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Deterring Nuclear Proliferation: The Importance of IAEA Safeguards

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DETERRING NUCLEAR PROLIFERATION

THE IMPORTANCE OF IAEA SAFEGUARDS



A TEXTBOOK
FEBRUARY 2019
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NATIONAL LABORATORY

[INSIDE FRONT COVER]

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LIST OF ACRONYMS AND ABBREVIATIONS

ABACC—Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials
AEC—Atomic Energy Commission
Am—Americium
CANDU—Canadian deuterium uranium
CFR—Code of Federal Regulations
CIA—Central Intelligence Agency
C/S—Containment and surveillance
CSA—Comprehensive safeguards agreement
Cu—Copper
DA—Destructive assay
DDG—Deputy Director General
DIQ—Design Information Questionnaire
DIV—Design information verification
DOE—Department of Energy
DPRK—Democratic People's Republic of Korea (also referred to as North Korea)
ENCD—Eighteen-Nation Committee on Disarmament
ERDA—Energy Research and Development Administration
ESARDA—European Safeguards Research & Development Association
Euratom—European Atomic Energy Community
FMCT—Fissile material cutoff treaty
HEU—High-enriched uranium
HM—Heavy metal (uranium plus plutonium)
HSP-Hexapartite Safeguards Project
INFCIRC—Information Circular
INIS—International Nuclear Information System
INMM—Institute of Nuclear Materials Management
JCPOA—Joint Comprehensive Plan of Action
KCNA—Korea Central News Agency (of the DPRK)
Kg—kilogram
LASCAR—Large-scale reprocessing
LEU—Low-enriched uranium
LOF—Location outside facilities
LWR—Light-water reactor
MAGNOX—Magnesium non-oxidizing
MBA—Material balance area
MOX—Mixed (uranium and plutonium) oxide
MT—Metric tons (or tonnes)
MUF—Material unaccounted for
MW—Megawatts (one million watts)
NAM—Non-aligned movement
NATO—North Atlantic Treaty Organization
NDA—Non-destructive assay

NNPA—Nuclear Non-Proliferation Act
NNSA—National Nuclear Security Administration
Np—Neptunium
NRC—Nuclear Regulatory Commission
NSG—Nuclear Suppliers Group
NWFZ—Nuclear-weapon-free zone
PFEP—Pilot Fuel Enrichment Plant
PIT—Physical inventory taking
PMDA—Plutonium Management and Disposition Agreement
POTAS—Program of Technical Assistance to IAEA Safeguards
Pu—Plutonium
R&D—Research and development
RSAC—Regional system of accounting for and control of nuclear material
SAGSI—Standing Advisory Group on Safeguards Implementation
SAL—Safeguards Analytical Laboratory
SILEX—Separation of isotopes by laser excitation
SLC—State-level concept
SLA—State-level approach
SNRI—Short-notice random inspection
SSAC—State system of accounting for and control of nuclear material
SQP—Small Quantities Protocol
SWU—Separative work unit
TC—Technical Cooperation
tHM—Tonnes of heavy medal
Tamper-indicating device—TID
TNT—Trinitrotoluene
UF₆—Uranium hexafluoride
UO₂—Uranium (di)oxide
USSP—U.S. Support Program to IAEA Safeguards
WMD—Weapons of mass destruction
ZRG—Zero real growth

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ABOUT THE AUTHORS

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Dr. Michael D. Rosenthal has an extensive background in nuclear non-proliferation and international security issues and broad experience with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the International Atomic Energy Agency (IAEA), international safeguards, United States nuclear cooperation, and United States Government and international programs aimed at reducing the risks of nuclear and other radioactive material and technology.

He served in the United States Department of State and the United States Arms Control and Disarmament Agency (ACDA) as a member of the Senior Executive Service as well as in the Department of Safeguards at the International Atomic Energy Agency. He also held positions at Brookhaven National Laboratory and the Domestic Nuclear Detection Office.

Dr. Rosenthal represented the United States Government in numerous bilateral and multilateral consultations and in international meetings, including at the IAEA, at NPT Review Conferences in 1990, 1995, and 2000, and in the Nuclear Suppliers Group and the Zanger Committee.

Dr. Rosenthal holds a Ph.D. in Physics from Cornell University and is a Fellow of the American Physical Society. He taught physics at Rutgers University and Swarthmore College and has a B.A. in Physics and Mathematics from Wesleyan University in Connecticut.

LESLIE G. FISHBONE

Dr. Leslie G. Fishbone has spent the last thirty-eight years working in the area of nuclear material safeguards. From 1989 to 1993 he worked in the Department of Safeguards of the IAEA. Since returning, he resumed his earlier position at Brookhaven National Laboratory, where he had been since 1977. He served in the Nonproliferation and Safeguards Group of the Brookhaven Nonproliferation and National Security Department until early 2014. He now works through LGF Consulting LLC.

His most recent responsibilities at Brookhaven were for tasks relating to upgrading and sustaining nuclear material protection, control and accounting in Russia, where he traveled many times during over eighteen years, and for tasks relating to the international verification work of the International Atomic Energy Agency, including contributions to the content and organization of the Brookhaven course *Nuclear Nonproliferation, Safeguards and Security in the 21st Century*. He also serves as the Associate Editor for Nonproliferation and Arms Control of *JNMM*, the *Journal of Nuclear Materials Management*.

Dr. Fishbone earned a Bachelor of Science degree in physics from the California Institute of Technology in 1968. He received a Doctor of Philosophy degree in 1972 from the University of Maryland, with a dissertation in the field of relativistic astrophysics, specifically about black holes. Thereafter, he went to the Soviet Union as a participant in the research exchanges between the

National Academy of Sciences and the Academy of Sciences of the U.S.S.R. He was attached to the Landau Institute of Theoretical Physics. From 1974 to 1977 he was a postdoctoral fellow at the University of Utah.

Dr. Fishbone expresses his profound appreciation to his wife Leslie Weitzner and sons Aaron and Daniel for love, support, and humor during the career that led to this writing.

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Dr. Linda Gallini has extensive experience and knowledge of international nuclear issues and detailed familiarity with the IAEA. Over 25 years, she directed numerous programs to prevent the further spread of nuclear weapons.

Her successes include: creating the United States program of support for IAEA safeguards; directing implementation of over \$50 million annually in United States voluntary contributions to the IAEA; successfully ensuring that the level of the annual United States assessed contribution to the IAEA was not reduced; helping to achieve indefinite extension of the NPT in 1995 and successful conclusion of the 2000 NPT Review Conference, including serving as the United States representative on a key Main Committee; and leading the creation of a new IAEA Programme on Nuclear Material Security to counter the threat of nuclear terrorism in response to the terrorist events of September 11, 2001.

Dr. Gallini held leadership positions in the Department of State including Director of the Office of Multilateral Nuclear Affairs and Director of the Office of Science and Technology for international organizations. She also held posts as Senior Advisor to the United States Ambassador to the IAEA, Senior Advisor in the Office of the Secretary of Defense, and as a Foreign Affairs Officer for nuclear non-proliferation in the ACDA.

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Dr. Allan Krass passed away in December 2012. His co-authors and his many colleagues in the Department of State and the ACDA deeply mourn his passing. Allan is recognized by them for his dedication, technical expertise, mentorship, the numerous contributions he made toward achieving important nuclear cooperation and non-proliferation objectives, and for his friendship and collegiality.

Before his retirement from the United States Department of State, Dr. Allan S. Krass served for ten years as a Physical Science Officer in the Department and ACDA. He was instrumental in helping to develop and implement United States nuclear cooperation programs. His technical expertise ensured that nuclear issues were resolved in a sound manner. He also provided technical support for and served as liaison with the Department of Energy's programs in Reduced

Enrichment for Research and Test Reactors, Foreign Research Reactor Spent Nuclear Fuel Return, and Russian Research Reactor Spent Nuclear Fuel Return.

Dr. Krass was a true expert in the science and technology of nuclear non-proliferation and verification and published several books in these areas: *Uranium Enrichment and Nuclear Weapons Proliferation*, 1983; *Verification: How Much Is Enough?* 1985; and *The United States and Arms Control*, 1997.

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Myron Kratzer, a chemical engineer, has been actively involved in the development, assessment and implementation of nuclear non-proliferation and international safeguards policy since joining the U. S. Atomic Energy Commission's Division of International Affairs in 1957. As Director of International Affairs and Assistant General Manager for International Activities, he negotiated numerous Agreements for Cooperation in the peaceful uses of nuclear energy; was the principal U. S. negotiator of the IAEA's safeguards system as contained in Information Circulars INFCIRC/26/ Add. 1, INFCIRC/66, and INFCIRC/153; and participated in the negotiation of the safeguards provisions of the NPT.

He joined the Department of State in 1971, serving as Deputy Assistant Secretary of State for Nuclear Affairs from 1975 to 1977. After leaving government service in 1977, Kratzer continued as a consultant in nuclear non-proliferation and safeguards policy.

As the author of the definitive "Review of the Negotiating History" of the IAEA's NPT safeguards system as well as a number of other publications, he has stressed the application of the system to undeclared nuclear materials and activities in contrast to its de facto limitation to declared activities. Kratzer has written, spoken and testified widely on the development and importance of international safeguards, emphasizing the essentiality of strong and effective safeguards to the widespread application of nuclear energy to electric power generation.

JONATHAN SANBORN

Dr. Jonathan Sanborn received a Ph.D. in applied mathematics in 1975. After a postdoctoral position at the State University of New York at Stony Brook, he joined Brookhaven National Laboratory, where he was involved with arms control and safeguards issues. He worked briefly at the IAEA as a cost-free expert and was a part of the United States delegation to the Conference on Disarmament as technical advisor to the Head of the United States delegation representing the

United States during the negotiation of the Chemical Weapons Convention. In 2000 he joined the United States Department of State, where he worked on IAEA safeguards issues as well as the Fissile Material Cutoff Treaty. He retired from the State Department in 2011.

WARREN STERN

Warren Stern is an internationally recognized leader and manager in the area of nuclear safeguards, safety and security. He is currently a senior advisor in Brookhaven Lab's Nonproliferation and National Security Department (NNSD). Stern has held leadership positions at the Central Intelligence Agency (CIA), Department of State, the International Atomic Energy Agency (IAEA) and the Department of Homeland Security (DHS).

President Barack Obama appointed him to lead DHS's Domestic Nuclear Detection Office in August 2010. He served in that position until June 2012. Before working for DHS, Stern headed the IAEA's Incident and Emergency Centre, managing international nuclear and radiological emergency preparedness and response.

At the State Department, Stern directed the office responsible for developing and implementing U.S. nuclear safety and radiological security policies. As senior technical advisor to the Office of International Nuclear Affairs at the U.S. Arms Control and Disarmament Agency, he developed and implemented nonproliferation, verification, and arms control policies. For the CIA, he served as an intelligence officer for the Office of Scientific and Weapons Research.

Stern earned a B.A. in physics from Brandeis University in 1985, and an M.S. in nuclear engineering from MIT in 1989. He also holds an M.S. in national security studies from the National War College, awarded in 1997.

BARCLAY WARD

Dr. Barclay Ward is Professor Emeritus of The University of the South in Sewanee, Tennessee. His teaching areas are arms control, United States foreign policy, international relations, and diplomacy. He has also taught for Vanderbilt University in its International Studies in London program and at Budapest University of Economic Sciences. Before taking up an academic career, Dr. Ward was a Foreign Service Officer, serving in Washington at the Department of State and at the United States Embassies in Ottawa and Warsaw.

Dr. Ward worked for ACDA and the Department of State, focusing principally on the NPT. He served on the United States Delegations to the 1990 and 1995 NPT review conferences, and in the State Department he backstopped the United States Delegation to the 2005 NPT Review Conference.

Dr. Ward is a graduate of Hamilton College. He received his Master's Degree from the School of Advanced International Studies of The Johns Hopkins University and his Ph.D. in political science from the University of Iowa.

NORMAN A. WULF

Ambassador Norman A. Wulf is retired from the Department of State, where he served both as the Special Representative of the President for Nuclear Nonproliferation with the rank of Ambassador and as the Deputy Assistant Secretary of State for Nonproliferation. Ambassador Wulf served as United States Representative to preparatory committee meetings and review conferences for the NPT; and dealt with all matters pertaining to the International Atomic Energy Agency (IAEA). Ambassador Wulf led the United States delegation to the highly successful 2000 NPT Review Conference and to the 2001 IAEA General Conference.

Prior to his service in the Department of State, he was the Deputy Assistant Director of the Bureau for Nonproliferation and Regional Arms Control in ACDA. In this capacity he dealt with nuclear, missile, and chemical proliferation as well as conventional arms transfers.

Among his activities, Ambassador Wulf led the first team of Americans to visit North Korea's nuclear facilities; was the United States representative to the IAEA Committee that negotiated the protocol to strengthen IAEA safeguards (the additional protocol), the first significant legal instrument for strengthening of safeguards in over twenty years; and was instrumental in securing the 1995 decision to make the NPT permanent.

Ambassador Wulf has a J.D. cum laude from the University of Iowa College of Law and an LL.M. in International Law from the University of Miami.

PREFACE

The National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy, commissioned this book as an introduction to the safeguards system of the International Atomic Energy Agency (IAEA). The first edition was made available on-line in early 2013. It reflected circumstances as of late 2012. In 2017, NNSA requested an update to the textbook to reflect events since then. This textbook is updated through the end of 2017.¹ In a few cases, changes reflect information available in 2018. One of the most important changes since 2012 is that the IAEA has to a large extent completed its development and implementation of safeguards at the State level, while in 2012, the development of State-level safeguards approaches was in a state of flux. The further development and implementation of State-level approaches is described in Chapter 8.

Another important event after 2012 is the conclusion of a plan of action agreed between Iran, China, France, Germany, Russia, the United Kingdom and the United States. It is intended to allay international concerns about the proliferation risks of Iran's nuclear program. In turn, it calls for the elimination of international and national nuclear sanctions imposed on Iran. The nuclear arrangement was endorsed by UN Security Council Resolution 2231, adopted on July 20, 2015; its formal name is the Joint Comprehensive Plan of Action (JCPOA). On May 8, 2018, President Donald Trump announced that the United States would withdraw from the JCPOA and reinstate U.S. nuclear sanctions on the Iranian regime.

The IAEA plays a significant role under the arrangement. In addition to applying safeguards under Iran's NPT safeguards agreement and its additional protocol, which it has adopted provisionally, the IAEA verifies and monitors the implementation of the non-proliferation requirements of the agreed plan. This effort is ongoing and consumes a considerable amount of IAEA resources. These changes are reflected in Chapter 9.

Other changes to the textbook are less dramatic. They consist of editing and reformulation of some sections and the updating of some, but not all data. For example, the number of States Parties to the NPT and the number of safeguards agreement in force reflect the situation as of the end of 2017. Other data, especially those in the Appendices, have not generally been updated. Nonetheless, they provide important information to readers about the way in which the IAEA safeguards system is operated with the support of its Member States.

The IAEA safeguards system plays a key role in promoting international peace and security: it deters the proliferation of nuclear weapons and helps to facilitate nuclear cooperation under sound non-proliferation conditions. The IAEA also investigates instances where States violate their safeguards commitments under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). As noted above, the IAEA has also played important roles at the request of States or the United Nations in verification and monitoring of other non-proliferation arrangements.

In addressing nuclear non-proliferation issues, a sound understanding of the NPT and the IAEA safeguards system is indispensable. Adherence to the NPT is almost universal, IAEA safeguards are applied in virtually all States that use nuclear material, and the IAEA has found itself deeply

¹ See <https://www.bnl.gov/NNS/IAEAtextbook.php>

engaged in efforts to address nuclear proliferation concerns. Anyone studying the field of nuclear non-proliferation will benefit from reading this book. Mastery of it will enable anyone entering the field to get a “running start.”

Part I describes the foundations of the international safeguards system. It traces the system’s origins from the 1930s - when new discoveries in physics immediately made it clear that nuclear energy held both peril and promise - through the entry into force in 1970 of the NPT. The NPT codified the role of the IAEA and its safeguards system as the means to verify States’ NPT commitments not to acquire nuclear weapons. Chapter 1 provides a description of the nuclear non-proliferation regime and elements of the regime other than safeguards in order to highlight the fact that the NPT and IAEA safeguards are parts of a complex array of national, bilateral, multinational, and international arrangements that are intended to reduce the threat of nuclear proliferation.

Chapter 2 focuses on the nuclear conundrum – how to take advantage of the benefits of nuclear energy for peaceful purposes in ways that do not encourage nuclear proliferation. Early efforts to resolve this conundrum through international control of atomic energy failed. Other initiatives followed, especially the U.S. 1953 Atoms for Peace proposal, which had a profound effect on global approaches to nuclear cooperation and nuclear control.

Atoms for Peace led to both extensive nuclear cooperation and the creation of the IAEA in 1957, an international organization that reflected both elements of the conundrum – promoting the benefits of peaceful uses of nuclear energy and applying safeguards to ensure that the peaceful uses are not turned to military purposes. The IAEA, its authorities, and its organization are described in Chapter 3.

Chapter 4 describes the negotiation of the NPT and its key features, including the embodiment in the Treaty of the themes – nuclear cooperation and nuclear safeguards to deter nuclear proliferation – plus an additional theme, nuclear disarmament. While all three themes are important in the context of this book, the requirement that non-nuclear-weapon States parties to the NPT accept the application of comprehensive IAEA safeguards is central to our examination of the NPT.

Part II describes the NPT safeguards system, which is based on a model safeguards agreement developed specifically for the NPT. All NPT comprehensive safeguards agreements follow this model, which has been published by the IAEA as Information Circular 153, or 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.”² (Such agreements are commonly called INFCIRC/153 agreements.)

Chapter 5 describes the background to INFCIRC/153 and the legal framework that it establishes for the implementation of NPT safeguards. Because of its non-proliferation significance, Section 5.3 focuses on the way in which INFCIRC/153 addresses safeguards implementation where there are suspicions about possible non-compliance.

Chapter 6 describes the safeguards measures and techniques that are used by the IAEA and highlights practical implementation issues. Safeguards are applied both to small research facilities

² Comprehensive safeguards agreements are ones where the State is required to accept, and the IAEA is required to apply, safeguards to all nuclear material in the State. NPT safeguards agreements (INFCIRC/153 agreements) do so, but these are not the only ones.

and to large industrial facilities. They cover all nuclear fuel-cycle activities that transform uranium ore into technologically sophisticated fuel assemblies that generate electricity in nuclear reactors. Although a detailed description of how nuclear facilities work is beyond the scope of this book, Chapter 6 makes reference to the particular features of facilities that have a strong influence on how safeguards are applied.

Part III describes the transformation that began in the early 1990s in the way in which safeguards were conceptualized and implemented. This transformation was triggered by events in the Democratic People's Republic of Korea (DPRK), Iraq and South Africa that took place at that time. These events were the discovery of an undeclared nuclear-weapon program in Iraq in violation of its NPT safeguards agreement; the IAEA's detection of the failure by the DPRK to declare all of its nuclear material in violation of its NPT safeguards agreement; and the IAEA's experience in South Africa in verifying the end of its nuclear-weapon program. The reaction to these events led to a new emphasis on improving the ability of the IAEA to detect undeclared nuclear activities. This led to the adoption in 1997 of a new safeguards agreement named the "Model Protocol Additional to the Agreements between State(s) and the International Atomic Energy Agency." The Model Protocol was particularly intended to strengthen the IAEA's ability to address undeclared nuclear material and activities. Chapter 7 describes the negotiation of the Model Protocol and the details and import of its provisions.

This transformation did not end when the Model Protocol was adopted. In order to implement commitments contained in the Model Protocol after adoption by States, the IAEA needed to develop a new set of procedures and guidelines to implement additional protocols as they came into force. In doing so, it also took into account its strengthened capability to detect undeclared nuclear material and activities. To reflect this enhanced capability, the IAEA was able to change the way it applied safeguards at declared facilities, for example, by a reduction in the detection probability used to plan safeguards approaches there. In 2002, the IAEA completed its development of a safeguards system that was based on a State-level approach. It called this system "integrated safeguards." Integrated safeguards were applied to States that had both an NPT safeguards agreement and an additional protocol in force. The IAEA continued to develop and refine State-level safeguards approaches. For example, it studied which State-level factors should be taken into account in developing State-level safeguards approaches. By 2017, this process had been largely completed, and became the basis for the design and implementation of State-level approaches. Of course, the Agency will use experience gained to refine these approaches. The development of State-level approaches is described in Chapter 8.

The IAEA invests its safeguards resources in a number of different ways. In routine circumstances, almost all of the effort of the IAEA Department of Safeguards is devoted to the implementation of safeguards in NPT non-nuclear-weapon States with some additional inspection in States that do not have comprehensive safeguards agreements. In addition, it must investigate and, if possible, resolve anomalies that might be indicative of non-compliance with a safeguards agreement.

The IAEA also plays a third important role. This is to use its verification and monitoring expertise to enhance the confidence of the international community that other nuclear non-proliferation arrangements are being implemented satisfactorily. It did so in the cases of the DPRK, Iraq, and South Africa in the 1990s. Today, as stated above, it is playing an important role, and devoting significant resources, in applying verification and monitoring measures in Iran under the terms of

an arrangement named the Joint Comprehensive Plan of Action (JCPOA). This is described in some detail in Chapter 9. Under the terms of the JCPOA, this effort would continue for many years. In light of the non-proliferation significance of the JCPOA and the considerable IAEA effort being applied in Iran under its terms, Chapter 9 describes the JCPOA and its background in some detail. Even though the United States is no longer participating in the JCPOA, the IAEA's role continues.

Chapter 10 ends the book with an assessment of the safeguards system, challenges to it that lie ahead, and ways in which safeguards experience to date might be used in new contexts.

Additional topics are found in the Appendices. Appendix A addresses why the manufacture of nuclear weapons is feasible and why uranium and plutonium are of nuclear non-proliferation concern. Section A.1 describes how nuclear explosions can be “ignited.” Section A.2 covers the non-proliferation concerns that emerged in the 1990s because of the growing availability of two other elements, americium and neptunium, from which nuclear explosive devices can be made. However, they are not covered by the NPT safeguards system or mentioned in the IAEA Statute. Section A.2 describes how these concerns were mitigated. Section A.2 also addresses the question of the extent to which variations in the isotopic composition of plutonium change its usability in making a nuclear weapon.

Appendix B describes the creation of Euratom safeguards, the safeguards system that is applied on a multinational basis to the members of the European Union.

Appendix C describes institutional aspects of the IAEA. They are of interest because the performance of the safeguards system cannot be divorced from the principles, rules, and practices of the institution that funds it. Appendix C covers a number of issues related to the budget and the staffing of the IAEA.

Appendix D describes the safeguards agreements that have been concluded by the five NPT nuclear-weapon States. Since these are not required by the NPT, they are sometimes called “Voluntary-Offer Agreements”, although they are obligatory when in force.

Appendix E describes “small quantities protocols”. These protocols are common for States that have few, if any, nuclear activities. Their effect is to suspend many of the provisions of a comprehensive safeguards agreement as long as nuclear-fuel-cycle activities remain below certain thresholds.

A word about the scope of the book is in order:

The implementation of IAEA safeguards was initially based on a set of principles and procedures set forth in INFCIRC/66 and various revisions of it that took into account more complex facilities. Safeguards agreements were called INFCIRC/66 agreements. Relatively scant attention is paid to this safeguards system as it developed from 1957, when the IAEA was created, until 1971, when the NPT safeguards system was launched.

The primary reason is that all of the INFCIRC/66 agreement in force at the time were suspended in favor of NPT safeguards agreements as they entered into force. As a result, a very large fraction of IAEA safeguards resources is devoted to the routine implementation of safeguards in connection

with the NPT. As noted above, in 2017 implementation of the IAEA’s additional responsibilities in Iran under the JCPOA also consumed significant resources.

In States outside the NPT, safeguards are applied in three of them, India, Israel, and Pakistan, and then only to some of their nuclear facilities. Because these safeguards are not comprehensive, their nuclear non-proliferation significance may be considered modest. This remains the case in India, even though in 2014 it brought into force an additional protocol, albeit one not conforming in many ways to the Model Protocol.

Not all elements of INFCIRC/153 are addressed in the book. For example, safeguards are applied to nuclear material used outside facilities at places that have become known as “locations outside facilities.” But the book rarely refers to them. This and other such omissions are by design in order to reduce the complexity of the book and to focus readers’ attention on areas of greater nuclear non-proliferation significance.

In addition, the book does not address one of the most important nuclear issues confronting the world today – nuclear terrorism, whether through the use of improvised nuclear explosive devices or through the use of radiological weapons, so-called dirty bombs. The salience of nuclear terrorism is demonstrated by four meetings of heads of State at nuclear security summits, the first in 2010 and biennially through 2016. The salience of nuclear terrorism was emphasized in the Nuclear Security Summit 2016 Communiqué, which began with the statement, “The threat of nuclear and radiological terrorism remains one of the greatest challenges to international security, and the threat is constantly evolving.” Despite the importance of this threat, it is not directly linked to the subject of this book.

A few nomenclatural points are in order:

The model agreement used to implement NPT safeguards requirements, “The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons,” is published by the IAEA in INFCIRC/153. NPT safeguards agreements with non-nuclear-weapon States follow this model and are called INFCIRC/153 agreements. Because they apply to all nuclear material in all peaceful nuclear activities, they are also known as comprehensive safeguards agreements (CSAs).³

The full name of the model safeguards agreement adopted in 1997 is “Model Protocol Additional to the Agreements between State(s) and the International Atomic Energy Agency.” It strengthens the IAEA’s ability to detect undeclared nuclear material and activities and, to this end, provides the IAEA with routine access to locations and information above and beyond what is required under INFCIRC/153 safeguards agreements. It has been published by the IAEA as INFCIRC/540, and safeguards agreements that follow this model are sometimes referred to as INFCIRC/540 agreements. In this book that term is not used. If the reference is to the Model itself, it is called the “Model Protocol.” If reference is made to an agreement that has been concluded by an

³ Readers may be aware of the term “full-scope safeguards.” This term refers to situations where all of a State’s nuclear activities are under safeguards. This can arise because they are covered by a comprehensive safeguards agreement such as an INFCIRC/153 safeguards agreement. Full-scope safeguards can also arise if all of a State’s nuclear activities are covered by INFCIRC/66 safeguards agreements that collectively cover all nuclear activities in the State. This situation has not existed for some time, as it is only possible for states that are not parties to the NPT.

individual State on the basis of the Model Protocol, the agreement is referred to as an additional protocol (AP), or an additional protocol agreement.

In the text, the International Atomic Energy Agency is most commonly referred to as the IAEA, but the term “Agency” is also used. Its members are referred to as Member States.

In its official documents, the IAEA follows the orthography for English used in the United Kingdom. Hence, some words in quotations from these documents have spellings that may seem unusual to American readers.

In addition, there are many terms or phrases that are terms of art in the IAEA safeguards world that have specialized meanings, for example, “nuclear material,” “facility,” “site,” and “high-enriched uranium.” Such terms and their definitions can be found in the “IAEA Safeguards Glossary,” the most recent version of which was published in 2001 as No. 3 in its International Nuclear Verification Series.⁴ We have made an effort to use these terms as they are defined by the IAEA wherever this is appropriate, for example, in the context of safeguards implementation or in discussions of the safeguards system.

Although it is often seen otherwise, the text uses the form “non-proliferation” when used in a general sense, and the form “Non-Proliferation” when used in the name of the NPT since its formal name is Treaty on the Non-Proliferation of Nuclear Weapons. Again, although often seen otherwise, the book uses the spelling in the NPT to describe the two categories of States that it formally creates, non-nuclear-weapon States and nuclear-weapon States.

Finally, any textbook is a compromise between breadth and depth of coverage. For readers seeking more depth, we refer you to the list of topically arranged Selected Additional Readings at the very end of this volume.

⁴ The text may be found at https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf

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THE SAFEGUARDS SYSTEM OF THE INTERNATIONAL ATOMIC ENERGY AGENCY

As of October 2017, the United Nations listed one-hundred and ninety countries as parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).⁵ Only five countries stand outside the NPT: the Democratic People's Republic of Korea (DPRK), India, Israel, Pakistan, and South Sudan. Of the 190, the NPT recognizes five, China, France, Russia, the United Kingdom, and the United States, as nuclear-weapon States. The other 186 countries are non-nuclear-weapon States. According to the Treaty, these 186 countries are obligated to accept the application safeguards by the IAEA on all nuclear material in all peaceful nuclear activities, i.e., comprehensive safeguards. Under the NPT, IAEA safeguards have "the exclusive purpose of verification of the fulfillment of [the non-nuclear-weapon States'] 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."

The NPT safeguards system plays a key role in international efforts to stem the proliferation of nuclear weapons. It is a complex verification system built on reporting by States of their nuclear material accounts and by on-site inspection by the IAEA. The goal of the system is to enable the IAEA to verify these accounts. The IAEA is satisfied when it can verify that the accounts are "correct" – everything has been reported correctly – and "complete" – everything has been reported – and, thus, the accounts represent the facts on the ground: namely, "all present and accounted for." The IAEA's ability to do this with high confidence and to detect discrepancies in a timely manner is intended to deter States from diverting nuclear material and to sound the alarm promptly if they are not deterred.

An intrinsic tension exists between the pursuit of nuclear energy and the effort to prevent the illicit development of nuclear weapons – after all, certain elements of the nuclear fuel cycle and the nuclear material used to produce energy can also be used to produce nuclear weapons. For example, the enriched uranium that fuels most power reactors is produced in facilities that have the capability to produce uranium at the enrichment levels suitable for nuclear weapons. Reprocessing plants produce plutonium by extracting it from used reactor fuel assemblies, which in some cases is well-suited for nuclear weapons. Consequently, uranium enrichment plants and reprocessing plants are regarded as sensitive facilities.

The tension is inescapable because of two conflicting objectives. The first is the need felt by some States to retain nuclear weapons as elements of their national security; the second is the development of nuclear power reactors to take advantage of the enormous energy obtained by splitting the atom for peaceful purposes.

Tension also arises between non-nuclear-weapon States and nuclear-weapon States, the former believing, for one, that the nuclear-weapon States should move more quickly toward disarmament as required by Article VI of the NPT and, as well, asserting that nuclear cooperation has been insufficient and too constrained. In contrast, the nuclear-weapon States point out their

⁵ This list is available at <http://disarmament.un.org/treaties/t/npt>

considerable accomplishments in reducing the number of nuclear weapons and argue that nuclear cooperation has been ample, even though sensitive technologies need special controls.

In response to the perception that the NPT nuclear-weapon States were failing to fulfil their disarmament obligations, a number of States negotiated and adopted under the auspices of the United Nations General Assembly “The Treaty on the Prohibition of Nuclear Weapons.” The Treaty has some overlap with the NPT but contains additional obligations, the most salient of which is the prohibition of possession of nuclear weapons or other nuclear explosive devices by all States Parties without exception. The proponents of such a treaty used the General Assembly because it takes decisions by majority vote.

All States possessing nuclear weapons, and many of their allies, refused to participate in the negotiations. The Treaty was adopted in the General Assembly on 7 July 2017, by a vote of 68-22 with 13 abstentions. According to the Nuclear Threat Initiative, a non-government organization, “Proponents of the Treaty have hailed it as an important step in delegitimizing nuclear weapons and reinforcing the norms against their use, while opponents have criticized the Treaty as political grandstanding which could undermine the NPT.”⁶

This nuclear conundrum – the potential for using the enormous energy released from the atom both as a weapon of war and as a tool for obtaining seemingly unbounded energy for powering industry and development – was recognized even before the dawn of the nuclear age. Leo Szilard realized that a nuclear chain reaction could release this energy and patented a nuclear weapon in 1934, even before nuclear fission, the underlying physical process to do this, had been discovered. Albert Einstein wrote to President Franklin D. Roosevelt in 1939 to warn him of the dangers of the possible development of nuclear weapons by Germany, but he also included in his letter reference to the potential benefits of peaceful uses of nuclear energy.

IAEA safeguards endeavor to make this conundrum manageable. On the one hand, they deter diversion of nuclear material from peaceful programs to nuclear-weapon programs and can provide warning if a diversion or significant safeguards violation is detected. On the other hand, a conclusion by the IAEA that nuclear programs are devoted to peaceful purposes can provide assurances that reduce regional and international tension. Comprehensive IAEA safeguards allow States to engage in nuclear cooperation with confidence that it will be used only for peaceful purposes. Thus, the IAEA safeguards system is intended to encourage peaceful uses and at the same time inhibit nuclear proliferation.

This book focuses on NPT safeguards, which constitute a central element of the nuclear non-proliferation regime. But safeguards are only one part of the nuclear non-proliferation regime. It has many elements and many ways to deter or inhibit the proliferation of nuclear weapons. The book places the IAEA safeguards system in the context of that wider regime. The book should enable the reader to become familiar with these other, ongoing activities. References are included to provide a path toward exploring elements of the broader non-proliferation regime that are beyond the scope of this book.

⁶ Nuclear Threat Initiative, <http://www.nti.org/learn/treaties-and-regimes/treaty-on-the-prohibition-of-nuclear-weapons/> (Accessed 3 March 2018.)

The book also places the present application of IAEA safeguards in the context of their historical development. An understanding of where the IAEA came from and the historical forces that shaped its development from the 1940s onwards will enable readers to understand their role today and how to think about areas where safeguards can be improved. Many of the tensions that exist today have longstanding histories, especially the tension between non-proliferation and peaceful nuclear cooperation, between nuclear-weapon States and non-nuclear-weapon States and between developed and developing countries.

In addition, safeguards are not applied in a vacuum. They must respond to events in the “real world.” For example, events in the early 1990s in Iraq, the DPRK, and South Africa played important roles in forcing the IAEA safeguards system to change how the role of safeguards is conceptualized and what is its appropriate focus. The ability of the IAEA to resolve future instances of non-compliance with safeguards agreements will speak to the strength of the IAEA and of the nuclear non-proliferation regime.

PART I

THE FOUNDATIONS OF THE INTERNATIONAL SAFEGUARDS SYSTEM

CHAPTER 1. THE NUCLEAR NON-PROLIFERATION REGIME

1.1 Background

The most important, and the most difficult, step in manufacturing a nuclear weapon is to acquire the necessary nuclear-weapon-usable nuclear material. The possible materials are called *fissile materials*⁷ and are characterized by their ability to sustain a nuclear *chain reaction*, which is the mechanism by which the nuclear explosion's energy is generated. The two fissile materials used in nuclear weapons currently deployed⁸ are *high-enriched uranium (HEU)* and *plutonium*. The isotope of uranium needed for a nuclear explosive device is uranium-235 (U-235). Because in nature only seven uranium atoms in 1,000 are U-235 - the rest being uranium-238 (U-238) – in order to obtain weapon-grade uranium, it is necessary to concentrate this isotope to a very high level through the process of enrichment. (The bomb detonated over Hiroshima used HEU with a concentration of about 80% U-235.) Plutonium is not found in nature; it is produced in reactors from the major uranium isotope U-238 by neutron capture and subsequent beta decay. It is then chemically separated from the uranium and radioactive fission products through reprocessing. The desired isotope for weapons is plutonium-239 (Pu-239).

High enriched uranium is defined as uranium with a percentage of 20% or more of the isotope U-235. Weapon-grade uranium is considered to be about 90% U-235.

Appendix A describes why HEU and Pu-239 have the properties needed to manufacture a nuclear explosive device and how they can be used in weapons. For our purposes, we assume that if the production and use of these fissile materials can be controlled, the risk of proliferation will be reduced. A corollary of this is that the nuclear facilities that can produce HEU (enrichment plants)

⁷ Fissile material, according to the U.S. Nuclear Regulatory Commission, means a nuclide that is capable of undergoing fission after capturing low-energy thermal (slow) neutrons. Although sometimes used as a synonym for fissionable material, this term has acquired its more restrictive interpretation with the limitation that the nuclide must be fissionable by *thermal neutrons*. With that interpretation, the three primary fissile materials are uranium-233, uranium-235, and plutonium-239. This definition excludes natural uranium and depleted uranium that have not been irradiated, or have only been irradiated in thermal reactors.

⁸ The text describes only weapons based on nuclear fission. Another class of weapons, known as thermonuclear weapons - often called “hydrogen bombs” – are extremely important. But they are far more technically sophisticated and difficult to make than fission weapons, and they have always been second or third generation designs that incorporate fission-based explosives as their trigger. Therefore, from the point of view of non-proliferation and safeguards, fission weapons are far more important.

or separated plutonium (reprocessing plants) are sensitive, and control of them would also reduce the risk of nuclear proliferation. As we will see below, many aspects of the nuclear non-proliferation regime have been directed towards this end. Of course, controls over nuclear material or technology are not the only means to reduce risks. Political measures are also important.

1.2 Nuclear Proliferation – A Status Report

Most developed nation-States have the means to acquire nuclear weapons, and more than a few have considered doing so. For example, Sweden⁹ and Switzerland¹⁰ explored the acquisition of nuclear weapons, although they have long since abandoned any such aspiration.¹¹ In addition, the globalization of technology has meant that one of the key barriers to proliferation – access to technology – has been lowered substantially. Nuclear weapons are within the reach of States whose technical and industrial infrastructures are underdeveloped. The DPRK, one of the poorest and least developed countries in the world, first tested a nuclear weapon test in 2006 and has conducted a series of tests since then. Figure 1 shows how States' interest in nuclear weapons has changed over time.¹²

In 1960, President John F. Kennedy worried that, “There are indications because of new inventions, that 10, 15, or 20 nations will have a nuclear capacity, including Red China, by the end of the Presidential office in 1964. This is extremely serious . . . I think the fate not only of our own civilization, but I think the fate of world and the future of the human race is involved in preventing a nuclear war.”¹³

Despite the widespread availability of technology unknown in the 1960s, the number of States today that have nuclear weapons is smaller than President Kennedy thought likely. Under the NPT, five States may retain nuclear weapons. China tested a nuclear weapon in 1964; France in 1960; Russia (as the Union of Soviet Socialist Republics) in 1949; the United Kingdom in 1952; and the United States in 1945.

With respect to non-parties to the NPT, India and Pakistan each conducted a series of nuclear tests in 1998.¹⁴ In connection with these tests, India stated that the tests, “have established that India

⁹ See for example, <http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB155/prolif-12.pdf>
National Intelligence Estimate 4-66, June 1966, “Likelihood of Further Nuclear Weapon Proliferation.” This is part of the National Security Archive hosted by The George Washington University at <http://www.gwu.edu/~nsarchiv/index.html>

¹⁰ Stüssi-Lauterburg, Jürg. 1997. Historischer Abriss zur Frage einer Schweizer Nuklearbewaffnung. In *Travaux & recherches/Beiträge zur Forschung* 1997, édité. Bern: Schweizerische Vereinigung für Militärgeschichte und Militärwissenschaft/Association suisse d'histoire et de sciences militaire.

¹¹ See Congressional Research Service Report to Congress, Nuclear, Biological, and Chemical Weapons and Missiles: Status and Trends, Updated February 20, 2008, Paul K. Kerr <http://www.fas.org/sgp/crs/nuke/RL30699.pdf>

¹² The categorizations in the figure, but not the numerical values, follow the ones cited by J. Li et. al., Progress in Nuclear Energy 52 (2010) 789-808. “Explore” indicates consideration of nuclear weapons and some exploratory work; and “pursue” means start of a nuclear weapon development program (no acquisition). The terms “acquire” and “test” are self-explanatory. Since nuclear-weapon programs are often pursued secretly, the numbers in the figure are not authoritative and may not be correct in all instances.

¹³ Third Nixon-Kennedy Presidential Debate, October 13, 1960. From <http://carnegieendowment.org/2003/11/17/jfk-on-nuclear-weapons-and-non-proliferation/3zcu> (July 17, 2012).

¹⁴ According to the United Nations Daily Highlights on 98-05-29 and 98-05-14: “The United Nations Security Council on Thursday strongly deplored the three underground nuclear tests conducted by India on 11 May and the two other tests on 13 May, despite overwhelming international concern and protests;” and “The Security Council on

has a proven capability for a weaponized nuclear programme. They also provide a valuable database which is useful in the design of nuclear weapons of different yields for different applications and for different delivery systems;”¹⁵ and Pakistan affirmed that it had “successfully conducted five nuclear tests.”¹⁶

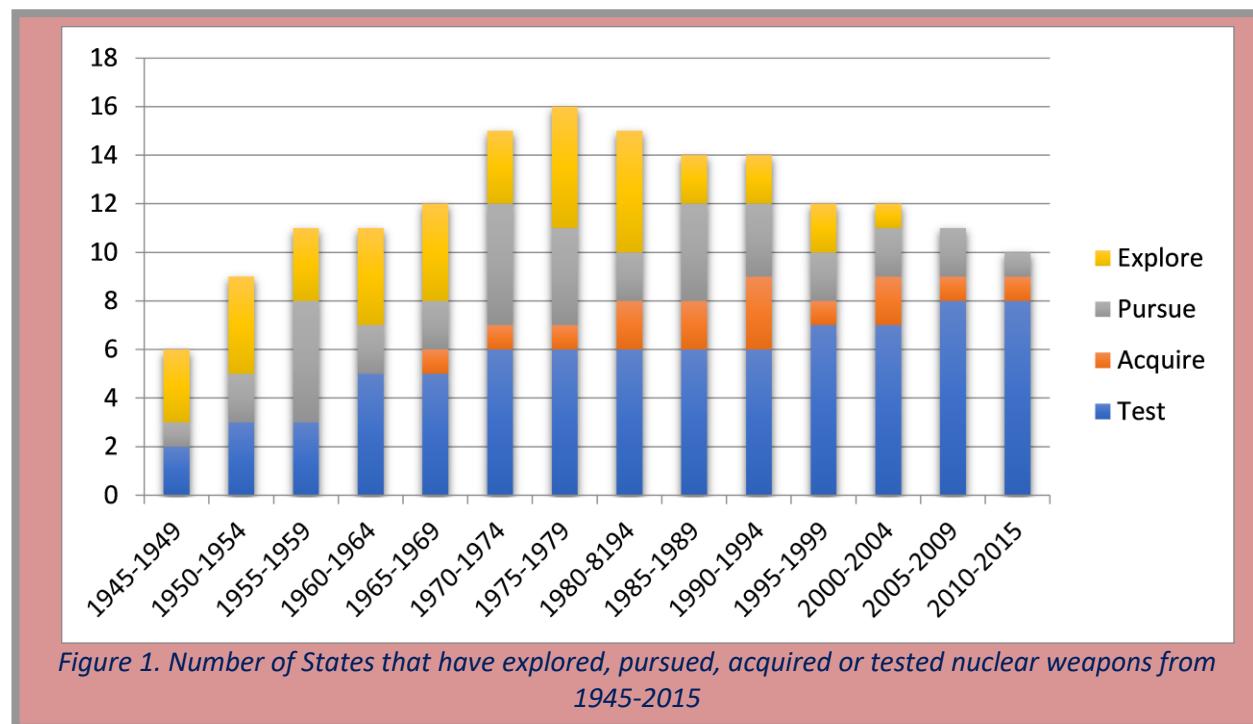


Figure 1. Number of States that have explored, pursued, acquired or tested nuclear weapons from 1945-2015

Despite the fact that the DPRK became a party to the NPT in 1985, as noted above, it has conducted a series of nuclear weapon tests since 2006. It considers them to be an important element of its national security. For example, the official news agency of North Korea stated that, “The nuclear test [on October 9, 2006] was conducted with indigenous wisdom and technology 100 percent. It marks a historic event as it greatly encouraged and pleased the KPA and people that have wished to have powerful self-reliant defense capability.”¹⁷

One State, South Africa, manufactured six nuclear weapons and made the decision to dispose of them. It dismantled them, eliminated its nuclear-weapon program, and joined the NPT as a non-nuclear-weapon State.¹⁸ When the Soviet Union dissolved in 1991, Russia and three of the other

Friday strongly deplored the underground nuclear tests conducted by Pakistan on 28 May despite international concern and calls for restraint.“ Respectively at,

<http://www.hri.org/news/world/undh/1998/98-05-14.undh.html>. (April 16, 2013).

