Canada issued an Agreed Declaration on November 15, 1945, which described three reasons to seek international control of nuclear activities: the massive destructive power of nuclear weapons; the likely futility of defense against such weapons; and the fact that no state could hope to have a monopoly on such weapons.

[1]For a discussion of the debates surrounding possible mechanisms of control, including the Acheson-Lilienthal Report, the Baruch Plan, and the Atoms for Peace proposal, see Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986); Rhodes, *Dark Sun* (New York: Simon and Schuster, 1995); Kai Bird and Martin J. Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer* (New York: Knopf, 2005); and Joseph F. Pilat, editor, *Atoms for Peace: A Future After Fifty Years?* (Baltimore: Johns Hopkins University Press/Woodrow Wilson Center Press, 2007).

Several months later, on January 7, 1946, the U.S. Secretary of State appointed a committee chaired by Dean Acheson with the following terms of reference:

> Anticipating favorable action by the United Nations Organization on the proposal for the establishment of a commission to consider the problems arising as to the control of atomic energy and other weapons of possible mass destruction, the Secretary of State has appointed a Committee of five members to study the subject of controls and safeguards necessary to protect this Government so that the persons hereafter selected to represent the United States on the United Nations Commission can have the benefit of the study.

The U.S. State Department committee subsequently appointed a Board of Consultants, including David Lilienthal and J. Robert Oppenheimer. The product of this committee, the so-called Acheson-Lilienthal Report, is remarkable for its vision and anticipation of problems that remain difficult and only partially solved today.[2]

The U.S. committee proceeded from the position that it was in the interests of the United States to seek international control of nuclear energy and weapons. They examined in some detail the possible treaty regimes and "safeguards" that would be necessary to enforce international control, including the role of inspections. Inspections to confirm the absence of nuclear weapons proliferation alone were seen as inadequate; additional legal and technical measures would be needed for effective international control of nuclear energy. The production of nuclear materials such as uranium and plutonium was noted as a technically difficult and strategically critical capability that should be a logical focus for international controls. The effective management and protection of nuclear materials was identified as a central objective and remains a primary mechanism of all nuclear safeguards efforts today.

The Acheson-Lilienthal Report recommended a distinction between "safe" and "dangerous" nuclear activities. Safe activities included use of tracer isotopes and small quantities of nuclear materials. Dangerous activities were uranium mining and refining; uranium enrichment; the operation of plutonium production reactors and associated reprocessing plants; and nuclear explosive research and development. Although a different list of safe and dangerous activities might be chosen today in light of the advances in nuclear technology and the wide availability of information, the process of determining proliferation risk associated with different elements of the nuclear fuel cycle remains central to current nonproliferation efforts.

The Acheson-Lilienthal Report recommended the creation of an international authority, an "international monopoly," to conduct all intrinsically dangerous operations in the nuclear field, with individual states and their citizens free to conduct, under license and a minimum of inspection, all nondangerous, or safe, operations. The proposed body would have authority to own and lease property and to carry on mining, manufacturing, research, licensing, inspecting, selling, or any other necessary operations. The analyses reflected in the Acheson Lilienthal report are an excellent example of the importance of combining technical and political expertise in dealing with nuclear nonproliferation.

The recommendations of the Acheson-Lilienthal Report were the basis for a presentation to the United Nations in 1946 by U.S. representative to the U.N. Atomic Energy Commission Bernard Baruch that became known as the Baruch Plan. The plan languished at the U.N. due to obstruction by the Soviet Union and its satellites. The Soviets had obtained the secrets of the Manhattan Project through espionage, and it is highly unlikely that any plan for international control would have been acceptable to them prior to their mastering nuclear weapons technology. The first Soviet atomic bomb was detonated in August 1949.

After the failure of the Baruch Plan, the United States followed a policy of maintaining secrecy around all nuclear matters and began slowly to expand its stockpile of nuclear weapons. However, many of the ideas considered in the Acheson-Lilienthal Report and the Baruch Plan

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[2] *A Report on the International Control of Atomic Energy*, Prepared for the Secretary of State's Committee on Atomic Energy, U.S. Government Printing Office, Washington, D.C., March 16, 1946 (the Acheson-Lilienthal Report).

would reemerge as part of President Dwight D. Eisenhower's Atoms for Peace initiative and would provide a foundation for the development of the nuclear nonproliferation regime.

Another important decision related to the future of nuclear energy occurred in 1946 when the U.S. Congress established the United States Atomic Energy Commission (AEC) to foster and control the peacetime development of atomic science and technology. The U.S. Atomic Energy Act of August 1, 1946, transferred U.S. control of atomic energy from military to civilian hands. This action reflected the view that atomic energy should be employed not only for national defense, but also to promote world peace, improve the public welfare, and strengthen free competition in private enterprise. The signing was the culmination of long months of intensive debate among politicians, military planners, and atomic scientists over the fate of this new energy source. President Harry S. Truman appointed David Lilienthal as the first Chairman of the AEC.