<http://www.hri.org/news/world/undh/1998/98-05-29.undh.html>. (April 16, 2013)

¹⁵ Official Press Statements Issued by Ministry of External Affairs, New Delhi May 11, 1998.

<http://www.indiagov.org/news/menu.htm>,

<http://www.meadev.gov.in/news/official/19980511/official.htm>. (<http://nuclearweaponarchive.org/India/Indianofficial.txt>, (April 16, 2013)

¹⁶ Text of Prime Minister Muhammad Nawaz Sharif Statement at a Press Conference on Pakistan Nuclear Tests, Islamabad, May 29, 1998. <http://nuclearweaponarchive.org/Pakistan/SharifAnnounce.txt>. (April 16, 2013)

¹⁷ DPRK Successfully Conducts Underground Nuclear Test, Pyongyang, October 9 (KCNA).

<http://www.kcna.co.jp/index-e.htm>. (April 16, 2009)

¹⁸ See the Nuclear Threat Institute Nuclear Profile of South Africa at

States that emerged (Belarus, Kazakhstan, and Ukraine) were “born nuclear,” that is, they had nuclear weapons on their territory. Belarus, Kazakhstan, and Ukraine each returned these weapons to Russia and joined the NPT as non-nuclear-weapon States. In 2004, Libya voluntarily abandoned a nuclear-weapon program that it was pursuing in violation of its NPT safeguards obligations.¹⁹

Other States with nuclear-weapon ambitions have had them thwarted. In accordance with a United Nations Security Council resolution after the first Gulf War in 1991, the elements of Iraq’s nuclear-weapon program were “removed, destroyed, or rendered harmless.”²⁰ In 2007, Israel destroyed a reactor in Syria from the air. Senior United States officials reported that this reactor, which was being built secretly with assistance from the DPRK, would have been capable of producing plutonium for nuclear weapons.²¹ In 2011, it was reported that an effort was made to stop or restrain the Iranian uranium enrichment program using cyber warfare.²²

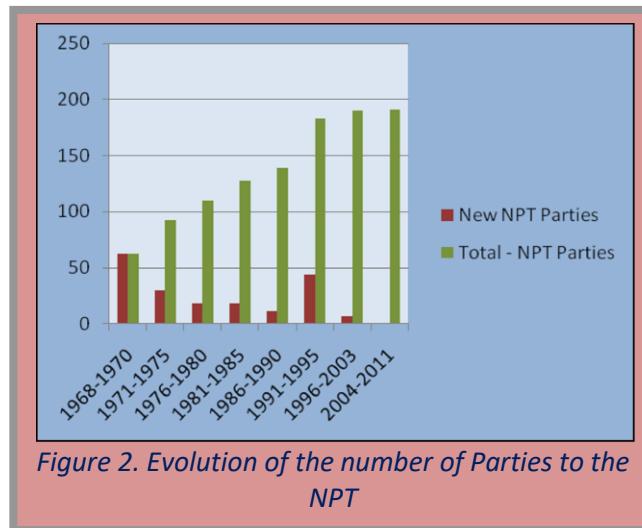


Figure 2. Evolution of the number of Parties to the NPT

Key questions about nuclear proliferation are: Why have so few States proliferated when so many have the capability to do so? What has reduced the risk of proliferation or turned it back? Figure 2 shows how the number of NPT parties has grown since 1970, when the Treaty entered into force. During the four years preceding the 1995 NPT Review and Extension Conference, the number of new parties increased significantly.

Is it because States have met their security needs in other ways? Because making a nuclear weapon is too costly or technical resources are lacking? Because the States lack a domestic constituency that sees nuclear-weapon acquisition as valuable? Or is it because they want to be part of a

http://www.nt1.org/e_research/profiles/SAfrica/Nuclear/index.html (as of April 29, 2011). See also, South Africa’s Nuclear Weapon Program: Lessons for U.S. Nonproliferation Policy, Frank V. Pabian, The Nonproliferation Review/Fall 1995 at <http://cns.miis.edu/npr/pdfs/31pabian.pdf>.

¹⁹ See IAEA document GOV/2004/12, Implementation of the NPT Safeguards Agreement of the Socialist People’s Libyan Arab Jamahiriya, <https://www.iaea.org/Publications/Documents/Board/2004/gov2004-12.pdf> (as of April 28, 2011).

²⁰ See United Nations Security Council Resolution 687 (1991). See <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/596/23/IMG/NR059623.pdf?OpenElement> (as of April 27, 2011).

²¹ Background Briefing with Senior U.S. Officials on Syria’s Covert Nuclear Reactor and North Korea’s Involvement, April 24, 2008 http://dn1.gov/interviews/20080424_interview.pdf (as of April 27, 2011).

²² See for example one of many news reports: Christian Science Monitor at <http://www.csmonitor.com/USA/2010/0921/Stuxnet-malware-is-weapon-out-to-destroy-Iran-s-Bushehr-nuclear-plant> (May 13, 2011).

community of States that sees the acquisition of nuclear weapons as being outside the norm? Of course, there is no one answer.^{23,24,25}

The answers influence views about what tools to use to reduce the risk of proliferation. Governments' decision makers are heterogeneous and often do not have a single view about what are the key drivers of proliferation or how best to reduce the risk. As a result, many different tools have been developed and coexist with one another, and the answer might differ from State to State, with the result that in specific instances, more than one of the tools available might be emphasized.

1.3 Tools Available to Reduce the Prospect of Proliferation

Some of the tools to reduce the prospect of proliferation focus on cost, while others focus on supply. One type increases the cost of proliferation, both political and financial. The other makes it harder to succeed by addressing the availability of the necessary knowledge, equipment, and materials. Still others reduce incentives to proliferate or increase incentives not to proliferate. These measures are often linked – what reduces availability of necessary technology might increase the financial cost and reduce incentives. The following is a brief review of some of the tools that have been employed.

1.3.1 Addressing capabilities

Secrecy and denial

The U.S. Atomic Energy Act of 1946 created a system to control information related to nuclear weapons. It recognized atomic energy information as being special and unique and placed it in a new and distinct category, “Restricted Data.” Except for declassified information, it covered all data concerning the manufacture or utilization of atomic weapons, the production of fissionable

²³ Why Do states Build Nuclear Weapons?: Three Models in Search of a Bomb, Scott D. Sagan, *International Security*, Vol. 21, No. 3. (Winter, 1996-1997), pp. 54-86. Stable URL:

<http://links.jstor.org/sici?&sici=01622889%28199624%2F199724%2921%3A3%3C54%3AWDSBNW%3E2.0.CO%3B2-1> Dr. Sagan has addressed the same issue in a more recent study, The Causes of Nuclear Weapons Proliferation, (Annu. Rev. Polit. Sci. 2011, 14:225-44), see

http://iis-db.stanford.edu/pubs/23205/Sagan_Causes of Nuclear Weapons Proliferation.pdf

Also of interest in this regard are: Kurt M. Campbell, Robert Einhorn, and Mitchell Reiss, editors. The Nuclear Tipping Point: Why States Reconsider their Nuclear Choices. Brookings Institution, 2004; Wyn Q. Bowen. Libya and Nuclear Proliferation: Stepping Back from the Brink. Adelphi Paper 380. International Institute for Strategic Studies, 2006; George Perkovich. India's Nuclear Bomb: The Impact on Global Proliferation. University of California Berkeley, 2001.

²⁴ Many authors have attempted to model nuclear proliferation decisions quantitatively with a view toward identifying key variables that would be indicative of proliferating behaviors. See for example, “Model-based calculations of the probability of a country’s nuclear proliferation decisions,” Jun Li, Man-Sung Yim, David N. McNeilis in *Progress in Nuclear Energy* 52 (2010) 789-808 at

http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V3X-50NH07W-1-1R&_cdi=5742&_user=2422869&_pii=S0149197010001034&_origin=search&_zone=rslt_list_item&_coverDate=11%2F30%2F2010&_sk=999479991&wchp=dGLzVlb-zSkz&md5=8df5693caf9828faf117c343a340b7fb&ie=/sdarticle.pdf (as of April 28, 2011).

²⁵ <http://belfercenter.ksg.harvard.edu/files/wmdcno41.pdf> “Learning from Past Success: The NPT and the Future of Non-proliferation,” Jim Walsh, 2010. Paper commissioned by the Weapons of Mass Destruction Commission.

material, or the use of fissionable material in the production of power.²⁶ Secrecy was intended to prevent other countries from proliferating, especially the Soviet Union. It failed to do so because the Soviet Union had pierced the veil of U.S. secrecy during the war and had many capable scientists and engineers who could exploit the information. In addition, what had been the greatest secret, that one could make a weapon, was exposed at Hiroshima.

The term "restricted data" means all data concerning (1) design, manufacture, or utilization of atomic weapons; (2) the production of special nuclear material; or (3) the use of special nuclear material in the production of energy, but shall not include data declassified or removed from the Restricted Data category pursuant to section 142.

In general, secrecy and denial are waning assets. One reason is that they impede nuclear cooperation. The United States, for example, declassified a considerable amount of information about reactors and reprocessing in 1954 in order to facilitate meaningful nuclear cooperation in support of nuclear energy programs. In addition, information or technology that is not readily available at one time may become readily available later as States industrialize, the pace of technology development quickens, and information becomes global.

Nonetheless, secrecy remains a key part of U.S. nuclear non-proliferation efforts. Almost all information about nuclear weapons remains classified, as do essential elements of key technologies such as uranium enrichment.

Export controls

If nuclear cooperation is a goal, then use of the tools of secrecy and denial must be curtailed. Export controls offer the opportunity to cooperate selectively with partners where the risk of proliferation is perceived to be low and to deny export to countries where the risk is perceived to be too high. Even when cooperation is pursued, criteria for supply may be used to reduce risks even further. The United States insists that specialized nuclear cooperation be allowed only under Agreements for Cooperation.²⁷ Under such agreements, a recipient country agrees, for example, not to use material supplied by the United States for any nuclear explosive device or for any other military purpose; to accept international verification; and to obtain the approval of the United States before it reprocesses, enriches, or transfers nuclear material subject to the agreement.

Thus, proliferation might violate an IAEA safeguards agreement or the NPT and an agreement with the United States (or another State with similar agreements). A State considering such a violation would need to consider what actions the United States or other States might take in addition to penalties and sanctions that might be invoked by the United Nations Security Council.

²⁶ See Restricted Data Declassification Decisions, 1946 to the Present, (RDD-7), U.S. Department of Energy, Office of Declassification (January 1, 2001). Found at <http://www.fas.org/sgp/othergov/doe/rdd-7.html>

(As of April 27, 2011). This reference contains both useful historical information as well as a description of the declassification decisions made through 2001. See also, Office of Nuclear and National Security Information, History of Classification and Declassification, July 22, 1996. <https://www.hsls.org/?view&did=447388>

²⁷ These are sometimes called 123 agreements because they are negotiated in accordance with Section 123 of the Atomic Energy Act of 1954, as amended. Text of the Atomic Energy Act as of January 2011 may be found at <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/v1/sr0980v1.pdf> (May 10, 2011).

The concept of export controls is built into the NPT. It stipulates that nuclear material and especially designed equipment and material can only be exported when IAEA safeguards are applied in the recipient State. In order for export controls to be effective, all relevant suppliers need to apply the same ground rules. To allow buyers to shop for the weakest non-proliferation condition would undermine the control system. In order to achieve common non-proliferation objectives and create a level playing field, likeminded States have joined together to create multilateral organizations. The first of these was an NPT exporters' committee, which convened first in 1971 to create export guidelines that would satisfy NPT requirements. Later, the Nuclear Suppliers Group (NSG) was created with a broader mandate. It covered topics not addressed in the NPT, physical protection for example, and it included France, a non-NPT party.²⁸

To evade these controls in order to pursue nuclear-weapon programs, some States began to procure items clandestinely and also to use "dual-use" items and technology. As a result, in the 1990s, multilateral export control arrangements were extended by the NSG to dual-use items and technology, including items related to nuclear weapons and to testing them. Because of their sensitivity, special controls have been placed on enrichment and reprocessing technologies and on materials and equipment related to them.²⁹

Unfortunately, illicit trafficking in nuclear equipment has undermined the effectiveness of export controls; some States have resorted to illegal and clandestine procurement practices; and some States have become suppliers that are not scrupulous about non-proliferation requirements.³⁰

Multinational facilities

If proliferation decisions depend on the availability of sensitive technologies, especially enrichment and reprocessing facilities, then nuclear fuel cycles that depend on these technologies have a technical risk. A number of means have been proposed for ensuring that nuclear material is available for peaceful purposes without increasing the number of countries that have national enrichment or reprocessing facilities. These include: continued reliance on a robust market that depends on present suppliers; a "fuel bank" that backs up this market by providing an assured supply of nuclear fuel in the event of a supply disruption not based on proliferation (see Section 3.3 below); and the development of multinational facilities where the technology holder does not

²⁸ The NPT Exporters Committee was founded in 1971 and is known as the Zangger Committee after its first chairman, Claude Zangger of Switzerland. (See www.zanggercommittee.org.) For information about the Nuclear Suppliers Group, see www.nuclearsuppliersgroup.org. Also, "The Nuclear Suppliers Group: Its Origins, Role and Activities" in IAEA Document INFCIRC/539/Rev.4, November, 2009, at:

<http://www.iaea.org/Publications/Documents/Infocircs/2009/infocirc539r4.pdf>. The Guidelines may be found at [nuclearsuppliersgroup.org](http://www.nuclearsuppliersgroup.org). They are also published by the IAEA at the request of the NSG and appear in a series Information Circulars that revise or modify INFCIRC/254. They consist of two parts. Part 1 covers nuclear transfers of specialized equipment and materials, while Part 2 covers dual-use items and technology.

²⁹ See McGoldrick, Fred, with contributions from Matthew Bunn, Martin Malin, and William H. Tobey, Limiting Transfers of Enrichment and Reprocessing Technology: Issues, Constraints, Options, Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard University Kennedy School, (May 2011).

³⁰ See, for example, Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies, David Albright, Free Press, March 2010; Unraveling the A. Q. Khan and Future Proliferation Networks, David Albright and Corey Hinderstein, *The Washington Quarterly* • 28:2 pp. 111–128, (Spring 2005). http://www.twq.com/05spring/docs/05spring_albright.pdf (as of April 29, 2011); and Shopping for Bombs: Nuclear Proliferation, Global Insecurity, and the Rise and Fall of the A.Q. Khan Network, Gordon Corera, Oxford University Press (2006).

share the technology with partners.³¹ In principle, these steps can enhance supply without spreading technology.

Counter-proliferation

Steps can also be taken that diminish proliferation capacity. Intelligence collection plays a key role in these activities. One example is the Proliferation Security Initiative, which is a “global effort that aims to stop trafficking of weapons of mass destruction (WMD), their delivery systems, and related materials to and from States and non-State actors of proliferation concern.”³²

1.3.2 Addressing incentives

Some means of reducing the risk of proliferation do not rely at all on limiting either a State’s technical capabilities or the availability of the ingredients for making a bomb.

Security alliances

If States’ national security interests are satisfied without possession of nuclear weapons, the incentive to acquire them is absent. One means of doing this is through security alliances. For example, the North Atlantic Treaty Organization (NATO) and the U.S. security alliance with Japan provide an environment in which U.S. partners have chosen not to pursue nuclear-weapon acquisition. Security assurances can also be provided to reduce incentives to proliferate even where an alliance is absent. Negative security assurances are guarantees from nuclear-weapon States that they will not use nuclear weapons against non-nuclear-weapon States parties to the NPT. (See “Security Assurances” in Section 4.3.3 below.)

Sanctions

Sanctions – diplomatic, economic, or military – may be employed to deter proliferation by threatening to impose penalties on States. The goal is to deter non-compliance with nuclear non-proliferation norms or obligations. In the area of nuclear non-proliferation, sanctions are typically associated with violations of nuclear non-proliferation agreements, both bilateral agreements and international treaties. For example, U.S. nuclear Agreements for Cooperation contain provisions that cancel such cooperation in the event that a partner violates a safeguards agreement or tests a nuclear weapon. Sanctions may also be imposed by the United Nations Security Council.³³ They

³¹ See for example, INFCIRC/640, 22 February 2005, “Multilateral Approaches to the Nuclear Fuel Cycle,” Expert Group Report submitted to the Director General of the International Atomic Energy Agency. <http://www.iaea.org/Publications/Documents/Infocircs/2005/infocirc640.pdf>

³² See <http://www.state.gov/t/isn/c10390.htm> (May 11, 2010).

³³ For an example, see S/RES/1929(2010) by which the United Nations Security Council imposed a broad array of economic and other sanctions on Iran in connection with its violation of its IAEA safeguards agreement, its continuing failure to comply with earlier United Nations Security Council actions, and continuing concerns about a possible military dimension to Iran’s nuclear program. <http://www.un.org/News/Press/docs/2010/sc9948.doc.htm>

(as of 2011-05-02). In 2015, these sanctions were lifted as a result of Iran’s agreement to a nuclear non-proliferation Arrangement called the Joint Comprehensive Program of Action. This is described in detail in Chapter 9.

can range from travel restrictions on individuals to economic embargoes. The Security Council may also authorize the use of blockades or other use of armed force.

Safeguards

The challenge of pursuing peaceful uses of nuclear energy and, at the same time, reducing the likelihood of proliferation was apparent as early as 1946. The U.S. drafted Acheson-Lilienthal Report concluded that the fuel cycle should be internationalized, and an international inspection system put in place. The report stated, “It must be a plan that provides unambiguous and reliable danger signals if a nation takes steps that do or may indicate the beginning of atomic warfare. Those danger signals must flash early enough to leave time adequate to permit other nations – alone or in concert – to take appropriate action.”³⁴

While internationalization of the fuel cycle has not taken place, the concept of an inspection system with early warning of diversion became a part of the IAEA safeguards system. It was incorporated into and made explicit in NPT safeguards agreements. This comprehensive safeguards system is discussed extensively in later chapters. There are also two regional safeguards systems in place: one in Europe that covers the States of the European Union, and one in Latin America that covers Argentina and Brazil. The latter reflects a bilateral arrangement between Argentina and Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC), which provides for reciprocal inspections. It was concluded in 1991 to build mutual confidence between Argentina and Brazil.

IAEA safeguards were also applied prior to entry into force of the NPT. These safeguards were applied to individual facilities, nuclear material and other items that were specified in the agreements. They also covered any nuclear material produced through the use of these items. These safeguards agreements were concluded in connection with exports where the supplier required safeguards as a condition of supply.³⁵

Nuclear-Weapon-Free Zone Treaties

Although the NPT is the primary international nuclear non-proliferation agreement, regional or multinational agreements can also enhance security and reduce the risk of proliferation. Nuclear-weapon-free zones (NWFZs) are important examples of regional frameworks for this purpose. Such treaties are in force in Africa, Central Asia, Latin America and the Caribbean, the South

³⁴ http://www.fissilematerials.org/ipfm/site_down/ach46.pdf. “A Report on the International Control of Atomic Energy,” The Acheson-Lilienthal Report on the International Control of Atomic Energy, Washington, D.C., (March 16, 1946).

³⁵ The safeguards agreements concluded before the NPT entered into force are often called INCIRC/26 or INFIRC/66 agreements after the Information Circulars that spell out the nature of the required safeguards arrangements.

Pacific, and Southeast Asia.³⁶ Mongolia has declared itself to be a NWFZ, but some States do not formally recognize it as such because it relates to only one State.³⁷

Several other treaties also establish NWFZs: in Antarctica through the 1961 Antarctic Treaty; in outer space through the 1967 Outer Space Treaty; and on the seabed and ocean floor through the 1972 Seabed Treaty.

³⁶ A useful reference to arms control and non-proliferation treaties, including nuclear-weapon-free zones, is, A Catalog of Treaties and Agreements, Amy F. Woolf, Mary Beth Nikitin, Congressional Research Service, (September 20, 2011). <https://www.hslc.org/?view&did=689048> (March 15, 2012). A map of the geographic coverage of nuclear-weapon-free zones is at the UN website <https://www.un.org/disarmament/wmd/nuclear/nwfz/>, and the texts of the treaties at <http://disarmament.un.org/treaties/>. (April 3, 2018).

³⁷ NWFZs have been addressed several times in the United Nations General Assembly and in the United Nations Commission on Disarmament, most recently in 1999. The 1999 UNCD report agreed on a number of principles and guidelines for NWFZs. The most relevant with respect to the question of one-state zones states that, “Nuclear-weapon-free zones should be established on the basis of arrangements freely arrived at by the states in the region concerned. The initiative to establish such a zone should emanate exclusively from states within the region and be pursued by all the states in that region.” Report of the Disarmament Commission, General Assembly, Official Records, Fifty-fourth session, Supplement No. 42 (A/54/42) 1999. [http://www.un.org/ga/search/view_doc.asp?symbol=A/54/42\(SUPP\)](http://www.un.org/ga/search/view_doc.asp?symbol=A/54/42(SUPP)). (July 12, 2012).

CHAPTER 2. THE NUCLEAR CONUNDRUM

The enormity of the energy that can be released from the atom – more precisely, from the atom’s nucleus – was recognized immediately when nuclear fission was first discovered in 1938. In the context of looming war, the initial concerns were military, and the first direct evidence of that enormity was witnessed in the destruction by the United States of two cities in Japan in 1945 at the end of World War II.

It was clear that harnessing the same source of energy held promise for peaceful purposes, and this duality created a conundrum that we have struggled with since: how to control the most destructive weapon every devised by humankind and yet capitalize on the immense promise of nuclear energy for peaceful purposes.

The development – and use – of nuclear weapons preceded the large-scale peaceful uses of nuclear energy by more than a decade. While some observers understood the nature of the conundrum when nuclear weapons were newly at hand and peaceful uses were still a vision, effective action by the international community did not take place until peaceful uses were becoming a reality.

Chapter 2 traces the historical development of the international safeguards system and the early development of nuclear cooperation. The focus is on nuclear cooperation arrangements initiated by the United States, the first country that required safeguards as a condition of supply. In many ways, these U.S. arrangements set the standards for the conditions of supply to be required in connection with other bilateral or multilateral nuclear cooperation arrangements.

2.1 Nuclear Control versus Nuclear Cooperation

2.1.1 Background

Trinity, the first test of a nuclear explosive device, took place on July 16, 1945 near Alamogordo, New Mexico. It was the culmination of almost three years of secret, intensely concentrated work on building a nuclear weapon. The Manhattan Project, as the effort was called, followed a number of significant initiatives, including a letter to President Roosevelt in August 1939, which was signed by Albert Einstein, and the British MAUD report of July 1941, which determined that an atomic bomb was feasible.

Einstein’s letter, drafted by Leo Szilard, a Hungarian expatriate, explained that it “had been made probable” that it “may be possible to set up a chain reaction in a large mass of uranium by which vast amounts of power and large quantities of new radium-like elements would be generated.”³⁸ It was conceivable, but not certain, the letter noted, that “extremely powerful” bombs of a new type could be constructed. According to the letter, such a weapon would probably be so heavy

³⁸ As noted above, Szilard had conceived of the idea of a nuclear chain reaction and patented it in 1934 before the discovery of fission demonstrated how to accomplish this. He understood that a sustained chain reaction would release enormous energy. Later, he and Enrico Fermi received a patent for a nuclear reactor. See Richard Rhodes, *The Making of the Atomic Bomb*, pp. 292-293

that it was unlikely it could be delivered by aircraft.³⁹ Because of the crisis in Europe as World War II began, the letter, signed in August, was not delivered to Roosevelt until October 1939.⁴⁰

The MAUD Report concluded that uranium isotope separation was possible, especially using gaseous diffusion, that it could produce the necessary HEU, and that construction of an atomic bomb was possible.⁴¹ The Report noted that Germany could also be working on an atomic bomb and recommended that a cooperative program be established with the United States. The resulting program, the Manhattan Project, was set up the following year and located in the United States.

Brigadier General Leslie Groves of the U.S. Army Corps of Engineers headed the Manhattan Project. J. Robert Oppenheimer, a physicist from the University of California at Berkeley, led the scientific effort and was the scientific director of the laboratory at Los Alamos, New Mexico, where the weapons were designed. Work was carried out at a number of other sites in the United States, among them Oak Ridge, Tennessee, where uranium was enriched, and Hanford, Washington, where plutonium was produced. Britain and Canada also participated in the Manhattan Project, and their scientists came to various Manhattan Project facilities in the United States.

Much of the driving force in building the atomic bomb was the fear that Germany, where Otto Hahn, Lise Meitner, and Fritz Strassman had first discovered nuclear fission, would be the first State to acquire nuclear weapons.⁴² Germany did, indeed, have a small nuclear-weapon program. It was not given a high priority during the war, and Germany did not develop a weapon. After Germany surrendered to the Allies in May 1945, two months before the Trinity test, all attention was now on the war against Japan. Two nuclear bombs were dropped on Japan in 1945, on Hiroshima on August 6 and on Nagasaki on August 9; Figure 3 shows the latter. The war against Japan ended shortly thereafter.



³⁹ The text of the letter may be found at

http://www.anl.gov/Science_and_Technology/History/Anniversary_Frontiers/aetofdr.html

⁴⁰ Richard Rhodes, *The Making of the Atomic Bomb*, pp. 306-314.

⁴¹ Ibid., p. 340. Rhodes takes the view that MAUD was not an acronym for Military Applications of Uranium Detonation but rather that the name was drawn from a cable from Lise Meitner, a well-known Austrian physicist, referring to Maud Ray Kent, a governess who taught English to Niels Bohr's sons.

⁴² Although sometimes referred to as "atomic bombs," the nomenclature used since 1970, when the NPT entered into force, is the phrase used in the NPT, "nuclear weapons or other nuclear explosive devices. This is both more accurate – it is the nucleus that fissions, not the atom, and more comprehensive. From the point of view of non-proliferation, the fact that a State might characterize its device as not a nuclear weapon would not reduce the security concerns of its neighbors.

2.1.2 International nuclear control

Even before the end of the war, leading scientists began to explore ideas of international control over nuclear weapons. Niels Bohr, a Danish physicist and mentor of many European physicists, made vigorous appeals to both President Roosevelt and Prime Minister Winston Churchill for international cooperation in controlling nuclear weapons, in particular cooperation with the Soviet Union. Bohr's efforts met with no success. Indeed, the Soviet Union had already started its nuclear-weapon project by 1943. As in Germany, it had not been pursued very seriously during the war. Only after the atomic bombings of Hiroshima and Nagasaki had demonstrated the feasibility of nuclear weapons did General Secretary Josef Stalin accelerate Soviet development of nuclear weapons.⁴³

The foreign ministers of the United States, Britain, and the Soviet Union met in Moscow in December 1945 and addressed the question of international control of nuclear weapons. U.S. Secretary of State James Byrnes represented the United States. The ministerial meeting agreed to support the establishment of a United Nations atomic energy commission as a forum for discussing international nuclear control. This meeting followed a meeting in November of President Truman and Prime Ministers William King of Canada and Clement Attlee of Britain. Their Declaration contained three important points that were later to guide U.S. thinking:

- (1) that the development of atomic energy, and its application in weapons of war, placed at the disposal of mankind "means of destruction hitherto unknown";
- (2) that there can be no adequate military defense against atomic weapons; and
- (3) that these are weapons "in the employment of which no single nation can in fact have a monopoly."

The three heads of government also agreed that international control over nuclear weapons was essential.⁴⁴

Because the United States had not yet adopted a formal position on international nuclear control, Secretary of State Byrnes called for a study to articulate the basis for a policy position. In early January 1946, he set up a Committee on Atomic Energy chaired by Undersecretary of State Dean Acheson (see Figure 4). Other members of the Committee included Vannevar Bush, James B. Conant, General Leslie Groves, and John J. McCloy. During the war, Bush, an engineer and former provost of the Massachusetts Institute of Technology, had been Director of the Office of Scientific Research and Development, which had overall control of the Manhattan Project. Conant, President of Harvard University, was a colleague of Bush on the National Defense Research Commission and was instrumental in creating the Manhattan Project. General Groves

⁴³ Ibid. pp. 526-536. For histories of the German and Soviet nuclear-weapon programs, see also: Jeremy Bernstein, Hitler's Uranium Club: The Secret Recordings at Farm Hall. New York: Copernicus Books, Springer-Verlag, (2001); and David Holloway, Stalin and the Bomb: The Soviet Union and Atomic Energy, 1939-1956. New Haven: Yale University, (1994).

⁴⁴ Declaration on Atomic Bomb by President Truman and Prime Ministers Attlee and King, Washington, November 15, 1945.

http://www.nuclearfiles.org/menu/key-issues/nuclear-energy/history/dec-truma-atlee-king_1945-11-15.htm (May 4, 2012).

had exercised command of the Manhattan Project. John J. McCloy, a lawyer, had been Assistant Secretary of the Army during the War.

Acheson's Committee on Atomic Energy appointed a Board of Consultants, all of whom had worked on the Manhattan Project. David Lilienthal, former head of the Tennessee Valley Authority, led the Board, and Oppenheimer was its chief scientific advisor. Its starting point was, "a political commitment already made by the United States to seek by all reasonable means to bring about international arrangements to prevent the use of atomic energy for destructive purposes and to promote the use of it for the benefit of society."⁴⁵

The Board worked intensively for more than seven weeks, and on March 17, 1946, its report was transmitted to the Secretary of State by Acheson's Committee on Atomic Energy. On March 28, 1946, the Department of State made public the report entitled "A Report on the International Control of Atomic Energy."⁴⁶

The Report, which came to be known as the Acheson-Lilienthal Report, emphasized that it was not intended to be a final plan but "a place to begin, a foundation on which to build."⁴⁷ The Report acknowledged the three elements of the Truman-Attlee-King Declaration described above and recognized that the U.S. nuclear monopoly would not last. Eventually other States would acquire the knowledge, fissile material, and infrastructure to build a nuclear weapon. Only international control of sensitive nuclear capabilities would prevent proliferation. The Report took a particularly dim view of international agreements trying to cope with national agencies and relying on a system of inspection and "similar police-like methods."

It was essential, the Report stated, that a new international organization implement a "workable system of safeguards [to] remove from individual nations or their citizens the legal right to engage in certain well-defined activities" that were "intrinsically dangerous" because they were "steps in the production of atomic bombs." This would include mining and the sensitive technologies of uranium enrichment and plutonium separation. Activities that were not considered "dangerous" would not be controlled by the authority.⁴⁸ The international organization would also promote peaceful uses of nuclear energy, which the Report concluded, were "within reach of actuality."⁴⁹ In transmitting the Report to the Secretary of State, the Acheson Committee noted that it was, "in



(From U.S. Department of State)

*Figure 4. Dean Acheson, the
51st Secretary of State of the
United States*

⁴⁵ The Acheson-Lilienthal Report – Report on The International Control of Atomic Energy, Prepared for the Secretary of State's Committee on Atomic Energy by a Board of Consultants, Chester I. Barnard, Dr. J. R. Oppenheimer, Dr. Charles A. Thomas, Harry A. Winne, David E. Lilienthal, Chairman. U. S. Government Printing Office, Washington, D. C., March 16, 1946, p. 1. The report is available at <http://www.learnworld.com/ZNW/LWText.Acheson-Lilienthal.html>. (February 21, 2012.).

⁴⁶ Acheson-Lilienthal Report.

⁴⁷ Ibid., p. XII.

⁴⁸ Ibid., pp. 26-29.

⁴⁹ Ibid., pp. 2-5, 17.

particular, impressed by the great advantages of an international agency with affirmative powers and functions coupled with powers of inspection and supervision”

2.1.3 International nuclear development

The Acheson-Lilienthal Report proposed the creation of an atomic development authority, but it recognized it would take some time to establish and bring into operation. The newly created United Nations Atomic Energy Commission⁵⁰ would need to discuss it and then the United Nations General Assembly.⁵¹ After General Assembly approval, creation of the authority would also have to be ratified by States. Finally, the authority would have to become operational.

Table 1. U.S. Nuclear Weapon Stockpile Data

YEAR	TOTAL	MEGATONAGE	BUILDS	RETIREMENTS
1945	2	0.04	2	0
1946	9	0.18	7	0
1947	13	0.26	4	0
1948	50	1.25	43	6
1949	170	4.19	123	3
1950	299	9.53	264	135
1951	438	35.25	284	145
1952	841	49.95	644	241

At this point, the United States, and to a lesser extent, Britain and Canada, had a virtual monopoly of information on producing fissile material for nuclear weapons as well as weapons design. Thus, one difficulty the United States faced was the transfer of knowledge from the United States to the authority – it would need knowledge sufficient to function but not so great that it would facilitate the spread of nuclear weapons. The Report determined this was possible. The information essential for nuclear development did not require the transfer of too much information.

Another key issue was what the United States would do with its own nuclear weapons, few as they were in early 1946. Table 1 shows the United States' steady buildup of nuclear weapons from 1945 to 1952.⁵² In particular, would the United States be prepared to give them up? If so, under what circumstances? The Report did not address this question directly, but it made clear that giving up nuclear weapons could only take place when a full transition had been made to the atomic development authority.

As planned, the United Nations Atomic Energy Commission took up the issue of international control in June 1946. Secretary Byrnes selected Bernard Baruch to present the U.S. position. He was then appointed as temporary chairman of the Commission's first session by UN Secretary-

⁵⁰ The United Nations Atomic Energy Commission was created by the United Nations General Assembly in UNGA Resolution 1, which was adopted unanimously on January 24, 1946.

⁵¹ U.S. Department of Energy, Office of History and Heritage Resources, “The Manhattan Project, December 1945-1946. http://www.cfo.doe.gov/Me70/Manhattan/international_control.htm.

⁵² Nuclear weapon stockpile data is from Restricted Data Declassification Decisions: 1946 to the Present, (RDD-7), January 1, 2001, U.S. Department of Energy, Office of Declassification, at <http://www.fas.org/sgp/othergov/doe/rdd-7.html#I47>

General Trygve Lie (Figure 5). Baruch opened his statement with dramatic flair: “We are here,” he said, “to make a choice between the quick and the dead.”⁵³



(From United Nations)

Figure 5. Bernard N. Baruch (left), U.S. Representative on the UN Atomic Energy Commission, with UN Secretary General Trygve Lie

When he accepted this task, Baruch (see also Figure 6) had said that he would contribute his own ideas. And he did. What he presented to the United Nations Commission in June 1946 included most of the basic elements of the Acheson-Lilienthal Report. But he made two major additions: the introduction of sanctions for States that violated the provisions of the International Atomic Development Authority, and the lifting of veto power in the Security Council when considering sanctions.

As had the Acheson-Lilienthal Report, Baruch proposed the creation of an Atomic Development Authority, which would exercise control over “all phases of the development and use of atomic energy, starting with raw materials.” The principal powers of the Authority would have included: (1) managerial control or

ownership of all activities potentially dangerous to international security; (2) the power to control, license and inspect all other nuclear activities; (3) the duty to foster beneficial uses of nuclear energy; and (4) R&D responsibilities “of an affirmative nature.”

Sanctions had not been discussed in the Acheson-Lilienthal Report, but Baruch made clear his view that the people of the world wanted a program of “enforceable sanctions – an international law with teeth in it.” It was imperative, Baruch said, for violations to be detected and punished quickly. The violations of the agreement that would trigger sanctions included:

- (1) illegal possession or use of a nuclear weapon;
- (2) illegal possession or separation of fissile material for nuclear weapons;
- (3) seizure of any plant that belonged to or was licensed by the Authority;
- (4) willful interference with the Authority’s activities; and
- (5) carrying out “dangerous projects” without a license granted by the Authority.

Finally, Baruch stated that there could be no veto power exercised when the Security Council considered violations. He thus introduced a scheme that looked similar to the “police-like methods” that the Acheson-Lilienthal Report sought to avoid.

As the Acheson-Lilienthal Report had proposed, under Baruch’s plan the United States would transfer sufficient atomic information to enable the Authority to function. It would do so by stages.

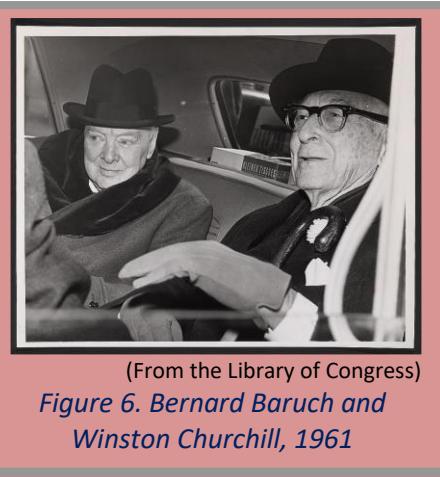
⁵³ The Baruch Plan, Presented to the United Nations Atomic Energy Commission, June 14, 1946. <http://www.atomicarchive.com/Docs/Deterrence/BaruchPlan.shtml>

Inescapably, this would leave at least two entities in possession of sensitive information, the Authority and the United States.

On disarmament, Baruch was somewhat more explicit than the Acheson-Lilienthal Report. Existing bombs would be disposed of and manufacturing of bombs would cease. Use would be renounced when an adequate system for control of atomic energy had been agreed upon, put into effective operation, and condign punishments set up for violations of the rules of control, which would be stigmatized as international crimes.

Andrei Gromyko, the Soviet representative, rejected the terms presented by Baruch. He proposed that nuclear disarmament, meaning disarmament by the United States, should take place before the Authority was set up. The Soviet Union was pursuing its own nuclear-weapon program and was also unwilling to forgo the veto. Debate in the United Nations Atomic Energy Commission continued for several years, but the Baruch plan was effectively dead by the summer of 1946. The Commission itself lapsed in 1952.

The most significant consequence of this was that there would be no centralized international control over nuclear technology and production as envisioned by the Acheson-Lilienthal Report and the Baruch Plan. Nuclear programs would now exist in an entirely decentralized world. Each State would determine for itself what its nuclear policies and programs would be. After 1946, the most that could be hoped for would be an international agreement among States under which they would consent to limit some of their activities.⁵⁴



(From the Library of Congress)
Figure 6. Bernard Baruch and Winston Churchill, 1961

2.2 Atoms for Peace – Nuclear Control and Nuclear Cooperation

2.2.1. U.S. Atomic Energy Act of 1946

While the Acheson-Lilienthal Committee was at work and Baruch was later presenting his plan to the United Nations Atomic Energy Commission, the U.S. Government was organizing its post-World War II regime for control of nuclear energy. Two major questions faced it: What would be the domestic arrangements? And how would the United States deal with other countries on nuclear matters?

With respect to the former, it had to address who would control nuclear development and production and what would be the nature of this control? Would the control be civilian or military? Would it be centralized or merely regulatory? With respect to international cooperation, with

⁵⁴ See The Failure of the United Nations Atomic Energy Commission: An Interpretation, Edward Shils, The University of Chicago Law Review, Vol. 15, No. 4, Summer, 1948 at stable URL <http://www.jstor.org/stable/1597971?seq=2>.

whom would the United States be willing to cooperate? Under what circumstances? And what would be allowed?

The Atomic Energy Act of 1946, passed in August of that year, answered these questions.⁵⁵

First, Congressional oversight was to be provided by the Joint Committee on Atomic Energy, a United States congressional committee that was tasked with exclusive jurisdiction over “all bills, resolutions, and other matters” related to civilian and military aspects of nuclear power. This exclusive jurisdiction made the Committee particularly powerful. It operated from 1946 through 1977. It was the overseer of the United States Atomic Energy Commission (AEC).

The Act also established the AEC. The AEC became the “exclusive owner of all facilities for the production of fissionable material,” except for material useful in research and development (R&D) and whose production rate was insufficient to produce weapon-grade fissile material. A Military Liaison Committee, made up of representatives from the Departments of War and Navy, would advise the Commission on military applications. The mandate to produce nuclear weapons was given to the Commission.⁵⁶

The Act defined and gave to the Commission the authority to control “restricted data,” which included all information on the production of fissionable material or the manufacture or use of atomic weapons. Penalties for transferring such data with the intent to injure the United States were, and remain, severe: life in prison or death.⁵⁷

The dissemination of scientific and technical information relating to atomic energy was encouraged. However, cooperation with other countries “with respect to the use of atomic energy for industrial purposes” was prohibited “until Congress declares by joint resolution that effective and enforceable international safeguards against the use of atomic energy for destructive purposes have been established.”⁵⁸ This provision mirrors the cautions expressed in both the Acheson-Lilienthal Report and the Baruch Plan about transferring information to the Atomic Development Authority.

In brief, the approach of the United States at the beginning of the atomic era was to deny other countries access to information on nuclear energy. It hoped that this would avoid the spread of nuclear weapons. The abandonment of this approach in favor of cooperation in peaceful uses required a wholesale revision of the Atomic Energy Act.

⁵⁵ Atomic Energy Act of 1946. Public Law 585, 79th Congress. <http://www.osti.gov/atomicenergyact.pdf>.

⁵⁶ Ibid., Sections 2, 4, 6.

⁵⁷ Ibid., Section 10(b)(2).

⁵⁸ Ibid., Sections 10(a)(1) and (2).

2.2.2 Atoms for Peace proposal

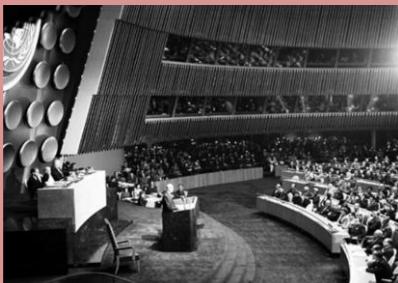
The Acheson-Lilienthal Report correctly predicted that the United States would not be able to retain its monopoly of nuclear weapons. The Soviet Union tested a nuclear device in 1949, followed by Britain in 1952.

In 1953, several developments significantly changed the international landscape. The leadership of both the United States and the Soviet Union changed: President Dwight D. Eisenhower took office in January, and Stalin died in March. Leadership changes can create opportunities for new beginnings. In addition, construction began in Britain on the Calder Hall reactor, which would be the world's first nuclear reactor to deliver power in commercial quantities. It began

operations in 1956.⁵⁹ This made concrete the view expressed in 1946 that peaceful uses of nuclear energy represented a plausible dream.

"The United States knows that peaceful power from atomic energy is no dream of the future. The capability, already proved, is here today. Who can doubt that, if the entire body of the world's scientists and engineers had adequate amounts of fissionable material with which to test and develop their ideas, this capability would rapidly be transformed into universal, efficient and economic usage?"

- Address by Mr. Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly, 8 December 1953.



(From Dwight D. Eisenhower Presidential Library and Museum)

Figure 7. President Eisenhower addressing the UN General



Figure 8. Atoms for Peace stamp designed by George Cox at Brookhaven National Laboratory and issued July 1955

On December 8, 1953 President Eisenhower addressed the United Nations General Assembly (Figure 7). Referring to the United Nations General Assembly Resolution of the previous month calling for "the Powers principally involved" to seek a solution to the armaments race, President Eisenhower said that the United States was prepared to engage in such discussions and in doing so would introduce a "new conception," known as "Atoms for Peace,"⁶⁰ commemorated in the postage stamp shown in Figure 8.

An international atomic energy agency would be established. To this agency, governments would contribute "normal uranium and fissionable material," and the agency would be responsible for storage and protection of the fissionable materials that had been contributed. More importantly, the agency would be responsible for devising and promoting the peaceful uses of nuclear energy.

⁵⁹ The first reactor connected to an electrical supply grid went into operation in 1954 at Obninsk in the Soviet Union. It produced about 5 MW of electricity, relatively small compared to the 60 MW of the Calder hall reactor.

⁶⁰ Atoms for Peace, Address given by Dwight D. Eisenhower before the General Assembly of the United Nations on Peaceful Uses of Atomic Energy, New York City, December 8, 1953.

http://www.eisenhower.archives.gov/research/online_documents/atoms_for_peace.html.

Eisenhower noted that one of the countries “principally involved” must be the Soviet Union.

Eisenhower’s proposal was sketchy, but it was enough to generate serious discussions that led in 1957 to the creation of the International Atomic Energy Agency.

2.2.3 The U.S. Atomic Energy Act is revised



(From Dwight D. Eisenhower Presidential Library and Museum)

Figure 9. President Eisenhower signs the Atomic Energy Act of 1954

President Eisenhower’s Atoms for Peace address captured the world’s enthusiasm for the promise of peaceful uses of nuclear energy. However, the door to international cooperation could not be truly opened as long as the restrictive provisions of the Atomic Energy Act of 1946 remained in effect. The necessary next step was accomplished with the adoption of the Atomic Energy Act of 1954 (Figure 9).⁶¹

While retaining strong nuclear defense provisions, the 1954 Atomic Energy Act called for both “the development and utilization of atomic energy for peaceful purposes” and “a program of international cooperation ... to make available ... the benefits of peaceful uses of atomic energy.” These new goals were adopted as a means to support non-proliferation

by heading off further development of independent nuclear programs already underway.

To ensure that nuclear cooperation was not turned to military use, the Act required guarantees by recipient countries that it would be used only for peaceful purposes. The Act also required that the cooperation be under safeguards to ensure compliance with these guarantees. The Act did not, however, require pledges by recipients not to acquire nuclear weapons through their own means. Indeed, the term “non-proliferation” does not appear in the legislation.

It was foreseen that non-proliferation benefits would emerge because independent nuclear development would be made unlikely. States would prefer the advantages of U.S. assistance. In most cases, this view proved to be correct. For some time, nearly all nuclear programs in the

⁶¹ For complete text, see NUREG-0980 at <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/>. The Atomic Energy Act has been amended frequently but earlier versions of some of its provisions are provided in footnotes in this reference. The principal provisions dealing with civil international cooperation are found in Section 123, which governs Agreements for Cooperation. However, another provision of particular importance is Section 57.b which makes it “unlawful for any person to engage *directly or indirectly* in the development or production of any [fissionable] material outside of the United States” [emphasis added] unless authorized either by an Agreement for Cooperation or by the Department of Energy. This extremely broad language – directly or indirectly – was the source of great difficulty and uncertainty at the outset of international cooperation, raising questions such as whether the teaching of nuclear physics to foreign students was unlawful without authorization. This uncertainty led to a general authorization in the Code of Federal Regulations (CFR), 10 CFR Part 110, for U.S. parties to engage in unclassified nuclear cooperation. This general authorization was later narrowed in 10 CFR Part 810 to continue the requirement for specific, case-by-case DOE authorization for cooperation involving production reactors, reprocessing, enrichment, heavy water production, plutonium fuel fabrication, or research reactors above 5 MWT. This regulation restricts even unclassified nuclear cooperation with countries that do not have full-scope IAEA safeguards.

Western world involved the use of U.S. supplied materials, making them subject to the peaceful use guarantees and controls required by the Atomic Energy Act.

The 1954 Act preserved oversight of both civil and defense nuclear programs by the civilian AEC. However, it included numerous new provisions to give effect to the new goals of peaceful nuclear development and international cooperation. In the area of domestic civil uses, governmental ownership of fissionable material was retained, but the Act authorized its distribution for civilian use -- under license -- by lease from the AEC. It also provided for the licensing of privately-owned civil nuclear facilities and established the framework for governmental support of the development of civil nuclear technology. Thus, the Commission was placed in the position of both promoting and regulating the domestic civil nuclear industry and owning its vital fuel materials.

As the nuclear industry matured, the belief grew that there was a conflict between these functions. The roles of promotion and regulation were first separated at the AEC staff level. In 1975 they were completely separated through dissolution of the AEC and creation of the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). ERDA was later merged with other energy-related agencies to form the Department of Energy (DOE).⁶² At the same time, the Joint Committee on Atomic Energy was eliminated, and Congressional oversight passed to existing committees of the House and Senate. Of considerable importance was that ownership of fissionable material was transferred from the government to private users in 1964. Nonetheless, the important function of uranium enrichment for both domestic and international civil use was not transferred to private ownership until 1998.

The Atomic Energy Act of 1954 did not end the availability and use, in appropriate cases, of secrecy and denial as non-proliferation tools, but it spelled their abandonment as a general policy.⁶³ The development of a robust private industry required extensive declassification of nuclear technology. This declassification proceeded rapidly, accelerated by the International Conference on Peaceful Uses of Atomic Energy held in Geneva, Switzerland in August 1955. This landmark event brought together for the first time nuclear experts from the East and West and the developed and less-developed countries.⁶⁴

⁶² The dissolution of the Atomic Energy Commission and creation of ERDA and the NRC was accomplished by the Energy Reorganization Act of 1974, which is also available in NUREG-0980. This legislation transferred the licensing authority of the Atomic Energy Commission to the NRC. At the same time, ERDA, now the DOE, retained the AEC's responsibilities for "authorizing" foreign activities by private U.S. parties other than the export of materials or equipment. Thus, the nuclear export control functions of the U.S. government are divided between the NRC and the DOE.

⁶³ Secrecy and denial are nevertheless a significant factor in the non-proliferation regime. Much uranium enrichment technology remains classified, and several technologies that are unclassified are subject to export control in the United States and in most cases denial. The Nuclear Non-Proliferation Act of 1978, discussed later, created a new category, sensitive nuclear technology, to facilitate the control of these technologies. The Nuclear Suppliers Group encourages tight control of these technologies and their related equipment as well.

⁶⁴ Not all observers consider Atoms for Peace to have been successful in restraining proliferation, as many scientists trained by the United States were later to explore nuclear weapon development in a variety of countries, including India and Pakistan.

2.3 U.S. Nuclear Cooperation

2.3.1 Early U.S. nuclear cooperation

The Atomic Energy Act was amended in 1954 to authorize and encourage international nuclear cooperation. Section 123 of the Act authorized the conclusion of Agreements for Cooperation with other countries. It made them a prerequisite for the most important kinds of U.S. international cooperation in peaceful uses of nuclear energy. An Agreement for Cooperation is mandatory for U.S. supply of nuclear reactors and other major facilities, including enrichment and reprocessing plants, and special nuclear material (that is, enriched uranium, plutonium and uranium-233). Many other forms of cooperation, such as exchange of unclassified technology and export of materials such as heavy water, can take place without an Agreement for Cooperation, but these agreements facilitate cooperation. The agreements, commonly known as “123 agreements,” must be submitted to Congress. After Congress has had an opportunity to review an agreement, it comes into effect after 90 days of continuous session unless Congress disapproves it.⁶⁵

In most cases, Agreements for Cooperation are with individual States, but agreements are also in place with the European Atomic Energy Community (Euratom) and with the IAEA. The negotiation of Agreements for Cooperation was initiated promptly after passage of the Atomic Energy Act of 1954. The first agreement was concluded in 1955. By 1960, more than twenty had been concluded. As of January 2017, there were 23 agreements in force with 48 countries, the International Atomic Energy Agency and the governing authorities on Taiwan.⁶⁶

The earliest agreements provided only for the transfer of research reactors and uranium enriched to no more than 20% U-235. These agreements had very limited safeguards - occasional U.S. visits to view the reactors and their fuel.⁶⁷ It was not long before agreements were negotiated that provided for the supply of power reactors and related technology and LEU fuel. In some cases, HEU fuel was supplied for research reactors, and significant quantities of plutonium were supplied for R&D related to breeder reactors. Agreements of this type included more elaborate safeguards provisions.

⁶⁵ Agreements that are submitted to the Congress in which the President has waived or exempted the Agreement from some of the requirements of Section 123 require positive approval by the Congress in order to enter into force, rather than entering into force after a fixed time in the absence of disapproval.

⁶⁶ A list of the Agreements for Cooperation that were in force in January 2017 can be found in the National Nuclear Security Administrations compilation at:

<https://nnsa.energy.gov/aboutus/ourprograms/nonproliferation/treatiesagreements/123agreementsforpeacefulcooperation>. (Accessed 3 Mar 2018)

<http://www.hsl.org/?search&collection=crs&so=date&submitted=Search&creatoremore=true&page=1&creator=N>

⁶⁷ An example of such an agreement is the 1956 agreement with the Republic of Korea, which can be found in the United Nations Treaty Series. The safeguards provisions of this agreement are rudimentary and consist primarily of South Korea’s agreement to assure that the items supplied under the agreement were used only for peaceful purposes. This focus reflects a common perspective in the earliest days of international cooperation that safeguards were not for verification of compliance but were rather actions taken by the recipient country to assure its own compliance with peaceful use guarantees. This seems to contemplate actions more properly viewed as physical security rather than safeguards, and as self-inspection. Only one brief sentence in the agreement, providing a U.S. right “to observe from time to time the condition and use of any leased material and to observe the performance of the reactor...,” corresponds to safeguards as they are now understood. The research reactor Agreements for Cooperation were of short duration and none remain in effect.

Power-reactor agreements generally specified maximum quantities of LEU that could be provided, but the quantity was increased from time to time in response to growing needs. In conjunction with these agreements, the DOE entered into contracts for the long-term supply of enrichment services. These commitments ensured that U.S.-origin light water reactor technology became and remained dominant. By providing assured supplies of reactor fuel under favorable terms and conditions, they also discouraged the development of independent enrichment programs.

The Atomic Energy Act of 1954, as originally drafted, prohibited cooperating partners from developing nuclear weapons from U.S.-supplied materials and equipment. It did not obligate them to relinquish their right to develop nuclear weapons or other nuclear-related military applications through their own efforts. In addition, inspectors from the AEC implemented the safeguards that the United States required. (The IAEA had not yet been created.) As the IAEA safeguards system developed later, these safeguards responsibilities were generally transferred from the United States to the IAEA.

2.3.2 Strengthening non-proliferation requirements

Over time, the non-proliferation commitments required in the earliest U.S. nuclear cooperation arrangements were seen to be inadequate. For example, the United States supplied heavy water to India's CIRUS research reactor under a 1956 contract. It was supplied without an Agreement for Cooperation, which was not needed for heavy water, and there were no safeguards requirements. It stipulated that the heavy water could be used only in "connection with research into and the use of atomic energy for peaceful purposes...." Canada supplied the CIRUS reactor itself under similar conditions.

This formulation left the door open to a claim that nuclear explosives developed for peaceful purposes were a permitted activity. Suspicions arose in the late 1960s that India would test a nuclear explosive device. This led the United States to make clear to India in 1970 that such a test would be "incompatible" with the contract if U.S. assistance were to be "employed in the development of peaceful nuclear explosive devices." The United States stated specifically that such use of plutonium produced in the CIRUS reactor would be considered a "contravention" of the terms of the agreement.⁶⁸ Canada also warned India not to do so.^{69,70}

⁶⁸ U.S. Aide Memoir to the Indian Atomic Energy Commission, November 16, 1970; declassified by Louis V. Nosenzo at the request of Senator John Glenn on September 19, 1980. (http://www.armscontrol.org/pdf/19701116_US_Aide_Memoire_Indian_AEC.pdf).

⁶⁹ According to U.S. Embassy Canada cable 391 to State Department, "India's Nuclear Intentions," 7 March 1972, Secret.[declassified 3/23/07] "Canadian Prime Minister Pierre-Eliot Trudeau followed by other officials [had] "directly" warn[ed] the "Indians that Canadian plutonium should not be used for any kind of nuclear device." From National Security Archive hosted by The George Washington University. <http://www.gwu.edu/~nsarchiv/nukevault/ebb367/index.htm>

⁷⁰ Note that in testimony before the Senate Foreign Relations Committee in 2006 in connection with the U.S.-India nuclear Agreement for Cooperation, a State Department official stated that, "the U.S. Government examined this matter around the time of India's 1974 test and was unable to reach a conclusive answer whether or not India violated the 1956 contract for heavy water supply to the CIRUS reactor," citing uncertainty as to whether the U.S. supplied heavy water contribute to the production of the plutonium used for the test. 109th Congress, Senate Reports 284-292. For a useful summary of historical documents related to India's nuclear-weapon program, see Nuclear Proliferation: The Indian Profile, Editor, Dr Noor Ul Haq; Assistant Editor, Tauqeer Hussain Taki (April 2008) <http://ipripak.org/factfiles/ff97.pdf> (September 2012), which is posted by the Islamabad Policy Research Institute.

Nonetheless, in 1974 India tested a nuclear explosive device using plutonium produced in the CIRUS reactor. This, India argued, made the test compatible with the peaceful use commitments made to Canada and to the United States.^{71,72}

Another concern stemmed from the fact that the U.S. Atomic Energy Act required non-proliferation commitments and safeguards only for the items that were supplied. This led to the possibility that U.S. nuclear cooperation could strengthen a recipient's nuclear capabilities and indirectly facilitate the production of fissile material and the manufacture of nuclear weapons.

The entry into force of the NPT in 1970 strengthened controls on nuclear cooperation by requiring IAEA safeguards as a condition of supply both for nuclear material and for specified equipment and material. As stated in NPT Article III.2, parties may not provide "equipment or material especially designed or prepared for the processing, use or production of special fissionable material" to any non-nuclear-weapon State unless the nuclear material would be subject to IAEA safeguards.

In order to create a "level playing field," nuclear suppliers established a committee to forge a common understanding of which equipment and material would be considered as "especially designed or prepared." The committee was called the Zangger Committee, named after its first chairman, Claude Zangger. It agreed on a list of items (a "trigger list") and on conditions of supply, including retransfer consent rights.⁷³ One example of strengthening was the inclusion on the trigger list of heavy water, but it was the NPT itself that represented a fundamental sea change in ensuring that nuclear exports would not contribute to nuclear proliferation either directly or indirectly.

In the 1970s, spurred in part by India's nuclear explosion, non-proliferation concerns gave impetus in the United States to efforts to improve the clarity of controls, to increase their scope, and to reduce the risk that safeguarded cooperation might be used to support unsafeguarded nuclear activities. The new approach was contained in the Nuclear Non-Proliferation Act of 1978 (NNPA). The NNPA provided for strict and detailed controls over significant nuclear

⁷¹ India's assertion that the nuclear explosion was for peaceful purposes should be viewed in the context of the times. Starting in 1961, the United States conducted a series of tests related to earth moving (creation of harbors, for example) and extracting resources deep underground, what is now sometimes called "fracking," though by a quite different method. The tests were part of the *Plowshare* series and were conducted in 1961, 1967, 1969, and 1973. The last four explosions conducted in the series were used to test methods for extracting natural gas from impermeable rock. See *A History of the Atomic Energy Commission*, Alice L. Buck, July 1983, DOE/ES-0003/1.

http://www.lanl.gov/history/admin/files/A_History_of_the_Atomic_Energy_Commission.pdf

⁷² Leonard Weiss, India and the NPT, Routledge: Strategic Analysis, Vol. 34, No. 2, March 2010, 255–271.

[http://iis-db.stanford.edu/pubs/22901/Weiss_India_and_the_NPT.pdf*.](http://iis-db.stanford.edu/pubs/22901/Weiss_India_and_the_NPT.pdf*)

⁷³ The home page of the Zangger Committee is at <http://www.zanggercommittee.org/Seiten/default.aspx>.

cooperation.^{74,75}

The major change was the requirement that significant nuclear cooperation could take place only if safeguards were being applied to all nuclear activities in a non-nuclear-weapon State at the time of the transfer, full-scope safeguards. This requirement is met for NPT non-nuclear-weapon States who are obligated to have comprehensive safeguards agreements in force. It could also be met by a non-NPT party if all of its nuclear activities were subject to safeguards under INFCIRC/66 agreements. Such full-scope safeguards coverage was called “de facto” full-scope safeguards rather than “de jure,” the contrast being the difference between the obligation to have comprehensive safeguards at all times, as required by the NPT, or not. In the latter case, there might be full-scope coverage at one time, but it might not be the case subsequently.

For some time, not all major nuclear suppliers required full-scope safeguards as a condition of supply. This situation ended when Germany announced at the NPT Review Conference in 1990 that it was adopting such a policy. The Nuclear Suppliers Group adopted this requirement in 1992.

⁷⁴ “Section 123a of the Atomic Energy Act lists nine criteria that a nuclear cooperation agreement must meet unless the President determines an exemption is necessary. These include guarantees that:

- safeguards on transferred nuclear material and equipment continue in perpetuity;
- full-scope IAEA safeguards are applied in non-nuclear-weapon states;
- nothing transferred under the Agreement for Cooperation may be used for any nuclear explosive device or for any other military purpose; except in the case of military cooperation agreements with nuclear-weapon states;
- the U.S. has the right to demand the return of transferred nuclear material and equipment, as well as any special nuclear material produced through their use, if the cooperating state detonates a nuclear explosive device or terminates or abrogates an IAEA safeguards agreement;
- there is no retransfer of material, equipment or components or classified data without U.S. consent;
- physical security on nuclear material is maintained;
- there is no enrichment or reprocessing by the recipient state of transferred nuclear material or nuclear material produced with materials or facilities transferred pursuant to the agreement without prior approval of the U.S.;
- storage for plutonium and HEU subject to the agreement is approved in advance by the U.S. and
- any material or facility produced or constructed through use of sensitive nuclear technology transferred under the cooperation agreement is subject to all of the above requirements.

From Nuclear Cooperation with Other Countries: A Primer, Paul K. Kerr, Mary Beth Nikitin, Congressional Research Service, August 11, 2011. <http://www.fas.org/sgp/crs/nuke/RS22937.pdf>.

This is a generally useful reference for background information on Agreements for Cooperation. Also useful is “Nuclear Energy Cooperation with Foreign Countries: Issues for Congress; Paul K. Kerr, Mark Holt, Mary Beth Nikitin; Congressional Research Service, July 11, 2011.

<http://www.hsl.org/?search&collection=crs&so=date&submitted=Search&creatormore=true&page=1&creator=Nikitin%2C+Mary+Beth+Dunham&fct>.

⁷⁵ Although an Agreement for Cooperation is required for significant nuclear cooperation, the Atomic Energy Act requires export licenses or authorizations for many, but by no means all, forms of nuclear cooperation. U.S. nuclear export controls are complex and may require export licenses from the Nuclear Regulatory Commission, the Department of Energy, the Department of State, or the Department of Commerce. The Department of Commerce, “Nuclear Exporter’s Guide,” May 2009, provides a brief overview of these controls.

[http://ita.doc.gov/td/energy/Civil%20Nuclear%20Exporters%20Guide%20\(FINAL\).pdf](http://ita.doc.gov/td/energy/Civil%20Nuclear%20Exporters%20Guide%20(FINAL).pdf).

The NNPA also added other requirements as conditions of supply under Agreements for Cooperation, for example, by tightening the ground rules for U.S. approval of any reprocessing of U.S.-provided nuclear fuel.⁷⁶

More recently, in 2006 the U.S. Congress adopted legislation that made another significant revision to the Atomic Energy Act. It permitted the President, under certain conditions, to conclude an Agreement for Cooperation with India that did not include the requirement of full-scope IAEA safeguards.⁷⁷ This legislation resulted from an initiative by President George W. Bush to improve relations between the United States and India across a range of topics. It represented a significant departure from the 1978 legislation because it permitted nuclear cooperation with a non-NPT party with significant unsafeguarded nuclear activities. Indeed, India had tested a nuclear explosive device in 1974 and conducted tests of acknowledged nuclear weapons in 1998. A U.S. Agreement for Cooperation with India entered into force in 2008, an outcome that many observers considered to be unfortunate because it reversed the long-standing policy of requiring full-scope safeguards as a condition of supply.^{78,79,80,81}

In recent years, strong U.S. interest in restraining the spread of enrichment and reprocessing capabilities has encouraged support for making U.S. nuclear cooperation contingent on a commitment to eschew the right to develop enrichment or reprocessing facilities. While not required by U.S. law, one State, United Arab Emirates, has done so on a voluntary basis.⁸²

2.3.3 Conclusion

At the outset of international nuclear cooperation, only the United States had the capability to export significant amounts of enriched uranium. Its supply at attractive prices under long-term contracts, together with the associated U.S.-developed light-water reactor technology, was largely responsible for the creation of the Western world's nuclear industry. With the spread of nuclear technology (much of it of U.S. origin) and related industrial capabilities, enriched uranium and

⁷⁶ LOOKING BACK: The 1978 Nuclear Nonproliferation Act, Sharon Squassoni, Arms Control Today, December 2008. http://www.armscontrol.org/act/2008_12/lookingback_NPT (March 15, 2010).

⁷⁷ P.L. 109-401, 120 Stat. 2734 (2006), The Henry J. Hyde United States-India Peaceful Atomic Energy Cooperation Act of 2006. Its text may be found at <http://www.gpo.gov/fdsys/pkg/BILLS-109hr5682enr/pdf/BILLS-109hr5682enr.pdf>. The Atomic Energy Act was amended to require that a U.S.-India Agreement for Cooperation require affirmative Congressional action before it could be implemented.

⁷⁸ Fred McGoldrick, The Road Ahead for Export Controls: Challenges for the Nuclear Suppliers Group, Arms Control Today » January/February 2011.

⁷⁹ Congressional Research Service (Order Code RL33016), Paul K. Kerr, Analyst in Nonproliferation, Foreign Affairs, Defense, and Trade Division, U.S. Nuclear Cooperation with India: Issues for Congress, Updated February 12, 2008. <http://fpc.state.gov/documents/organization/103700.pdf> (July 31, 2012).

⁸⁰ Malik Qasim Mustafa, The Indo-Us Nuclear Deal: An Overview of IAEA Safeguards and Nuclear Trade With NSG, Copyright 2008-2011, The Institute of Strategic Studies, Islamabad.

⁸¹ Paul Leventhal. Nuclear Deal with India: Sacrificing the NPT on an Altar of Expediency, Nuclear Control Institute, Friday, December 8, 2006, <http://www.nci.org/06nci/12/nuc-india-deal.htm>. July 31, 2012.

⁸² The commitment was made to the United States in the U.S.-UAE Agreement for Cooperation as described in testimony of Ellen Tauscher, Under Secretary for Arms Control and International Security before the House Foreign Affairs Committee, Washington, DC, July 8, 2009. <http://www.state.gov/t/us/125782.htm>. (January 16, 2013).

reactors are now available from a variety of sources, and the dominance of the United States in nuclear industry has to a large extent disappeared.

The early program of U.S. nuclear cooperation with its insistence on safeguards to verify peaceful use was the key to the development of the non-proliferation regime. The concepts of peaceful-use guarantees and safeguards to verify compliance promoted sound non-proliferation controls on exports and a strong IAEA safeguards system. They were novel in 1954 but later became a baseline for nuclear cooperation. In addition, verification of treaty commitments by an international organization is also incorporated into other arms control and disarmament treaties, for example, the Chemical Weapons Convention (CWC)⁸³ and the Comprehensive Nuclear-Test Ban Treaty (CTBT).⁸⁴ They each have verification organizations in place. For the CWC, there is the Organization for the Prohibition of Chemical Weapons (OPCW), which is based in The Hague, Netherlands. For the CTBT, even though it is not in force, the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) was established as an interim organization based in Vienna, Austria tasked with building up the verification regime of the Treaty in preparation for its entry into force.

⁸³ See <https://www.opcw.org/>

⁸⁴ See <https://www.ctbto.org/>

CHAPTER 3. THE CREATION OF THE IAEA

In 1953 President Eisenhower proposed the establishment of a new international organization to support international nuclear cooperation and, at the same time, to prevent its use for nuclear weapons. This centerpiece of the Atoms for Peace proposal was realized in 1957 when international agreement was reached on the Statute of the International Atomic Energy Agency. A second international body dealing with nuclear energy was also established that year. It was the European Atomic Energy Community (Euratom), established by one of the Rome Treaties. Both bodies have dual missions: promoting peaceful uses of nuclear energy and applying safeguards.

The focus in this text is on IAEA safeguards. Nonetheless, it is important to recognize the significance of Euratom, which applies safeguards within its own community of European States and plays a role in safeguards under the NPT. Interested readers will find a discussion of the creation of Euratom in Appendix B.

The application of safeguards is a major function of the IAEA, and its budget, governance, and institutional and organizational constraints all affect how safeguards are applied. This chapter touches on some of these matters; Appendix C contains a more detailed description of IAEA institutional issues.

3.1 International Control of Nuclear Cooperation

The central concept of the U.S. proposal to establish a new international organization was that it could play a key role both in international nuclear cooperation and in disarmament. The nuclear arms race could be tempered by removing some fissionable material from the growing stockpiles of the United States and the Soviet Union and transferring it to peaceful uses under international control.

In furtherance of this concept, the IAEA's Statute gives the Agency the dual roles of encouragement of peaceful uses of nuclear energy and verification of their peaceful use.⁸⁵ Encouragement and promotion of peaceful uses were to be accomplished, for example, by information sharing, development of nuclear safety guidelines, and the supply of what was expected to be a limited quantity of nuclear fuel. Its allocation to Member States needed to be objective and nonpolitical. Verification was accomplished through a system of on-site inspections.

The IAEA is within the United Nations family of organizations, and membership is open to all United Nations members. However, the IAEA is an autonomous organization with its own governing body and budget. Significantly, the veto power that prevails in the United Nations Security Council is absent in the IAEA Board of Governors. As of December 2017, the IAEA had 169 Member States.⁸⁶ It is headquartered in Vienna, Austria.

⁸⁵ A comprehensive and detailed description of both the establishment of the IAEA and its further development is contained in: "History of the International Atomic Energy Agency, The First Forty Years;" (1997) by David Fischer, Published by and obtainable from the Division of Publications, IAEA, Wagramerstrasse 5, PO Box 100, A-1400., Vienna, Austria. The book is also available online at http://www-pub.iaea.org/mtcd/publications/pdf/pub1032_web.pdf.

⁸⁶ <https://www.iaea.org/about/governance/list-of-member-states> (accessed 5 April 2018)

Despite the importance given to the IAEA in President Eisenhower's address, what the world focused on and adopted with enthusiasm was the promise of peaceful uses of nuclear energy. The result was that the Atomic Energy Act of 1954 emphasized bilateral cooperation, and the bilateral program of the United States was well underway even before the negotiation of the IAEA's Statute began in 1956. By the time the Agency was established in July 1957, the Geneva conference on the Peaceful Uses of Atomic Energy had taken place in 1955;⁸⁷ a score or more of bilateral Agreements for Cooperation had been negotiated by the United States; and it had initiated a bilateral program of safeguards implementation.

The Agency encountered early difficulties in assuming key responsibilities. The novelty of international verification of the undertakings of sovereign nations by on-site inspection, coupled with the strains of the Cold War and Soviet opposition, delayed the development of the necessary technical capabilities as well as their acceptance by Member States. The IAEA's nuclear fuel supply function was utilized only sparingly. It was supplanted by bilateral arrangements that had been initiated before the creation of the IAEA. In addition, most members preferred securing nuclear material directly from producer countries rather than through an international organization. The unexpected, worldwide abundance of uranium also undermined the anticipated need for the IAEA to play a role in the fair allocation of nuclear material.

3.2 The Negotiation of the Statute of IAEA

While formal negotiation of the IAEA Statute did not begin until February 1956, preparatory work began in late 1954 in a group of eight Western nations: the United States, the United Kingdom, France, Canada, Australia, South Africa, Belgium and Portugal. Participation of the last four countries, all uranium producers, reflected the importance attached to the supply of natural uranium. (As noted above, uranium was believed to be a scarce commodity whose control would be a key non-proliferation tool.) The early drafts of the Statute emphasized the concept that the IAEA would act, in effect, as a broker of nuclear assistance, especially the supply of nuclear material such as enriched uranium. The Agency was expected to allocate fairly to the many countries eager to pursue nuclear programs the limited supplies of nuclear material that could be made available by the few extant producers. In this way, the IAEA would acquire control rights over the nuclear material to assure its peaceful use.

The Soviet Union expressed reservations about Atoms for Peace and the creation of a new organization. Nevertheless, the enthusiasm with which the concept was embraced in both developed and developing States ultimately brought it to the negotiating table. A Soviet bloc uranium producer, Czechoslovakia, joined the negotiation. Developing country participation was seen to be desirable, and India and Brazil were invited to join. The negotiation of the Statute, held at United Nations Headquarters in New York, was completed in April 1956. In another expression of the nearly universal appeal of Atoms for Peace, the document was approved unanimously in October 1956 by the United Nations General Assembly. The Statute came into force in July 1957

⁸⁷ “The International Atomic Energy Agency: Origins and early years,” John Hall, IAEA Bulletin 2/1987 describes both the background and significance of the 1955 Geneva Conference and the subsequent founding of the IAEA and its early years. See <https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull29-2/29201284754.pdf>.

after ratification by the required number and mix of States, including the United States and the Soviet Union.⁸⁸

Since the Statute is an international treaty in its own right, the IAEA, although a part of the United Nations family, is not a specialized agency of the United Nations. This distinction is an important one since it allowed the development of the IAEA safeguards system to take place without oversight by the United Nations Security Council. Freedom from the threat of veto eased the path forward.

There is no requirement in the Statute that Member States make use of the Agency for nuclear supply or otherwise adopt its safeguards. Thus, the Statute, in common with the Atomic Energy Act of 1946, does not explicitly address non-proliferation as a goal. The Statute of the IAEA reflects the tenor of the times. It was presumed that the few nations able to do so would engage in peaceful nuclear cooperation only under controls that would assure its peaceful use. This would diminish rather than enlarge the risk of proliferation by reducing the incentive of countries to develop their own capabilities to produce nuclear material.

3.3 The Missions of the IAEA

Article II of the Statute frames the Agency's missions: the promotion of peaceful uses of nuclear energy, assuring their safety, and assuring their application exclusively for peaceful purposes.⁸⁹ The Statute authorizes the Agency to accomplish these missions through a variety of functions set forth in Article III. In practice, these functions have evolved in ways not clearly foreseen, or indeed foreseeable, when the Statute was drafted. The functions are specified in the following:

- Paragraph A.1 authorizes assistance in research and development (R&D) on peaceful applications. In practice, although the Agency was not expected to and is not funded to perform R&D in any significant way, it does play an active role in bringing together major national and private sector actors through a variety of means, including conferences and seminars, and is an important source of organizing and publishing the results of such cooperation.

The IAEA also manages coordinated research projects that bring together scientists from the most advanced institutes with other scientists, especially

IAEA STATUTE ARTICLE II – OBJECTIVES

"The Agency shall seek to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity" and to "ensure ... that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose"

⁸⁸ The IAEA Statute can be found at <http://www.iaea.org/About/Statute.html>

⁸⁹ As in the case of the U.S. AEC, the combination in the IAEA of the promotional and quasi-regulatory functions (safeguards and nuclear safety) has attracted criticism and suggestions that these be separated by creation of a new agency. While such criticism resulted in dissolution of the AEC, it has not gained traction in the case of the IAEA. The reasons include the fact that, while encouraging the use of nuclear power in appropriate cases, the Agency has been seen to be objective and conservative in exercising its promotional function with respect to nuclear power and sensitive technologies. This reflects to a significant degree the lack of enthusiasm or even opposition of some Member States to nuclear power programs and the view among some major suppliers, including the United States, that the spread of sensitive nuclear technology should be resisted.

from developing countries, to work on different aspects of a common research agenda.

- Paragraph A.2 authorizes the Agency to act as the intermediary in the supply of nuclear material and equipment. As noted earlier, this role has been little used by Member States, but the few cases where it has been called on were of importance.⁹⁰ In 2009, two proposals were adopted for the establishment of a nuclear fuel bank under IAEA supervision. The fuel banks would act as a supplier of last resort of LEU fuel for supply disruptions not based on non-proliferation concerns.⁹¹ In August 2017, the IAEA LEU Bank Storage Facility was formally inaugurated in Ust-Kamenogorsk, Kazakhstan.⁹²
- Paragraph A.3 covers exchange of scientific and technical information. As already noted, this is an especially active area. One mechanism for accomplishing exchange is the International Nuclear Information System (INIS), originated and run by the Agency. INIS is currently the repository of 4.1 million bibliographic records on peaceful uses on nuclear science and technology.⁹³
- Paragraph A.4 authorizes the exchange of experts and training of scientists. Training continues to be a major part of the Agency's Technical Cooperation program, which is focused on developing countries.⁹⁴ This program, which emphasizes applications other than nuclear power, such as the use of isotopes in research and medicine, is largely funded by States' voluntary contributions.
- Paragraph A.5 authorizes the establishment of a safeguards program to verify the peaceful use of nuclear activities. IAEA safeguards, as provided for in Article XII of the Statute, are the focus of this textbook.
- Paragraph A.6 covers the Agency's mission in the area of nuclear health and safety. The Agency participates actively in the development of internationally recognized standards for the conduct of nuclear activities. It provides, on a voluntary basis, expert reviews of the safety of operating nuclear power plants. (The Agency is also authorized in Article XII to include verification of the

⁹⁰ Major nuclear power projects that have been undertaken using the IAEA as an intermediary include the Laguna Verde Nuclear Power Plant in Mexico, the Karachi Nuclear Power Plant in Pakistan, and the Krsko Nuclear Power Plant in Slovenia. In addition, a number of research reactors or their fuel were provided through the IAEA.

⁹¹ In 2009 the IAEA Board of Governors approved a proposal by the Russian Federation to establish a reserve of LEU for supply to IAEA Member States. The IAEA signed an agreement with Russia in 2010 to establish the reserve, which will be located at the International Uranium Enrichment Center in Angarsk, Russia. A proposal by the Nuclear Threat Initiative (NTI) for an IAEA-operated nuclear fuel bank received approval by the IAEA Board of Governors in December 2010. This proposal is supported by a fund of \$125 million and €25 million created through private and governmental contributions, which would be used for purchase of the fuel inventory to be held by the bank. Additionally, Russia and the IAEA have agreed on the establishment of a nuclear fuel bank, with the fuel to be located in Russia.

⁹² See INFCIRC/916, 22 March 2017

⁹³ https://www.iaea.org/sites/default/files/18/03/18-02331_inis-infographic.pdf (Accessed 5 April 2018)

⁹⁴ The IAEA's Technical Cooperation Program is funded through voluntary contributions made by Member States to the Technical Cooperation Fund. The Board of Governors sets a target for contributions to the fund, and Member States are expected to contribute the same percentage of the target that they do to the regular budget of the IAEA. In 2015, the target was €69.8 million, and the IAEA provided assistance to 138 countries. The largest single category of assistance was health. Other major program areas include food and agriculture, nuclear safety, and radioisotope production.

safety of nuclear activities in the on-site inspections that form the core of the safeguards system, but this authority has not been exercised and is unlikely to be implemented in the future.)

- Paragraph A.7 is a catch-all provision authorizing the Agency to acquire or establish facilities of its own in support of its functions. In fact, the IAEA operates near Vienna a modern analytical laboratory devoted to safeguards support and other nuclear science applications, as well as a marine environmental laboratory in Monaco.

Since the IAEA Statute was concluded, new nuclear threats have emerged, especially the threat of nuclear terrorism, which United States President Barack Obama called “one of the greatest threats to global security.” Although not explicitly contained in the IAEA Statute, the international community has turned to the IAEA to provide assistance in reducing this threat, especially to help States reduce the risk that sub-national actors could acquire nuclear or other radioactive material to use for destructive purposes.

Protection against sub-national threats is a national responsibility, and the Agency has no authority to monitor national protection measures. The Agency does play an active role in relevant areas such as physical protection, combating illicit trafficking of nuclear and other radioactive materials, and enhancing nuclear forensics. The primary means to do so is by providing advice and technical support to governments through missions, training, and other forms of technical cooperation. Examples of its work include the development of guidelines for physical protection of nuclear material and facilities;⁹⁵ playing a leading role in the negotiation and adoption of the International Convention on the Physical Protection of Nuclear Material, which covered nuclear material in international transport, and the negotiation of an amendment to the Convention that extended its scope to nuclear material in domestic use.⁹⁶ It also provides a forum for establishing guidelines for best practices in establishing nuclear security programs and in fighting illicit trafficking.

3.4 The Statute’s Safeguards Provisions

The Agency’s safeguards “rights and responsibilities” are established in Article XII of the Statute, but several other articles include provisions relevant to safeguards. Of particular importance is Article III.5, which specifies the three circumstances under which nuclear activities can become subject to IAEA safeguards. These are:

- When the Agency itself provides nuclear assistance, such as nuclear fuel made available to it by a Member State. In this case, safeguards on the assisted project are mandatory.
- At the request of the parties to a bilateral or multilateral arrangement. This route covers the circumstance where assistance such as the supply of nuclear

⁹⁵ The guidelines for physical protection, INFCIRC/225 can be found at www.iaea.org/publications/documents/infcircs/199/infirc225. The Code of Conduct on the Safety and Security of Radioactive Sources is available at <http://www-ns.iaea.org/tech-areas/radiation-safety/code-of-conduct.asp?s=3&l=22>. Although not binding, these guidelines are widely used as the basis for states’ regulations and nuclear cooperation.

⁹⁶ The Convention entered into force in 1987 and had 156 parties as January 2018. The Amendment was adopted in 2005 and entered into force on 8 May 2016.

fuel or equipment is provided by one State to another on the condition that IAEA safeguards will apply. This was the usual circumstance triggering Agency safeguards before adoption of the NPT but is still in use in a few cases, for example, in Pakistan.

- At the request of a State, the IAEA may apply safeguards to any or all of its own nuclear activities. In this fashion, non-nuclear-weapon States parties to the NPT request the IAEA to apply safeguards to all of their peaceful nuclear activities. Likewise, the five NPT nuclear-weapon States (China, France, Russia, the United Kingdom, and the United States) as well as India have voluntarily requested the IAEA to apply safeguards to some or all of their civil nuclear activities under Agency safeguards.

Article XIV specifies the means for financing the Agency's regular budget, the part that is funded from assessments on Member States. The scale of assessments is based on the one used by the United Nations taking into account their differing memberships. Since the founding of the Agency, the U.S. base assessment has been 25% of the total, although its actual share is somewhat larger as a result of a so-called "safeguards shielding formula," which is described in Appendix C.

Although the Statute admits of several possibilities for financing safeguards, the costs of applying safeguards have been funded, to date, under the assessed budget. However, a modified scale of assessments is used for safeguards costs. It reduces the share paid by developing countries in comparison with the remainder of the assessed budget.⁹⁷ The IAEA also receives part of its resources from voluntary contributions by various Member States, and a considerable amount of safeguards-related activities has been funded in this way, although not the actual application of safeguards.⁹⁸

The heart of Article XII is found in paragraph 6, which authorizes the Agency "to send...inspectors...who shall have ***access at all times to all places and data and to any person....***" [Emphasis added.] This unprecedented language is extremely broad. Although common now, on-site inspection by an international organization was unprecedented in 1957. The breadth of the Statute remains unique. Other provisions of Article XII call for the examination of facility design, the maintenance of operating records, and reporting. One provision of particular interest is paragraph 5, which allows for Agency approval of the means of chemical processing "to ensure that it will not lend itself to diversion of materials." Even at this early date, the international community recognized the special problems of safeguarding reprocessing plants. It makes clear, though, that reprocessing was to be allowed if effective safeguards could be applied. While the Agency's approval right has not been exercised, the IAEA has developed and implemented special safeguards measures for reprocessing plants.

⁹⁷ For allocating costs to Member States, the IAEA adopted a formula in 1971 that splits the regular budget into a safeguards and a non-safeguards component. Countries with relatively low levels of gross national product are shielded from paying the full costs of safeguards, which increases the total share of the higher income states. The Board of Governors decided in 2000 on a phase-out of the shielding formula over 25 years. See Appendix C for more detail.