International Collaboration and Technology Sharing: Atoms for Peace to the Late 1960s

By 1953 the Soviet Union and the United Kingdom had tested nuclear weapons and the U.S. was fully engaged in the development of thermonuclear warheads. An arms race between the United States and the Soviet Union had developed. It was clear that the U.S. policy of secrecy and denial was not having much effect on the control of nuclear weapons. On December 8, 1953, President Eisenhower delivered an address on peaceful uses of atomic energy to the U.N. General Assembly. The ideas outlined in this speech and its follow-on policies became known as the Atoms for Peace initiative.

The Atoms for Peace initiative included the following key proposals:

- States with nuclear materials should make joint contributions from their stockpiles of normal uranium and fissionable materials to an international Atomic Energy Agency that should be set up under the aegis of the United Nations.
- The Atomic Energy Agency could be made responsible for storing and protecting the contributed fissionable and other materials.
- The more important responsibility of this Atomic Energy Agency would be to devise methods whereby this fissionable material would be allocated to serve the peaceful pursuits of mankind, including agriculture, medicine, and the provision of electrical energy in the power-starved areas of the world.
- Also central to the Atoms for Peace initiative was the idea that states receiving assistance in peaceful uses of nuclear energy would allow inspections to ensure that the nuclear technology and materials were not used for military purposes.

The dramatic change in U.S. policy arising from the Atoms for Peace initiative had wide-ranging impacts on the development of both domestic and international nuclear safeguards. Atoms for Peace and the changes to the Atomic Energy Act of 1954 permitting international collaborations and private ownership of nuclear materials in the U.S. would require expanded thinking about how to manage nuclear materials outside secret government installations, as well as how to manage exports of technology and materials.

The shift in U.S. policy was motivated partly by the now confirmed view that nuclear technology could not be kept secret. It was also based on the idea that the United States and its allies could use their advanced nuclear capabilities to strike a bargain with the developing world. The basic structure of the bargain is the provision of nuclear materials and technology by the United Sates and others to the developing nuclear states in exchange for verifiable assurances that the recipient states would only use nuclear energy for civilian, not military, purposes.

International Nuclear Safeguards

Prior to 1953, the concept of international safeguards had not yet evolved in international discourse, and no international nuclear safeguards were applied at any facilities. International developments followed two paths: the negotiation of a statute to create the IAEA, and U.S.

bilateral agreements for cooperation involving sharing with certain countries carefully selected nuclear technologies. Early bilateral agreements with close allies required minimal or no safeguards, but later agreements included bilateral (really unilateral) inspection provisions. The specific inclusion of safeguards in the IAEA Statute and the use of inspections in bilateral agreements for cooperation laid a sound foundation for international safeguards.[3]

In 1957, the European Community established under Chapter VII of the Euratom Treaty a nuclear material control system. Euratom safeguards are designed to ensure that nuclear materials were not diverted from their intended use and to guarantee "that the Community complies with its international obligations concerning the supply and use of nuclear materials."[4] Supply agreements with Euratom employed Euratom safeguards in lieu of bilateral safeguards, in recognition of the multinational character of its safeguards system.[5] After the full development of IAEA safeguards, special arrangements and cooperative mechanisms between Euratom and IAEA inspections were worked out and continue to evolve. The safeguards and inspection arrangements that originated from bilateral nuclear agreements and the Euratom safeguards measures provided useful experience and a context for the development of safeguards agreements between the IAEA and individual member states. All these international safeguards activities had the common objective of providing assurances from the state in which the safeguards were applied to other states or an international organization that nuclear technology was not being misused for military purposes.

IAEA safeguards began very slowly, in part because the agreements for cooperation among states included bilateral nuclear safeguards provisions and partly because of strong Soviet opposition to the safeguards role of the IAEA. However, in the early 1960s, the Soviet position shifted from one of opposition to safeguards as an "imperialistic mechanism" to hold back nuclear have-not countries to one of cautious support.[6] This shift, coupled with U.S. encouragement to shift the implementation of safeguards under agreements for cooperation to the IAEA, provided strong support for the further development of the international safeguards system.[7]

Domestic Safeguards

As mentioned, changes to the U.S. Atomic Energy Act of 1954 permitting private ownership of nuclear materials in the United States also required new approaches for managing nuclear materials outside of secret government installations.[8] Such safeguards originally consisted of nuclear process operating records, with little or no independent verification of nuclear materials inventories.[9]

The original foundation for United States domestic nuclear safeguards within the emerging private civil sector licensed by the Atomic Energy Commission (AEC) was simply the health risks and intrinsic monetary value of these still rare materials. Physical security was little

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[3]Myron Kratzer, "The Origin of International Safeguards," *Journal of Nuclear Materials Management*, special issue: "20 Years of Safeguards at Los Alamos National Laboratory," vol. XV, no. 4, July 1987, pp. 27–33.