⁹⁸ In 2016, safeguards expenditures totaled €130.7 million in the operational portion of the regular budget and €27.0 million in extrabudgetary expenditures. The latter fund activities such as the development and purchase of safeguards instrumentation, inspector training, and provision of experts.

Article XII includes a phrase that has had an important impact on the development of safeguards. This is the statement that the IAEA's safeguards rights and responsibilities only apply "to the extent relevant" to the project or arrangement. In practice, the safeguards system has evolved in such a way that its very broad statutory authority has been narrowed and constrained.

IAEA STATUTE
ARTICLE XII: AGENCY SAFEGUARDS

A. With respect to any Agency project, or other arrangement where the Agency is requested by the parties concerned to apply safeguards, the Agency shall have the following rights and responsibilities to the extent relevant to the project or arrangement:....

6. To send into the territory of the recipient State ... inspectors ... who shall have access at all times to all places and data and to any person who by reason of his occupation deals with materials, equipment, or facilities which are required by this Statute to be safeguarded, as necessary to account for source and special fissionable materials supplied and fissionable products and to determine whether there is compliance with the undertaking against use in furtherance of any military purpose

Another provision of Article XII could have assumed considerable importance if it had been implemented. It allows the IAEA to require States to deposit with the Agency any special fissionable material that they recover or produce in excess of their current needs. The possible implementation of this provision has been seriously considered in the past, but it proved impossible to reach agreement on several issues, especially the ground rules for the release of the stored material. Article XII also includes other provisions that have never been implemented, for example, the extension of the safeguards system to include assurances of compliance with health and safety standards. While the Agency has been active in the field of health and safety, e.g., in the publication of recommended safety standards, it is generally understood that the establishment and enforcement of health and safety standards, as well as nuclear security, is a national responsibility.

Article XII.C specifies the Agency's response in the event of non-compliance with a safeguards agreement. It includes reporting non-compliance to the United Nations Security Council and, in the event non-compliance is not remedied, suspension of any further assistance. If a State has "persistently violated the Statute or its safeguards agreement, the IAEA can suspend the privileges of IAEA membership."

It is generally understood that IAEA "safeguards" means only the system for verifying compliance or detecting non-compliance with safeguards agreements. Remedial or punitive measures that might follow in the event of non-compliance are not, properly speaking, among the responsibilities of the IAEA. The enforcement of international obligations falls within the mandate of the United Nations Security Council. Nonetheless, in the event of non-compliance with safeguards agreements, it is the responsibility of the IAEA to send to the Security Council a report that might trigger action.

It is also worth noting that even absent a finding of non-compliance, Article III.B.4 of the Statute calls for the IAEA to notify the Security Council if, "in connection [sic] with the activities of the Agency there should arise questions that are within the competence of the Security Council ... as the organ responsible for the maintenance of international peace and security"

This provision authorizes the IAEA to notify the Security Council of activities that might not involve a violation of a safeguards agreement. This could include, for example, discovery of parts of a nuclear-weapon program that did not involve nuclear material.

3.5 Nuclear Supply and IAEA Safeguards

The IAEA Statute gives the Agency the authority to supply nuclear material, equipment or technology. This triggers safeguards if it does so. However, almost all significant nuclear assistance has been supplied bilaterally without the Agency's direct involvement. As described above, before the IAEA safeguards system was developed, nuclear cooperation was initiated with bilateral rather than IAEA safeguards. After 1957, the United States preferred that IAEA safeguards be applied to its assistance when feasible, but in the case of Member States of Euratom it preferred Euratom safeguards. An important reason for this was that other suppliers were entering the international market, and it was essential that their supply arrangements be covered by effective and uniform safeguards. This would not be the case if every supplier applied safeguards itself.

Somewhat surprisingly, the transfer of safeguards responsibility to the IAEA met with resistance from some cooperating countries. They expressed a preference for U.S. safeguards to those of an international organization. According to David Fischer,

... every bilateral partner of the USA, except Japan, at first objected strenuously to the application of IAEA in place of US safeguards, apparently preferring the US inspectors, with whom they were on friendly terms, to the unknown officials of the IAEA who might be nationals of a State with which their relations were strained or hostile. However, many co-operation agreements were coming up for amendment and this, together with the fact that the partner nations still depended on the United States for nuclear supplies, provided the United States with enough leverage to induce them, however reluctantly, to accept the new US policy.⁹⁹

A key test of the new U.S. policy requiring IAEA safeguards for bilateral supply came with the negotiation in 1963 of an Agreement for Cooperation with India for the supply of the Tarapur power reactors and their fuel. Although India strongly favored bilateral safeguards, it agreed to accept IAEA safeguards after certain conditions were met.

The first ad hoc application of safeguards by the IAEA was in Japan in 1959 and that year, the IAEA concluded its first safeguards agreement, both in connection with the supply of natural uranium from Canada to Japan for a small research reactor. The safeguards system developed slowly from then on, only changing in a major way when the NPT came into force.

As the IAEA's safeguards capabilities developed, U.S. Agreements for Cooperation calling only for bilateral safeguards were amended as their terms expired or additional material was needed. This made both past and future bilateral supply subject to Agency safeguards. The Agency's safeguards responsibilities were spelled out in "safeguards transfer agreements" that suspended the inspection rights of the United States while the IAEA was applying safeguards.

⁹⁹ Op. cit. Fischer 1997, p. 250.

Japan's 1963 safeguards agreement was the first based on safeguards principles and procedures agreed by the Board of Governors. They were published in 1961 in INFCIRC/26 and provided a uniform basis for the implementation of safeguards. They covered small research, test, and power reactors. These safeguards principles and procedures were soon extended to cover additional nuclear facilities: first in 1964 to large reactor facilities (INFCIRC/26/Add.1); in 1965 in a revised safeguards system that covered all sizes of nuclear reactors (INFCIRC/66); in 1966 to cover reprocessing plants (INFCIRC/66/Rev.1); and in 1968 to cover fuel fabrication plants (INFCIRC/66/Rev.2).

Most suppliers required IAEA safeguards as a condition of supply, and the number of INFCIRC/66 safeguards agreements grew as nuclear cooperation flourished. A key feature of these safeguards agreements was that safeguards were applied only to: (1) items that were supplied and listed in the safeguards agreement; importantly, (2) the nuclear material produced as a result of the use of these items; and (3) facilities containing these items. The last proviso meant that facilities not covered by a safeguards agreement under the first provision might become subject to safeguards only temporarily – i.e., while they contained nuclear material subject to safeguards, but not otherwise. In any case, there were no requirements in IAEA safeguards agreements that would limit a State's ability to pursue unsafeguarded nuclear activities, including nuclear-weapon programs if they did not make use of items subject to safeguards.¹⁰⁰

Not surprisingly, inspected States were concerned that international civil servants were implementing safeguards. They could learn nuclear technology, provide it to their home States, and allow them to gain a commercial advantage. INFCIRC/66 reflects these concerns through an overall proviso that safeguards be implemented “in a manner designed to avoid hampering a State's economic or technical development” and that inspectors were to “take every precaution to protect commercial and industrial secrets.” As will be seen later, the same concern was expressed during the negotiation of the NPT and was reflected in the safeguards agreements required by the NPT. Interestingly, in the evolution of international safeguards, concerns over the intrusiveness of safeguards diminished in comparison to concerns about the risk and reality of nuclear proliferation. Over time, new and more extensive safeguards measures were adopted.

One effect of the adoption of NPT comprehensive safeguards agreements starting in 1971 was the suspension of existing INFCIRC/66 safeguards agreements and elimination of the need for new ones in non-nuclear-weapons States that are NPT parties. The use of INFCIRC/66 agreements is now limited to States that stand outside the NPT.

The primacy of IAEA safeguards is now established, and the bilateral safeguards of the early years of international cooperation are no longer in effect.¹⁰¹ Nevertheless, the extended period of bilateral safeguards implementation and the special status accorded Euratom safeguards constituted a major issue affecting safeguards development for many years. In the United States,

¹⁰⁰ A good description of how the IAEA safeguards system developed is found in, The Evolution of IAEA Safeguards, International Nuclear Verification Series No. 2, IAEA, Vienna, 1998.

http://www-pub.iaea.org/MTCD/publications/PDF/NVS2_web.pdf

¹⁰¹ Note that the safeguards transfer agreements referred to above suspend U.S. inspection rights only as long as the IAEA is applying safeguards. They do not eliminate them. Similarly, while U.S. Agreements for Cooperation require the application of IAEA safeguards, they also require fall-back safeguards – i.e., in the event the IAEA is unable to apply safeguards, the cooperating partner is required to enter into arrangements with the United States under which the United States is entitled to apply equivalent safeguards.

the reliance on bilateral and Euratom safeguards was often criticized as “undercutting the IAEA,” which, as the critics pointed out, had been established as a result of a U.S. initiative. Elsewhere, especially in the Soviet bloc, the U.S. view that Euratom safeguards were international and not regional was not fully accepted, and the Euratom system was criticized as self-inspection. The role of Euratom safeguards became a key issue in the negotiation of the NPT and threatened for a time to prevent its conclusion.

3.6 Organization of the IAEA

The IAEA is structured into three principal components: the General Conference, the Board of Governors, and the Secretariat.

3.6.1 The IAEA General Conference

Article V of the IAEA Statute established the IAEA General Conference, the annual meeting of the IAEA, which is open to all States that are members of the IAEA (commonly referred to as “Member States”¹⁰²). As specified in the Statute, the General Conference is entrusted with a number of functions, including election of some members of the Board of Governors, approval of new IAEA Member States, approval of the Agency’s budget,¹⁰³ and suspension of a Member State from its rights and privileges of membership.

The General Conference convenes in Vienna each year in the fall. During its early years, the IAEA General Conference served as a principal international forum for discussion of technical nuclear issues among senior officials from States with advancing or advanced nuclear programs. The technical nature of many of the issues addressed both at the General Conference and in the Agency’s day-to-day work helped foster the technical expertise of the IAEA programs and, increasingly, the perception among Member States that it was a specialized international organization.

As IAEA Member States increased in number and diversity, political issues were introduced more often. This complicates the proceedings of the Board of Governors and the General Conference and may make it more difficult to reach agreement on safety, security and safeguards matters. Controversial early issues were South Africa’s apartheid policy and Israel’s 1981 bombing of the Osirak reactor in Iraq. Israel’s status as the only non-NPT party in the Middle East continues to generate political controversy within the General Conference.

3.6.2 The IAEA Board of Governors

Article VI of the IAEA Statute defines the composition and purpose of the Board of Governors. It specifies that the Board “shall have authority to carry out the functions of the Agency in accordance with this Statute....”¹⁰⁴ This ensures the Board serves as the dominant executive body of the IAEA.

¹⁰² The Member States of the IAEA are listed at <https://www.iaea.org/about/governance/list-of-member-states>.

¹⁰³Under Article XIV of the Statute the General Conference cannot change the budget but can make recommendations for changes to the Board of Governors. The Board then submits a revised budget to the General Conference for approval.

¹⁰⁴ Ibid. Article V1.F.

Since creation of the IAEA, the Board has directed the Agency's program and budget to a greater degree than is true in most other international organizations, and it is the Board that addresses issues of non-compliance with safeguards agreements.

Membership on the Board is determined by a complex formula designed to ensure both representation by the most advanced nuclear States and wide geographic distribution. The formula reflects the view that the States significantly advanced in nuclear development would be the principal providers of nuclear material and expertise. It was, therefore, appropriate that they provide considerable program direction for the new Agency. Geographic distribution is ensured by selecting the most advanced States and drawing remaining Board members from each of eight defined geographical regions. Over time the size of the Board increased from 23 seats in 1957 to 35 seats in 2011.¹⁰⁵ Although the formula has been amended, the composition of the Board still reflects the 1957 Cold War distribution of power. As a consequence, Board membership has a heavy concentration of States from North America and Western and Eastern Europe.¹⁰⁶

Each year the outgoing Board designates the thirteen States most advanced in nuclear technology, including mining and uranium production, to serve as members of the next Board.¹⁰⁷ The General Conference elects twenty-two Board members drawn from each of the eight geographic regions for two-year terms.¹⁰⁸

Regular meetings of the Board are typically held in March, June, and in the fall, before and after the General Conference, and in December. Special sessions of the Board can be convened at any time as necessary. Virtually all representatives from Member States serving on the Board hold the rank of Ambassador.

The Board makes most of its decisions and recommendations by consensus. This reflects both the technical character of the IAEA and the long-standing view that the work of the IAEA is strengthened by the support of all its members. A number of political issues, especially dealing with non-compliance with safeguards agreements have required the Board to resort to voting. For

¹⁰⁵ The Statute does not name any state as a Board member nor specify precisely its size. It was expected in 1957 that Canada, France, U.S.A., U.S.S.R., and the United Kingdom would always be on the Board. This has proven to be the case. China and India have been added to this group. The size and composition of the Board is determined by the designation of which States are the most advanced in nuclear technology in each geographic region. Since the development of nuclear energy programs is generally quite slow, the size of the Board has been stable except for amendments to the Statute that have increased its size. Entry into force of a 1999 amendment to Article VI of the IAEA Statute to increase the size of the Board from its current 35 to 44 awaits ratification by the requisite two-thirds of IAEA membership. (As of 7 Jul 2017, 60 of the necessary 112 members had ratified the amendment.)

¹⁰⁶ After the dissolution of the Soviet Union, the association with the West of most states in "Eastern Europe" became strong, even extending to NATO membership. This shifted the balance of political influence within the Board.

¹⁰⁷ According to Article VI of the IAEA Statute, the Board selects the 10 most advanced States worldwide, plus the most advanced in the regions in which none of the ten are located, which now number three. As a result, there are thirteen "permanent" members of the Board: Argentina, Brazil, Australia, Canada, China, France, Germany, India, Japan, Russia, South Africa, United Kingdom, U.S.A. plus one additional State from Western Europe, which rotates. (As a matter of practice, Argentina and Brazil alternate as one of the 10 most advanced States. The other is always elected to the Board.) The current membership of the Board of Governors is listed at <https://www.iaea.org/about/governance/board-of-governors>

¹⁰⁸ Board membership, in practice, results from selection of candidates by regional groups since their recommendations are with rare exceptions endorsed by the Board and the General Conference.

example, the Board of Governors addressed for some time non-compliance issues in Iran and Syria, each of which proved to be very controversial.

Turmoil in Syria has made it infeasible for the IAEA to address safeguards issues there actively. In Iran, the conclusion of the “Joint Cooperative Programme of Action” in 2015 and concurrent resolutions adopted by the IAEA Board of Governors and the United Nations Security Council led to a request to the IAEA to monitor and verify non-proliferation commitments under the JCPOA. This will be described in some detail in Chapter 9.

3.6.3 The IAEA Secretariat

Article VII of the IAEA Statute outlines the characteristics of the Agency’s staff, referred to as the Secretariat. The overall head of the Secretariat is the Director General. The Director General is “the chief administrative officer of the Agency”¹⁰⁹ and serves as principal liaison between the Secretariat and the Board. The Director General is appointed by the Board of Governors and approved by the General Conference to serve a four-year term with the option of subsequent terms. The Director General is “responsible for the appointment, organization, and functioning of the staff and shall be under the authority of and subject to the control of the Board of Governors.”¹¹⁰

Since 1957, there have been five Directors General. Former U.S. Congressman W. Sterling Cole served as the first Director General from 1957 to 1961. Cole’s appointment reflected the major role played by the United States in creating the IAEA. Thereafter, a general understanding prevailed among IAEA members that no future Director General should come from a nuclear-weapon State. From 1961 to 1981, Swedish scientist Dr. Sigvard Eklund held this post, followed by Dr. Hans Blix, a former Swedish Foreign Minister, who served from 1981 to 1997. Dr. Mohamed ElBaradei of Egypt replaced Dr. Blix in 1997 and served until November 2009. Mr. Yukiya Amano from Japan assumed this post in December 2009. He was re-appointed in 2013 and, then again, in 2017 to four-year terms. His present term will end in November 2021.

The work of the Secretariat is divided into six major Departments: Nuclear Science and Applications; Technical Cooperation; Nuclear Safety and Security; Nuclear Energy; Safeguards; and Management. To some degree selection of staff over time has been guided by informal understandings among Member States about the staffing of certain key positions. For example, a

IAEA STATUTE ARTICLE VII STAFF

C. The staff shall include such qualified scientific and technical and other personnel as may be required to fulfill the objectives and functions of the Agency. The Agency shall be guided by the principle that its permanent staff shall be kept to a minimum.

D. The paramount consideration in the recruitment and employment of the staff and in the determination of the conditions of service shall be to secure employees of the highest standards of efficiency, technical competence, and integrity. Subject to this consideration, due regard shall be paid to the contributions of members to the Agency and to the importance of recruiting the staff on as wide a geographical basis as possible.

¹⁰⁹ IAEA Statute, Article VI1.A.

¹¹⁰ IAEA Statute, Article VI1.B.

U.S. citizen has always held the position of Deputy Director General (DDG) for Management. For many years the Budget Director was also an American. A citizen of the Russian Federation (formerly of the Soviet Union) has always been the DDG for Nuclear Energy. There continues to be support for selecting the DDG for Safeguards from a non-nuclear-weapon State that is seen as impartial and neutral and that has a safeguarded nuclear program. The latter is important to some States because they believe that it makes the DDG for Safeguards sensitive to the burden of safeguards;¹¹¹ the current DDG is from Finland. The DDG for Nuclear Science and Applications is from Brazil; the DDG for Technical Cooperation is from China; and the DDG for Nuclear Safety and Security is from Spain.

In recognition of the importance of its work, the IAEA received the Nobel Peace Prize in 2005. The Norwegian Nobel Committee awarded the Prize in two equal shares – one to the IAEA Secretariat and one to the Director General, Dr. Mohamed ElBaradei. It was awarded for their work “to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way.”¹¹²

¹¹¹ The text refers frequently to the “burden of safeguards” or their intrusiveness. In the context in which it is used, the negative implications of these word choices reflect the concerns of non-nuclear weapon States about loss of competitive status and the degree of discrimination between non-nuclear-weapon states and nuclear-weapon states. Not all States share this view. They consider that safeguards, voluntarily entered into, provide benefits to non-nuclear weapon States because they provide assurance to others of a state’s peaceful intentions and, thereby, facilitate nuclear cooperation and promote regional and international security.

¹¹² http://www.nobelprize.org/nobel_prizes/peace/laureates/2005.

CHAPTER 4. THE NUCLEAR NON-PROLIFERATION TREATY

By the 1960s, the international political landscape was becoming more complex. Many States were increasingly aware of the danger that would result if additional countries acquired nuclear weapons. Momentum began to build in the United Nations for negotiation of a treaty to prevent nuclear proliferation.

In the first half of the 1960s, there were notable tensions between the U.S.-led Western Bloc of States and the Soviet Union-led Eastern Bloc. These Cold War tensions were fueled by many events, including notably the aborted four-power summit meeting in Paris in 1960,¹¹³ the Bay of Pigs debacle, construction of the Berlin Wall in 1961, and the Cuban missile crisis in 1962.

Adding to the complexity of nuclear proliferation issues and East-West relations was the U.S. proposal in the North Atlantic Treaty Organization (NATO) to create a multilateral nuclear force, whereby ships capable of carrying nuclear weapons would have a NATO crew. This was a response to Allied concerns that NATO nuclear policy was essentially in the hands of the United States. Although the proposal was never adopted by NATO, in 1964 it experimented with a mixed NATO crew on a cruiser with nuclear-weapon capability.

The Soviet Union was highly critical of any possibility that NATO countries could gain some measure of control over nuclear weapons, a concept known as “nuclear sharing.” Soviet officials were particularly concerned about the prospect that the Federal Republic of Germany would control nuclear weapons. While Germany had been soundly defeated in World War II, Soviet leaders still perceived Germany as a threat to Soviet national security.

By the mid-1960s, the international community had been addressing the proliferation threat principally through dialogue at the United Nations. Starting in 1958 however, Ireland introduced annual resolutions in the First Committee of the United Nations General Assembly (which deals with nuclear arms control and proliferation issues). Until 1961, Ireland’s resolutions did not attract sufficient support to prompt action. While the resolutions of 1959 and 1960 passed the General Assembly, several important countries, including the United States, France, and the Soviet Union, abstained on one or the other resolution.

UNGA RESOLUTION 1665(XVI)

The General Assembly,

... Calls upon all States, and in particular upon the States at present possessing nuclear weapons, to use their best endeavors to secure the conclusion of an international agreement containing provisions under which the nuclear States would undertake to refrain from relinquishing control of nuclear weapons and refrain from transmitting the information necessary for the manufacture to States not possessing such weapons, and provisions under which States not possessing nuclear weapons would undertake not to manufacture or otherwise acquire control of such weapons.

¹¹³ The Soviet Union shot down a U.S. U-2 spy plane near Sverdlovsk on May 1, 1960. At a Four-Power Summit in Paris (France, the United States, the United Kingdom, and the U.S.S.R.) two weeks later, President Eisenhower refused Premier Khrushchev's demand for an apology, and the Soviet Union walked out of the Summit.

However, on December 4, 1961, the General Assembly adopted a revised Irish Resolution unanimously as Resolution 1665(XVI).¹¹⁴

The principal element in the 1961 Resolution called for conclusion of an international agreement under which States with nuclear weapons would refrain from relinquishing control over these weapons and would not transfer information necessary for their manufacture. States not possessing nuclear weapons would not manufacture or otherwise gain control of nuclear weapons. Missing from the 1961 Resolution was any mention of disarmament, nuclear-weapon-free zones, or peaceful uses of nuclear energy.¹¹⁵

The Eighteen-Nation Committee on Disarmament (ENCD) was established in late 1961, and for the next several years, the members of the ENCD discussed the topics raised by the Irish Resolution. Much of the energy of the ENCD was directed toward reduction or elimination of nuclear testing, resulting in conclusion of the Limited Test Ban Treaty in 1963.^{116,117}

4.1 The Negotiation of the NPT

Negotiations on the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) began in earnest in 1965 when both the United States and the Soviet Union presented draft treaties.

Several non-aligned members of the ENCD, the United Arab Republic (Egypt and Syria) in particular, wanted negotiations to follow agreed principles. They introduced a United Nations General Assembly resolution to that effect. General Assembly Resolution 2028 (XX) laid out the basis for a treaty.¹¹⁸

The “Five Principles,” as they were called, specified that:

- The treaty should be “void of any loopholes” that might permit proliferation.
- The treaty should have “an acceptable balance of mutual responsibilities and obligations of the nuclear and non-nuclear powers.”

¹¹⁴ Mohamed L. Shaker, *The Nuclear Non-Proliferation Treaty: Origin and Implementation 1959-1979*, pp. 3-33. UNGA Resolution 1665(XVI), December 4, 1961. (See also, UNGA Resolution 1252D (XII), November 4, 1958; UNGA Resolution 1380(XIV), November 20, 1959; UNGA Resolution 1576(XV), December 20, 1960.)

¹¹⁵ UNGA Resolution 1665(XVI), Prevention of the wider dissemination of nuclear weapons, December 4, 1961. <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/167/18/IMG/NR016718.pdf?OpenElement>.

¹¹⁶ UNGA Resolution 1722(XVI), Question of disarmament, December 20, 1961. <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/167/75/IMG/NR016775.pdf?OpenElement>. The ENCD was created from the membership of a previous body, the Ten-Nation Committee on Disarmament, which was established in 1959. The Ten-Nation Committee was essentially an East-West committee, consisting of the Soviet Union, Bulgaria, Czechoslovakia, Poland, Romania, the United States, Canada, Italy, Britain, and France. To this group of ten, eight new members were added to form the Eighteen-Nation Disarmament Committee: Brazil, Burma, Ethiopia, India, Mexico, Nigeria, Sweden and the United Arab Republic (Egypt and Syria). France refused to participate, explaining that it would join in discussions aimed at nuclear disarmament only with other nuclear powers. Notwithstanding its non-participation, a seat was always held for France.

¹¹⁷ The Limited Test Ban Treaty prohibits nuclear weapon tests “or any other nuclear explosion” in the atmosphere, in outer space, and under water. While not banning underground nuclear explosions, they are prohibited if they lead to radioactive debris to be present outside the borders of the state conducting the explosion.

¹¹⁸ UNGA Resolution A/RES/2028(XX), November 19, 1965. See <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/217/91/IMG/NR021791.pdf?OpenElement>.

- The treaty should be a step toward “general and complete disarmament and, more particularly, nuclear disarmament.”
- There should be “acceptable and workable” measures to assure effectiveness of the treaty.
- Regional treaties establishing nuclear-weapon-free zones (NWFZs) should be permitted.

These principles made the scope of negotiations of the NPT noticeably broader than the 1961 Irish Resolution. Disarmament and NWFZs now became elements to be included in the treaty. Resolution 2028 omitted any mention of peaceful uses of nuclear energy. That element emerged during the negotiations.

The following discussion outlines several of the more difficult issues in the negotiations.¹¹⁹

4.1.1 Stationing

Although the negotiators generally agreed that nuclear-weapon States should not share materials and technology with non-nuclear-weapon States, the Soviet Union also favored a prohibition of stationing nuclear weapons on the territories of non-nuclear-weapon States. Eventually, the Soviet Union agreed to the formulation now in Article I of the Treaty: that nuclear-weapon States agree not to transfer nuclear weapons or control over such weapons to non-nuclear-weapon States.¹²⁰ The corollary commitment by non-nuclear-weapon States in Article II is that they will not receive the transfer of nuclear weapons or seek to acquire such weapons.¹²¹

4.1.2 Safeguards

By far, the most difficult issue in negotiations was that of safeguards. In fact, the first Soviet draft of the Treaty in 1965 included no provision for safeguards. Broadly stated, there were two overriding questions:

- (1) Which parties would be required to have safeguards? All Treaty parties or only non-nuclear-weapon States; and
- (2) Which organization or organizations should apply safeguards?

The two leading candidates to apply safeguards were the IAEA and, for its members, the Euratom, which at that time had six Member States (France, Germany, Italy, the Netherlands, Belgium, and Luxembourg).

¹¹⁹ The George Washington University “Nuclear Vault” contains declassified U.S. documents generated during the negotiation of the NPT that relate to many of the issues below.

See <http://www.gwu.edu/~nsarchiv/nukevault/ebb253/index.htm> (December 2, 2011). Of particular interest is a 1968 policy memorandum from William C. Foster to the Secretary of State’s Special Assistant arguing why it was in the interest of the United States to ratify the NPT at an early time. It addresses many of the issues discussed in Sections 4.2. See <http://www.gwu.edu/~nsarchiv/nukevault/ebb253/index.htm>.

¹²⁰ The concerns of the Soviet Union were strongly motivated by the stationing of nuclear weapons in Europe by the United States in the context of NATO.

¹²¹ Op. cit. Shaker, pp. 97-106.

Who is to be subject to safeguards?

On the first question, nuclear-weapon States asserted that safeguards were unnecessary for them because they were hardly likely to divert fissile material from peaceful purposes to weapons production when they openly acknowledged that they were manufacturing nuclear weapons in facilities designed specifically for that purpose. In such a situation, requiring nuclear-weapon States to have safeguards would squander scarce resources. On the other hand, many non-nuclear-weapon States, including some NATO members, believed that safeguards would be a burden and were not happy with the prospect that the nuclear-weapon States might be left off the hook entirely. To assuage the concerns of these countries, especially Germany, which was engaged in establishing a major nuclear industry, the United States, soon followed by Britain, pledged that once a nuclear non-proliferation treaty was in force, it would voluntarily conclude a safeguards agreement with the IAEA that would cover essentially all of its peaceful nuclear facilities.^{122,123}

Who is to apply safeguards?

The second question was the more difficult. To Euratom Member States, the viability of Euratom was seen as critical to the process of integrating the six Member States economically and politically. Moreover, Euratom had already established its own safeguards system. Taking away this responsibility would undermine the viability of Euratom. It would have been difficult for the United States not to be sensitive to these arguments. All Euratom members were important allies of the United States, and the United States had long supported European economic and political integration.

The Soviet Union had a different view. At that time, it was deeply suspicious of European integration. Moreover, the Soviet Union contended that Euratom safeguards would simply be a form of self-regulation. Soviet opposition to Euratom safeguards was intensified by the fact that Germany was a member of Euratom.¹²⁴

To find a way to break the impasse, an experts group addressed the issue. It was headed by lawyers, George Bunn on the U.S. side and Alexey Roschin on the Soviet side. They agreed on a draft, which was sent back to Washington and Moscow for approval by their governments. It is now incorporated into Article III, paragraph 4 of the NPT, which states that NPT non-nuclear-weapon States parties shall conclude safeguards agreements with the IAEA “either individually or with other States.” Thus, the IAEA was designated by the Treaty as the sole agency responsible for safeguards, but Euratom was given an implied and subordinate role. This outcome also satisfied the ENCD members who insisted that only one organization be responsible for safeguards.¹²⁵

¹²² Ibid., p. 657.

¹²³ The United Kingdom and the United States subsequently concluded safeguards agreement with the IAEA, as did the other three NPT nuclear-weapon states, China, France, and Russia. These agreements, now known as “voluntary-offer agreements” are described in Appendix D.

¹²⁴ Op. cit. Shaker, pp. 107-108.

¹²⁵ Glenn Seaborg with Benjamin S. Loeb, *Stemming the Tide: Arms Control in the Johnson Years*, pp. 293-294 and 299-302. Also, Shaker, pp. 695-697.

4.1.3 Disarmament and arms control

UN General Assembly Resolution 2028 articulated the principle that the “treaty should be a step toward the achievement of general and complete disarmament and, more particularly, nuclear disarmament.” This is reflected in Article VI’s requirement that, “Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control.”

4.1.4 Peaceful uses of nuclear energy and NPT duration

The inclusion of peaceful uses came relatively late in the negotiations. The initial U.S. and Soviet drafts did not include a provision for peaceful uses, and UN General Assembly Resolution 2028 did not identify peaceful uses as a principle upon which the Treaty was to be negotiated. As negotiations proceeded, it became clear that many non-nuclear-weapon States, especially among the developing countries, were unlikely to support a treaty without an acknowledgement of their right to develop peaceful uses of nuclear energy.

4.1.5 Duration of the NPT

The duration of treaties is normally not an issue in most treaty negotiations. Almost all nuclear non-proliferation-related treaties (and others) have an indefinite duration. Nonetheless, reaching agreement on this issue proved difficult in the case of the NPT. The Soviet Union, the United Kingdom, and the United States favored indefinite duration for the NPT. They were concerned that if the Treaty had a fixed duration, afterwards there would be great uncertainty whether the ethos of non-proliferation would be maintained. On the other hand, some States argued that to “subscribe to an indefinite commitment” seemed hardly conceivable in a field where development was as rapid and unpredictable as nuclear science and its technical, economic, political and military implications.¹²⁶

Final agreement on duration (Article X.2) was reached quite late in the negotiations. It stipulates an initial duration of 25 years, with the Parties to convene a conference 25 years after the entry into force of the NPT in order to decide whether to extend the Treaty indefinitely or for a fixed period or periods.¹²⁷ The entry into force occurred in 1970 and the conference called for by Article X.2 took place in 1995, the same year as the 5th NPT Review Conference. The Parties decided to combine them into one conference, the 1995 Review and Extension Conference.

¹²⁶ Op. cit. Shaker, Vol. II, pp. 859-866.

¹²⁷ Article X.2 reads, “Twenty-five years after the entry into force of the Treaty [1970], a conference shall be convened to decide whether the Treaty shall continue in force indefinitely or shall be extended for additional fixed period or periods. This decision shall be taken by a majority of the Parties to the Treaty.”

4.1.6 Other issues

A number of other issues attracted considerable attention during the negotiation of the NPT. One of particular interest to non-nuclear-weapon States was the assurance that having renounced the



(Photo: Courtesy of Lyndon B. Johnson
Presidential Library, at
<http://www.gwu.edu/~nsarchiv/nukevault/ebb253/index.htm>)

Figure 10. President Lyndon Johnson looking on as Secretary of State Dean Rusk prepares to sign the NPT, 1 July 1968

acquisition of nuclear weapons, they would not be subject to nuclear threats or attacks. Such an assurance is called a “negative security assurance” (as opposed to an assurance of assistance in case of a nuclear attack, which is called a “positive security assurance”). The principal impediment to agreement was that the United States and the Soviet Union did not want to give blanket negative security assurances to all NPT non-nuclear-weapon States. The United States did not want to include, for example, members of the Warsaw Pact who might act in concert with the Soviet Union in an attack. The Soviet Union, in turn, did not want to include members of NATO who had nuclear weapons stationed on their territories. Since they could not agree, there is no provision in the Treaty for negative security assurances.

Other provisions included:

- Article VIII, an extremely challenging procedure for amendment (agreement required from a majority of the parties, all nuclear-weapon States, and all members of the IAEA Board of Governors);
- Article VII, encouragement of NWFZs; and Article V, delineating conditions for nuclear explosions for peaceful purposes.

No State has conducted a peaceful nuclear explosion for decades, and the NPT provision for making their potential benefits available to non-nuclear-weapon States has never been exercised.^{128,129}

The Treaty was opened for signature July 1, 1968 (see Figure 10) and entered into force March 5, 1970.¹³⁰ The United States, the United Kingdom, and the Soviet Union (now Russia) became parties to the Treaty upon entry into force and also serve as depositary governments. France and

¹²⁸ The United States has not conducted a peaceful nuclear explosion since 1973. See U.S. Information Pertaining to the Treaty on the Non-Proliferation of Nuclear Weapons, 2010 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT/CONF.2010/45). If asked, U.S. representatives would generally respond that they see no “potential benefits.” The Soviet Union conducted 122 nuclear tests for peaceful purposes between 1965 and 1989, when it declared a moratorium on nuclear testing. An excellent overview of both U.S. and Soviet peaceful nuclear test program is in The Soviet Program for Peaceful Uses of Nuclear Explosions, M. D. Nordyke, UCRL-ID-124410 Rev 2, September 1, 2000. <https://e-reports-ext.llnl.gov/pdf/238468.pdf>

¹²⁹ A good review of the history of U.S. nuclear-fuel-cycle controls is in the draft Nonproliferation Impact Assessment for the Global Nuclear Energy Partnership, National Nuclear Security Administration, Office of Nonproliferation and International Security. December 2008.

http://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/GNEP_NPIA.pdf

¹³⁰ The full text of the Treaty may be found at <http://www.un.org/en/conf/npt/2005/npttreaty.html>.

China did not participate in NPT negotiations and did not become parties until 1992. As noted above, the Treaty currently has 190 parties and is the most widely adhered-to arms control treaty in history. Membership in the Treaty is nearly universal – only four States stand outside the Treaty, the DPRK, India, Israel, and Pakistan.

4.2 The NPT: Legal Commitments

The three key objectives that emerged during negotiations -- preventing the spread of nuclear weapons, encouraging peaceful nuclear cooperation, and promoting nuclear arms control and disarmament, are frequently referred to as the “Three Pillars” of the NPT.

4.2.1 Non-proliferation – The first pillar

The NPT codifies two classes of States. It specifies that, “For the purposes of this Treaty, a nuclear-weapon State is one which has manufactured and exploded a nuclear weapon or other nuclear explosive device prior to January 1, 1967.”¹³¹

Five States, the permanent members of the United Nations Security Council, meet this definition: the United States (1945), the Soviet Union (1949), the United Kingdom (1952), France (1960) and China (1964). These are the five States recognized today under the NPT as “nuclear-weapon States.”¹³²

Under the Treaty all other States are deemed to be “non-nuclear-weapon States.” The NPT does not have a provision for admitting other States into the ranks of the nuclear-weapon States; such a provision would defeat the purpose of the Treaty. From the very beginning, the NPT embodied an inherent tension between those States with nuclear weapons (“the haves”) and those without such weapons (“the have-nots”).

Articles I and II

Articles I and II of the NPT spell out reciprocal non-proliferation obligations for both nuclear-weapon States and non-nuclear-weapon States. Under Article I, the nuclear-weapon States agree “not to transfer to

NPT ARTICLE I

Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

NPT ARTICLE II

Each non-nuclear-weapon State Party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices.

¹³¹ Treaty on the Non-Proliferation of Nuclear Weapons, Article IX.3

¹³² In October 1971 in Resolution 2758, the United Nations General Assembly replaced the Nationalist Republic of China (Taiwan) (ROC) with the Communist People's Republic of China (PRC) and recognized the latter as one of the five permanent members of the Security Council.

any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such...devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons....”

Under Article II, the non-nuclear-weapon States agree not to “receive,” “manufacture,” “or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices.”

The criteria for compliance with Articles I and II are not specified in the NPT. Compliance with Article I has not been a significant issue, although it has been asserted that Article I is violated by “nuclear sharing” arrangements made within NATO with respect to U.S. nuclear weapons stationed in Europe.¹³³

Article II compliance is a more salient issue, raising the question of when a non-nuclear-weapon State has crossed the lines drawn: What does manufacture a nuclear explosive device mean? Is it when an entire device is manufactured? Or components of one? Is nuclear-weapon R&D prohibited? What does it mean to seek assistance in the manufacture of nuclear weapons? Does this include, for example, means to produce weapon-grade nuclear material via enrichment or reprocessing?

The views of the United States on these questions were expressed during remarks by William Foster, then the Director of the U.S. Arms Control and Disarmament Agency, when he testified before the Senate Foreign Relations Committee in connection with the ratification of the NPT in 1968. His remarks included the following:

While the general intent of this provision seems clear, and its application to cases such as those discussed below should present little difficulty, the United States believes [sic] it is not possible at this time to formulate a comprehensive definition or interpretation. There are many hypothetical situations which might be imagined, and it is doubtful that any general definition or interpretation, unrelated to specific fact situations could satisfactorily deal with all such situations.

Some general observations can be made with respect to the question of whether or not a specific activity constitutes prohibited manufacture under the proposed treaty. For example, facts indicating that the purpose of a particular activity was the acquisition of a nuclear explosive device would tend to show non-compliance. (Thus, the construction of an experimental or prototype nuclear explosive device would be covered by the term ‘manufacture’ as would be the production of components which could only have relevance to a nuclear explosive device.) Again, while the placing of a particular activity under safeguards would not, in and of itself, settle the question of whether that activity was in compliance with the treaty, it would of course be helpful in allaying any suspicion of non-compliance.

It may be useful to point out, for illustrative purposes, several activities which the United States would not consider per se to be violations of the prohibitions in

¹³³ For example, see The Origins of the NPT and NATO’s Nuclear Sharing Arrangements, William Alberque, 2017. (https://www.ifri.org/sites/default/files/atoms/files/alberque_npt_origins_nato_nuclear_2017.pdf, (accessed March 2018)

Article II. Neither uranium enrichment nor the stockpiling of fissionable material in connection with a peaceful program would violate Article II so long as these activities were safeguarded under Article III. Also, clearly permitted would be the development, under safeguards, of plutonium fueled power reactors, including research on the properties of metallic plutonium, nor would Article II interfere with the development or use of fast breeder reactors under safeguards.¹³⁴

NPT
ARTICLE III

1. Each Non-nuclear-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 fulfilment 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.

Article III

Between 1961 and 1970 there was a gradual but steady expansion in the scope and methodology of the safeguards system. The entry-into-force of the NPT in March 1970 changed this quickly. Under Article III.1 of the Treaty, non-nuclear-weapon States agreed to accept “comprehensive” safeguards that obligated the Agency to apply safeguards to all nuclear material and all nuclear facilities in a State. This comprehensive approach replaced the piecemeal approach of INFCIRC/66 agreements where safeguards were only applied to specifically designated items.

The comprehensive scope of NPT safeguards and their purpose are set forth in Article III.1. It did not escape notice that Article III of the NPT obligates only the non-nuclear-weapon States to accept comprehensive safeguards. As noted earlier, during negotiation of the Treaty many non-nuclear-weapon States objected strongly to the “safeguards burden” imposed on them because the nuclear-weapon States were entirely exempt from it.

In response to this concern the United States offered to make peaceful nuclear facilities in the United States eligible for IAEA safeguards, and the U.S. offer was soon followed by a similar offer from the United Kingdom.

The U.S. offer allowed safeguards to be applied to all of its nuclear facilities except only those “facilities

associated with activities with direct national security significance to the United States.” This offer was intended to level the nuclear industrial playing field by subjecting the U.S. nuclear industry to the same safeguards conditions as in NPT non-nuclear-weapon States. This would equalize the financial, technical and political costs of safeguards between nuclear-weapon States and non-nuclear-weapon States. For its part, the United States expected its offer to encourage States to join the NPT. In order to conserve resources but still meet the intent of the offer, it was expected that

¹³⁴ From <http://totalwonkerr.com/1774/foster-criteria>.

safeguards would be applied to U.S. facilities engaged in international competition and to power reactors with advanced designs. Over time the five NPT nuclear-weapon States (China, France, the Russia, Federation, the United States and the United Kingdom) accepted IAEA safeguards on parts of their nuclear programs. These offers, known as “voluntary-offer” safeguards agreements reinforce the perception that international safeguards serve the security of all States, and that all States should support safeguards. Since virtually all States are parties to the NPT and the States outside the NPT are unlikely to join, the encouragement to join the NPT that voluntary-offer safeguards once had has certainly become dormant. Voluntary-offer safeguards agreements are discussed in Appendix D.

4.2.2 Peaceful nuclear cooperation – The second pillar

Article IV

Balancing the constraints defined in Articles II and III on non-nuclear-weapon States, Article IV of the NPT makes clear that all States parties to the Treaty have an equal right to pursue peaceful nuclear development. Article IV.1 specifies that,

Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination....

The Article makes clear, though, that peaceful nuclear development must be pursued “in conformity with Articles I and II of this Treaty.” To comply with the NPT, it must also be pursued in conformance with Article III.

Article IV.2 adds to the emphasis in Article IV.1 on the right of States to pursue peaceful nuclear programs. It calls for other States to facilitate and assist these pursuits when they are in a position to do so.

The extent and nature of peaceful nuclear cooperation envisaged under Article IV have been a source of considerable, and at times acrimonious, debate among NPT parties. Nuclear cooperation and assistance, covering more than nuclear-fuel-cycle activities, are now widespread (as examples, Figure 11 shows a cancer patient receiving radiation treatment in May 2003 from a cobalt therapy unit at Kandy General Hospital in Sri Lanka and Figure 12 shows a field of a hardy variety of rice developed using

**NPT
ARTICLE IV**

1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty.

2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.



(Petr Pavlicek/IAEA)

Figure 11. Cancer patient receiving radiation treatment



(Lothar Wedekind/IAEA)

Figure 12. Field of a hardy variety of rice

radiation technology at the Institute of Agricultural Genetics in Hanoi with the IAEA's support). As of the end of 2016, 146 countries were receiving support through the IAEA¹³⁵. The United States alone has nuclear cooperation agreements with nearly 50 countries. However, the nuclear non-proliferation regime includes numerous elements whose intention is to ensure that nuclear cooperation takes place only under sound non-proliferation conditions. This includes the requirements of the NSG and national export control arrangements.

Of particular concern to developing countries are efforts to curtail the spread of technology and equipment considered to be sensitive by nuclear suppliers, especially uranium enrichment and reprocessing technologies, but also including heavy water production and plutonium fuel fabrication technology. The NSG Guidelines (see Section 4.4) incorporate a provision calling for suppliers to show restraint in the transfer of sensitive technology, as well as special controls on sensitive exports and special arrangements for export of enrichment facilities.¹³⁶

In the United States, there is a long history of efforts to control the spread of sensitive technology. For example, U.S. efforts led to the cancellation of sales of uranium enrichment and reprocessing technology in the 1970s to Pakistan and Brazil. In addition, the U.S. Congress enacted laws at that time calling for sanctions in certain circumstances in the event of the transfer of uranium enrichment or reprocessing technology.¹³⁷

In 2004, President George W. Bush proposed that “the members of the Nuclear Suppliers Group ensure that States which renounce enrichment and reprocessing technologies have reliable access, at reasonable cost, to fuel for civilian reactors” and that the “40 States in the Nuclear Suppliers Group should refuse to sell uranium enrichment or reprocessing equipment or technology to any State that does not already possess full-scale, functioning enrichment or reprocessing plants.”¹³⁸

¹³⁵ IAEA Annual Report 2016, available at <https://www.iaea.org/publications/reports> (Accessed 6 April 2018)

¹³⁶ The NSG Guidelines can be reached through the web-site of the NSG at <http://www.nuclearsuppliersgroup.org/en/guidelines> (accessed 3 Mar 2018)

¹³⁷ U.S. law also provides for sanctions in many other circumstances as well, for example, testing a nuclear weapon or violating a safeguards agreement. A useful summary of U.S. sanctions legislation related to all WMD and missiles can be found in Nuclear, Biological, Chemical, and Missile Proliferation Sanctions: Selected Current Law, Congressional Research Service, Dianne E. Rennack, November 30, 2010 at <http://www.fas.org/sgp/crs/nuke/RL31502.pdf>.

¹³⁸ See The White House, "President Announces New Measures to Counter the Threat of WMD," Fact Sheet, February 11, 2004, <http://georgewbush-whitehouse.archives.gov/news/releases/2004/02/20040211-5.html>.

The recognition that enrichment and reprocessing technologies are sensitive is not limited to nuclear supplier States. For example, former IAEA Director General ElBaradei told a group of experts assembled to review multinational approaches to the nuclear fuel cycle that, “Given the emerging threats to the nuclear non-proliferation regime, it is time to consider possible multilateral approaches to better control sensitive parts of the nuclear fuel cycle – that is, uranium enrichment and plutonium separation.”¹³⁹ This meeting was a follow-up to his statement to the 2003 IAEA General Conference that “wide dissemination of the most proliferation sensitive parts of the nuclear fuel cycle could be the Achilles heel of the nuclear non-proliferation regime.”¹⁴⁰

On the other hand, many States, particularly developing countries, are acutely sensitive to any actions or policies by nuclear supplier States that are perceived to curtail or limit peaceful nuclear cooperation, especially in the area of sensitive technology.¹⁴¹ The working paper by the Non-Aligned Movement¹⁴² submitted to the 2015 NPT Review Conference makes this clear.¹⁴³ It stated that:

In that context, the Group of Non-Aligned States Parties to the Treaty rejects, in principle, any attempt aimed at discouraging certain peaceful nuclear activities on the grounds of their alleged “sensitivity”. The Group further underlines that concerns related to nuclear proliferation shall not, in any way, restrict the inalienable right of any State party to develop all aspects of nuclear science and technology for peaceful purposes, without discrimination, as stipulated in article IV of the Treaty. In that regard, the Group expresses its concern that some States parties have set conditions such as concluding and bringing into force an additional protocol on nuclear exports in contravention of article IV of the Treaty and calls upon those States parties to promptly remove any such condition.

¹³⁹ Multilateral fuel cycle approaches are discussed in Multilateral Nuclear Fuel-Cycle Arrangements, Harald Müller, Paper No. 35 commissioned by the Weapons of Mass Destruction Commission (Website: www.wmdcommission.org). At <http://www.blixassociates.com/wp-content/uploads/2011/03/>. (March 15, 2012).

¹⁴⁰ See <http://www.iaea.org/newscenter/news/2004/bettercontrols.html>.

¹⁴¹ Nuclear Technical Cooperation: A Right or a Privilege? Jack Boureston and Jennifer Lacey. Arms Control Today. September 2007. http://www.armscontrol.org/act/2007_09/NuclearCoopFeature (March 15, 2012).

¹⁴² The Non-Aligned Movement is an informal association of states that meet periodically at the level of heads of state. It was originally created in 1961 as a counter to the Cold War blocs, and, as its name suggests, its membership consisted of states outside the two power blocs. It is intended to give a voice to the collective view of its members, which by and large, consist of less developed countries that are not closely aligned with or allied to the United States or Russia. Its membership and the texts of its declarations may be found at <http://www.nam.gov.za/background/members.htm>.

¹⁴³ The inalienable right to develop research, production and uses of nuclear energy for peaceful purposes. Working paper submitted by the Group of Non-Aligned States Parties to the Treaty on the Non-Proliferation of Nuclear Weapons , NPT/CONF.2015/WP.5 (http://www.un.org/en/ga/search/view_doc.asp?symbol=NPT/CONF.2015/WP.5. (accessed March 2018)

4.2.3 Nuclear disarmament – The third pillar

Article VI

Article VI of the NPT encapsulates the view of many non-nuclear-weapon States that those States with nuclear weapons should take steps to rid themselves of these weapons. Under Article VI,

Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to the cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control.

The language of Article VI is general and does not stipulate how the nuclear-weapon States should pursue nuclear disarmament. Still, many non-nuclear-weapon States are critical of the nuclear-weapon States because they consider that the steps taken by the nuclear-weapon States to move toward nuclear disarmament are both grudging and inadequate. In NPT review conferences, the issue of nuclear disarmament is often the most contentious.

There is a growing body of statements and documents that highlight the salience of Article VI issues in the international community. For example:

- I. “Principles and Objectives for Nuclear Non-Proliferation and Disarmament,” one of the three decision documents adopted by the 1995 NPT Review and Extension Conference, includes a number of specific targets for nuclear disarmament.¹⁴⁴
- II. Responding to a 1994 United Nations General Assembly resolution, the International Court of Justice issued several advisory opinions on the legality of nuclear weapons and in so doing took into account Article VI of the NPT. The Court unanimously agreed that, “there exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control.”¹⁴⁵
- III. At the 2000 NPT Review Conference the five nuclear-weapon States agreed to an “unequivocal undertaking … to accomplish the total elimination of their

**NPT
ARTICLE VI**

Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.

¹⁴⁴ 1995 Review and Extension Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons. Final Document, Part I, Annex. Decision 2, “Principles and Objectives for Nuclear Non-Proliferation and Disarmament,” (NPT/CONF.1995/32 (Part I)).

¹⁴⁵ Legality of the Threat or Use of Nuclear Weapons (Request by the United Nations General Assembly), International Court of Justice Advisory Opinion, 8 July 1996, paragraph 105 F. See also Laurence Boisson de Chazournes and Philippe Sands, editors, *International Law, the International Court of Justice and Nuclear Weapons* (Cambridge, UK: Cambridge University Press, 1999). The United States does not subscribe to the International Court of Justice.

nuclear arsenals leading to nuclear disarmament, to which all States parties are committed under Article VI.”¹⁴⁶

Notwithstanding the considerable reductions in the number of nuclear weapons since U.S.-Soviet negotiations began in 1969 (see Figure 13 and Figure 14), there has been a growing sentiment among many non-nuclear-weapon States to negotiate a nuclear-weapon convention that would prohibit for all parties the development, testing, production, possession, transfer, use, and threat of use of nuclear weapons. It would also require those States that possess nuclear weapons to eliminate them in phases. Such a convention was negotiated and approved by majority vote in the United Nations General Assembly in June 2017. This was done without the participation of States possessing nuclear weapons and many of their allies.



(From DOE.gov)

Figure 13. Dismantling the final B53 bomb in 2011

¹⁴⁶ 2000 Review Conference of the Parties to the Treaty on Non-Proliferation of Nuclear Weapons. Final Document. Volume I Review of the Operation of the Treaty, taking into account the decisions and the resolution adopted by the 1995 Review and Extension Conference, Article VI and eighth to twelfth preambular paragraphs, paragraph 15.6. (NPT/CONF.2000/28 (Parts I and II)). This is one of the 13 “practical steps” agreed upon to implement Article V1. <http://daccess-dds-ny.un.org/doc/UNDOC/GEN/G11/605/15/PDF/G1160515.pdf?OpenElement>.

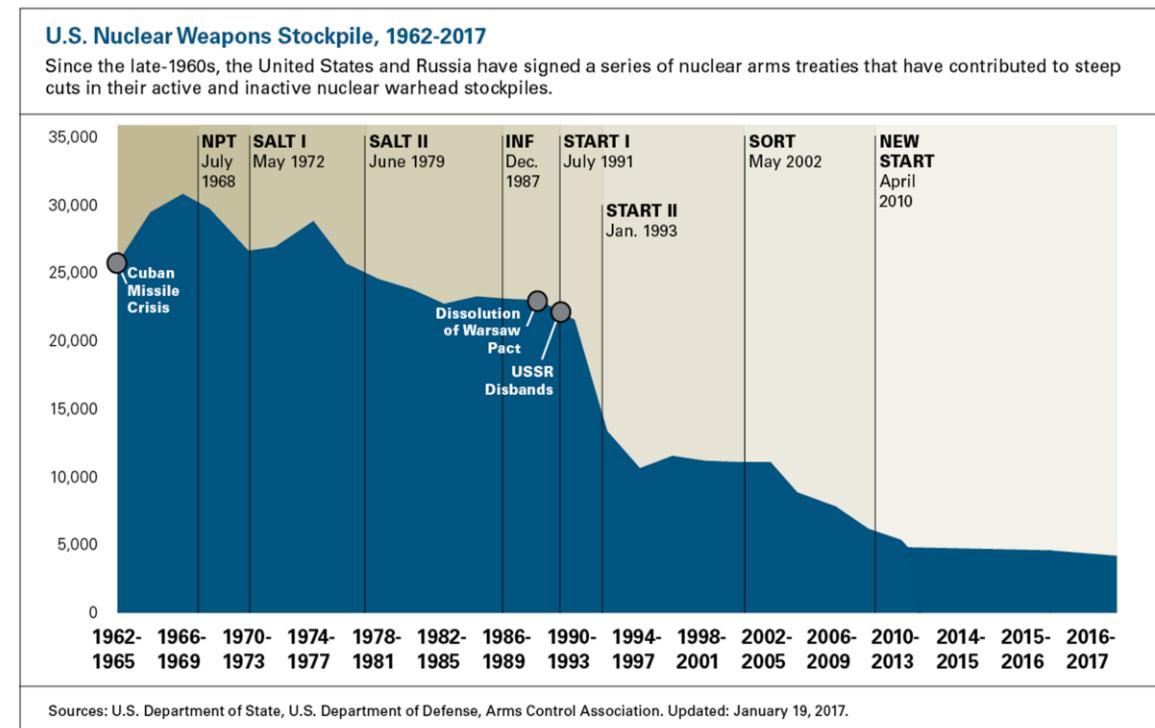


Figure 14. Reduction in U.S. Nuclear Stockpile

Targets for disarmament agreed at the 1995 NPT Review and Extension Conference:

- (a) *The completion ... of the negotiations on a universal and internationally and effectively verifiable Comprehensive Nuclear-Test-Ban Treaty no later than 1996. Pending the entry into force of a Comprehensive Test-Ban Treaty, the nuclear-weapon States should exercise utmost restraint;*
- (b) *The immediate commencement and early conclusion of negotiations on a nondiscriminatory and universally applicable convention banning the production of fissile material for nuclear weapons or other nuclear explosive devices...;*
- (c) *The determined pursuit by the nuclear-weapon States of systematic and progressive efforts to reduce nuclear weapons globally, with the ultimate goals of eliminating those weapons, and by all States of general and complete disarmament under strict and effective international control.*

NPT nuclear-weapon States, though, assert that the nuclear arms race has ended and that significant nuclear disarmament continues to take place. For example, as seen in Figure 14, the U.S. nuclear stockpile was reduced about six-fold from 1967-2009. Further reductions have taken place since then. Under the New START Treaty, the United States and Russia agreed on limits of 1,550 nuclear warheads on deployed intercontinental ballistic missiles, deployed submarine-launched ballistic missiles, and deployed heavy bombers equipped for nuclear armaments.¹⁴⁷ On January 11, 2017, Vice President Joseph Biden disclosed that the number of nuclear weapons in the Pentagon's nuclear weapons stockpile was 4,018 warheads.¹⁴⁸ NPT nuclear-weapon States also believe that actions by all States, including strict compliance by the non-nuclear-weapon States

¹⁴⁷ U.S. Department of State fact sheet, <https://www.state.gov/t/avc/newstart/> (accessed 20 Mar 2018)

¹⁴⁸ Federation of American Scientists <https://fas.org/blogs/security/2017/01/obama-cuts/> (accessed 21 Mar 2018)

with their NPT commitments, are essential to achieving nuclear disarmament. According to this view, nuclear-weapon States should not be expected to pursue disarmament absent credible assurances that non-nuclear-weapon States are complying with their undertakings not to acquire a nuclear-weapon capability.¹⁴⁹

4.2.4 Other key NPT provisions

NPT review process

Article VIII.3 of the NPT calls for a “conference of Parties” to convene five years after the Treaty first entered into force “in order to review the operation of this Treaty with a view to assuring that the purposes of the Preamble and the provisions of the Treaty are being realized.” The Treaty also provides the option of holding subsequent conferences every five years.

The first NPT Review Conference was held in

NPT
ARTICLE VIII

3. Five years after the entry into force of this Treaty, a conference of Parties to the Treaty shall be held in Geneva, Switzerland, in order to review the operation of this Treaty with a view to assuring that the purposes of the Preamble and the provisions of the Treaty are being realised. At intervals of five years thereafter, a majority of the Parties to the Treaty may obtain, by submitting a proposal to this effect to the Depositary Governments, the convening of further conferences with the same objective of reviewing the operation of the Treaty.



(U.S. Department of State)

Figure 15. 2015 NPT Review Conference at UN Headquarters

Geneva, Switzerland in 1975. Additional review conferences have been held every five years since. To prepare for each review conference, a two-week meeting of a preparatory committee is held in each of the three years preceding the review conference. The first four review conferences were held in Geneva. Since 1995, review conferences have been held at United Nations Headquarters in New York, as depicted in Figure 15.

The NPT review process is often characterized as an important litmus test of the viability of the overall nuclear non-proliferation regime. To some, the success of a review conference is determined by whether it reaches agreement on a final document. Others consider a review conference to be a success

¹⁴⁹ For example, a May 7, 2010 U.S. statement to Main Committee I at the 2010 NPT Review Conference by Ambassador Laura Kennedy included the point that, “It is often said that the key bargain for non-nuclear-weapon states is that, in exchange for their commitment not to acquire nuclear weapons, they gain a commitment from the nuclear-weapon states to disarm. This is an important part of the NPT bargain, but it is a bargain that works both ways. The non-proliferation undertakings by non-nuclear-weapon states help create a stable and secure international environment that makes it possible to work confidently toward the goal of nuclear disarmament.”

if it meets the requirements of Article VIII, which is to review the operation of the Treaty, but which has no requirement for documentation of the review or recommendations for subsequent actions.

Only half of the review conferences have been able to reach consensus agreement on a substantive final declaration. Whether this is considered to be a success or a failure, the absence of a final document, which must be agreed by consensus – one State can block agreement – is indicative of a substantive difference that could not be resolved by compromise.

Regardless of a consensus outcome, the deliberations and committees' reports of a review conference have made important contributions to the NPT and to the nuclear non-proliferation regime generally. Two positive examples from the “failed” 1990 conference were the encouragement for nuclear suppliers to require full-scope safeguards (i.e. all nuclear material being subject to safeguards even if not required by a comprehensive safeguards agreement) for significant nuclear exports and for the implementation of the “special inspections” provided for in NPT safeguards agreements¹⁵⁰ (see Chapter 5 for a discussion of special inspections).

Withdrawal

Article X.1 provides for the right of any NPT party to withdraw from the Treaty “if it decides that extraordinary events, related to the subject matter of the Treaty, have jeopardized the supreme interests of its country.” The State intending to withdraw must inform the other NPT States and the United Nations Security Council and provide “a statement of the extraordinary events it regards as having jeopardized its supreme interests.” The State’s withdrawal would then take place in 90 days.

The DPRK is the only NPT Party that has announced its intention to withdraw from the Treaty. It did so in 1993, but after negotiation of a “framework agreement” with the United States in 1994, it agreed to remain a Party and suspended its withdrawal on the 89th day.¹⁵¹ In 2003, the DPRK again announced its intention to withdraw from the Treaty and lifted its suspension and asserted that it took effect the next day. The DPRK counted the first 89 days after its 1994 announcement and counted the “next day” in 2003 as the 90th.

NPT ARTICLE X

1. Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests.

To “comply” with the 90-day requirement, the DPRK counted the first 89 days after its 1994 announcement and counted the “next day” in 2003 as the 90th.

¹⁵⁰ See NPT/CONF.IV/MC.II/1, Page 10, in <https://unoda-web.s3.amazonaws.com/wp-content/uploads/assets/WMD/Nuclear/pdf/finaldocs/1991%20-%20Geneva%20-%20NPT%20Review%20Conference%20-%20Final%20Document%20Part%20%20II.pdf> (Accessed 6 April 2018)

¹⁵¹ A thorough account of developments leading to the Agreed Framework can be found in Joel S. Wit, Daniel B. Poneman and Robert Gallucci, *Going Critical: The First North Korean Nuclear Crisis* (Washington, DC: Brookings Institution Press, 2004).

The DPRK's actions on withdrawal initiated a debate among NPT Parties as to what constitutes withdrawal: for example, whether the DPRK had complied with the procedural requirements of Article X and, if not, what steps should be taken. While the Treaty contains an explicit right to withdraw, withdrawal raises significant questions about violations of the Treaty that might have taken place before withdrawal from the NPT and what subsequent actions should be taken by the international community. This could include consideration by the United Nations Security Council of an appropriate response to withdrawal from the Treaty by a violator. This may well be coupled with the intention to acquire nuclear weapons, which would raise questions of the potential consequences for international peace and security. This might also be the case in the event of withdrawal absent any prior violation. The Security Council, in fact, decided that instances of non-compliance "shall be brought to the attention of the Security Council."^{152,153}

4.3 Development of the Nuclear Non-Proliferation Regime

While the NPT forms the basis of the regime, the Treaty by no means covers all aspects of nuclear non-proliferation. Already noted are security assurances. Other areas not covered in the NPT are numerous: the technical characteristics of safeguards; export control requirements that go beyond those of Article III; physical protection; nuclear safety; and nuclear security, for example, illicit trafficking of nuclear and other radioactive material or sabotage of nuclear facilities. United Nations Security Council Resolution 1540 (2004) contains a list of steps that the Security Council requires States to take in order to reduce the possible threats posed by non-State actors if they acquired nuclear material or materials, equipment and technology related to the manufacture of nuclear weapons or other nuclear explosive devices (the Resolution also covers chemical and

¹⁵² A number of governments submitted working papers on the topic of withdrawal to the 2010 NPT Review Conference. U.S. views are in NPT/CONF.2010/PC.I/WP.22. A joint statement made to the 2010 NPT Review Conference by the People's Republic of China, France, the Russian Federation, the United Kingdom of Great Britain and Northern Ireland, and the United States of America included the point, "However we call for the United Nations Security Council to address without delay any State Party's notice of withdrawal from the Treaty, including the events described in the required withdrawal statement by the State pursuant to Article X." The Statement went on to say, "A State Party remains responsible under international law for violations of the NPT committed prior to its withdrawal. We welcome discussion of modalities under which NPT States Party could respond collectively to a notification of withdrawal, including the disposition of equipment and materials acquired or developed during NPT membership. At the same time, we are convinced that any decision taken in relation to withdrawal from the NPT should not lead to the revision of Article X, reopen the text of the Treaty, or undermine the commonly recognised principles and norms of international law."

In Resolution 1887 (2009), Maintenance of international peace and security: Nuclear non-proliferation and nuclear disarmament, adopted on 24 September 2009, the Security Council stated in paragraph 1 that: "a situation of non-compliance with non-proliferation obligations shall be brought to the attention of the Security Council, which will determine if that situation constitutes a threat to international peace and security, and emphasizes the Security Council's primary responsibility in addressing such threats;" and in paragraph 17, "*Undertakes to address without delay any State's notice of withdrawal from the NPT, including the events described in the statement provided by the State pursuant to Article X of the Treaty, while noting ongoing discussions in the course of the NPT review on identifying modalities under which NPT States Parties could collectively respond to notification of withdrawal, and affirms that a State remains responsible under international law for violations of the NPT committed prior to its withdrawal;*"

¹⁵³ U.S. views on withdrawal from the NPT may also be found in Article X of the Nuclear Non-proliferation Treaty: Deterring and Responding to Withdrawal by Treaty Violators, U.S. Department of State, Bureau of International Security and Nonproliferation, February 2, 2007 at <https://www.hsl.org/?view&did=234438> (March 15, 2012).

biological weapons). This section briefly outlines several developments in the nuclear non-proliferation regime.

4.3.1 Duration of the NPT

As noted above the 5th NPT Review Conference fell in the same year, 1995, as the conference required by the NPT to be held 25 years after the Treaty entered into force, 1970, to decide its further duration by a majority vote. The Parties decided to hold a single conference, the 1995 NPT Review and Extension Conference.

NPT parties agreed without a vote to extend the Treaty indefinitely. They agreed on a simple statement that, “as a majority exists” among the parties to extend the treaty indefinitely, the treaty shall continue in force indefinitely. This decision was not easily reached. A significant number of parties supported an extension of 25 years with a further extension then. This would, they thought, put pressure on the nuclear-weapon States to proceed to fulfil their Article VI obligations more expeditiously.

The extension of the NPT was agreed to without explicit conditions, but, at the time of extension, the parties also agreed on two other “decision” documents and on a Resolution about the Middle East.¹⁵⁴ The decision on extension and the other documents are regarded by many NPT parties as a package. The second decision adopted the “Principles and objectives for nuclear non-proliferation and disarmament.” It expressed the expectations and aspirations of the parties with respect to non-proliferation and disarmament, including conclusion of a comprehensive nuclear test ban treaty. The Conference also adopted a second document, “Strengthening the Review Process.” It identified an expanded role for the preparatory committee meetings that precede review conferences, including substantive discussions, and a commitment to continue holding review conferences every five years. The Resolution on the Middle East called for measures to create a zone free of weapons of mass destruction in the region.¹⁵⁵

4.3.2 Security assurances

Security assurances were discussed during negotiation of the NPT but were not included in the Treaty. During the 1968 United Nations debate on the NPT, concern by a number of States led the Security Council to adopt Resolution 255. Resolution 255 deals not only with negative security assurances but also with positive security assurances, i.e., assurances that if an attack or threat of attack with nuclear weapons occurs, action will be taken to assist the victim. The Resolution “welcomes” the intention of “certain States” to provide or support immediate assistance in the event of an attack or threat of attack; no specific action was identified.¹⁵⁶

¹⁵⁴ 1995 Review and Extension Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons. Final Document. Part 1. Annex: Decision 1 “Strengthening the review process of the Treaty, Decision 2 Principles and objectives for nuclear non-proliferation and disarmament,” Decision 3 “Extension of the Treaty on the Non-Proliferation of Nuclear Weapons”, “Resolution on the Middle East.”

¹⁵⁵ The text of the Resolution is at http://www.un.org/disarmament/WMD/Nuclear/1995-NPT/pdf/Resolution_MiddleEast.pdf.

¹⁵⁶ United Nations Security Council Resolution 255(1968), June 19, 1968.
See <http://daccess-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/248/36/IMG/NR024836.pdf?OpenElement>.

In 1978 at the United Nations General Assembly Special Session on Disarmament, the United States presented the first U.S. presidential statement on negative security assurances. This statement, reaffirmed by subsequent presidents, gave assurances that the United States would not use nuclear weapons against any non-nuclear-weapon State with a binding legal commitment not to acquire nuclear weapons, except in cases in which such a non-nuclear-weapon State was assisting a nuclear-weapon State or was associated with a nuclear-weapon State in an attack on the United States or its allies.¹⁵⁷

The other nuclear-weapon States also made negative security assurances with differences. For example, the negative security assurance of the Soviet Union excluded States where nuclear weapons were stationed (for example, the Federal Republic of Germany). The Chinese assurance was simple: it committed itself to “no first use” of nuclear weapons.

In 1995 the United States, Britain, France, and Russia were able to agree on a common formulation that generally conforms to the original U.S. statement in 1978. China retained its policy of “no first use.”¹⁵⁸

Such assurances were formally recorded in United Nations Security Council documents, and on April 11, 1995, the Security Council adopted Resolution 984, which “takes note” of the statements by the nuclear-weapon States on both negative and positive security assurances¹⁵⁹

Since 1978, U.S. presidents have reiterated a negative security assurance. Each had caveats, some related to the possession by non-nuclear-weapon States of other WMD. In the April 2010 Nuclear Posture Review, this caveat was removed by President Obama, but the negative security assurance was made contingent on compliance with nuclear non-proliferation obligations, which includes adherence to safeguards agreements. The 2010 Nuclear Posture review stated that,

Since the end of the Cold War, the strategic situation has changed in fundamental ways. With the advent of U.S. conventional military preeminence and continued improvements in U.S. missile defenses and capabilities to counter and mitigate the effects of [chemical and biological weapons], the role of U.S. nuclear weapons in deterring non-nuclear attacks – conventional, biological, or chemical – has declined significantly. The United States will continue to reduce the role of nuclear weapons in deterring non-nuclear attacks.

¹⁵⁷ The full 1978 text is, “The United States will not use nuclear weapons against any non-nuclear-weapons state party to the NPT or any comparable internationally binding commitment not to acquire nuclear explosive devices, except in the case of an attack on the United States, its territories or armed forces, or its allies, by such state allied to a nuclear-weapon state or associated with a nuclear weapons state in carrying out or sustaining the attack.” (The exclusion may be understood to refer to NPT non-nuclear-weapon state members of the Warsaw Pact.) “Statement of Secretary of State Vance: U.S. Assurance on Non-Use of Nuclear Weapons, June 12, 1978,” *Department of State Bulletin*, August 1978, p. 52, ACDA, *Docs. on Disarm.*, v. 1978, p. 384. See Bunn, George. “The Legal Status of U.S. Negative Security Assurances to Non-Nuclear Weapon States,” *The Nonproliferation Review*, Spring-Summer 1997. <http://cns.miis.edu/npr/pdfs/bunn43.pdf>.

¹⁵⁸ Statements of the nuclear-weapon states at the Special Session on Disarmament 1978: Soviet Union: May 26, 1978, UNGA 120th Special Session, 5th Meeting, paragraphs 84-85. Britain: June 28, 1978, UNGA 10th Special Session, 26th Meeting, paragraph 12. France: June 30, 1978, UNGA 10th Special Session, 27th Meeting, paragraph 190. United States: November 17, 1978, A/C/33/7, Annex. China: A/S-10/AC.1/17Annex, paragraph 9.

¹⁵⁹ United Nations Security Council Resolution 984(1995), April 11, 1995.

To that end, the United States is now prepared to strengthen its long-standing “negative security assurance” by declaring that the United States will not use or threaten to use nuclear weapons against non-nuclear-weapon States that are party to the NPT and in compliance with their nuclear non-proliferation obligations.

Throughout the history of the NPT, some non-nuclear-weapon States have pressed for an internationally, legally binding treaty on security assurances, but no negotiations have taken place.¹⁶⁰

4.3.3 Nuclear-Weapon-Free Zones

Encouraging the establishment of NWFZs was one of the five principles of the 1965 United Nations General Assembly Resolution 2028 cited in Section 4.2. It is articulated in Article VII of the NPT. Negotiation of the Latin American Nuclear-Weapon-Free Zone was concluded in 1967, the year before conclusion of NPT negotiations. Since then, four other NWFZs have been established: South Pacific, Africa, Southeast Asia, and Central Asia. Each of these NWFZ treaties has a protocol, which the nuclear-weapon States are asked to join, in which the nuclear-weapon States make legally binding negative security assurances not to attack or threaten to attack parties to the NWFZ and not to deploy nuclear weapons in the zone.¹⁶¹

Although not of the same character, several other treaties also establish NWFZs: in Antarctica through the 1961 Antarctic Treaty; in outer space through the 1967 Outer Space Treaty, which, for example, bars placement of nuclear weapons in orbit around the earth or by installing them on the moon; and the 1972 Seabed Treaty, which prohibits the emplacement of nuclear weapons or other weapons of mass destruction on the seabed or the ocean floor.

4.3.4 Zangger Committee

The Zangger Committee, named after its first chairman, Claude Zangger of Switzerland, is an informal group of fifteen States created at the initiative of the United States soon after the NPT entered into force for the purpose of harmonizing interpretations of NPT Article III, paragraph 2, which requires NPT safeguards for export “(a) of source or special fissionable material; or (b) equipment especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this article.”

¹⁶⁰ Nuclear-weapon states have different views about the legally binding nature of their security assurance statements, France and the UK consider theirs to be legally binding, while the United States considers its to be a policy declaration. A useful discussion of the issue and the history of negative security assurances is in Arms Control Today » October 2008 » Looking Back: Carter’s 1978 Declaration and the Significance of Security Assurances by John Steinbruner at http://www.armscontrol.org/act/2008_10/lookingback.

¹⁶¹ When made in the context of adherence to a NWFZ treaty, security assurances made by the nuclear-weapon states are legally binding. Each nuclear-weapon state has its own interpretation of whether security assurances made in other contexts are legally binding or not. The status of U.S. adherence to NWFZ protocols is found in “A Catalog of Treaties and Agreements,” Amy F. Woolf, Mary Beth Nikitin, Congressional Research Service, September 20, 2011. <https://www.hsl.org/?view&did=689048> (March 15, 2012.).

The Zangger Committee's first list of items whose export would trigger the application of safeguards, the "trigger list," was published by the IAEA as INFCIRC/209 in 1974. INFCIRC/209 has undergone a number of additions and revisions, all of which have been published as updates to INFCIRC/209.

4.3.5 Nuclear Suppliers Group

As described in Section 2.3.2, on May 18, 1974 India tested a nuclear explosive device using a research reactor supplied by Canada as the source of plutonium (and heavy water supplied by the United States). India claimed it was a peaceful nuclear explosion and that it conformed with its contractual requirements with Canada and the United States not to use the reactor for any military purpose. India's test, coupled with concerns about the spread of sensitive nuclear technology, spurred the international community to act. Representatives of seven States with significant exports of nuclear material and technology met in London in 1975.¹⁶² The seven were Canada, the Federal Republic of Germany, France, Japan, the Soviet Union, the United Kingdom, and the United States.) As a result, this group was called the "London Club" but later became the NSG. The NSG agreed on a set of guidelines for nuclear exports, among other things calling for restraint in the export of sensitive technology.

In 1978, the NSG guidelines were published by the IAEA in INFCIRC/254. The NSG has revised its guidelines a number of times to cover additional fuel cycle technologies and made a major addition to cover the export of "dual use" items. (The IAEA publishes each of the revisions as a revision or modification of INFCIRC/254.) At the end of 2017, the NSG had 48 participants.¹⁶³ Like the Zangger Committee guidelines, the NSG guidelines are not legally binding on NSG members. They provide common ground rules for the orderly export of nuclear material, specialized materials and equipment and dual use items and technology in ways that advance non-proliferation goals.¹⁶⁴

4.3.6 Safeguards in Brazil and Argentina

For many years, Brazil and Argentina were suspected by other States of trying to develop nuclear weapons. In the 1980s, after military dictatorships in both countries fell, political relations between the two countries improved and their views on nuclear non-proliferation issues converged. In 1991, Argentina and Brazil agreed on a system of bilateral nuclear safeguards, and they created a joint agency to carry out mutual inspections known as ABACC (the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials). ABACC, Argentina, and Brazil then concluded a comprehensive safeguards agreement with the IAEA that covered both countries. As a result,

¹⁶² The inclusion of France was considered important in order that it adopt similar controls. France was not a party to the NPT in 1978 and therefore not a member of the Zangger Committee.

¹⁶³ Argentina, Australia, Austria, Belarus, Belgium, Brazil, Bulgaria, Canada, China, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Kazakhstan, Republic Of Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Serbia, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, and United States. The European Commission and the Chair of the Zangger Committee participate as observers.

¹⁶⁴ INFCIRC/539/Rev.4, November 5, 2009 provides a good overview of the work of the NSG.

Argentina and Brazil are subject to inspection by both ABACC and the IAEA. After Argentina and Brazil became NPT parties in 1995 and 1998 respectively, the quadripartite safeguards agreement was recognized as meeting the requirements of both the NPT and the Treaty of Tlatelolco, which established the Latin American Nuclear-Weapon-Free Zone.

4.3.7 The Model Protocol

After the 1991 Persian Gulf War, a major clandestine nuclear-weapon program was discovered in Iraq. This alarmed the international community, and the IAEA Secretariat and a number of IAEA Member States, led by the United States, launched a dedicated effort to strengthen IAEA safeguards, particularly to strengthen its capability to detect “undeclared” or secret nuclear activities. Strengthening efforts began immediately, including the reaffirmation of the applicability of safeguards to both undeclared and declared nuclear material and the Agency’s right to use special inspections to obtain access to additional information and locations. In 1997 the IAEA Board of Governors approved a new safeguards agreement to strengthen safeguards. It is generally referred to as the Model Protocol. Chapter 7 details the negotiation and the features of the Model Protocol.¹⁶⁵

¹⁶⁵ INFCIRC/540/Corr.1, October 12, 1997.

PART II

THE NUCLEAR NON- PROLIFERATION TREATY SAFEGUARDS SYSTEM

CHAPTER 5. NPT SAFEGUARDS

The IAEA first began to apply safeguards in 1961 on the basis of safeguards agreements that covered only the specific items listed in a safeguards inventory. The basic safeguards framework was agreed to by the Board of Governors and published in INFCIRC/66. The framework evolved over time as more complex facilities became subject to safeguards, with each new change published as a revision to INFCIRC/66. For States parties to the NPT, the item-by-item approach was superseded by an obligation to accept safeguards on all nuclear material in all peaceful nuclear activities, i.e., comprehensive safeguards. To reflect this comprehensive coverage the Board of Governors adopted a new model safeguards agreement, published in INFCIRC/153. Importantly, the model emphasized the use of nuclear material accountancy, but it also provided for the first time an explicit right for the IAEA to use containment and surveillance.

Section 5.1 of this Chapter describes the negotiation and development of the NPT model safeguards agreement.

Section 5.2 reviews the obligations of the State and the IAEA under INFCIRC/153. They reflect a balance between ensuring that safeguards do not impose a burden on States beyond what is necessary and ensuring that the IAEA is able to apply safeguards effectively and can draw sound, independent conclusions. This section also describes the process used to reach agreement with States on the details of routine safeguards implementation.

Routine safeguards implementation is continuing implementation of safeguards under INFCIRC/153 using procedures agreed in advance with a State. Nonetheless, errors are unavoidable, and anomalies and inconsistencies may arise. For example, a poorly calibrated instrument could give anomalous results. Other results might be indicative of a potential diversion. Clearly, additional activities will be needed when such circumstances arise. Ultimately, if significant anomalies or inconsistencies cannot be resolved, concerns about non-compliance would arise. If so, additional steps may be needed. INFCIRC/153 has provisions to address such a case. Because of their importance, these are treated separately in Section 5.3.

5.1 Background to the NPT Model Safeguards Agreement – INFCIRC/153

The entry into force of the NPT ushered in a new era in the application of safeguards for non-nuclear-weapon States parties to the Treaty. According to NPT Article III:

- Each non-nuclear-weapon State must have safeguards on **all** nuclear material in **all** of its peaceful nuclear activities. (Article III.1). [Emphases added].
- Safeguards agreements are to be applied under agreements negotiated with the IAEA,¹⁶⁶ and,
- IAEA safeguards would be needed as a condition of supply by all Treaty parties of nuclear material or certain “especially designed or prepared equipment or material,” even to non-nuclear-weapon States that are not NPT parties.

Safeguards were no longer required only as a condition of supply or at the request of a host State—they were now required by the NPT itself. Thus, all nuclear activities in an NPT non-nuclear-weapon State would be under safeguards, and those safeguards were to be administered by the IAEA.

The NPT also specifies that safeguards are to be applied “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.”¹⁶⁷

The comprehensive coverage of nuclear material represented a significant broadening of both the scope of safeguards and their role. They were required on all of a State’s nuclear activities regardless of whether they were indigenous or were based on imports or cooperation with other States. They, thus, acquired an explicit and important role in helping to prevent nuclear proliferation.

As the verification agent of the NPT, the IAEA also acquired a new prominence in the nuclear non-proliferation regime. Also significant was the requirement by the Treaty that safeguards be applied as a condition of supply even to non-nuclear-weapon States not party to the NPT. Although that was already the practice of many suppliers, it would now be done through an international obligation rather than as a matter of national policy.¹⁶⁸

¹⁶⁶ The agreements with the IAEA could be with one State, or, in order to accommodate Euratom, with groups of States.

¹⁶⁷ Although the IAEA Statute calls for safeguards that prohibit any military purpose, the NPT does not prohibit military use of nuclear material by either nuclear-weapon states or non-nuclear-weapon States. Nuclear weapons and nuclear explosive devices are prohibited to non-nuclear-weapon states, but the NPT and NPT safeguards agreements accommodate the possibility that a non-nuclear-weapon State may wish to pursue, for example, a naval reactor program.

¹⁶⁸ NPT Article III requires as a condition of supply that nuclear material transferred or produced as a result of the supply of equipment, material, or facilities be subject to “the safeguards required by [Article III].” Since in NPT non-nuclear-weapon States, Article III requires comprehensive safeguards, some States have interpreted this as requiring similar comprehensive safeguards in recipient states. The United States did not use this interpretation but after the NPT entered into force continued to export to States without comprehensive coverage but requiring under Agreements for Cooperation that safeguards apply to U.S. exports. Any other position would have created turmoil at that time

When the NPT was opened for signature in 1968, the requirement for non-nuclear-weapon States to negotiate a safeguards agreement with the IAEA led almost immediately to efforts within the IAEA to investigate the technical, legal, and financial ramifications of implementing NPT safeguards. Meeting of consultants and experts were convened, and by late 1969, the IAEA had drafted a complete agreement. The IAEA Board of Governors then established an open-ended committee, the Safeguards Committee, to negotiate the terms of a model NPT safeguards agreement using the IAEA draft as a starting point.¹⁶⁹



Figure 16. Kurt Waldheim chairing the 1970 IAEA Safeguards Committee

The Committee met (see Figure 16) for the first time in April 1970. It completed its work quickly in March 1971 because it took advantage of earlier work of experts, consultants, and the IAEA Secretariat. Perhaps, not surprisingly, the Committee did not come to agreement on a safeguards financing formula until the end of its work.¹⁷⁰

The Committee's report to the Board of Governors noted that the model safeguards agreement incorporated "a number of fundamental technical principles, concepts and criteria, some of which were novel and of considerable complexity."¹⁷¹ Indeed, this was true, since it involved on-site inspection by an international

organization of an entire industry and independent verification of the flows and inventories of radioactive and potentially dangerous materials. In addition, implementation of the model safeguards agreement would require the development and deployment of new equipment and technology needed to meet the requirements of safeguards. Especially important in this regard is maintaining the ability of the IAEA to draw independent conclusions assuming that a State will wish to defeat this capability. This imposes unique and challenging requirements on verification equipment and techniques. The IAEA would also need to recruit and train a team of inspectors.¹⁷²

In April 1971, the Board of Governors adopted the model as the basis for negotiation of NPT safeguards agreements between non-nuclear-weapon States and the IAEA.¹⁷³ The model safeguards agreement was subsequently published as INFCIRC/153, "The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on The

since several major U.S. partners were still considering ratification of the NPT. In due course, these partners ratified the NPT and concluded safeguards agreements with the IAEA, thus effectively ending the controversy for most states.

¹⁶⁹ An open-ended committee is one in which any Member State can participate at its own discretion.

¹⁷⁰ The financing arrangements that were agreed in 1971 established a two-tier system, whereby the countries with the lowest GDPs would pay a smaller fraction of the share of safeguards costs than they did for other costs of the Agency. Known as the "shielding formula," it was agreed in 2000 to phase it out over 25 years. (See GC(44)/RES/9 (2000), which was revised by GC(47)/RES/5 (2003).

¹⁷¹ GOV/1451, Third Report by The Safeguards Committee (1970), 16 March 1971.

¹⁷² A good description of modern safeguards equipment and technology used by the IAEA is contained in its pamphlet, *Safeguards Techniques and Equipment*, IAEA, Vienna, Austria, 2003 International Nuclear Verification Series No. 1 (IAEA/NVS/1).

¹⁷³ In practice, all NPT safeguards agreements are identical for all practical purposes and follow precisely the model agreement.

Non-Proliferation of Nuclear Weapons.”¹⁷⁴ Approved by the Board in 1971, it requires that each NPT non-nuclear-weapon State conclude its own agreement with the IAEA; that each agreement contain all of the provisions of the model; and that the implementation of safeguards can only commence after the agreement enters into force in accordance with a State’s legal requirements.¹⁷⁵ (U.S. safeguards agreements with the IAEA have been handled as treaties and submitted to the U.S. Senate for its advice and consent to ratification.)¹⁷⁶

All of the NPT safeguards negotiated since 1971 are essentially identical to the model. Exceptions are: the NPT safeguards agreements with States in Euratom, with Japan, and with Argentina and Brazil. The Euratom agreement reflects its unique circumstances and Japan’s insistence that its agreement match the agreement covering Euratom States. The safeguards agreement with Argentina and Brazil is a quadripartite agreement. In addition to the two States, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and the IAEA are also parties.¹⁷⁷

In order to reduce implementation costs to States with little or no nuclear material, the IAEA developed soon thereafter a “Small Quantities Protocol (SQP).”¹⁷⁸ The SQP suspends most of the provisions of the accompanying NPT safeguards agreement until such time as the State acquires a threshold amount nuclear material. This made sense because there is little or no risk that a nuclear explosive device could be manufactured where an SQP is applicable. In addition, it was seen as a means to encourage all States to bring safeguards agreements into force. (Much

INFCIRC/153

BASIC UNDERTAKING

1. The Agreement should contain ... an undertaking by the State to accept safeguards ... on all source or special fissionable material in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices.