[4]European Commission, Directorate-General for Energy and Transport, "Nuclear Safeguards—Europe remains vigilant," 2006; see http://europa.eu.int/comm/energy/nuclear/safeguards/doc/2006_brochure_nuclear_safeguards_en.pdf.

[5]Kratzer, JNMM, p. 31.

[6]Kratzer, JNMM, p. 32.

[7]Scheinman, *The International Atomic Energy Agency and World Nuclear Order*, pp. 36–37.

[8]See, for example, www.eh.doe.gov/oepa/laws/aea.html.

[9]Samuel C. T. McDowell, "U.S. Safeguards Before DOE," *Journal of Nuclear Materials Management*: special issue, "20 Years of Safeguards at Los Alamos National Laboratory," vol. XV, no. 4, July 1987, pp. 34–36.

more than standard industrial security designed to keep the public away from hazardous and valuable operations.[10] However, in the middle of the 1960s, concern began to grow about accounting and control for all nuclear materials in AEC contractor and licensee facilities. A major finding of nuclear material unaccounted for (MUF) at the NUMEC Apollo, Pennsylvania, plant that processed strategically and financially valuable materials provided major impetus for independent safeguards arrangements, oversight, and regulations as well as measurement capabilities to detect and account for special nuclear materials.[11] It was during this period that the AEC established formal domestic safeguards offices and a safeguards R&D program. Eventually, there evolved a comprehensive system of regulations and inspections of the safeguards and security measures at U.S. commercial nuclear facilities. This pattern has been followed in much of the world. There is also a similar, if not more stringent, system of safeguards in place at U.S. government-owned nuclear facilities.

Efforts to Stem Nuclear Proliferation: The 1970s Through the 1980s

Since the dawn of the nuclear age, most strategic thinkers concluded that these weapons were so destructive that their uncontrolled proliferation would create insecurity in the international system and be unacceptable. This view motivated early proposals for international nuclear controls such as the Baruch Plan. In the 1960s and 1970s, these concerns grew in the strategic community. National security strategists like Albert and Roberta Wohlstetter warned of "life in a nuclear-armed crowd."[12] The dangers of increased proliferation included increased chance of nuclear accidents, miscalculation, and regional arms races in addition to the heightened possibility of nuclear use in conflict or the loss of control of nuclear weapons. In 1963 President John F. Kennedy claimed that by 1975, 15 to 20 countries might possess nuclear weapons.[13] Kennedy urged all nations to act to slow the spread of nuclear weapons and sought to curb the arms race with the Soviet Union.

As a consensus regarding the dangers of nuclear proliferation was emerging, the U.N. General Assembly adopted a resolution proposed by Ireland in 1961 that called for the "prevention of the wider dissemination of nuclear weapons." The desire to address the issue of nuclear proliferation continued to evolve in the General Assembly and the Eighteen-Nation Committee on Disarmament (ENDC). By 1965, the General Assembly adopted Resolution 2028, setting out five principles on which a treaty to prevent the proliferation of nuclear weapons should be based:

- The treaty should be void of any loopholes which might permit nuclear or nonnuclear powers to proliferate, directly or indirectly, nuclear weapons in any form.
- The treaty should embody an acceptable balance of mutual responsibilities and obligations of the nuclear and nonnuclear powers.
- The treaty should be a step toward the achievement of general and complete disarmament and, more particularly, nuclear disarmament.

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[10]W. C. Myre and J. M deMontmollin, "History of Physical Security R&D," *Journal of Nuclear Materials Management*: special issue, "20 Years of Safeguards at Los Alamos National Laboratory," vol. XV, no. 4, July 1987, pp. 61–63.

[11]McDowell, JNMM, p. 35.

[12]Albert Wohlstetter et al., *Moving Toward Life in a Nuclear Armed Crowd? Report to the U.S. Arms Control and Disarmament Agency* (Los Angeles: Pan Heuristics, 1976).

[13]Public Papers of the Presidents of the United States: John F. Kennedy, 1963 (Washington, D.C.: USGPO, 1964), p. 2890. Also see National Planning Association, *1970 Without Arms Control*, Planning Pamphlet 104 (Washington, D.C.: NPA, 1958), p. 42, and National Planning Association, *The Nth Country Problem and Arms Control*, Planning Pamphlet 108 (Washington, D.C.: NPA 1960), p. 27.

- There should be acceptable and workable provisions to ensure the effectiveness of the treaty.
- Nothing in the treaty should adversely affect the right of any group of states to conclude regional treaties in order to ensure the total absence of nuclear weapons in their respective territories.[14]

In early 1968, the ENDC submitted to the General Assembly a draft treaty incorporating these principles; the Assembly adopted a resolution commending the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and expressing the desire that it be joined by the greatest possible number of states. By the time the NPT was opened for signature in 1970, five states had exploded nuclear weapons: the United States, the Soviet Union, the United Kingdom, France, and China. But several key states, some with emerging nuclear weapons programs, did not sign the NPT at the time, including Israel, China, India, Pakistan, Brazil, and Argentina. In addition, growing commerce in nuclear technology and materials was making nuclear technology more available.