APPLICATION OF SAFEGUARDS

2. The Agreement should provide for the Agency's right and obligation to ensure that safeguards will be applied ...on all source or special fissionable material in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices.

CO-OPERATION BETWEEN THE AGENCY AND THE STATE

3. The Agreement should provide that the Agency and the State shall co-operate to facilitate the implementation of the safeguards provided for therein.

¹⁷⁴ The full text of INFCIRC/153 is at <https://www.iaea.org/publications/documents/infcircs/structure-and-content-agreements-between-agency-and-states-required-connection-treaty-non-proliferation-nuclear-weapons>

¹⁷⁵ As of August 5, 2011, all but 15 of the 186 NPT non-nuclear-weapon State parties had brought an NPT safeguards agreement into force. None of the fifteen had any nuclear activities.

¹⁷⁶ The United States has concluded numerous safeguards agreements with the IAEA in connection with nuclear cooperation that were not treated in the United States as treaties that required Senate consideration.

¹⁷⁷ Another exception is the comprehensive IAEA safeguards agreement that Albania concluded before it adhered to the NPT. Although not identical to INFCIRC/153, the Board of Governors decided that it was valid with respect to meeting Albania’s NPT safeguards obligations. (In some ways, the agreement is “tougher” than INFCIRC/153, for example, it is of indefinite duration.)

¹⁷⁸ The text is at See GOV/INF/276 (1974) <http://ola.iaea.org/OLA/documents/GINF276.pdf>.

later events led the IAEA and Member States to conclude in 2005 that the 1971 SQP left the IAEA with too few inspection rights, and its text was revised. This is described in Appendix E.)

5.2 The Structure and Content of INFCIRC/153

INFCIRC/153 is divided into two parts. Part I contains the main rights and responsibilities of the IAEA and the State. It provides the framework in which safeguards are to be carried out. This includes, for example, the relations between the IAEA and States when non-compliance with the safeguards agreement becomes an issue.

Part II of INFCIRC/153 establishes the technical basis of safeguards, including the objective of safeguards, the safeguards measures to be used, the intensity of inspections, and where inspections may be carried out. It also specifies the information and access that States must provide to the IAEA in order for it to do its job.¹⁷⁹

5.2.1 INFCIRC/153 – Part I

Basic undertaking and application of safeguards

Part I of INFCIRC/153 begins with the basic obligations of the State and the IAEA – the former to accept the application of safeguards on *all nuclear material* in all peaceful nuclear activities and the latter the obligation to apply such safeguards (paragraphs 1 and 2; emphasis added). Soon after INFCIRC/153 was adopted, differing views developed about whether these obligations covered only nuclear material declared by States to the IAEA or whether they also covered undeclared nuclear material.

States that argued for the more limited coverage suggested that the alternative would call into question the credibility and trustworthiness of non-nuclear-weapon States, curtail their nuclear programs, and strengthen the differences between the nuclear-weapon States and the non-nuclear-weapon States with respect to the burden of safeguards. The Federal Republic of Germany and Japan took this view. The narrower interpretation would also reduce the inspection resources needed to implement safeguards.

States that argued for the broader coverage, including the United States, took the view that the existence of undeclared nuclear activities should be assumed in planning and implementing safeguards, and that, without that assumption, the IAEA could not fulfill its obligation to apply safeguards to “all” nuclear material.¹⁸⁰

¹⁷⁹ Many of the terms used in this section are either defined terms or have assumed particular meanings in the context of safeguards implementation. As a result, the IAEA has compiled a Safeguards Glossary, which is an invaluable reference tool. See IAEA Safeguards: Glossary, 2001 Edition, IAEA, Vienna, Austria, 2002 (IAEA/NVS/3) at https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf.

¹⁸⁰ Wolfgang Fischer and Gotthard Stein, Experiences from Nuclear Safeguarding, On-Site Inspections: Common Problems, Different Solutions, *Disarmament Forum: On-Site Inspections: Common Problems, Different Solutions*, United Nations (1999 No. 3) http://unidir.org/bdd/fiche-periodique.php?ref_periodique=1020-7287-1999-3-en .

The tension between these views dissipated slowly. The first step was agreement that the IAEA should be able to detect undeclared activities at declared facilities, for example, the undeclared production of plutonium at reprocessing plants and reactors or HEU at uranium enrichment facilities. The IAEA designed and implemented safeguards approaches at declared facilities that included activities whose purpose was detection of undeclared activities.

However, the issue as a practical matter, was only resolved definitively in favor of coverage of all undeclared nuclear material and activities in a State after the discovery of Iraq's clandestine nuclear-weapon program in 1991. This discovery demonstrated that the risk that States with comprehensive safeguards agreements might pursue undeclared nuclear activities at undeclared locations was not hypothetical. This realization and the fact that the IAEA had not detected them led to a major re-evaluation of the safeguards system. Ultimately, this led to the adoption of a new safeguards arrangement, the Model Protocol, in 1997. The events that led to the Model Protocol, its contents, and the ramifications for safeguards that followed are described in detail in Chapter 7.

Cooperation and implementation of safeguards

Part I continues with a provision requiring the parties to cooperate in the implementation of safeguards (paragraph 3). Paragraphs 4-7 require safeguards implementation to “avoid hampering economic and technological development” and “avoid undue interference” in a State’s peaceful nuclear activities, and to be consistent with the economic and safe conduct of nuclear activities. The Agency has to “take every precaution to protect commercial and industrial secrets and other confidential information coming to its knowledge in the implementation of the Agreement.” These provisions reflect the concerns of non-nuclear-weapon States that the inspection system might jeopardize their competitive status vis-à-vis nuclear-weapon States in an industry that held high promise.

Paragraph 6 reflects the view of some States that the intensity of safeguards should be as low as possible. While paragraph 6 helpfully refers to taking full account of technological developments, it also refers twice to achieving optimum cost-effectiveness, conducting measurements only at “*strategic points*,” and concentrating verification activities on more sensitive nuclear material while minimizing them elsewhere. The principle of concentration on the flow of special fissionable material at strategic points is in the Preamble of the NPT. This reflects the importance attached by some States to reducing the intrusiveness and, thereby, the burden of safeguards.

State system of accounting for and control of nuclear material

Paragraph 7 requires the State to “establish and maintain a system of accounting for and control of all nuclear material subject to safeguards.” (The system is known as a State system of accounting for and control of nuclear material or SSAC). The paragraph calls for the IAEA “to verify … findings of the State’s system” and not, simply, to accept the State’s assertion that there had been no diversion. Importantly, the IAEA should do so on the basis of independent measurements. (Paragraph 74(b), “Scope of Inspections,” also provides that the IAEA may make independent measurements.)

IAEA verification is based on data transmitted to it from the SSAC. As a result, an effective SSAC is vital to effective safeguards. An SSAC is also important to the State and the facility operator as a tool to reduce the threat that insiders will remove nuclear material without authorization; and to recover it if they do. (It may also be used to limit nuclear material quantities in some areas to ensure safety and to keep track of facility operations.) Thus, an effective SSAC can help to protect nuclear material and reduce the risks of theft and nuclear terrorism as well as provide the backbone for IAEA verification. Because of this, the IAEA, Euratom, Japan, the United States, and others have programs to help States improve their SSACs. The effective operation of an SSAC requires not only staff trained in techniques of nuclear material accountancy and measurement, but also the national legislation and regulations that specify who is able to own or use nuclear material, the requirements for nuclear material accounting, control, and reporting, and penalties for failures to comply with these requirements.¹⁸¹

Non-application of safeguards to nuclear material to be used in non-peaceful activities

One element of Part I that is worth noting is paragraph 14. Although it has never been used, it allows a State to withdraw nuclear material from safeguards to pursue an activity that does not require them because it is not a “peaceful nuclear activity.” The provision was primarily directed toward the field of naval propulsion. (It could not allow withdrawal of material for use in nuclear explosives, which is forbidden by the NPT.) While paragraph 14 has never been invoked, several States, for example, Italy and the Netherlands considered nuclear submarine programs, and in the mid-1980s, Canada seriously considered establishing such a program. It abandoned its plans before they got very far.¹⁸² Brazil has an on-going naval reactor program.

IAEA STATUTE ARTICLE XII.C

... The inspectors shall report any non-compliance to the Director General who shall thereupon transmit the report to the Board of Governors. The Board shall call upon the recipient State or States to remedy forthwith any non-compliance which it finds to have occurred. The Board shall report the non-compliance to all members and to the Security Council and General Assembly of the United Nations.

Measures in relation to verification of non-diversion

One of the most important aspects of Part I is its explication of steps that the Board of Governors may take in the event of concerns about compliance. The Board can “call upon States to take

¹⁸¹ In 2004, the United Nations Security Council adopted Resolution 1540, which requires that States take a number of steps intended to reduce the risk of terrorism involving WMD. To that end, one of its provisions requires States to “Develop and maintain appropriate effective measures to account for and secure [nuclear material] in production, use, storage or transport.”

¹⁸² See NY Times at

<http://www.nytimes.com/1987/05/03/world/canada-considers-10-nuclear-subs-to-patrol-arctic.html?src=pm>. While not an NPT issue, the use of HEU as fuel for naval reactors in the United States, Russia, UK, France, and China has proven to be an obstacle in developing verification arrangements for a Fissile Material Cut-off Treaty.

action without delay” if it decides that the action is “essential and urgent” to ensure that nuclear material is not diverted (paragraph 18). This step indicates heightened concern but not necessarily that a State is in non-compliance. The Board would be calling on a State to act urgently to permit the IAEA to provide the necessary assurances, for example, allow a special inspection. Paragraph 18 also makes clear that the Board may take this step regardless of whether the arbitration provisions of INFCIRC/153 have been invoked. To do otherwise would permit States to use the lengthy dispute resolution process in paragraph 22 of INFCIRC/153 to avoid taking action.

The Board can go further. Indeed, if the IAEA is “not able to verify that there has been no diversion of *nuclear material* … to nuclear weapons or other nuclear explosive devices,” the Board may report its concerns to the United Nations General Assembly and to the Security Council.¹⁸³ Such reports have been made a few times, including about Iraq and the DPRK. Of note is that paragraph 19 makes clear that action by the Board does not depend on a positive finding of non-compliance but only on an inability to verify compliance. Thus, the Board can act if the IAEA’s verification efforts are stymied. It does not need to draw a “guilty” verdict.

The Board does not have to rely on the authorities of the safeguards agreement to report to the United Nations Security Council. Article XII.C of the Statute may be used without reference to paragraph 19 of the safeguards agreement. This has been the procedure followed, for example, in the cases of Iran in 2006,¹⁸⁴ Libya in 2004¹⁸⁵ and most recently Syria in 2011.¹⁸⁶ In the Libyan situation, centrifuges for enrichment had not been reported to the IAEA and were removed from Libya in 2002 (see Figure 17). In these cases, the Board reported that the States had either constructed nuclear facilities clandestinely or had used nuclear material without reporting it, or both. Article III.B.4 of the Statute also calls for the IAEA to report to the United Nations if questions arise in connection with its work, “that are within the competence of the Security

**IAEA STATUTE
ARTICLE III
FUNCTIONS**

In carrying out its functions, the Agency shall:

B. 4. Submit reports on its activities annually to the General Assembly of the United Nations and, when appropriate, to the Security Council: if in connection with the activities of the Agency there should arise questions that are within the competence of the Security Council, the Agency shall notify the Security Council, as the organ bearing the main responsibility for the maintenance of international peace and security, and may also take the measures open to it under this Statute, including those provided in paragraph C of Article XII.

¹⁸³ The Board may also suspend assistance and initiate the process of suspending a State’s membership privileges.

¹⁸⁴ See GOV/2006/14,

<https://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/Disarm%20GOV200839.pdf> (accessed 5 March 2019).

¹⁸⁵ See GOV/2004/18,

<https://www.securitycouncilreport.org/atf/cf/%7B65BFCF9B-6D27-4E9C-8CD3-CF6E4FF96FF9%7D/Disarm%20GOV200418.pdf> (accessed 5 March 2019).

¹⁸⁶ See GOV/2011/41, <https://www.iaea.org/sites/default/files/gov2011-41.pdf> (accessed 5 March 2019)..

INFCIRC/153
STARTING POINT OF SAFEGUARDS

33. The Agreement should provide that safeguards shall not apply thereunder to material in mining or ore processing activities.

34. The Agreement should provide that:
(a) When any material containing uranium or thorium which has not reached the stage of the nuclear fuel cycle described in sub-paragraph (c) below is directly or indirectly exported to a non-nuclear-weapon State, the State shall inform the Agency of its quantity, composition and destination, unless the material is exported for specifically non-nuclear purposes; (b) When any material containing uranium or thorium which has not reached the stage of the nuclear fuel cycle described in sub-paragraph (c) below is imported, the State shall inform the Agency of its quantity and composition, unless the material is imported for specifically non-nuclear purposes; and (c) When any nuclear material of a composition and purity suitable for fuel fabrication or for being isotopically enriched leaves the plant or the process stage in which it has been produced, or when such nuclear material, or any other nuclear material produced at a later stage in the nuclear fuel cycle, is imported into the State, the nuclear material shall become subject to the other safeguards procedures specified in the Agreement.

Council,” referring to the Security Council’s “responsibility for the maintenance of international peace and security.”



(From Oak Ridge National Laboratory “Review”)

Figure 17. President George W. Bush “inspecting” centrifuges stored at Oak Ridge National Laboratory

Entry into force and duration

An INFCIRC/153 safeguards agreement enters into force when a State notifies the IAEA that its legal requirements have been met. Since these safeguards agreements are concluded as a result of States’ obligations under the NPT, they remain in force “as long as the State is party to the NPT” (paragraph 26).

5.2.2 INFCIRC/153 - Part II

Part II of INFCIRC/153 provides specifics about the implementation of the safeguards provisions of Part I.

Objective of safeguards

Of particular importance is the section on the Objective of Safeguards contained in paragraphs 28-30. They specify three “ground rules” from which the nature of the implementation of NPT safeguards follows:

- The objective of safeguards is the timely detection of diversion of significant quantities of *nuclear material* from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection;
- Material accountancy is a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures; and

- The technical conclusion of the Agency's verification activities shall be a statement, in respect of each *material balance area*, of the amount of *material unaccounted for* over a specific period, giving the limits of accuracy of the amounts stated.

The first “ground rule” calls for detection that is timely, that is, it must be early enough to deter diversion through the risk of detection. It also specifies what is to be detected – “diversion of significant quantities of nuclear material.” In order to plan for safeguards, it is important to quantify the terms used: How much nuclear material is significant? How early is early enough? And what would make it too risky for a State to consider diversion? These quantitative questions are not addressed in INFCIRC/153 but were considered later by the IAEA’s Standing Advisory Group on Safeguards Implementation (SAGSI)¹⁸⁷.

The selection of numerical values was based on a combination of political judgments and technical factors: How much nuclear material would be needed to make a nuclear weapon? How long would it take to do so starting from a particular form of nuclear material? And what was the probability of detection needed to make it too risky? The judgment made was that it was important to detect a diversion before a State could use the diverted material to manufacture even one nuclear weapon.

For the answers to the first two questions, how much nuclear material is needed and how long would it take to manufacture a nuclear weapon, the Secretariat turned to nuclear-weapon States for advice. For the detection probability, it selected 90-95% for sensitive nuclear material and lower values for other nuclear material. The delineation of the objective of safeguards also introduced the useful phrase “diversion for … purposes unknown.” This makes clear that the Secretariat does not need to know diverted material was actually used for nuclear explosives. A finding of non-compliance can be reached without a determination of motive.

The second and third “ground rules” make material accountancy and containment and surveillance (C/S) the basic safeguards measures and describe the technical content of the Agency’s conclusions. These methods and the way they are used are described in Chapter 6.

INFCIRC/153

OBJECTIVE OF SAFEGUARDS

28. The Agreement should provide that the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.

29. To this end the Agreement should provide for the use of material accountancy as a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures.

30. The Agreement should provide that the technical conclusion of the Agency's verification activities shall be a statement, in respect of each material balance area, of the amount of material unaccounted for over a specific period, giving the limits of accuracy of the amounts stated.

¹⁸⁷ SAGSI consists of safeguards experts invited by the Director General to provide advice to him on safeguards implementation. The experts serve in their individual capacity and not as representatives of their countries.

The remainder of Part II outlines the obligations of the State to maintain an SSAC that can meet specified performance objectives (paragraphs 31-32) and to provide the IAEA with the information and access that it needs to carry out its inspection duties. The State, for example, must arrange that accounting and operating records are kept (paragraphs 51-58), and it must provide information to the IAEA through, for example, reports (paragraphs 59-69) and notifications (paragraphs 12, 92, and 95). In order to fulfill these obligations, the State must put in place a legal and regulatory framework that ensures that all plant operators carry out the activities necessary to provide the information that the State must report to the IAEA under INFCIRC/153.

Coverage of safeguards – Starting point, termination, exemptions

The scope of NPT safeguards agreements is very broad – “all [nuclear material] in all peaceful nuclear activities.” It is so broad that it would be impossible to fulfill if practiced literally. For example, uranium is everywhere in dilute form – in seawater, granites, and uranium ores – and for this uranium, it was considered impractical to apply safeguards and of little or no value because of their low non-proliferation significance. The result is that INFCIRC/153 contains provisions that define when safeguards begin, the starting point; when they could terminate if material again has little or no non-proliferation significance or similarly, when amounts are small. Of the aforementioned forms, only uranium ores have a sufficient concentration of uranium to be used for nuclear fuel-cycle applications. In addition, uranium must be converted to useful forms and chemical compositions. This section describes the considerations that shaped how INFCIRC/153 addresses these issues.

Starting point of safeguards. As Table 2 shows, uranium is widely distributed.¹⁸⁸ In recognition of this, the definition of “source material” in the IAEA Statute excludes ore and ore residue, and INFCIRC/153 does not require safeguards for uranium in mining or ore processing activities. INFCIRC/153 also defines a “starting point” of safeguards, which is the point at which accountancy and inspection activities begin. Paragraphs 33 and 34 address these points. (INFCIRC/153 has some reporting requirements for import or export of material before the starting point.)

At a certain point, the full application of safeguards begins. This is known as the starting point of safeguards, and its definition uses both chemical composition and purity as the trigger point. It is defined as the point “When any *nuclear material* of a composition and purity suitable for fuel fabrication or for being isotopically enriched leaves the plant or the process stage in which it has been produced....”

¹⁸⁸ Table 2 is from the World Nuclear Association at <http://www.world-nuclear.org/info/inf75.html>. (5 August 2011).

Table 2. Typical Uranium Concentration in Various Forms

Very high-grade ore (Canada) - 20%	200,000 ppm U
High-grade ore - 2% U,	20,000 ppm U
Low-grade ore - 0.1% U,	1,000 ppm U
Very low-grade ore (Namibia) - 0.01% U	100 ppm U
Granite	4-5 ppm U
Sedimentary rock	2 ppm U
Earth's continental crust (average)	2.8 ppm U
Seawater	0.003 ppm U

Note: ppm = parts per million

Uranium is ubiquitous on the Earth. It is a metal approximately as common as tin or zinc, and it is a constituent of most rocks and even of seawater.

Termination and exemption.

Once safeguards have “started,” in principle there is no end if one looks at the broad scope of coverage of the NPT and INFCIRC/153. On the other hand, sometimes there are good practical and legal circumstances for terminating the application of safeguards under an agreement. This can occur, for example, if nuclear material is consumed

(converted to another element); becomes so diluted that it is no longer usable for a nuclear purpose; or because it becomes “practically irrecoverable” (paragraph 11).

Industrial practice may also lead to circumstances where nuclear material is transformed into a form from which recovery of nuclear material is not considered “for the time being practicable or desirable.” In this case, a new set of more appropriate safeguards may be negotiated between the State and the IAEA (paragraph 35).¹⁸⁹ The complexities and diversity of actual scientific and industrial practice also lead to many situations where the application of safeguards would seem to be uncalled for because the amounts may be very small. Such small quantities of uranium might not warrant the investment of resources needed to safeguard them and should be exempted from safeguards. INFCIRC/153 addresses all of these situations. Nuclear material may also be put to use in a non-nuclear activity.¹⁹⁰

Although the circumstances and the rules developed might seem esoteric and very complicated, they are important because of the potential of their abuse to conceal diversions of nuclear material. For example: nuclear material reaches the starting point of safeguards and the State should declare it, but it doesn’t. Or, the State claims that nuclear material has been transferred to non-nuclear use, but it has not been transferred or it has been transferred to an undeclared nuclear use.

In addition, complications arise in practice because nuclear material is exported and imported in a variety of forms and concentrations for both nuclear and non-nuclear purposes. Also, industrial practices generate waste containing nuclear material, sometimes in relatively high concentrations. IAEA safeguards should cover all of these aspects. As described in Chapter 7, some of them are not completely covered by INFCIRC/153, an omission that was “corrected” by the Model Protocol.

¹⁸⁹ High-level waste from reprocessing of spent fuel may fit in this category.

¹⁹⁰ Uranium is widely used for a number of non-nuclear applications, especially to take advantage of its high density, for example, as radiation shielding, counterweights on airplanes and ship ballast, and in armor penetrating munitions.

INFCIRC/153
PURPOSES OF INSPECTIONS

71. The Agreement should provide that the Agency may make ad hoc inspections in order to: (a) Verify the information contained in the initial report on the nuclear material subject to safeguards under the Agreement; (b) Identify and verify changes in the situation which have occurred since the date of the initial report; and (c) Identify, and if possible verify the quantity and composition of, nuclear material in accordance with paragraphs 93 and 96 below, before its transfer out of or upon its transfer into the State.

72. The Agreement should provide that the Agency may make routine inspections in order to: (a) Verify that reports are consistent with records; (b) Verify the location, identity, quantity and composition of all nuclear material subject to safeguards under the Agreement; and (c) Verify information on the possible causes of material unaccounted for Shipper/receiver differences and uncertainties in the book inventory.

73. The Agreement should provide that the Agency may make special inspections subject to the procedures laid down in paragraph 77 below: (a) In order to verify the information contained in special reports; or (b) If the Agency considers that information made available by the State, including explanations from the State and information obtained from routine inspections, is not adequate for the Agency to fulfill its responsibilities under the Agreement. An inspection shall be deemed to be special when it is either additional to the routine inspection effort provided for in paragraphs 78-82 below or involves access to information or locations in addition to the access specified in paragraph 76 for ad hoc and routine inspections, or both.

Safeguards in one State should end when it exports nuclear material to another State and the recipient State takes responsibility for it (paragraph 12). As noted above, nuclear material may be used in non-nuclear activities that do not require the application of safeguards (paragraph 13).

In INFCIRC/153, paragraphs 36-38 delineate the conditions and quantities of nuclear material that may be exempted from safeguards.

5.2.3 Safeguards implementation – Subsidiary Arrangements

Subsidiary Arrangements are agreements between the State and the IAEA. They record the details of safeguards implementation as negotiated and agreed by the two parties (paragraph 39). Subsidiary Arrangements deal primarily with the routine implementation of safeguards and routine inspections. They specify, for example, the scope, access, frequency, and intensity of inspections. Subsidiary Arrangements are in two parts. In accordance with INFCIRC/153, the Subsidiary Arrangements also list the design information to be provided and when; the records that need to be kept; and the reports to the IAEA that need to be made about the flow and inventory of nuclear material. They specify how the IAEA is to conduct routine inspections.

There is no way to specify when the negotiation of Subsidiary arrangements will be completed. In order to ensure that safeguards are not applied during this negotiation, INFCIRC/153 provides for ad hoc inspections. Ad hoc inspections commence upon receipt by the Agency of a State's initial report on the nuclear material subject to safeguards under the agreement (paragraph 71). The access to be provided for verification of the initial inventory and any changes in it is specified in

paragraphs 76 (a) and (b), including everywhere that nuclear material is located. Implementation of ad hoc inspections ends at the conclusion of Subsidiary Arrangements.

5.2.4 Negotiation of Subsidiary Arrangements

Subsidiary Arrangements have two parts. The general part serves as an umbrella that covers matters that are common to all nuclear activities in a State – specifying, for example, points of contact and reporting formats. There are also rules for designation of inspectors, i.e., who is allowed to inspect in a given State, and for the notice that has to be given before an inspection. The State is allowed to have its representatives accompany inspectors if it wishes, as long as this does not delay or impede the inspectors. INFCIRC/153 reflects the worries of States about interference, but at the same time it requires States to cooperate and protects the rights of the inspectorate to pursue inspections effectively and without interference.

In addition, a “Facility Attachment” is included in each facility’s Subsidiary Arrangements. It records the details of safeguards implementation there.

In general, the negotiation of a Facility Attachment is based on a model safeguards approach developed by the IAEA for each major facility type – a light water reactor (LWR) or a gas centrifuge uranium enrichment plant, for example. For each major facility type, the IAEA developed a Model Facility Attachment, and the end result of the negotiation would be a Facility Attachment that adapted the model to the actual facility. The models and the results would also reflect the development of new safeguards instrumentation and new conceptual approaches to safeguards implementation. The development of safeguards approaches is discussed in Chapter 6.

The process of arriving at Facility Attachments comprises a series of steps. It begins when facility plans and design information are provided to the IAEA. It ends when the IAEA and the State have agreed on the inspection activities, their location and timing, and the portable and installed instrumentation to be used at a specific facility or location.¹⁹¹ To minimize any incentive for a State to stretch out the negotiation of the Subsidiary Arrangements in order to avoid inspection, INFCIRC/153 allows ad hoc inspections to begin even before the conclusion of the Subsidiary Arrangements. These inspections may be more intensive than the routine inspections undertaken later.

The following describes the process of reaching agreement on Subsidiary Arrangements:

1. The State submits design information for a facility in stages (paragraphs 42-48):

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116. "Strategic point" means a location selected during examination of design information where, under normal conditions and when combined with the information from all "strategic points" taken together, the information necessary and sufficient for the implementation of safeguards measures is obtained and verified; a "strategic point" may include any location where key measurements related to material balance accountancy are made and where containment and surveillance measures are executed.

¹⁹¹ The description above relates to States that are already parties to the NPT, have safeguards agreement in force, and are building new facilities. It is somewhat different if a State joins the NPT and brings a new safeguards agreement into force. However, it is unlikely for this situation to arise any time soon.

- It identifies plans for new nuclear facilities and for any modifications to existing facilities and provides preliminary design information;
- It provides the Agency with further information on designs as they are developed; and
- It provides the Agency with a completed Design Information Questionnaire (DIQ) for each new facility based on preliminary construction plans as early as possible and, in any event, not later than 180 days prior to the start of construction. A DIQ based on “as-built” designs should be provided as early as possible, and, in any event, not later than 180 days before the first receipt of nuclear material at the facility.¹⁹²

2. As construction or modifications proceed, the IAEA visits facilities to verify that the facility is being constructed in accordance with the design information. This facilitates the timely development of safeguards approaches and ensures that features designed to conceal a diversion are not incorporated into the facility.
3. Based on actual facility design, the IAEA adapts a model safeguards approach¹⁹³ for that facility type to the specific facility, including the material accountancy structure. The Agency and the State agree on the safeguards approach, including the frequency and intensity of inspections; the instrumentation to be deployed; and the locations, called “strategic points,” i.e., the places where, when taken altogether, the information obtained and verified is “necessary and sufficient” for the implementation of safeguards. This includes, for example, places where equipment is installed.¹⁹⁴
4. This agreement is codified in the Subsidiary Arrangements as a Facility Attachment and is the basis for IAEA routine inspections.
5. As changes are made to the facility design, including changes to the flow of nuclear material or type of material processed, the State must submit a revised DIQ, which may lead to a revised Facility Attachment.
6. IAEA inspectors have the right to verify facility design information on a continuing basis, to ensure that the flow of nuclear material or other operational features have not changed in a way that affects the implementation of safeguards or to monitor what has changed so that appropriate changes can be made to the Facility Attachment.

This process of planning and implementing routine safeguards is both complex and highly constrained. Both the broad outline and many of the details of routine implementation of

¹⁹² This description of the provision of design information reflects current practice. Before 1992, Subsidiary Arrangements did not include any reference to notifying the Agency of plans, construction, or preliminary designs of facilities. This would permit a state to essentially build a complete facility before notifying the IAEA. In 1992, the Board agreed that paragraph 42 should be interpreted to mean all of the steps outlined above and called on states to incorporate this interpretation in their Subsidiary Arrangements by modifying “Code 3.1.” See Section 5.5 for further information.

¹⁹³ Model safeguards approaches are developed through careful analysis of the means by which a state could carry out and conceal a diversion. Ideally, the model safeguards approach would provide a robust and timely detection capability for all diversion paths. This is not necessarily the case in practice because of technological limitations and resources.

¹⁹⁴ The full definition of “strategic point” is in textbox and in para. 116 of INFCIRC/153.

safeguards are specified in an agreement between the Agency and the State. As a result, the IAEA's inspection approaches must be designed to take into account steps that a State might employ to conceal a diversion, including using its prior knowledge to defeat the measures implemented by the IAEA. Section 6.2 discusses this safeguards dilemma. From the verification perspective, this may appear to put the inspectorate at a disadvantage because many, but by no means all, of its activities are preplanned, prescribed, and known to the State in advance. As a result, a State planning a diversion would be able to minimize the chance of detection by taking advantage of this prior knowledge of what its "adversary," the IAEA, had planned and assumptions about what the IAEA was capable of doing. This would include timing, means to defeat IAEA containment and surveillance measures, and concealment methods.

However, the development of safeguards approaches takes into account the problem of prior knowledge on the part of the inspected State. Safeguards implementation includes measures to compensate for this difficulty, including a provision that permits a portion of routine inspections to be made without advance notice. The IAEA develops safeguards approaches intended to cover all credible diversion paths, taking into account concealment measures, and the State provides the IAEA or makes available to the IAEA a wealth of information about the design and operation of facilities. In addition, many inspection tools such as environmental sampling are difficult to defeat. Furthermore, no State can rule out having its diversion plans and concealment methods go wrong. Regardless of judgments about the technical effectiveness of safeguards, no meaningful diversion of declared nuclear material or misuse of declared nuclear facilities subject to safeguards has been detected or reported.¹⁹⁵

5.3 Non-Routine Safeguards Implementation

Section 5.2 describes routine implementation of safeguards, but events are not always routine. Circumstances often arise where "routine" measures no longer suffice because anomalies or inconsistencies arise – a camera fails, an IAEA measurement is very different from a reported value, an item is missing. In these instances, the IAEA must investigate in order to resolve the inconsistency or satisfy itself that the anomaly is not indicative of a diversion. No subsidiary arrangement can cover all of the circumstances that can arise, and inspectors now enter into an investigatory phase that can challenge their ingenuity. Almost all concerns are readily resolved, but this phase, in principle, could lead to tension between the IAEA and State over what measures should be used and where. Ultimately, the Board of Governors could address the issue if the

**INFCIRC/153
SPECIAL INSPECTIONS**

73. The Agreement should provide that the Agency may make special inspections ... if the Agency considers that information made available by the State, including explanations from the State and information obtained from routine inspections, is not adequate for the Agency to fulfill its responsibilities under the Agreement.

¹⁹⁵ As will be described later, in the case of the DPRK the IAEA detected its failure to report fully its initial inventory of nuclear material, and in a few other instances, States produced quantities of Pu much smaller than a significant quantity at research reactors without reporting it and without being detected. In other instances, states have failed to report nuclear facilities or nuclear material, but, clearly, the IAEA is not in a position to detect diversion from such facilities or their misuse.

differences between the IAEA and a State are not resolved or if there is suspicion of non-compliance.

One of the key authorities available to the IAEA in such circumstances is the right to conduct special inspections. This authority is specified in paragraphs 73 and 77 of INFCIRC/153. A special inspection may be called for in connection with “special reports,” which relate to unusual or unexpected circumstances. However, the IAEA can seek special inspections whenever it considers that the information available to it under routine conditions “is not adequate for the Agency to fulfill its responsibilities.” Reflecting the “anytime, anywhere” safeguards provision of the IAEA Statute, this authority is a powerful tool, in principle, for investigating possible instances of non-compliance. In such a circumstance, the “specialness” of special inspections is the right conveyed to the IAEA to receive information and make inspections at locations in addition to the information and access that the State is otherwise required to provide.

The special inspection authority has been used rarely. The Board requested a special inspection in 1993 in the case of the DPRK, but the request was rejected. It is foreseeable that States will deny access to a location or activity where a safeguards violation has taken place or is underway, but the denial itself constitutes actionable non-compliance and can trigger remedial action as happened for the DPRK. Also, in 1993, a special inspection was requested by Romania, shortly after a change in its regime. The new Romanian government reported that the previous regime had produced a small quantity of plutonium at a research reactor but had not reported it to the IAEA.

Many observers believe that the IAEA should use special inspections more often. They consider that the IAEA’s failure to do so may have undermined its ability to use the special inspection authority in the future.^{196,197,198} Syria’s construction of a clandestine reactor that was destroyed by Israel in 2007 would clearly seem to warrant a request for a special inspection in light of Syria’s lack of cooperation. However, the IAEA did not request one, and recent fighting makes IAEA visits to Syria too dangerous. In any case, as of November 2017, the IAEA had not requested one.

Non-routine safeguards implementation – An example

The IAEA detected inconsistencies in the nuclear material inventory declared by the DPRK just after its safeguards agreement entered into force in 1991. Using the special inspection authority, the IAEA requested access to particular additional locations and asked for additional information. The DPRK rejected these requests. This led ultimately to a report of non-compliance by the Board of Governors to the United Nations Security Council; the DPRK resignation of its membership in the IAEA; its threat to withdraw from the NPT; and the negotiation of a freeze on its nuclear

¹⁹⁶ See, for example, a presentation by Pierre Goldschmidt, *The Future of the NPT: Should It be Enhanced, Changed or Replaced?* At an International Seminar on Nuclear Disarmament and Nonproliferation – The Future of the NPT in Rio de Janeiro, October 29-30, 2009, at http://www.carnegieendowment.org/files/goldschmidt_cebr1.pdf.

¹⁹⁷ In his plenary statement at the INMM Annual Meeting in 2011, IAEA Deputy Director General for Safeguards, Herman Nackaerts, said, “I believe that we should now be less wary of deploying [special inspections].” http://www.inmm.org/AM/Template.cfm?Section=Evolving_the_IAEA_State_Level_Concept&Template=/CM/ContentDisplay.cfm&ContentID=2971. (July 30, 2012)

¹⁹⁸ Special Inspections Revisited, John Carlson and Russell Leslie, Australian Safeguards and Non-Proliferation Office, *Paper presented at INMM 2005 Symposium Phoenix, U.S.A. – July 2005* http://www.dfat.gov.au/asno/publications/inmm2005_special_inspections.pdf (March 15, 2012)

program under the Agreed Framework.^{199,200} While the situation in the DPRK remains unresolved, the key consideration for the safeguards system is that it detected the inconsistency, pursued steps to resolve it, and, failing that, brought the violation to the attention of the Board of Governors. The Board, in turn, took the political decisions designed to deal with it. Sounding the alarm, not enforcement, which is under the purview of the United Nations Security Council, is the function that the IAEA is intended to perform through its safeguards, and it did so in this instance.

¹⁹⁹ The text of the Agreed Framework and an excellent description of the Framework and its subsequent implementation can be found at the Nuclear Threat Institute's site, http://www.nti.org/e_research/official_docs/inventory/pdfs/agframe.pdf.

²⁰⁰ A detailed description of the events leading up to the Agreed Framework by knowledgeable insiders, indeed they negotiated the Agreed Framework, is found in *Going Critical: The First North Korean Nuclear Crisis*, Daniel B. Poneman, Joel S. Wit and Robert L. Gallucci, Brookings Institution Press 2004.

CHAPTER 6. SAFEGUARDS IMPLEMENTATION UNDER COMPREHENSIVE SAFEGUARDS AGREEMENTS

This Chapter describes how the IAEA develops model safeguards approaches that specify what inspectors should do for specific facility types. This in turn depends on understanding what the inspector is looking for. The goal is to deter diversion through the risk of detection, but how big a diversion and how quickly should it be detected? What tools and resources are available? Since deterrence derives from the ability to detect, we concentrate on the latter here.

The safeguards approach must also reflect assumptions that the IAEA makes about States. The IAEA's objective is to detect diversions. But how should it plan? On the assumption that any State might divert? Or just a few? Or none? What diversion paths or concealment methods might be used? Are they the same for all States, or do they depend on State-specific factors? The answers to these questions that were adopted in the 1970s are described below. Regardless of the answers, the IAEA cannot discriminate between States. (Chapter 7 describes events in the early 1990s in Iraq and the DPRK that changed how the international community viewed the role of the IAEA. As will be seen there, this led to a reconsideration of how to answer these questions to accommodate an emphasis on addressing safeguards at the level of an entire State and take into account all available information.)

In order to draw sound conclusions, the IAEA must take into account what opportunities exist for a State to divert nuclear material and to conceal the diversion. For each such opportunity, called a diversion path, the IAEA needs to find technical measures that will enable it to detect the use of this path for diversion even in the face of efforts to conceal the diversion. In addition, what inspectors can do depends on the tools available. The set of technical measures and their timing define a safeguards approach.

But inspectors do not inspect theoretical facilities based on model safeguards approaches; they mostly inspect large, industrial facilities, often with intense radioactive fields present in process areas. It is important to understand the technical and industrial environment in which safeguards operate. This understanding will convey the difficulty of the task confronting the inspectors and the difference between applying safeguards on paper versus the reality of applying them in the field.

6.1 Safeguards Objectives and Conclusions

Paragraph 28 of INFCIRC/153 provides that the objective of safeguards is “the timely detection of diversion of significant quantities of *nuclear material* from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.” Paragraph 29 identifies material accountancy and containment and surveillance as the measures to be used. To carry out inspections, these terms need to be operationalized. For example, inspectors need to know where to go, what measures to use, what measurements to take and how many. The following section describes how the terms used in paragraphs 28 and 29 of INFCIRC/153 have been interpreted and put into practice.

6.1.1 Safeguards measures and safeguards objectives

Since the objective of safeguards is detection of a “diversion,” it is critical to understand the concept. Although the term is drawn from Article III of the NPT, it has no legal definition. As part of its comprehensive explanations of safeguards technical terminology, the 2001 IAEA Safeguards Glossary²⁰¹ defines “diversion” as “the undeclared removal of declared nuclear material from a safeguarded facility; or the use of a safeguarded facility for the introduction, production or processing of undeclared nuclear material....”

The first element of this definition is straightforward: removing declared material and not declaring it would clearly be a diversion. The second element of the definition might also seem straightforward. A diversion would seem to include naturally the use of a facility to produce undeclared nuclear material, for example, production of more plutonium at a reactor than declared; or production of high-enriched uranium (HEU) at an enrichment plant that is supposed to produce only low-enriched uranium (LEU). It may also seem straightforward because the language of INFCIRC/153 is clear. Paragraph 2 states that the IAEA is “obligated to apply safeguards to all nuclear material” in a non-nuclear-weapon State – not some of it, all of it.

The definition quoted above is from 2001. However, as noted in Section 5.2.1, after INFCIRC/153 was adopted in 1971, a number of States took the view that diversion referred only to nuclear material that was declared by a State to the IAEA. To a certain extent, IAEA safeguards implementation reflected this perspective, especially when NPT safeguards began in the 1970s. In part, this interpretation prevailed because the safeguards system was in its infancy, there was a steep learning curve for detecting diversions of declared nuclear material, and the tools available were limited. This role, i.e., verifying what has been declared, has been characterized as verifying the “correctness” of the reported elements of a State’s declaration.

Not all States held this view, and this narrow approach was broadened over time. The first change was motivated by the plans of non-nuclear-weapon States to supply uranium enrichment services based on the gas centrifuge process.²⁰² The concern was that gas centrifuge plants can, in principle, be rapidly converted to produce high-enriched, nuclear-weapon-usable uranium. The IAEA role could be limited to verifying the flow and inventory of declared material – correctness. However, this would not confirm that the plant had not produced HEU, which would pose a significant non-proliferation concern. After an intensive study by technology holders, it was agreed that the IAEA should be responsible for both roles, namely, that the IAEA should be responsible for verifying both the correctness of the information provided and also the “completeness” of a State’s declaration.

²⁰¹ IAEA Safeguards Glossary, 2001 Edition, IAEA/NVS/3,

https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf(accessed 1 March,2019).

²⁰² In 1971, the Treaty of Almelo entered into force between the Federal Republic of Germany, the Netherlands, and the United Kingdom. It created a limited liability company called URENCO to develop a gas centrifuge enrichment program to supply enrichment services on a commercial basis. Its first commercial plant opened in the Netherlands at Almelo in the early 1980s. The safeguards approach for the plant and reaching agreement on pursuing both correctness and completeness was established by the Hexapartite Safeguards Project, which included a small group of technology holders, Germany, Japan, Netherlands, United Kingdom, and the United States, and two inspection organizations, IAEA and Euratom.