The successful negotiation and initial signing of the NPT marked a major milestone in the evolution of the nonproliferation regime and international nuclear safeguards. With its requirement that all nonnuclear weapon state parties place under IAEA safeguards all their peaceful nuclear activities, the treaty provided further support and challenges to the still embryonic international safeguards system.[15] When the NPT was negotiated, the IAEA safeguards system was conducted according to procedures described in an IAEA document known as Information Circular (INFCIRC)/66.[16] However, a number of states wanted to revisit the Agency safeguards system to be implemented under the NPT. The result of extensive negotiations was a new document, INFCIRC/153, which has become the cornerstone of international safeguards.[17]

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[14]United Nations Committee on Disarmament, http://disarmament.un.org/wmd/npt/nptbi.html (Feb. 2007).

[15]NPT Article III.1: Each nonnuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices. Procedures for the safeguards required by this Article shall be followed with respect to source or special fissionable material whether it is being produced, processed or used in any principal nuclear facility or is outside any such facility. The safeguards required by this Article shall be applied on all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere.

[16]The Agency's Safeguards System (1965, as Provisionally Extended in 1966 and 1968), as approved by the Board of Governors in 1965 and provisionally extended in 1966 and 1968. INFCIRC/66/rev 2. The development of the system from 1961 onward has been as follows:

- The Agency's Safeguards System (1961) INFCIRC/26
- The 1961 system as extended to cover large reactor facilities: The Agency's Safeguards System (1961, as Extended in 1964) INFCIRC/26 and Add.1
- The revised system: The Agency's Safeguards System INFCIRC/66 (1965)
- The revised system with additional provisions for reprocessing plants: The Agency's Safeguards System (1965 as Provisionally Extended in 1966) INFCIRC/66/Rev.1
- The revised system with further additional provisions for safeguarded nuclear material in conversion plants and fabrication plants: The Agency's Safeguards System (1965, as Provisionally Extended in 1966 and 1968) INFCIRC/66/Rev.2

[17]INFCIRC/153: The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons.

This document became the basis for all Comprehensive Safeguards Agreements between NPT member states and the IAEA. These agreements have a number of important features worth highlighting. One is the requirement to place under safeguards *all* nuclear materials in peaceful uses in the state, which would later prove to have significance in determining the Agency's authority to search for undeclared nuclear materials and activities. A second feature is the requirement for states to establish so-called State's Systems of Accounting and Control (SSACs) to track domestic inventories of nuclear materials and provide reports to the IAEA. In many countries, these SSACs are also the national authorities regulating nuclear activities, including domestic safeguards and security. A third feature worthy of mention is that the agreement obligates the IAEA to apply safeguards with all states that have such agreements. This requirement has implications for IAEA budgets and the funding of safeguards. Part II of INFCIRC/153 outlines detailed procedures for the application of IAEA safeguards under the agreement.

The international safeguards system evolved considerably during the period from the 1970s to the early 1990s. Among the developments were technologies for the independent detection and assay of nuclear materials by Agency inspectors, nuclear materials containment and surveillance systems, and the development of systematic approaches to safeguards at the nuclear facility types that were being constructed and operated around the world. IAEA safeguards inspectors were becoming expert in their profession, with considerable technical and training support from key member states. In short, the NPT and the IAEA's international safeguards system became one of the primary international mechanisms designed to prevent the spread of nuclear weapons to additional states.

India's nuclear test explosion in 1974 sent shockwaves through the nuclear nonproliferation community. Most of India's civilian nuclear facilities were not under safeguards, and it had built several secret facilities with the help of technology obtained from commercial partners, including Canada and the United States. This event spurred greater interest on controlling nuclear trade, with the emergence of what was to become the Nuclear Suppliers Group, an association of states exporting nuclear technology that would agree to enforce similar rules and require similar commitments to nonproliferation from recipient states. In the U.S., the Nuclear Nonproliferation Act (NNPA) of 1978, which was a direct outgrowth of growing concerns about proliferation, driven in large part by India's nuclear test, placed new restrictions on international nuclear activities.[18]

Domestic safeguards and security were also evolving in the United States and elsewhere. At U.S. nuclear facilities licensed by the NRC and contractor facilities under the Department of Energy (DOE), requirements for increased quality and timeliness of nuclear materials accounting and control, in particular to deal with insider threats, as well as increased security against outsider threats, were promulgated and implemented. States which signed the NPT and brought into force comprehensive safeguards agreements with the IAEA had to develop national systems of accounting and control (SSACs) for their inventories of nuclear materials. The terrorist kidnapping and killing of Israeli athletes at the Munich Olympics in 1972, although having no nuclear dimension whatsoever, heightened concern about terrorism and greatly spurred interest in increasing physical security around nuclear installations of all kinds.[19] The NNPA required the U.S. DOE to conduct training in establishing SSACs and in physical protection for key individuals from developing nuclear states.

Safeguards and security R&D budgets were increasing from the 1970s through the 1980s, with new technologies applied to both domestic and international safeguards challenges. By the

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[18]Public Law 95-242 (3/10/78) Nuclear Non-Proliferation Act: Declares it U.S. policy to: (1) pursue the establishment of international controls of nuclear equipment, material, and technology; (2) enhance the reliability of the United States as a supplier of nuclear reactors and fuels; (3) encourage ratification of the Treaty on the Non-Proliferation of Nuclear Weapons; and (4) aid other nations in identification and adaptation of appropriate energy production technology.

[19]Myre, JNMM.

end of the 1980s, advanced instruments operating in unattended conditions in nuclear facilities had been demonstrated, containment and surveillance systems were tracking material and people in real time, and the quantity of nuclear material being independently verified by domestic and international inspectors had grown dramatically.[20] Safeguards technology and implementation appeared to be keeping up with the growth of materials and facilities to be safeguarded. That perception, however, was about to change.

Cheaters, Rogue States, and Terrorists: The Early 1990s to 2006

The inspections in Iraq under the authority of U.N. Security Council Resolutions following the end of the Gulf War in 1991 provided a new shock to the nonproliferation regime in general and to IAEA safeguards in particular. The Iraqis had run an extensive clandestine nuclear weapons development program right under the noses of the IAEA inspectors who had been dutifully inspecting declared inventories of nuclear materials but were unaware of Iraq's clandestine activities. Later, the Democratic People's Republic of Korea (DPRK) would also present major challenges to the IAEA safeguards system by denying inspectors the ability to verify their declared nuclear activities and eventually withdrawing from the NPT. The discoveries in Iraq after the 1991 Gulf War and the actions by the DPRK shattered the assumption that the threats to the nuclear nonproliferation regime lay only in states that had refused to sign the NPT. It became clear that some states would try to deceive the international community by joining the treaty and conducting secret efforts to develop military nuclear capabilities.

These events resulted in an acknowledged need for a major strengthening of IAEA safeguards designed to detect states' efforts to conduct undeclared nuclear activities. Efforts to strengthen the international safeguards system focused on increased access to information about a state and its nuclear enterprise, increased access to locations in a state (not just those with declared nuclear materials), and increased access to the U.N. Security Council to follow up on evidence of safeguards violations. Strengthening measures that could be implemented under existing IAEA authorities included the use of environmental sampling to find evidence of undeclared nuclear activities at declared sites, earlier provision of nuclear facility design information to the IAEA, and the use of open source and third-party information in assessing safeguards compliance. Additional strengthening measures such as requiring states to provide additional information on nuclear R&D not involving nuclear materials and providing broader access to declared sites and other locations were deemed to require additional authorities beyond those contained in INFCIRC/153. In 1997, the IAEA Board of Governors approved the so-called Additional Protocol INFCIRC/540, which provides for these additional measures for states that sign and ratify it.[21]

When states bring into force an Additional Protocol (AP), the IAEA has available to it an expanded set of safeguards tools that have the potential to provide greater confidence in both the correctness and completeness of the state's declarations of its nuclear materials and activities. Verifying the correctness of a state's declaration requires confirming that its description of its nuclear activities and quantities of nuclear materials is accurate. Verifying the completeness of the declaration requires developing confidence that the state has faithfully informed the IAEA of all its nuclear activities and is not concealing any efforts to use nuclear technology for military purposes or for purposes unknown.

The IAEA safeguards system in general, and for states under the AP in particular, is evolving to one that looks at the "state as a whole." All relevant information available to the

[20] For a case study describing a modern unattended monitoring system, see *Remote and Unattended Monitoring Systems*, by Mark Schanfein.

[21] "Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards," INFCIRC/540 (Corrected), 1997.

Agency about a state is examined and evaluated to reach safeguards conclusions. Safeguards inspectors visiting nuclear facilities and conducting complementary access "visits" to additional locations under the AP are of central importance to the effectiveness of the safeguards system. Curious and observant humans inside the facilities and "under the roof" can provide information not available through other means. However, the role of open source information, including satellite imagery and the Internet, has also grown enormously in importance to safeguards and is now a key focus of the IAEA.[22] The three types of assessment—facility inspections, complementary access visits, and open source information analysis—are the major tools of the strengthened IAEA safeguards system.