The IAEA adopted the same approach for other facilities that produce nuclear material, reactors and reprocessing plants. Its goal at such facilities was to confirm the absence of the undeclared production of plutonium. Thus, starting in the early 1980s, the IAEA planned its inspections at declared nuclear facilities to achieve completeness and correctness - to detect diversion of declared nuclear material and to detect undeclared activities at declared locations. How, or whether, it should address undeclared nuclear activities away from declared nuclear facilities remained unsettled, although it was clear to some States that the IAEA's obligation to apply safeguards to "all nuclear material" was unambiguous. "All" meant all, and it did not matter whether it was declared or not. The issue would be addressed in a broad-based, serious manner only in the 1990s, and it is the subject of Chapter 7.²⁰³

It is worth re-emphasizing that the Agency does not have to determine why nuclear material has been diverted or where the material is before it can act. This is covered by the phrase "or for purposes unknown" in INFCIRC/153, paragraph 28, and in INFCIRC/153, paragraph 19. This permits the IAEA to report to the Board without detection of a diversion. It can do so based on the fact that it is not able to verify that there has been no diversion of nuclear material. This covers situations, for example, where the Agency can come to no conclusion because it is forbidden access or is prohibited from carrying out its duties. The Agency may also report to the United Nations Security Council under the provisions of the Statute related to non-compliance (Article XII.C) or in connection with matters related to international peace and security (Article III.B.4).²⁰⁴

6.1.2 Technical goals

The objective of safeguards contains the concepts of *timeliness* and *significant quantity*. The numerical values chosen for these terms establish some of the main characteristics of inspection planning. How often does a facility need to be visited to obtain "timely detection" and, for planning purposes, what is the quantity of nuclear material whose diversion is considered significant?²⁰⁵

For both timeliness and quantities of significance, the numerical values were selected to meet the core objective of the NPT: prohibition of the manufacture of nuclear weapons by a non-nuclear-weapon State. The issues are technical: How much nuclear material is needed to manufacture a nuclear explosive device; and how long would it take? The former depends on knowledge available on the basis of experience only to nuclear-weapon States. The latter depends on the chemical and physical form of particular materials.

Because the former relies on specialized knowledge, the IAEA turned to other sources, and, in this instance relied on a 1967 United Nations report.²⁰⁶ Not as a technical or legal matter, because

²⁰³ INFCIRC/153 gives the Agency some tools to detect undeclared activities, especially special inspections. The IAEA may also act if information about undeclared nuclear activities is brought to its attention by third parties.

²⁰⁴ A matter that is of concern with respect to international peace and security does not necessarily require non-compliance with a safeguards agreement. For example, manufacture of the non-nuclear components of a nuclear weapon by a non-nuclear-weapon State might violate the NPT but not an NPT safeguards agreement.

²⁰⁵ This does not mean that the IAEA would overlook the diversion of nuclear material in smaller quantities than is considered "significant." The numerical value of "significant quantity" is used for planning purposes, for example in selecting sample sizes for nuclear material measurement.

²⁰⁶ "IAEA Safeguards: Aims, Limitations, Achievements," IAEA/SG/INF/4 (IAEA, 1983) refers to the report "Effects of the Possible Use of Nuclear Weapons ...," United Nations, A/6858, 6 Oct 1967.

INFCIRC/153 speaks of “significant quantities,” but as a policy matter, it was decided to use the quantity of nuclear material needed to manufacture a single nuclear weapon, i.e., the first in a non-nuclear-weapon State. The time needed to transform a given type of material into metallic form was more amenable to evaluation on the basis of unclassified industrial processes.

Table 3. Significant Quantities of Nuclear Materials

ELEMENT	SIGNIFICANT QUANTITY
Plutonium	8 kg
U-233	8 kg
U-235 in HEU	25 kg of contained U-235
U-235 in LEU	75 kg of contained U-235 or 10 t natural uranium 20 t depleted uranium
Thorium	20 t

The definition of “significant quantity,” i.e., “the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be excluded,” and the quantitative values that have been adopted for

different elements are found in the IAEA Safeguards Glossary.^{207,208} The numerical values found in Table 3 have been adopted for the “significant quantity” of different forms of nuclear material.²⁰⁹

The IAEA also adopted quantitative goals for the timeliness of detection: the time within which the diversion of a significant quantity of nuclear material should be detected. These were based on the approximate time it would take to process diverted nuclear material into the metallic components of a nuclear explosive device. The goals are:

- One month for fresh (unirradiated) nuclear fuel containing HEU, plutonium or mixed oxides of plutonium and uranium;
- Three months for irradiated fuel containing plutonium or HEU;
- Twelve months for material consisting of natural uranium, LEU, or thorium.²¹⁰

http://www-pub.iaea.org/MTCD/publications/PDF/IAEA_INF_4_web.pdf.

²⁰⁷ IAEA Safeguards Glossary, 2001. IAEA/NVS/3.

https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf.

²⁰⁸ The numerical value for significant quantity has been challenged a number of times as being too high. For example, in “The Amount of Plutonium and High-enriched Uranium needed for Pure Fission Nuclear Weapons, Thomas Cochran and Christopher Paine, 1995, Natural Resources Defense Council, the “correct amount” is asserted to be as low as 1-3 kg of Pu and 2.5-5 kg of HEU for states with high technical capability. Text is available at <http://www.nrdc.org/nuclear/fissionw/fissionweapons.pdf>. (November 2011). It is generally accepted that it is feasible to manufacture a nuclear weapon with amounts of nuclear material smaller than 1 significant quantity. According to a 2001 document from the Department of Energy, Restricted Data Declassification Decisions 1946 to the Present (RDD-7), “Hypothetically, a mass of 4 kilograms of plutonium or uranium-233 is sufficient for one nuclear explosive device.” See <http://www.fas.org/sgp/othergov/doe/rdd-7.html#I23>.

²⁰⁹ See, for example, “The Evolution of IAEA Safeguards” IAEA/NVS/2, available on the IAEA website at https://www-pub.iaea.org/MTCD/Publications/PDF/NVS2_web.pdf.

²¹⁰ The timeliness goal of one year for low enriched, natural, and depleted uranium date from the same period, when the dominant enrichment technology was gaseous diffusion. Because of the large sizes and hold-ups of such plants converting them to produce HEU could not be done quickly, if at all. If the timeliness goals were selected today and took into account centrifuge enrichment technology, the goal would be much less than one year. As will be seen in Chapter 7, the timeliness goal for spent fuel is relaxed for states that have the most up-to-date safeguards agreement in force, i.e., an additional protocol.

The differences arise primarily from the number of steps needed to complete the necessary processing. For example, starting with spent fuel, a diverting State must, as a first step, move the highly radioactive spent fuel assemblies to a reprocessing plant. Then the plutonium must be separated from the uranium and from the fission products in the fuel assemblies. The resultant plutonium needs to be converted to metallic form and then to a nuclear-weapon component. Starting with unirradiated plutonium makes the reprocessing step unnecessary. These times are very rough estimates, at best, and the use of a “one size fits all” approach doesn’t take into account varying technical capabilities in different States.

The choice of timeliness goals has a major impact on IAEA resources because they determine the frequency of IAEA inspections. For example, the goal for the timely detection of the diversion of plutonium in spent fuel is three months. To meet this objective, inspectors must visit reactors four times a year. If the goal were one year, because the flow of nuclear material at powers reactors is infrequent, inspection might be needed only once per year.²¹¹

There is another parameter that must be established in order to plan inspection activities, the goal for probability of detection. This parameter is used primarily to determine sample sizes for material accountancy verification, but it may also arise in the context of randomly timed inspections. Unlike the size of the significant quantity and the timeliness goals, which are derived from characteristics of nuclear weapons and nuclear material processing capabilities, there is no analogous extrinsic factor that can determine the detection probabilities.

According to INFCIRC/153, the goal is to “deter diversion” by creating a “risk” of early detection. But it is hardly feasible to determine what a State would consider to be a “risk.” That may depend not only on detection probability but also on a State’s judgments about the likelihood of detection if concealment methods are used, the consequences of detection of diversion, or other domestic political factors. As a result, the IAEA focuses only on the variable under its control, the probability of detection. In practice, the IAEA uses detection probabilities that vary from high (90%) to low (20%) depending on the type of nuclear material.²¹²

6.1.3 Design and evaluation of safeguards implementation

Design

After the basic concepts and goals were established in the late 1970s, the IAEA began to develop model safeguards approaches for each type of nuclear facility. Model safeguards approaches contain the list of inspection activities that need to be implemented to meet the objectives just described (for example, sampling plans, nuclear material measurements, or containment and surveillance measures). Also included are the location and time needed for each of the activities as well as the time needed to resolve inconsistencies or anomalies if they arise. In this fashion, a

²¹¹ A useful description of these goals and how they were used, as well as an IAEA perspective on the development of safeguards through 1983, is found in its publication IAEA/SG/INF/4 “IAEA Safeguards: Aims, Limitations, Achievements,” (November 2011) found at:

http://www.pub.iaea.org/MTCD/publications/PDF/IAEA_SG_INF_4_web.pdf.

²¹² While the detection probability to be achieved is given a numerical value, for some IAEA measures such as surveillance, quantifying its performance has not proved to be feasible.

model safeguards approach specifies the activities needed for inspectors to meet both “quantity” and “timeliness” goals.

The development of model safeguards approaches reflected a set of assumptions that were applied uniformly across States. The assumptions for each State were:

- The probability of diversion is not zero;
- Attempts to conceal diversions are plausible; and
- Subsequent use of diverted nuclear material to manufacture a nuclear explosive device is practicable – that is, the necessary processing and manufacturing steps were assumed to be possible regardless of whether available information suggested otherwise.²¹³

In addition, the IAEA used the same quantitative goals and the same model safeguards approaches for all States. This helped to ensure uniformity of safeguards implementation among States and fulfilled an important political objective of the Agency, the need to avoid discrimination. It also created internal cohesion in how to implement safeguards, provided a uniform basis for evaluating safeguards performance and simplified training needs for the inspectors.

The process described above may seem straightforward. However, during the late 1970s and early 1980s, the IAEA was on a steep learning curve. It had to define and reach agreement on how to develop safeguards approaches and choose and develop safeguards instrumentation and techniques that would meet the unique requirements of implementing on-site inspections.²¹⁴ Because the IAEA has had no research or development (R&D) program of its own, a number of Member States, especially the United States, initiated safeguards support programs to develop and transfer to the IAEA safeguards instrumentation and investigate techniques. These programs also provided training and other technical support.²¹⁵

By the late 1980s, the IAEA had sufficient confidence in this process that it was able to develop detailed inspection approaches for all facility types. These approaches were codified collectively as the “Safeguards Criteria”; they were intended to serve as a stable and uniform basis for the implementation and evaluation of safeguards in all NPT non-nuclear-weapon States.²¹⁶

Evaluation

Model safeguards approaches were available to IAEA Member States, but Facility Attachments are confidential, in accordance with the provisions of INFCIRC/153. The details of safeguards implementation are also treated as confidential. One result of States’ interest in confidentiality is to make it difficult for the IAEA to bring to the attention of Member States concerns about

²¹³ For example, this would mean that if a State had not declared a reprocessing plant, it would nonetheless still be considered possible for a state to divert plutonium in spent fuel, extract the plutonium, and turn it into a weapon.

²¹⁴ Germany and Japan did not bring their INFCIRC/153 safeguards agreements into force until 1977. Thus, in the late 1970s, the IAEA faced a significant and abrupt increase not only in the number of facilities subject to safeguards but also in their size and sophistication.

²¹⁵ The U.S. program started in 1977. By 2017, there were 20 national safeguards support programs and one multinational program.

²¹⁶ After the Model additional protocol was adopted in 1997, the IAEA adopted a more flexible approach to selecting “timeliness” goals. This is discussed in Chapter 7.

safeguards implementation. This could include, for example, failure to meet inspection goals; inadequate performance by a State System of Accounting and Control (SSAC); or failure to make nuclear material available for verification.

On the other hand, States have a strong interest in understanding how effective the safeguards system is. It serves for many as the basis for nuclear cooperation. Also significant is that IAEA safeguards serve States' national security interests. By reducing the risk of proliferation of nuclear weapons and providing timely warning if it were to occur, a strong safeguards system can reduce regional and international tensions.

The IAEA balances these interests by publishing an annual summary of its safeguards implementation in the IAEA Annual Report.²¹⁷ Appearing there are the overall conclusions about States (not individually identified) with the various agreement types, identified problem situations, brief descriptions of the types of verification done, and prospects for improvement. In addition, the IAEA provides Member States annually, but not the public, with a Safeguards Implementation Report that provides substantial detail about the implementation of safeguards during the previous year.

6.2 Basic Technical Elements of Safeguards

6.2.1 Material accountancy – A fundamental safeguards measure

Nuclear material accounting is the set of activities used by facility operators and SSACs that is needed to establish the quantities of nuclear material within defined areas and the changes in those quantities within defined periods²¹⁸ It has a strong analogy with accounting for money. The amount of money in a bank account changes as deposits are added to the account or money is withdrawn from the account. At the end of the month, there should be a balance – the amount left should equal the amount one started with (the beginning balance) plus the deposits and interest, less the amount withdrawn and fees. If there has been a “diversion” (or an accounting error), the calculated value and the actual cash balance will not agree.

Nuclear material accounting is a similar arrangement for nuclear material that can determine whether there have been losses. Although this analogy may be conceptually useful, there are important differences: for example, nuclear material is difficult to measure, and all measurements are subject to uncertainty or error. The error might be zero if the measurement is “counting,” but even counting errors can occur, especially for large numbers of objects. For measurements such as enrichment levels or isotopic concentration, weight, or volume, measurement errors are always non-zero. Nuclear material also changes chemical and physical form or isotopic composition. In some places it disappears, and in others it is created. (For example, some uranium in a reactor fuel “disappears” when it fissions or when plutonium is created.)

²¹⁷ IAEA Annual Reports are available at <https://www.iaea.org/publications/reports> (accessed 12 April 2018)

²¹⁸ IAEA Safeguards Glossary 2001, paragraph 6.2. On the other hand, INFCIRC/153 (paragraph 29) specifies that “material accountancy” is to be established as a safeguards measure “of fundamental importance.” “Material accountancy” is broader. It refers to both to the accounting for nuclear by facility operators and states and the activities needed by the IAEA to verify independently operators’ records and States’ reports (Safeguards Glossary, paragraph 6.1).

For nuclear material accounting, the first step is to establish the accounting area. For purposes of tracking nuclear material, this is called a material balance area (MBA), comparable to a bank account. Generally, a nuclear facility has more than one MBA, each of which usually corresponds to a physical area, such as a storage vault, a reactor core, or a processing area.

In accordance with INFCIRC/153, the State is obligated to ensure that facility operators maintain detailed nuclear material accounting records. All transfers of nuclear material into and out of an MBA need to be measured and recorded in facility records, and they must be periodically reported by the State to the IAEA. Facility operators must also periodically determine how much material is in the MBA, i.e., “take” the physical inventory. In some cases, these determinations will be based on measurements in the facilities; in others they will be based on measurements done at other facilities or on calculations. These results are also reported to the IAEA by States. The period of time between successive physical inventory takings (PITs) is called the material balance period.²¹⁹

Consider a very simple MBA. At the end of a material balance period, the facility operator can calculate the “book inventory” of the MBA: that is, the facility operator can start with the amount of nuclear material in the MBA at the last PIT, add the amount of nuclear material received at the MBA, and subtract the amount of nuclear material shipped from the MBA:²²⁰

$$\text{Book Inventory} = \text{Beginning Inventory} + \text{Receipts} - \text{Shipments}$$

The book inventory is the amount of nuclear material one expects to be in the MBA at the end of the material balance period. But how much material is actually there? In order to determine this, the facility operator needs to measure what is present, i.e., take the physical inventory. However, wherever the flows and inventory are measured, measurement errors occur, and uncertainties exist and must always be taken into account.²²¹ As a result, even on the assumption that no nuclear material has been diverted or lost, there will be uncertainty about what is the true nuclear material inventory.

INFCIRC/153

110. “Material balance area” means an area in or outside of a facility such that:
(a) The quantity of nuclear material in each transfer into or out of each “material balance area” can be determined; and (b) The physical inventory of nuclear material in each material balance area” can be determined when necessary, in accordance with specified procedures, in order that the material balance for Agency safeguards purposes can be established.

²¹⁹ The nuclear material accountancy system is generally at three levels: at one level is the facility operator, who must control the flow and inventory of nuclear material, perform the measurements and keep the records required by INFCIRC/153; the State, which must ensure that the requirements of INFCIRC/153 are fulfilled, including, for example, that access is provided to inspectors; that the quality of the operator’s performance is acceptable, and that reports results are reported to the IAEA in a timely fashion; and the IAEA that verifies findings of the State.

²²⁰ In a more complicated MBA, receipts would be one of several additions to inventory and shipments would be one of several subtractions from inventory.

²²¹ If the measurement is counting, the error could be zero, although counting errors can occur, especially for large numbers of items.

The difference between the ending inventory and the book inventory is the MUF, or material unaccounted for:

$$\text{MUF} = \text{Beginning Inventory} + \text{Receipts} - \text{Shipments} - \text{Ending Inventory}$$

INFCIRC/153

102. Book inventory of a material balance area means the algebraic sum of the most recent physical inventory of that material balance area and of all inventory changes that have occurred since that physical inventory was taken.

This equation represents the nuclear material balance. For measured nuclear material, the MUF cannot be zero if there is measurement uncertainty and error. The challenge for the operator and the State is to be satisfied that the non-zero amount is acceptable. Is all nuclear material present or is the non-zero amount indicative of a potential loss of material, which could be the result of theft?

This process produces a “finding” for each MBA, i.e., what is the quantity of nuclear material present,

what is the MUF, and what is the limit of error on the MUF.²²² All of the data and findings are reported to the IAEA, whose job it is to verify the findings of the State. Conceptually, the situation is straightforward:

1. The State reports the beginning inventory and the IAEA verifies it.
2. During the material balance period, the State reports the flows of nuclear material into and out of the MBA, and the IAEA verifies them.
3. At the end of the material balance period, the State reports the ending inventory and the IAEA verifies it.
4. MUF is calculated, and if the difference between the State’s finding and the IAEA’s is small, the MUF is low enough, and there are no other indications that would indicate otherwise, a positive conclusion of non-diversion can be drawn for that material balance area.²²³

The situation becomes complicated when the assumption is introduced that the State might divert nuclear material and attempt to conceal the diversion. Not only does the IAEA need to ensure that all of the records at the facility are internally consistent and match the reports sent by the State, but also the IAEA must ensure that the results are valid. It needs to ascertain whether reported values have been falsified or if measurements have been tampered with or spoofed. Or have items been partially or completely removed and replaced by substitutes? The IAEA must plan for and be alert to all of the credible concealment methods. The following section illustrates some of the different ways that a State could attempt to conceal a diversion and how IAEA inspection approaches take these into account.

²²² The “limit of error” is a statistical term representing the range of values around the “true value” in which 95% of measured values should fall.

²²³ Paragraph 30 states “the technical conclusion of the Agency’s verification activities shall be a statement, in respect of each *material balance area*, of the amount of *material unaccounted for* over a specific period, giving the limits of accuracy of the amounts stated.” This may overstate the importance of MUF, as there are other indicators of diversion such as a surveillance finding of unreported activities or discovery of a dummy item.

6.2.2 *Diversion strategies*

Should it choose to do so, there are numerous ways for a State to divert nuclear material and conceal the diversion- too many ways to enumerate. Not only does the State choose how much to divert, but it also chooses the timing. It may divert small amounts over time in order to accumulate nuclear material slowly, or it may divert all of the nuclear material it wants at one time. These are called respectively protracted and abrupt diversions.

At facilities where there are many items or many streams of nuclear material the State may also falsify the values of any of these streams or items in these streams. Misstatements may refer to all of the items in the streams or just a portion of them, and they may be small or large.

The State may also choose to understate or overstate flows or inventories of nuclear material that are in a form that is hard to measure. For example, measurements of nuclear material in waste typically have large measurement uncertainties. It might, therefore, be possible to conceal the removal of easy-to-measure product material by overstating the amount of nuclear material that is in the waste. The desirable, product material has been diverted, but the MUF can be made small because the amount of product material missing is cancelled by overstating the amount of nuclear material in waste.

A different choice that a State can make to conceal a diversion, particularly for a facility with large flows or inventories, is to declare accurately the amount of the nuclear material remaining. Since the reported amounts are true, all of the measurements made independently by the IAEA will agree with the declaration (since it has been reported without falsification). The amount of missing nuclear material will appear in the MUF. Depending on the amount of nuclear material taken and the measurement uncertainties, the MUF might be small enough in relative terms that it would not trigger an alarm.²²⁴

On the other hand, the State could declare false information and overstate the quantity of nuclear material in the inventory by an amount equal to the amount of nuclear material diverted. According to the State's reports, everything is normal. In this case, the MUF according to the State would be within normal bounds, and it would not by itself be a good indicator of diversion. Whenever the IAEA measured an item whose content had been falsified to conceal the missing material (that is, it would be overstated), it would expect there to be a difference between the reported value and its measurement. Again, depending on the measurement error and the size of the falsification, the IAEA might detect this scheme in single items or through the accumulation of differences over many items.²²⁵

²²⁴ This is called “Diversion into MUF”, which is defined in the IAEA Safeguards Glossary as “a concealment method ... in which an amount of declared material M is removed from a material balance area and the accounting records are adjusted to account for the amount M removed. Because the operator’s accounting records reflect the removal of M, there is no falsification of these records. This diversion strategy causes an imbalance in the MUF equation, and the diversion amount M shows up as part of a non-zero MUF....” (See Glossary 10.4.)

²²⁵ This is called “Diversion into D.” The IAEA Safeguards Glossary defines “Diversion into D” as a concealment method ... in which the diverter removes an amount of declared material M but does nothing to the operator’s accounting records to hide the diversion. The accounting records are therefore now false (and have thus been falsified). The diversion causes a discrepancy (i.e. defect) ... between the material declared to be present and the material actually present (see Glossary 10.6.). In order to detect this means of concealing a diversion, the IAEA has developed a statistic

Additionally, the State could attempt to conceal a diversion by taking steps that would render the IAEA's measurement results as invalid without its knowledge. For example, if the measurement technique was weighing, the State could substitute different material of the same weight as that removed. If the technique is a video camera, the State could, in principle, place in front of the camera an object that made the video results appear the same as the normal situation even though diversion activities were taking place.

Of course, the State may use a combination of these means to conceal a diversion. In order to address these different means, the IAEA must also adapt its safeguards approach – using, for example, very simple methods to detect a large falsification, methods with a good, but not the best, measurement capability on many of the items, and measurements that are the state of the art on a few of the items. The IAEA would need to pick a sample plan for each method that optimizes its overall detection capability. It must also choose a set of measures that detect concealment methods such as substitution. (For this case, the IAEA could both weigh the material and take and analyze a sample.)

Some examples

The following is a greatly simplified description of the alternatives that might be used by a State to conceal a diversion.

Figure 18 shows what the situation might be at the start of a material balance period. It represents a storage location where there are forty cans of nuclear material, each containing about two kg of nuclear material, say plutonium. The fluctuations in the values are indicative of a variation in the content of each item by 10% around the average. Keep in mind that the State has made a declaration to the IAEA of the amount in each can.

Imagine that the IAEA returns at the end of the material balance period, and 40 containers remain there. The inspector can verify this using a simple inspection measure: counting.

called the D-statistic, which represents the sum of the differences between what the IAEA measures and what is reported by the state.

Suppose the State has removed all of the contents of four cans, and about 0.1 kg from the other 36, but the cans remain so that counting them would not detect any falsification. Figure 19 displays this possibility. The red is indicative of a concealment method, in this case leaving behind four empty cans so that counting alone cannot detect the removal.²²⁶

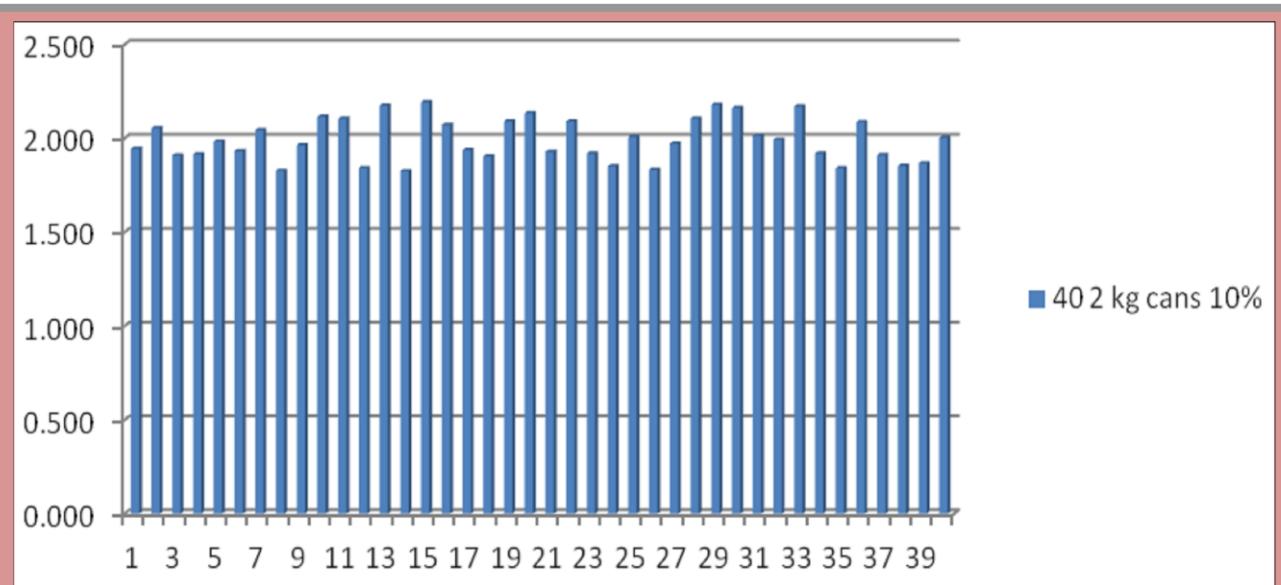


Figure 18. Contents of forty cans with a 10% variation around an average of 2 kg

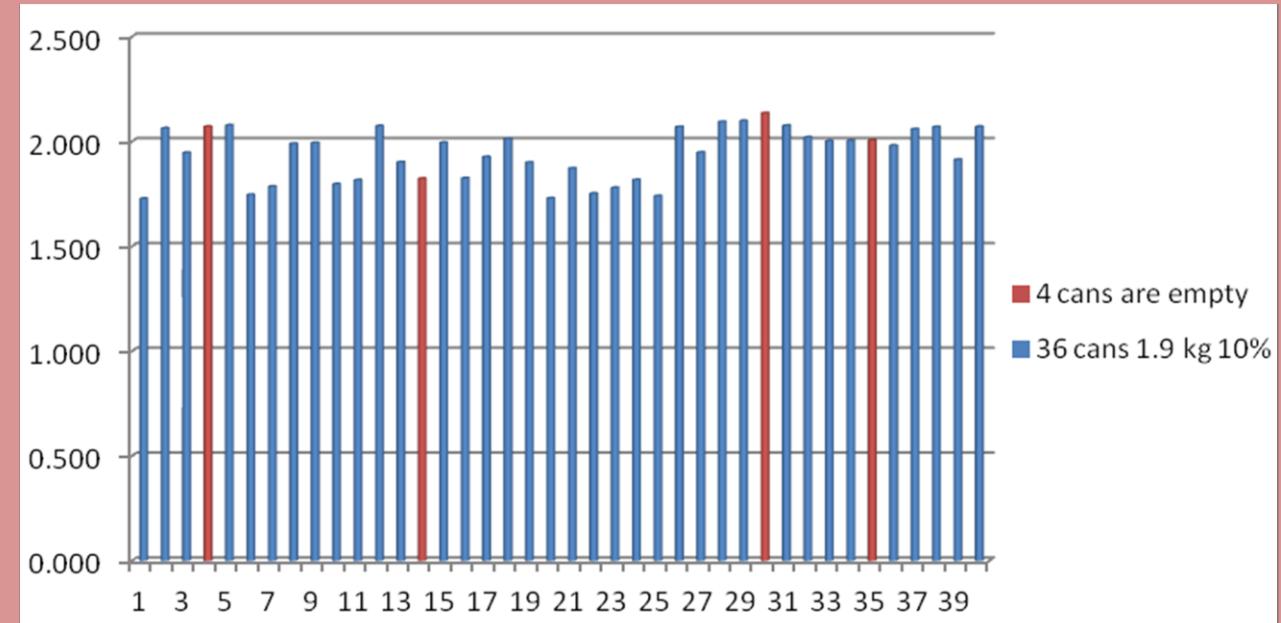


Figure 19. Contents of 36 cans with a 10% variation around an average of 1.9 kg, and with four empty cans

²²⁶ This is not the only possibility. The state could divert the plutonium by removing the four cans together with their contents. When the inspectors arrive, the state could report that the four items had been shipped to another facility.

In this scenario, the inspection strategy is to select and detect one of the four empty cans. The inspector could examine all of the cans and obtain a 100% detection probability (if the examination would detect the falsification), but this is resource intensive and would exceed what is required. Random sampling can be used to make the process more efficient and still meet inspection goals.

If the inspector selects eighteen containers at random, there is a 90% probability of picking one of the four empty cans. If the inspection measures used can reveal that the plutonium is missing, this would meet the inspection goal for plutonium. (The detection probability depends on the sample size. Selecting only one can, for example, gives a detection probability of 10%.)

What type of inspection activities should the inspector carry out to detect a diversion in this scenario? If the cans were empty, a very simple inspection measure would work – just tipping the can would reveal a major discrepancy in weight. This measurement technique would detect what are called “gross defects.”

But it is straightforward for the State to ensure that each can has the correct weight, just by adding two kg of some other material. This would defeat the simple measure of tipping the can. The inspector, though, could use another inspection measure - a portable neutron detector - and identify whether the container emitted the neutrons that are characteristic of plutonium. This would counter the concealment method of inserting a non-radioactive substance that made the weight correct. Such a measurement would be called an “attribute measurement.”

The reader might have noticed that the average height of the bars in the Figure 19 is a bit lower than in the Figure 18. That is because the State has also removed on average about 0.1 kg from the 36 containers that are not empty. Now counting the containers doesn’t work; tipping the cans won’t work; weighing the cans is ineffective if the State has replaced the missing plutonium with 0.1 kg of an inert material; and the attribute measurement won’t work because all of the cans have the attribute of emitting neutrons that are characteristic of plutonium. After all, each can has almost the amount of plutonium that was originally there.

The inspector must use more sophisticated or complex inspection measures to detect this concealment method. For example, if the inspector could measure the number of neutrons that were emitted, compare that with the number that was determined by a previous measurement, and do that with sufficient accuracy, the inspector’s measurement would differ from the reported amount by enough to trigger an alarm. Even if a single measurement did not result in a large discrepancy, the results of a series of measurements could do so because all of the items are falsified.

Alternatively, the inspector could open a can and “look” for the surrogate material that had been inserted to get the weight right. Since “looking” might require that a sample of material be taken from the can and shipped to an IAEA laboratory for chemical and isotopic analysis, this inspection measure is operationally difficult and expensive. It also imposes a cost on the faculty operator who carries out the operation in a safe and secure manner. However, discovery of a significant amount of surrogate material would be an unambiguous sign that something was wrong.

To address the possible concealment methods, the IAEA has at its disposal a variety of tools:

- *Independent measurement of nuclear material items.* These measurements can be taken at a variety of levels of accuracy and different parameters can be

measured. As noted above, some measurement techniques can detect “gross” defects, others look at attributes, and others can make very accurate measurements of nuclear material. Inspectors may make measurements in the field or ship samples of nuclear material to IAEA laboratories for analysis. Deciding whether a set of measurements is indicative of a diversion or not must take into account random and systematic errors that are intrinsic to the measurement process.

- *Containment and surveillance:* Inspectors rely on seals and surveillance devices to maintain “continuity of knowledge” of nuclear material. If nuclear material is put under seal or surveillance and the sealing and surveillance measures are “successful,” i.e., the inspector can verify that the seal is intact or that the surveillance shows no unexplained access to nuclear material, then the results of previous measurements can be accepted.²²⁷
- *Sampling strategies:* Inspectors don’t have to measure every item or all batches of nuclear material. As illustrated above, they can use statistical inference to extrapolate the results of measurements of a subset of the items in a material balance component to draw conclusions about all of them. For this to be true, all of the items must be available for measurement, if selected, and the selection process must be truly random. For example, if there are 1,000 fuel pellets on inventory, an inspector may select ten from the 1,000 at random instead of measuring them all. The sample size is determined on the basis of the desired probability of detecting the absence of a significant quantity of nuclear material or a falsification of fuel pellets.

Based on its inspection activities and taking into account the measurement errors involved and the means available to conceal a diversion, the IAEA draws a conclusion about whether or not there has been a diversion. There is a rich and varied literature about the statistical techniques used as the basis for this conclusion, but they are well beyond the scope of this book.²²⁸

6.2.3 Containment and surveillance

Since measurements and other on-site verifications by inspectors are time-consuming and require specialized equipment, resources can be saved, and effectiveness maintained if the IAEA can rely on the results of previous measurements or other verifications. This can be done through the use of containment and surveillance (C/S) measures. These consist mainly of physical containment, cameras, radiation or motion sensors, and seals (also known as tamper-indicating devices or TIDs). Cameras are widely used at spent fuel ponds, and seals are frequently applied to containers that store nuclear material. The former can confirm that no fuel assemblies have been removed from

²²⁷ The IAEA may also measure some nuclear material again even when the C/S is successful. This provides an additional level of assurance that protects against a mechanism that defeats the C/S without detection.

²²⁸ Interested readers may turn to the “IAEA Safeguards Technical Manual, Part F. Statistical Concepts and Techniques,” Volume 3. IAEA-TECDOC-261 (1982), which is available at http://www-pub.iaea.org/MTCD/publications/PDF/te_261_web.pdf. It is a comprehensive review of the techniques for treating measurement errors, selecting sample sizes, and analyzing inspection data.

the spent fuel pool since the previous inspection and the latter that the contents of containers have remained unchanged.

C/S measures can also detect the unreported removal of nuclear material or other indicators that a facility is not operated in accordance with declarations or operating records. As such, they provide a potential means that are independent of nuclear material accounting to detect indications of diversions.

C/S measures may also be used to ensure that IAEA equipment, working papers, and supplies have not been tampered with or to “freeze” nuclear material that has not been verified until it can be measured.

As with material accounting, C/S methods and devices have practical limitations. Even modern cameras with high resolution and large storage capacities cannot completely replace the presence of an inspector, and it is not always clear what is happening in a surveillance image. Lighting and power failures occasionally happen. Objects may wind up blocking the field of view of a camera. Seals can be broken accidentally.

The IAEA must also consider circumvention – i.e., a seal or surveillance system could be defeated. One example would be to remove a seal, remove nuclear material, and then replace the seal with another that looks identical. Or the container, itself, might be penetrated, material removed, and the penetration repaired to make it “invisible” to the inspector. Needless to say, the IAEA takes steps to ensure that it can detect such concealment methods. Regardless of the steps taken, there cannot be 100% certainty of this. As a result, the IAEA may remeasure nuclear material even when the seal or surveillance appears to be successful.

Environmental sampling may also be considered a form of surveillance. It relies on the fact that when a facility processes nuclear material, complete containment of the material is extremely difficult. If nuclear material does escape, even at sub-microscopic levels, trace amounts can be captured by “swiping” a surface with a clean cloth and sending the cloth to a measurement laboratory. Modern techniques can locate and measure particles smaller than one micrometer (femtograms of uranium, containing just millions of atoms). As a result, environmental sampling may detect undeclared nuclear material or activities by finding nuclear material forms not consistent with declared nuclear operations. For example, if analysis of environment samples at an enrichment plant declared to be producing only LEU detected HEU, this would, needless to say, be a major discrepancy.

6.2.4 Design information verification

The verification of a facility’s design is an essential element of planning a safeguards approach and includes confirming the features of the plant in enough detail to do so. Design information is provided to the IAEA by the State using standard IAEA forms, Design Information Questionnaires (DIQs). Design information verification (DIV) must take into account all possibilities: diversion of nuclear material, production of undeclared nuclear material, and the conduct of other undeclared nuclear activities. In that sense, the DIV is not merely mechanical; the IAEA needs to know the operating characteristics of facilities and whether they can support undeclared nuclear activities.

The IAEA Board of Governors decided in 1992 to clarify the interpretation of when design information should be submitted. As a result, States submit design information in stages, and the DIV process can be spread over many years. It may be an elaborate process. In the case of a reprocessing plant, inspectors will make many visits to a facility during construction to ensure that piping is as declared; and there can be hundreds of kilometers of piping, some of which penetrates thick concrete walls.

For new facilities, States provide the IAEA with their plans to build them and provide preliminary design information. As described in Section 5.2.4, States then provide design information on a continuing basis, ending with submission of a completed DIQ based on “as-built” designs. The DIQ contains not only the physical layout of the facility but also the flow and characteristics of nuclear material at the facility, information which the IAEA needs to develop a safeguards approach for the facility. If the design of a facility is modified (before or after operation begins), the State is also required to provide a revised DIQ to the IAEA.²²⁹

This continuing provision of design information and its validation by inspectors throughout the process via design information examination and DIV gives the IAEA confidence that it understands the final design of the facility. This, in turn, gives it confidence that the safeguards approach for a facility has the right coverage – the approach is based on a good understanding of the pathways along which nuclear material might move and it addresses the ability of a facility to conceal the diversion of nuclear material or to produce undeclared nuclear material. For example, in some processing facilities, the IAEA relies on samples in solution that are delivered by tubes to a sampling point. It is the verification of the piping that gives the inspector confidence in the authenticity of the sample; i.e., the sample actually came from the right point.

The IAEA also has the authority to re-examine design information to ensure that the safeguards approach remains valid and that no changes have been introduced that could facilitate the production of undeclared nuclear material. It does this on a continuing basis. The means by which design features are examined range from the simple, observation and tape measures, to the sophisticated, laser range-finder devices, such as shown in Figure 20, that can produce a highly accurate, three-dimensional, digital model of a facility and detect very small design changes that

²²⁹ Model Safeguards approaches are developed through careful analysis of the means by which a State could carry out and conceal a diversion. Ideally, the Model Safeguards approach would provide a robust and timely detection capability for all diversion paths. This is not necessarily the case in practice because of technological limitations and resources.

may have taken place. Efforts to develop tools to make this process more effective and efficient are ongoing.²³⁰

6.2.5 Anomaly resolution

Even if routine safeguards implementation does not produce a “smoking gun” – clear evidence that a State has diverted material - inspectors may still not be satisfied with preliminary results. Inconsistencies, discrepancies, or “anomalies” may occur that must be investigated further. This is not an uncommon element of safeguards implementation. “Anomaly” is defined in the IAEA Safeguards Glossary as:

An unusual observable condition which might result from diversion of nuclear material ... or misuse of safeguarded items, or which frustrates or restricts the ability of the IAEA to draw the conclusion that diversion or misuse has not occurred.

Follow-up actions taken to resolve an anomaly may range from the simple (finding the source of a transcription error), to the more difficult (re-measuring nuclear material protected by a broken seal or reverifying the contents of a spent fuel pool where surveillance results were inconclusive). These efforts can have significant impact on facility operations, for example, if they require a process line to be shut down while inventories are reverified.

To the extent that these follow-up actions indicate the need for atypical measures to provide a conclusion, the issue may be raised at a political level between the IAEA and the State. For example, to resolve a large MUF, there may be a need for significant technical effort by the State together with the inspectorate to find material held up in process equipment. Clearly, if the evidence points to a real diversion of material, the issue would go to the IAEA Board of Governors or beyond.

6.2.6 Challenges and limitations inherent in the application of safeguards

Putting “real-world” safeguards into practice at industrial nuclear facilities involves challenges and difficulties at a number of levels. At the most practical level, nuclear facilities present a difficult inspection environment. Beyond the size and technical complexity of the plant itself, plant operations are highly organized for reasons of efficiency, safety, security, and health. While the high degree of organization simplifies safeguards implementation, facility staff have to respond not only to their own management but also to heavy regulatory oversight. Adding or changing inspection activities in this operational environment generally requires approval by the State. If



(From Idaho National Laboratory)

Figure 20.
Laser-based system to create a three-dimensional image of a room or a facility

²³⁰ Robert S. Bean, et. al., "Design Information Verification for Nuclear Safeguards." Institute of Nuclear Materials Management Annual Meeting, July 2009. Idaho National Laboratory INL/CON-09-16395.

new equipment must be installed, to ensure plant safety, this would almost always be the case. For these reasons putting in place safeguards procedures can be time-consuming and expensive.²³¹

At the level of technological implementation, even without concealments, the conceptually simple idea of verifying a material balance turns out to be complicated in practice. Equipment and techniques for material measurements and C/S have technical limitations, and there are practical difficulties that must be taken into account in the design of the safeguards approach:²³²

- *Measurement error (or uncertainty).*²³³ Both an operator's measured value and an inspector's measured value for the nuclear material content of an item will have uncertainties. Some of the uncertainties can be random error, for example, radioactivity counting statistics, and some may be systematic errors, for example, incorrect calibration of a measurement device. Any comparison of an operator's declaration against an inspector's measurement has to take these into account. Likewise, since the MUF is an algebraic sum of measured values for individual items,²³⁴ the value of MUF will generally be non-zero for reasons of measurement error alone. So, assessing whether a non-zero MUF value is indicative of diversion becomes, in part, a statistical inference involving measurement uncertainties, some of which may be large and some of which may not be known.
- *Measurement difficulties.* Many elements of the flow or inventory of nuclear material are difficult or impractical to measure. For example, because of its high radiation fields, measuring the quantity of plutonium in a spent fuel assembly is very difficult without taking it apart and doing chemistry on small samples, which is impractical, though this is in effect done at reprocessing plants (see Section 6.4.7). It is difficult to estimate the nuclear material content of some process equipment in processing facilities, and facility operators may store nuclear material in ways that make some of it practicably inaccessible. There may also be plant discards and other waste containing nuclear material in low concentrations that are very difficult to measure.
- *Flow verification.* For the IAEA to verify MUF, inspectors have to be present at periodic PITs, and they also need to verify the flows into and out of each MBA. Resource limitations have historically limited the ability of the Agency to do this. In particular, if a facility is large and shipments and receipts frequent, the IAEA cannot afford to station inspectors at each MBA full-time to be on hand to perform such verification. Techniques have been developed to permit flow verification without full-time inspector presence at certain plant types by using short-notice random inspections. These are described in Section 6.3.6.

²³¹ For this reason the concept of "safeguards by design," in which safeguards considerations are designed into facilities from the start is important. (See Section 8.1.2.)

²³² To some extent, these limitations can be addressed by good system design in which multiple systems play compensatory roles: if a seal on a container fails, one is able to remeasure the container. Methods for compensating for these limitations are discussed in the sections below on specific facility types.

²³³ These two terms are used synonymously here. However, a true measurement error, better termed a blunder, would be, e.g. weighing the wrong item.

²³⁴ We expect MUF to be zero when it involves only items which are not remeasured between inventories.