A part of the IAEA's approach for assessing the completeness of a state's safeguards declaration is based on the concept of a state's nonproliferation bona fides. This approach involves looking at a broad range of information on a state's past behavior with respect to its nuclear declarations, its compliance with international treaties, its nuclear export behavior and the effectiveness of export control systems, enforcement of domestic safeguards, and counterterrorist activities. Although the IAEA cannot verify intent, if a positive assessment can be reached on all or most of these categories it logically increases confidence in a state's willingness to uphold its nonproliferation obligations and the completeness of its safeguards declaration. More important, such positive nonproliferation behavior provides the IAEA with essential information about all aspects of the state's nuclear enterprise. As a consequence, assessing states' nonproliferation bona fides can thus provide important supporting information that, combined with the results of technical inspections at facilities, could help reach safeguards conclusions. Conversely, a negative change in the assessment could raise concern that a greater safeguards effort or increased access may be needed to verify the correctness and completeness of declarations.

When states have had the AP in force for a number of years and the IAEA has been able to use the additional information and access available to it, as called for in the AP, the IAEA can, in principle, draw a positive conclusion about both the correctness and completeness of the declaration. In these situations, the state can come under so-called *integrated safeguards*, in which the IAEA makes use of the optimum combination of measures available to it, with the possibility of reducing some traditional safeguards efforts on some declared materials. States and the IAEA thus can benefit from integrated safeguards conclusions through reduced impacts on a state's nuclear facilities and cost savings for the IAEA on implementing safeguards.

Implementing the new measures in the Additional Protocol, as well integrating INFCIRC/153 and INFCIRC/540 safeguards, remains a work in progress. 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 it. The Agency and IAEA member states are trying to remedy this situation and the problem of the universality of comprehensive safeguards agreements as well.

More Wake-Up Calls for Nuclear Security

The terrorist attacks in the United States on September 11, 2001, were a wake-up call to the international nuclear community. As noted previously, concerns about terrorism and its impact on the nuclear industry had been growing since the Munich Olympics in 1972, but the dedication, sophistication, and planning evident in the 9/11 attacks challenged many assumptions regarding the severity of the terrorist threat to nuclear facilities around the world as well as possible terrorist interests in using nuclear weapons or radiological materials. In the immediate aftermath of the September attacks, rapid assessments of nuclear security were conducted on many fronts. It was also recognized that although nuclear security is first a

[22]For a detailed description of both open source analysis and the use of satellite imagery, see Chapter 11, by Arvid Lundy and Rick Wallace, and Chapter 12, by Frank Pabian.

sovereign responsibility, the prospect of nuclear terrorist attacks threatens all states. This led many leading states' to realize that it was in their security interests to provide technical and financial assistance for improving nuclear materials security to states that have difficulty with this task.[23] The IAEA also has a significant program to provide information and training to help states improve nuclear materials security and to detect and respond to incidents of illicit nuclear trafficking.[24]

The late 2003 disclosure of a major clandestine nuclear trade network supplying Libya with nuclear materials, uranium enrichment technology, and nuclear weapon designs provided another wake-up call to the nonproliferation regime and to the international safeguards system. The same network, run by Pakistani nuclear scientist A. Q. Khan, is also suspected of supplying similar technology and information to Iran and North Korea.[25] Iran's admission to the IAEA that it had operated a secret enrichment R&D effort for more than 18 years, the DPRK's withdrawal from the NPT, and the revelations about Libya's weapons program were all factors in stimulating new measures to strengthen the nonproliferation regime and international safeguards. Furthermore, growing concerns about a "nexus" of proliferation and terrorism also began to blur the boundaries between domestic and international safeguards.

In response to these new challenges, in October 2003 the IAEA Director General, Mohamed ElBaradei, called for limiting the processing of weapons-usable material in civilian nuclear programs as well as new production of such materials by restricting these operations to facilities under multilateral control; deploying nuclear energy systems that avoid the use of materials that may be directly applied to making nuclear weapons; and consideration of multinational approaches to the management and disposal of spent fuel and radioactive waste.[26]

In a major nonproliferation policy address delivered in February 2004, President George W. Bush outlined a broad seven-point program to strengthen the nonproliferation regime and to counter nuclear terrorism. The President's proposals called for strengthening the Proliferation Security Initiative, calling on all states to strengthen laws and international controls that govern proliferation, expanding cooperative threat reduction activities, imposing restraints on enrichment and reprocessing coupled with nuclear fuel supply assurances, making the adoption of the AP a condition of nuclear supply to all states, creating a special committee of the IAEA Board of Governors to focus on safeguards and verification, and excluding states under investigation for safeguards violations from participating in IAEA Board decisions.[25]

In April 2004 the U.N. Security Council passed Resolution 1540, which, among other things, declares that all states shall:

- Refrain from providing any form of support to nonstate actors in acquiring or using nuclear, chemical, or biological weapons and their means of delivery.

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[23]Charles B. Curtis, "Reducing the Nuclear Threat in the 21st Century," *Proceedings of the Symposium on International Safeguards: Verification and Nuclear Material Security*, International Atomic Energy Agency, Vienna, Austria, Oct. 29, 2001, IAEA-SM-367/1/04.

[24]This is the IAEA's Nuclear Security Plan and it is implemented by the Agency's Office of Nuclear Security. See http://www-ns.iaea.org/security/default.htm.

[25]The White House, Remarks by the President on Weapons of Mass Destruction Proliferation, National Defense University, Washington, D.C., Feb. 11, 2004, www.whitehouse.gov/news/releases/2004/02/print/20040211-4.html.

[26]Mohamed ElBaradei, "Towards a Safer World," op-ed piece published in *The Economist*, Oct. 16, 2003, www.iaea.org/NewsCenter/Statements/2003/ebTE20031016.html. The IAEA subsequently convened an international group to examine fuel cycle issues and published "Multilateral Approaches to the Nuclear Fuel Cycle: Expert Group Report Submitted to the Director General of the International Atomic Energy Agency," INFCIRC/640, Feb. 22, 2005.

- Adopt and enforce laws which prohibit any nonstate actor from acquiring or using such WMD and means of delivery.
- Take and enforce effective measures to establish domestic controls to prevent proliferation of WMD, including measures to account for and secure relevant materials, physical protection measures, border controls and law enforcement, and effective export controls.[28]

The first steps in implementing Resolution 1540 have been taken, with most U.N. member states submitting reports to a U.N. "1540 committee" on the status of their efforts to meet the resolution's objectives. States are also identifying areas in which they might need assistance or offering to provide needed assistance to other member states.

In February 2006, the Bush administration announced the Global Nuclear Energy Partnership (GNEP), which envisions major new nuclear energy technology developments closely coupled with nonproliferation measures. Prominent among the nonproliferation features are the concept of a small number of states that possess fuel cycle facilities employing advanced technologies to provide assured nuclear fuel cycle services, including fresh reactor fuel supply and spent fuel take-back services, to a much larger number of states that have foregone sensitive fuel cycle technologies and that use a range of tailored reactors to meet their energy demands.[29]

Although some of the nonproliferation and safeguards challenges of this most recent period are new, such as the discovery of an active international black market in sensitive nuclear technologies and the threat of sophisticated international terrorism, many were anticipated in the Acheson-Lilienthal report 60 years ago. The ElBaradei and Bush proposals to limit the spread of enrichment and reprocessing are simply more modern attempts to address some of the "dangerous" activities described in 1946 within the constraints of today's realities.

It remains uncertain, however, whether the majority of states will see advantages in some of these new proposals for preventing nuclear proliferation. The recommendations by both the IAEA Director General and President Bush are widely seen to impact the basic structure of rights and responsibilities under the NPT. Those rights have been interpreted by some as allowing any state that upholds its NPT obligations to develop the full nuclear fuel cycle, including the right to produce plutonium and highly enriched uranium, the materials that can be used to manufacture nuclear weapons. Any proposals that appear to compromise these rights by restricting the production of nuclear materials to international centers or existing "supplier states" is likely to be opposed by many NPT members, presenting challenges to the treaty. This is the way international efforts to stem Iran's nuclear weapon ambitions are being portrayed by Iran. The IAEA has suspicions regarding Iran's nuclear intentions and has evidence of safeguards violations that it has not yet fully resolved.[30] Iran for its part insists that it is using nuclear energy only for peaceful purposes and will move ahead with the completion of a large-scale uranium enrichment plant.

The Continuing Evolution of IAEA Safeguards

Because the international nuclear safeguards system has its legal foundation in the IAEA Statute and the NPT, it is a truly international approach and has developed widespread support in the international community over the years, even after the problems uncovered in the wake of the Gulf War and subsequently. The IAEA's safeguards system demonstrates to the world that relatively intrusive on-site inspections can be manageable, not only theoretically but by building confidence in on-site inspections through the experience of states with safeguards that are cost-effective, politically acceptable, and technically workable.

IAEA safeguards inspections have also been used to verify compliance with other treaties, such as the nuclear weapons-free zones agreed to in Latin America, the South Pacific,

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[28]United Nations Security Council S/RES/1540 (2004).

[29]DOE Website for the Global Nuclear Energy Partnership, www.gnep.energy.gov.

[30]See Chapter 12, "Commercial Satellite Imagery: Another Tool in the Nonproliferation Verification and Monitoring Toolkit," by Frank Pabian.

Africa, and Southeast Asia. The Fissile Material Production Cutoff Treaty (FMCT) proposed by the United States does not have verification provisions, but many believe that if an FMCT with verification provisions were agreed, it would be logical to verify it through IAEA safeguards.

The IAEA's experience with respect to protocols and for inspections has been utilized in many areas, including allowing key breakthroughs in certain regions such as South America. In 1990, Argentina and Brazil signed an agreement to create a joint system for accounting and control of nuclear materials in the two countries. The agreement is administered by the Argentinean-Brazilian Agency for Accounting and Control (ABACC). In December 1990, the two countries signed a quadripartite agreement with ABACC and the IAEA for application of safeguards on existing nuclear material in Brazil and Argentina. Regimes in other arenas, including chemical weapons disarmament efforts under the Chemical Weapons Convention (CWC), closely follow the techniques and organizational structures that have proved effective through years of IAEA experience.

There has also been significant innovation and improvement in safeguards procedures and technologies allowing the IAEA to meet new challenges. These improvements to safeguards have been made on a continuous basis, and the IAEA has built up an unparalleled technical base in this area. For example, 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, time consuming, and in some cases impractical to obtain by other means. These instruments include neutron coincidence counters for quantitative measurements of unirradiated plutonium in a variety of forms as well as gamma spectroscopy instruments for determining isotopics of plutonium and uranium.[31] 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.

Continuous unattended monitoring of activities in nuclear facilities has improved the efficiency of inspections by reducing the time inspectors spend 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 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 secure remote transmission of these data that would further reduce the need for inspector presence in facilities.[32]

In addition to technology advances, the IAEA has made innovations in procedures that enhance effectiveness and efficiency. Examples include new ways of working with regional safeguards systems such as the New Partnership Agreement with Euratom, where the agency saved significant numbers of inspection days through coordinating activities and sharing equipment and duties with 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 other international agreements with on-site inspections, such as the Chemical Weapons Convention, and sought to incorporate certain inspection features into its own safeguards where appropriate and acceptable.

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. To deal with the anticipated growth in nuclear energy use worldwide, it is essential

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[31]For more detailed discussion of these measurement instruments, see Chapters 3B and 3C, by Mark E. Abhold and Doug Reilly, respectively.

[32]See Chapter 6, "International Atomic Energy Agency Unattended Monitoring Systems," by Mark Schanfein.

that the international safeguards system be both credible and effective. The IAEA, however, faces limits on safeguards inspections inherent to the agreements that authorize them. For example, even the Additional Protocol's complementary access authorities allow only limited access to locations in a state other than those declared as nuclear facilities. This is far short of "anytime, anyplace" inspections that have been called for in some cases. Limits to the effectiveness of safeguards in a given state can also stem from residual cultural issues, gaps in available technology such as wide-area environmental sampling, and cost issues. These limits are exacerbated by the fact that the Agency does not fully use all its authorities, especially the authority to conduct special inspections. And the IAEA has limited technological tools to address such issues as detection of undeclared facilities/activities, especially related to uranium enrichment and bulk-handling facilities.

The Future of Domestic and International Safeguards

Improving the responsiveness of both domestic and international safeguards to identified emerging threats and to future, unanticipated threats remains a critical challenge for global nuclear security. To achieve this goal, the IAEA must constantly seek ways that it can strengthen its management of the inspections process and utilize its authorities with NPT member states. This includes full implementation of the Additional Protocol in all member states. The IAEA and key member states with advanced fuel cycles should continue to make appropriate investments in new safeguards technologies and apply them efficiently. The international community needs to consider new political and legal mechanisms that can make nonproliferation safeguards more efficient and manageable as the global use of nuclear energy expands. By what authority will enrichment and reprocessing capabilities be limited to "supplier" or "fuel cycle" states? Is it possible to establish and enforce international standards for the physical protection of nuclear materials?

If advanced nuclear fuel cycle technologies are deployed as envisioned by the U.S. Global Nuclear Energy Partnership and the nuclear development plans of other states, several specific safeguards challenges either exist now or can be anticipated. For example, safeguards technologies for large, increasingly complex new facilities with high material throughputs will be needed and where current technology cannot meet IAEA detection goals. New techniques will be needed for difficult-to-measure nuclear materials such as those that will result from advanced fuel reprocessing, pyroprocessing, and electrorefining. These new technologies will have to operate reliably in harsh environments with high radiation dose rates and temperatures. They will need to be capable of measurements of both continuous flows of nuclear materials in various forms (solid, liquid, gas) and of nonnuclear process parameters such as temperature, density, and flow rate, which can help confirm safeguards declarations. New technologies and procedures will also be needed to detect possible nuclear materials diversions without physical changes to a plant through process controls, chemistry, and advanced surveillance techniques. The current state of the art for safeguards technologies and some advanced concepts are discussed in subsequent chapters of this volume.

Summary

The international nuclear safeguards system faces institutional, political, and technical challenges in its efforts to ensure that states are meeting their safeguards obligations. To a large extent, there is also a vital feedback loop that the IAEA must maintain with the domestic nuclear safeguards systems. For some less developed states with limited nuclear infrastructures, interaction with the IAEA through SSAC development and other technical assistance is the primary mechanism via which to improve their domestic nuclear security. In a related fashion, the advanced domestic nuclear safeguards capabilities in states with highly developed nuclear fuel cycles are often adopted by the IAEA for use in safeguarding other facilities. Thus the benefits flow both ways, with the IAEA serving a positive integrating function.

The IAEA is a vital institution for global efforts to maintain nuclear security that enjoys the support of the leading nuclear powers. It needs to remain innovative and flexible as the global nuclear energy sector expands and additional states potentially reconsider their commitment to foreswear nuclear weapons.

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