- *Other difficulties.* Aside from measurement error, there are a number of benign reasons that MUF may be non-zero. The most important of these is process “hold-up,” which consists of residual nuclear material distributed in the process equipment.²³⁵ For example, the surfaces of pipes, tanks, and the insides of glove boxes in a plant may retain very thin layers or pockets of nuclear material that altogether is a significant amount.²³⁶ If not estimated and included in the calculations, unmeasured nuclear material in hold-up will show up in the MUF and make it more likely that it will indicate a diversion.
- *Reliability and other limitations of C/S.* The problems of material accountancy have led the Agency to rely more heavily on other methods, particularly C/S. But C/S is difficult to apply where material is not essentially static.²³⁷ Although the new generation of digital cameras produces high quality images, the presence of a camera is not equivalent to the presence of an inspector, and analysis of large numbers of images can be very time-consuming. While reliability of C/S devices has improved vastly, and is further improved by redundancy, unexpected failures can still occur. When this happens, and continuity of knowledge is lost, inspectors must fall back on measurements to re-establish confidence that material is not missing.

As noted above, in addition to intrinsic difficulties in verifying material balances, IAEA safeguards approaches and procedures must take into account plausible concealment strategies on the part of a State. To summarize, these include:

- *Substitution.* Replacement of diverted nuclear material with a substitute that is similar in appearance or characteristics but lacks the declared nuclear material. As a result, item counting may not be adequate, and measurements or C/S must be applied.
- *Borrowing.* Material at one facility may be “borrowed” temporarily from another facility for the purposes of the physical inventory verification at the first facility. The safeguards approach must take this into account, for example, by simultaneous inspections at both. A similar approach would be the assertion that the nuclear material diverted was in transit, and a report to this effect could be made.
- *Tampering.* Any installed equipment, including seals, cameras, or in-line measurement devices, may be tampered with. All such equipment must be protected by tamper-indicating measures. In addition, information flows must be authenticated, for example, by protecting data transmission lines physically or with authentication measures such as encryption.

²³⁵ There is a strong incentive on the part of facility staff to eliminate hold-up, namely to avoid dangerous nuclear criticality accidents. See “A Review of Criticality Accidents—2000 Revision,” LA-13638, Los Alamos National Laboratory; it is available at <https://www.orau.org/ptp/Library/accidents/la-13638.pdf> (Accessed 13 April 2018)

²³⁶ See Chapter 3C “Measurement of Nuclear Material Hold-up” in “Nuclear Safeguards, Security, and Non-Proliferation,” Jim Doyle, editor, Elsevier, 2008.

²³⁷ For very large facilities, especially reprocessing plants, even the best measurements might have uncertainties such that a loss of one significant quantity of nuclear material might be concealed by the large MUF. C/S and other techniques must then be employed.

- *Circumvention of C/S devices.* Placing a seal on a container or a storage vault only makes sense if the container itself cannot be emptied without breaking the seal or leaving detectable traces; backup surveillance can be set up in such a way that all removal routes are visible to the camera.
- *Circumvention of measurements.* The inspector cannot assume that the measurement of any characteristic of an item is necessarily valid. For example, the measured weight of an item might match the reported value, but the nuclear material contents may have been replaced with lead shot. Or, the declared nuclear material could be replaced by other radioactive material designed to have similar radiation signatures. To address this possibility, the IAEA may use a combination of measurements designed to detect more than one characteristic signature for the declared form of nuclear material.
- *Optimized removal strategies.* The diversion of a significant quantity of nuclear material may involve a large removal from a single item (abrupt diversion), or many small removals from a large number of items during a material balance period (protracted diversion). Random sampling strategies and measurement accuracies must be designed to cope with all possibilities to provide the target probability of detection.²³⁸

This is not an exhaustive list. For every safeguards measure and safeguards approach, one can conceive of means to try to circumvent it.

The possibility of concealment and the identification of “countermeasures” turn the problem of designing a safeguards approach into one that has analogies in game theory, one involving inspector and diverter strategies.²³⁹ It is a “game” in which the IAEA is at some disadvantage, even though safeguards approaches are designed to cover all practicable or credible concealment methods and to cover all credible diversion paths. The IAEA’s safeguards approach is largely known to its potential adversary, whereas the IAEA does not know precisely what sorts of strategies the “adversary” may employ. Furthermore, the State has constant physical access to the entire facility, while the IAEA may have only intermittent access to portions of the facility.²⁴⁰ As a result, a State planning a diversion could be expected to select the timing and means to do so, including concealment methods that are based on prior knowledge of what its “adversary,” the IAEA, had planned and assumptions about what the IAEA was capable of doing.

However, the development of safeguards approaches takes into account the problem of prior knowledge on the part of the inspected State. Safeguards implementation includes measures to compensate for this difficulty, including a provision that permits a portion of routine inspections to be made without advance notice. The IAEA develops safeguards approaches intended to cover all credible diversion paths taking into account concealment measures, and the State provides the

²³⁸ These alternatives are sometime called “abrupt” or “protracted” diversion. Not that protracted diversions could be carried out over many years, which would make detection progressively more difficult. Also, the removal of a large quantity of material at a single time could be concealed by overstating the amount contained in many items or flows.

²³⁹ There is an extensive literature on safeguards as game theory. See, for example "Safeguards Systems Analysis" by R. Avenhaus, Springer, 1986. A more practical approach from the point of view of classical statistical theory is given by John Jaech in "Statistical Methods in Nuclear Material Control," (1973)

²⁴⁰ One means of redressing this balance is for the Agency to use inspection options that cannot be anticipated. An example of this is randomly choosing items to measure in verifying an inventory; another is randomly timed inspection visits.



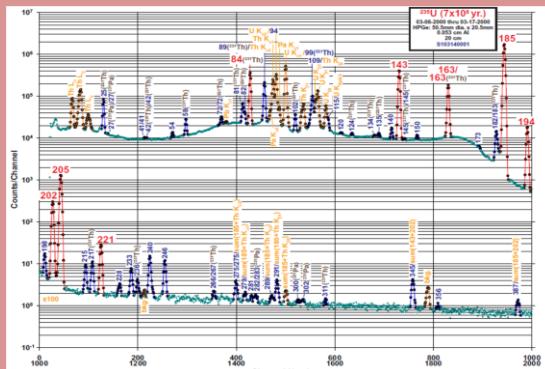
(Source: URENCO, UK Limited)

Figure 21. Gamma ray measurement of a uranium hexafluoride cylinder



(Source: Safeguards Techniques and Equipment – 2003 Edition)

Figure 22. Active Well Neutron Coincidence Counter for uranium measurements



Channel Number

Figure 23. Low-energy gamma-ray spectrum of Uranium-235

IAEA, or makes available to the IAEA, a wealth of information about the design and operation of facilities. In addition, many inspection tools such as environmental sampling are difficult to defeat. Furthermore, no State can rule out having its diversion plans and concealment methods go wrong through its own mistakes.

Given the level of resources that can be deployed by a State, it is easy to imagine that it is a “game” the State might win if it chose to play. The historical evidence, though, is that regardless of judgments about the technical effectiveness of safeguards, no meaningful diversion of declared nuclear material or misuse of declared facilities subject to NPT safeguards agreements has been detected or reported. NPT non-nuclear-weapon States intent on pursuing nuclear-weapon programs have generally done so at clandestine, undeclared locations that are not connected to declared activities.²⁴¹

This might speak well of the effectiveness of IAEA safeguards at detecting – or at least deterring – diversions and undeclared activities at declared facilities. Nonetheless, the IAEA recognizes that “past performance is no guarantee of future results” and that safeguards must continue to improve to stay ahead of potential adversaries. This is reflected in the title of a recent IAEA publication “Staying Ahead of the Game.”²⁴²

²⁴¹ There have been some instances, in Romania for example, where very small quantities of Pu were produced at a research reactor without being declared to or detected by the IAEA. As will be described later, in the case of the DPRK, the IAEA detected its failure to report fully its initial inventory of nuclear material. In other instances, States have failed to report nuclear facilities or nuclear material, but, clearly, the IAEA is not in a position to detect diversion from such facilities or their misuse. Iran, Syria, and Libya are examples of States that chose the clandestine route.

²⁴² See <http://www.iaea.org/Publications/Booklets/Safeguards3/safeguards0707.pdf>

6.3 Safeguards Measures and Techniques

The more important verification techniques and measures used by the IAEA are described below. It is not an exhaustive list and interested readers can pursue the topic in more depth in the safeguards technical literature, including papers published in the proceedings of the IAEA safeguards symposia, in proceedings of Annual Meetings of the Institute of Nuclear Materials Management (INMM) and the European Safeguards Research and Development Association (ESARDA), and the journals of INMM and ESARDA.

Furthermore, this section does not address detection of undeclared nuclear material or activities at undisclosed locations.

6.3.1 Non-destructive assay measurements

Non-destructive assay (NDA) techniques measure the radiation emitted from nuclear material and do not require the taking of samples for chemical analysis. They require less time and expense than destructive analysis (DA) measurements, which are typically chemical analyses. NDA measurements are generally not as accurate or precise as DA measurements.

Uranium and plutonium isotopes both emit gamma rays as they decay to “daughter” nuclei, and they emit neutrons when they fission; two important measurement techniques are gamma spectroscopy and neutron coincidence counting. Figure 21 and Figure 22, show representative measurement equipment.

Gamma spectroscopy: Uranium and plutonium nuclei emit gamma rays that vary in intensity over a range of energies that depend on the isotope. The intensities of the gamma rays vary with energy. The spectrum of intensity versus energy uniquely characterizes an isotope. For example, the spectrum shown in Figure 23 for the measurement associated with the decay of U-235 has a strong gamma ray with an energy of 185.7 keV (thousands of electron volts, a unit of energy). This peak is the one commonly used for identifying U-235. Modern gamma ray spectrometers consist of detectors, amplifiers, pulse counters, and computers. In measurements over a time period sufficiently long to yield the desired sensitivity, spectrometer systems acquire and interpret these spectra. By means of gamma ray spectrometry, IAEA inspectors can verify the presence of uranium or plutonium. With sufficiently high resolution, the spectrometer can also determine the relative abundance of different isotopes.

Neutron Coincidence Counting. Neutrons are little attenuated by the nuclear material from which they originate. One measurement technique, coincidence counting, relies on the fact that several nuclear isotopes undergo both spontaneous fission and induced fission, which results at the moment of fission in a burst of neutrons. These “coincident” neutrons can be captured and counted in detectors that are designed specifically to measure only coincident neutrons. When more than one neutron is captured almost simultaneously (i.e., they are coincident), there is a high probability that they came from a fission, rather than from separate “background” events. The measured rate of fission can be used to infer the mass of a nuclear material sample if the abundance of the various isotopes in the sample is known. (One way to determine this is gamma spectroscopy.)

One important application of neutron coincidence counting is to help determine the contents of cans of plutonium oxide powder in a reprocessing plant or a mixed-oxide fuel fabrication plant.

Some detector systems are also outfitted with a neutron source because the neutrons can induce fission in a nuclear material sample. This type of counter is used more frequently for uranium assay. One such detector used by the IAEA, the active well coincidence counter shown in Figure 23, can assay the U-235 content of a sample to high accuracy.

6.3.2 Destructive analysis measurements

Destructive analysis (DA) can provide more accurate measurements than NDA measurements, and they are important for closing a material balance with as little uncertainty as possible. DA is not possible for nuclear reactors, but for nuclear facilities that chemically or physically alter nuclear material, for example, enrichment and reprocessing plants, it is an important tool.

To determine chemical concentration or isotopic abundance, inspectors take samples of the nuclear material for analysis at the IAEA Safeguards Analytical Laboratory (SAL), located in Seibersdorf, not far from Vienna. (At the large reprocessing facility at Rokkasho in Japan, the IAEA uses an on-site laboratory.) In order to increase its capacity, the IAEA also sends samples to one of twenty IAEA affiliated analytical laboratories (its “network of analytical laboratories”).

Samples must be conditioned before they are packaged for dispatch to the IAEA’s laboratory. Chemical or electrochemical analysis determines the amount of plutonium or uranium in the sample (and therefore, the element concentration). Mass spectrometry may be used to determine the ratios of the different isotopes present, which provides, for example, information about uranium enrichment levels.

To provide valid results, the samples must be representative of the batches from which they are drawn. This can be difficult to ensure for process materials, which are often caustic, highly radioactive, or prone to precipitation or stratification. (For example, the contents of a large cylinder of uranium hexafluoride might have uranium enrichment levels that are not uniform unless the cylinder contents are first heated to liquefy the contents and allow them to become homogenous.) The amount of nuclear material in a single vessel might be the product (in the mathematics sense) of a volume and the concentration; in this case, the IAEA must verify other information, for example, the volume of the process vessel or tank. The total amount of nuclear material in a large facility would be the sum of many such determinations. To ensure the validity of its conclusions, IAEA must have confidence that this information remains valid.

6.3.3 Tamper indicating devices – seals

Containment refers to the use of containers and structural aspects of a facility or equipment that can be maintained under surveillance or sealed with a TID. Items are not literally closed or sealed by the IAEA. The facility operator is responsible for the handling and storage of nuclear material. The IAEA seal, one type of which is shown in Figure 24, is designed, selected, and used in a way that should provide unambiguous evidence if a container has been opened and nuclear material possibly removed – with or without reporting. Containment could be as small as a can of nuclear material or as large as the top cover of a reactor, as shown in Figure 25. The containment could

hold either nuclear material or specialized equipment belonging to the IAEA, such as IAEA cameras, calibration standards, or reference material. IAEA surveillance cameras, for example, are placed in specially designed, tamper-indicating enclosures to protect the integrity of surveillance data.

If the integrity of the containment and seals is verified, IAEA inspectors can rely on previous determinations of the type and quantity of nuclear material and can be confident of the integrity or nonuse of specialized equipment. This is referred to as preserving the “continuity of knowledge.”

To perform their roles, sealing systems must be tamper-indicating, uniquely identifiable, and very difficult to counterfeit. Inspectors at facilities verify the integrity of the containment and verify the integrity of the seal in situ or remove it, replace it, and send the removed one to IAEA Headquarters for verification. It is important to keep in mind that TIDs are designed to be tamper-resistant and tamper-indicating. They are not tamper-proof, i.e., they are not able to or intended to prevent access to a sealed container or room. Seals or surveillance systems might also have flaws not anticipated by the system designer. This could leave open the possibility that a C/S measure could be defeated without leaving evidence that could be detected by the inspector. As a result, the IAEA inspector will, on occasion, remove a seal and remeasure nuclear material even when the seal or surveillance shows no evidence of unreported access to the material.²⁴³

6.3.4 Surveillance

Camera surveillance systems provide an observational record of events at a facility under safeguards; Figure 26 shows such a situation in a reactor hall. While in the past the IAEA used film cameras for surveillance, the IAEA now uses digital video cameras and electronic recording. Images may be made continuously, on a time-lapse basis, or on the basis of changes in



Figure 24. Enhanced fiber optic general purpose seal



Figure 25. COBRA Seal System being applied by an inspector



(Images from IAEA Imagebank)

Figure 26. IAEA surveillance camera to record activities near the top of a reactor core

²⁴³ Tamper-Indicating Seals, Roger G. Johnston, American Scientist, November-December 2006, indicates why the assumption of being “foolproof” may not be appropriate.

the scene. In the latest generation of surveillance systems, the images are stored on computer hard drives. Figure 27 depicts such a system. They can then be collected by an inspector during a periodic visit or sent electronically directly to IAEA Headquarters from the facility. To ensure that the results are valid, the data must be authenticated and encrypted. Inspectors review the images with the help of specialized review stations and software algorithms because of the large number of images acquired. The installation and deployment of surveillance must also take account of possible efforts by a State to defeat the system by “spoofing.” For example, it may be possible for an image to be placed between the lens of a camera and the actual scene being viewed. If the image near the camera makes it “see” the same scene, the camera image has been rendered useless. Using two cameras with different focal lengths is a way to defeat such deception.

6.3.5 Environmental sampling

Environmental sampling is a powerful safeguards tool whose strength lies in the fact that very small particles containing nuclear material invariably escape and migrate away from nuclear processing operations.²⁴⁴ These particles contain information about the process that produced them, and even extremely small particles can be identified and analyzed for uranium or plutonium using modern techniques such as electron microscopy or mass spectrometry.

Most commonly, an environmental sample is collected by swiping a clean cloth over a surface, although other forms of samples (soil, vegetation) are possible; Figure 28 shows a sampling kit.



Figure 27. Multi-camera digital surveillance system designed for unattended or remote monitoring

²⁴⁴ A review of the efficacy of environmental sampling is in U.S. Congress, Office of Technology Assessment, *Environmental Monitoring for Nuclear Safeguards*, OTA-BP-ISS-168 (Washington, DC: U.S. Government Printing Office, September 1995). <http://www.fas.org/ota/reports/9518.pdf> (March 15, 2012). Also, Remote environmental sampling for the detection of clandestine nuclear weapons production and testing, Martin B. Kalinowski, ESARDA Training Course “Nuclear Safeguards and Nonproliferation,” Ispra, 14-18 April 2008 http://esarda2.jrc.it/internal_activities/WC-MC/Web-Courses/01-Background/09-Environmental-Kalinowski.pdf (March 15, 2012).

The primary set of information obtained involves the ratios of isotopic abundances in the particles in the sample:

- U-235/U-238 ratios indicate enrichment activity, and identification of HEU at a facility where only LEU was declared would be a significant anomaly to be investigated;
- the ratios of other, minor uranium isotopes can provide additional information about the nature of the enrichment process, ruling in or out certain sources for the enriched uranium;
- detection of fission products can indicate processing of spent fuel, and plutonium isotope ratios can indicate the nature of a reactor and the duration of irradiation;
- certain ratios in the chains of decaying isotopes (e.g., Am-241/Pu-241) will allow a calculation of the last time those isotopes underwent chemical separation; and
- the presence of plutonium at a hot cell producing medical isotopes could signal undeclared reprocessing experiments.

Environmental sample analysis is a complex process. Samples are received from the field at the SAL. They are given a code number to maintain confidentiality about their origin and subjected to a number of screening tests. They may then be analyzed there or sent to one or more of the laboratories in the network of analytical laboratories. Particles containing uranium and plutonium isotopes must be identified and may be looked at individually (“particle analysis”).

The basic analytical tool is mass spectroscopy, which measures the isotopic ratios mentioned above. Special techniques are needed to find particles and prepare them for analysis. One interesting variant is the fission-track method, in which the material collected from an environmental sample is spread over a special film and then irradiated by neutrons from a reactor. Uranium or plutonium nuclei will fission, leaving tracks in the film that can be made visible, and the individual particles can be removed for further analysis. Detailed information about the sophisticated techniques used for environmental sample analysis is beyond the scope of this book.²⁴⁵

Environmental sampling is an important safeguards measure at enrichment plants, where a primary technical objective of safeguards is assurance that the facility is not producing higher-than-declared enrichment levels. Field trials carried out by the IAEA in the mid-1990s²⁴⁶ suggested that local environmental samples would show a history of the enrichment levels produced at the plant. To take advantage of this possibility, current safeguards approaches to enrichment plants



(Image from IAEA)

Figure 28. Cotton swipe kit for environmental sampling

²⁴⁵ See “Safeguards Techniques and Equipment,” IAEA, 2003, available on the IAEA website; and, D. Donohue, “Environmental Sample Analysis – Advances and Future Trends,” IAEA-CN-184/159.

²⁴⁶ See for example, D.M. Hembree, et. al., “Workshop and Field Trial at the Oak Ridge K-25 Site,” Martin Marietta, K/NSP-274, March 1994 available at <http://www.ost1.gov/bridge/servlets/purl/82515-JgcGom/webviewable/82515.pdf>.

establish a “baseline” followed by periodic swipe sampling. Another important application is at hot cells whose declared use is processing medical isotopes or other non-fissile-material uses. Environmental sampling is used routinely at such locations to confirm the absence of plutonium and, thus, the absence of undeclared processing of plutonium.

Environmental sampling is a valuable tool in investigating undeclared activities. A recent example is the IAEA’s investigation of suspected enrichment-related sites in Iran in 2004. The IAEA took a large number of samples and found indications of the presence of LEU and HEU that called into question the completeness of Iran’s declarations. In one instance, Iran refused permission to take samples, relenting only after it had dismantled equipment at one site and renovated another before IAEA inspectors arrived.²⁴⁷

6.3.6 Random and short-notice inspections

As described earlier, the inspection measures and the timing of routine inspections are agreed in advance. Under INFCIRC/153, the Agency generally provides advance notice of inspections, but unannounced inspections are possible. Random unannounced inspections may serve two distinct purposes. In the first, a short-notice inspection that surprised the facility operator could catch it “red-handed,” i.e., in the act of conducting operations inconsistent with those declared.

Such inspections are used at centrifuge enrichment plants to address the possibility of undeclared production of HEU. Under this application, inspectors carry out “limited frequency unannounced access” to the cascade hall to confirm the absence of this diversion method.²⁴⁸

Catching a diverter “red-handed” may not be feasible. For example, a State may use its entry requirements at the border or a facility operator at the boundary of the facility to delay inspectors long enough to eliminate signs of diversion. In addition, the arrival of the inspector to conduct an unannounced inspection may have been “announced” to the State because of the need for airlines to transmit passenger manifests.

However, an important application of short-notice random inspections (SNRIs) is to verify the flows of nuclear material at large facilities without stationing inspectors there. Measurement of flows into and out of material balance areas poses no problem for facility operators. But if the IAEA makes scheduled, periodic visits to a facility, there will almost always be items that are shipped or received between visits, especially for big plants. In this case, there will be no opportunity for the IAEA to verify flows. The SNRI approach is intended to provide a cost-effective means to address this problem.

To provide such an opportunity, the IAEA developed the concept of “mailbox declarations,” i.e., irrevocable declarations by the operator about the status of nuclear material in a plant.²⁴⁹ The mailbox declaration is combined with an agreed period of time during which the plant operator will hold the declared material. The holding times create “windows of opportunity” for inspection,

²⁴⁷ GOV/2004/83, Nov. 2004, <https://www.iaea.org/sites/default/files/gov2004-83.pdf>.

²⁴⁸ See F. Brown, “The Hexapartite Safeguards Project, a Review by the Chairman,” IAEA-SM-260/57, Vienna, 1983.

²⁴⁹ A mailbox declaration could be made by sending an email to the IAEA, but more often the operator enters the information into an IAEA computer on-site. The reader is invited to deduce why the declaration must be “irrevocable.”

and the IAEA chooses these “windows” at random and verifies that the nuclear material present matches the declaration.

Uranium enrichment plants and LEU fuel fabrication plants are two facility types where the SNRI approach has proven to be valuable. At an enrichment plant, for example, verification of the material balance requires the IAEA to verify the flow of uranium hexafluoride cylinders into and out of the facility. However, the IAEA does not have the resources needed to station an inspector full-time at the facility.²⁵⁰ The technique devised to enable flow verification in a more cost-effective way is to have the facility operator make a “mailbox” declaration of the characteristics of each cylinder - weight, enrichment, identification number, and the production date of the cylinder - and hold the cylinder for an agreed length of time. The inspector arrives at random times and measures the cylinders being held on inventory.

The preconditions for effective use of randomly timed inspections may not exist everywhere. It is questionable whether an IAEA inspector can make a “surprise” inspection or a short-notice inspection in some States; one has to assume, for example, that State authorities will know when an inspector crosses some borders, and some facilities take considerable time to reach once an inspector is in the country. On the other hand, there are States in which inspectors are stationed at field offices (Canada and Japan), and IAEA inspectors can travel freely throughout much of Europe.

6.3.7 Unattended and remote monitoring

Although the Agency has always made use of unattended monitoring (e.g., seals and surveillance cameras), the number and diversity of such systems has grown, and they now include systems that send information off-site to IAEA field offices or to IAEA Headquarters. Remote monitoring is thus an important element in efforts to increase efficiency. States are not obligated to allow the IAEA to transmit data off-site, and remote monitoring has to be negotiated as part of the Facility Attachment.

Examples of unattended monitoring systems are:²⁵¹ power monitors for reactors, which record power levels either by measuring coolant flows and temperatures or neutron fluxes; entrance gate monitors, which can record the passing of plutonium-containing fuel assemblies or spent fuel assemblies as they move between the spent fuel pool and the reactor core during light water reactor fueling; and in-line measurement instrumentation in processing facilities, which is discussed in the next subsection.

According to the IAEA 2016 Annual Report, “By the end of 2016, a total of 164 unattended monitoring systems were in operation in 24 States and the Agency had 872 video surveillance systems with 1436 individual cameras operating at 266 facilities in 35 States.”

²⁵⁰ Inferences about all items in the flow via random sampling are only valid if all items are available for random sampling. At large facilities, items arrive and leave frequently, and the residence time is short. Inspectors could not sample them without full-time presence.

²⁵¹ See: “Safeguards Techniques and Equipment” IAEA, 2003, http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.

The Agency is also taking advantage of systems that send information from the field to Vienna. This information can include information about both the status of equipment and data or images needed for verification. According to the 2016 Annual Report, “By the end of 2016, remote data transmission infrastructure ensured the collection of 887 unattended safeguards data streams from 122 facilities in 25 States”. Of these, 299 data streams were produced by surveillance systems, 111 by unattended monitoring systems and 477 by electronic seals.”

Unattended safeguards instrumentation must be designed to very high standards. It must be highly reliable because failure of the device may mean loss of continuity of knowledge about a nuclear material inventory and re-establishing that knowledge may be expensive and intrusive. Surveillance failures at spent fuel pools were a significant problem for the IAEA in the 1980s. The fact that radiation can affect modern integrated electronic circuitry even at modest levels has to be taken into account. Safeguards instrumentation must be highly secure: it must protect the information it gathers and protect itself and its data from tampering. Considerable effort is devoted to addressing authentication problems.²⁵²

Approaches to ensure instrumentation and data security include procedures (e.g., vulnerability assessment, equipment examination and testing, unannounced inspections), hardware (e.g., tamper-indicating enclosures), and software (e.g., encryption systems).²⁵³ These unique requirements mean that IAEA systems must be designed especially for IAEA purposes, are manufactured in very small quantities, and must undergo a rigorous process to be certified for safeguards implementation. These requirements also make procurement and maintenance expensive; for example, the rapid evolution of products of the electronics industry can require the IAEA to purchase and stockpile a large quantity of spare components along with the instruments themselves to avoid later unavailability.

6.3.8 Sector approaches

A number of safeguards approaches have been designed and implemented that treat States as a whole or divide their fuel cycles into sectors.

The sector concept (sometimes called the zone approach) treats a State, or some subset of the facilities in the State, as a single large facility consisting of one material balance area. The sector concept can make safeguards more efficient and effective because there is no need to verify the flows of nuclear material that take place inside the new, large MBA. On the other hand, it is a challenge to carry out the equivalent of a physical inventory because that typically requires all nuclear material in an MBA to be available for inventory verification, including sampling, during one short period of time.

The choice of sectors looks at the physical nature of the processing, rather than at the boundaries of buildings or facilities. It seeks the most effective and efficient way to divide a fuel cycle into sectors containing one or two types of nuclear material with a boundary between sectors that is a

²⁵² K. Tolk, “Authentication Issues in Safeguards,” IAEA-CN-184/175, IAEA 2010 Safeguards Symposium

²⁵³ Most systems have layered protection; four layers of protection for the new IAEA surveillance system is described in: “The IAEA’s XCAM Next Generation Surveillance System,” IAEA-CN-184/260.

“choke point” through which nuclear material must pass so that a verification measurement can be made.²⁵⁴

For example, one sector might consist of locations with spent fuel assemblies, including those in a reactor spent fuel storage pond, in away-from-reactor storage, and in the pool at a reprocessing plant. The point where those assemblies are dissolved is the boundary between the sector containing intact spent fuel assemblies and the sector containing nuclear material being processed in solution.

The approach was originally developed and applied in Canada, which had the advantage of using a natural break in activities at year’s end to carry out physical inventories. Plus, Canada’s natural uranium fuel cycle can be divided naturally into sectors that process unirradiated material -- mines, mills, conversion, and fuel fabrication facilities -- and facilities that produce or store plutonium -- power reactors, research reactors, dry spent fuel storage, and critical assemblies. Today, the Canadian integrated safeguards approach is sector-based and takes advantage of the IAEA’s field office in Canada to conduct, readily, short-notice random inspections and unannounced inspections.²⁵⁵

Another example of the sector concept involves a set of plutonium facilities in Japan.²⁵⁶ The safeguards approach covers the Tokai Reprocessing Plant, the Plutonium Conversion Development Facility, and the Plutonium Fuel Production Facility. An important objective of the system, which began with a period of extensive testing in 2008, was a reduction in the field effort needed to meet the timeliness objective for the large inventories of separated plutonium.

This safeguards approach incorporates many of the advanced safeguards features that have been discussed in this section. The three facilities are partitioned into seven sectors, each of which contains a unique material type or a transition between two types.²⁵⁷

The flows between sectors are verified, either by a measurement point or a C/S system, which is unattended and remotely monitored. For example, the input accountability tank at the reprocessing plant measures the flow of material between the spent fuel pool and the beginning of the chemical separation and purification process. At the fuel production plant, in addition to unattended NDA instruments, there is also other in-line instrumentation that measures in-process inventories of solution and powder.²⁵⁸

²⁵⁴ Zone approaches were studied early in the 1980s, and Canada tested one successfully from 1981-1984. See, e.g., Leslie G. Fishbone and William A. Higinbotham, *A Study of a Zone Approach to IAEA Safeguards: the Low-Enriched-Uranium Zone of a Light-Water-Reactor Fuel Cycle*, June 1986.

<http://www.osti.gov/bridge/servlets/purl/7229141-9MPMVi/7229141.pdf>.

²⁵⁵ E. Franklin Saburido, et. al., “Information driven safeguards: new concepts for implementing the State Level Integrated Safeguards Approach in Canada,” IAEA-CN-184/257. Integrated safeguards are described in Chapter 7. <http://www.iaea.org/OurWork/SV/Safeguards/Symposium/2010/Documents/PapersRepository/257.pdf>.

²⁵⁶ M. Kikuchi, et. al., “The site approach – lessons learned from the integrated safeguards approach for JNC-1,” IAEA Safeguards Symposium 2010, IAEA-CN-184/56.

²⁵⁷ Sector A is the TRP spent fuel pool and dissolution process up to the input accountability tank; Sector B is the TRP chemical purification process up to an output plutonium nitrate accountability tank; Sector C includes nitrate storage in TRP and PCDF and the MOX conversion process in PCDF; Sector D is MOX powder storage in PCDF and PFPF, Sector E is the PFPF fuel fabrication process; and Sector F is the fuel storage area in PFPF.

²⁵⁸ J. Ninagawa, et. al., “Experiences and Achievement on Safeguards by Design for the Plutonium Fuel Production Facility (PFPF),” IAEA-CN-184/66.

Randomly timed inspections to verify inventories of material can take place on approximately two hours' notice by resident inspectors, based on mailbox-type declarations. A combination of frequent provision of inventory data and the measurement data available to the IAEA from NDA instruments, environmental sampling, and DA allow the IAEA to verify nuclear material balances for the sectors on a timely basis.

6.4 Safeguards Implementation at Facilities

This section provides an overview of safeguards implementation for the more important types of nuclear facilities based on the concepts and safeguards measures described above. The focus is on commercial-scale plants: power reactors, conversion plants, fuel fabrication plants, uranium enrichment plants, and reprocessing facilities.

While these are important from the perspective of safeguards and nuclear non-proliferation, especially enrichment and reprocessing plants, other facilities have safeguards significance. The IAEA applies safeguards to more than 150 research reactors and critical assemblies. Large

research reactors can produce significant quantities of plutonium annually, and the IAEA must ensure that any plutonium produced is declared. Even small research reactors may have non-proliferation significance since they may be used to irradiate small quantities of uranium, which can then be used for reprocessing R&D activities. Some critical assemblies have large quantities of unirradiated weapon-useable HEU or plutonium.

The IAEA also applies safeguards to more than 200 additional facilities that it categorizes as “separate storage facilities” or “other facilities.” These facilities range from ones that have large quantities of

nuclear-weapon-useable material (the storage facility in South Africa contains HEU from its dismantled nuclear-weapon program) to much smaller facilities with nuclear material of little non-proliferation significance (facilities that store uranium residues).

Safeguards approaches for these facilities are not described. The facilities are diverse in terms of size, operating characteristics, and types of nuclear material, and generalizations are difficult. A brief description of the nuclear fuel cycle and the worldwide distribution of facilities is provided in order to place safeguards implementation in context. Subsequent sections describe the basic safeguards principles for given facility types.

6.4.1 Nuclear fuel cycle

Figure 29 illustrates the important elements of the nuclear fuel cycle and captures the great majority of activities currently under safeguards.²⁵⁹ The fuel cycle facilities that start with mining

²⁵⁹ The fuel cycle diagram is from the Congressional Research Service report, *Managing the Nuclear Fuel Cycle: Policy Implications of Expanding Global Access to Nuclear Power*, Mary Beth Nikitin, Anthony Andrews, Mark Holt, March 5, 2010.

and milling and supply fuel for reactors are referred to as the “front end” of the nuclear fuel cycle. The fuel cycle elements after reactors are referred to as the “back end.”

States have many different fuel cycles. Canada’s fuel cycle is based on natural uranium and consists of mining, conversion, fuel fabrication, heavy-water reactors, and heavy-water production facilities (not in Figure 29), disposition, and research reactors. Japan’s fuel cycle is based on LWRs using enriched uranium, which requires enrichment services, and it includes all of the nuclear activities shown in Figure 29 except for mining and conversion.

Table 4 provides IAEA data for nuclear-fuel-cycle facilities (not including reactors) and Figure 30 shows the number and distribution of nuclear power reactors worldwide as of the end of 2011. The reactor fleet is highly concentrated in a relatively small

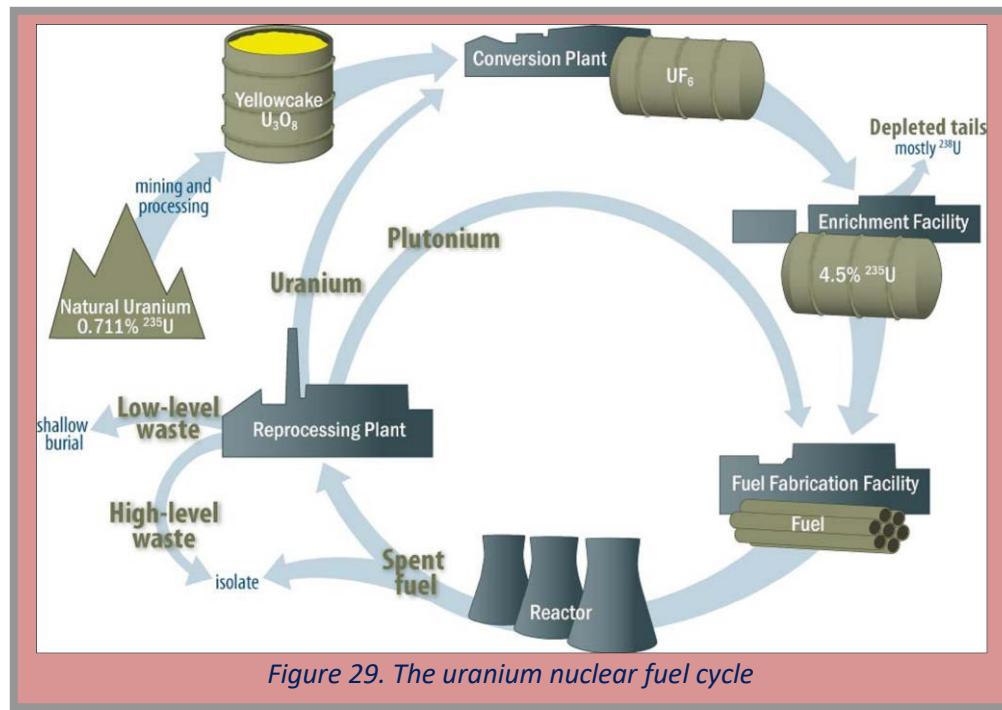


Figure 29. The uranium nuclear fuel cycle

Table 4. Number of Nuclear-Fuel-Cycle Facilities by Type			
Type	In Operation	Stand-By*	Total
Uranium Mining and Milling	56	15	71
Conversion	22	1	23
Enrichment	19	1	20
Uranium Fuel Fabrication	54	2	56
Spent Fuel Storage	111	1	112
Spent Fuel Reprocessing and Recycling	19	3	22
Spent Fuel Conditioning	0	2	2
Related Industrial Activities	32	1	33
Total	313	26	339

Data is from the IAEA Nuclear Fuel Cycle Information System. According to the IAEA, it might be incomplete due to the unavailability of data.

(*) Stand-By includes: Stand by, Refurbishment phases.

number of countries.^{260,261}

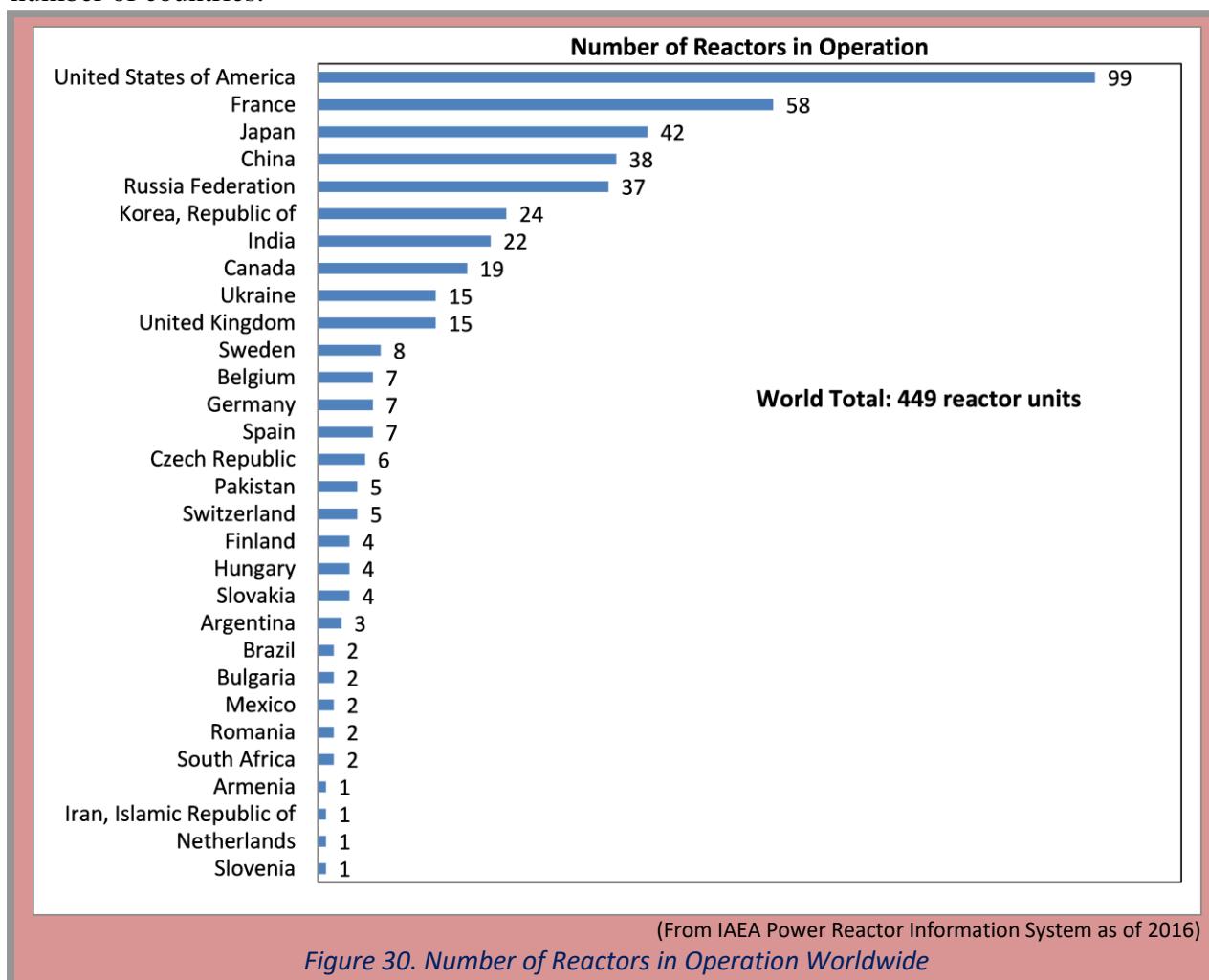


Figure 30. Number of Reactors in Operation Worldwide

6.4.2 Uranium mining and milling

Deposits of natural uranium ore are found in many parts of the world. In 2015 more than 60% of the known recoverable resources were located in Australia, Kazakhstan, Canada, and Russia.²⁶² The largest producers of uranium in 2016 were Kazakhstan, Canada and Australia, which were

²⁶⁰ A list of facilities subject to IAEA safeguards is published each year in the section “Additional Annex Information” of the IAEA’s Annual Report. The list for 2016 may be found at <https://www.iaea.org/sites/default/files/publications/reports/2016/gc61-3-annexinfo.pdf>.

²⁶¹ A rich source of information about the nuclear fuel cycle; civilian nuclear-fuel-cycle facilities; country profiles; and many other elements of peaceful uses of nuclear energy may be found at <http://nuclear.iaea.org/>, which requires registration but is otherwise open. The website of the World Nuclear Association also provides useful descriptions of the nuclear fuel cycle and its worldwide distribution. See <http://www.world-nuclear.org/info/inf03.html>.

²⁶² World Nuclear Association Supply of Uranium, <http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx> (accessed 20 March 2018). The IAEA and the Nuclear Energy Agency also maintain databases about uranium resources.

responsible for more than 72% of world production that year.²⁶³ (For both resources and production, the listings are in quantitative order.) Naturally occurring uranium has almost the same isotopic composition regardless of where it is found, about 0.7% U-235.

The two main methods of extracting uranium from the ground are: (1) removing ore from open pit or underground mines, crushing it, and extracting concentrated uranium by chemical leaching; or (2), injecting a solution into the ground and pumping dissolved uranium to the surface, called in situ recovery. Both processes produce an impure oxide of uranium (primarily U_3O_8) that is called uranium ore concentrate, or yellow cake. The product material is a powder and is stored and transported in large drums.

Uranium mining activities, ores, and concentrates are activities and materials before the “starting point” of safeguards defined in INFCIRC/153. There are some reporting requirements on imports or exports of uranium ore concentrate, and mines must be declared under the Model Protocol (see Chapter 7). However, uranium ore and ore concentrates are not subject to material accounting measures. This absence problems in detecting undeclared nuclear material or activities.

6.4.3 Uranium conversion

Conversion facilities. Natural uranium ore concentrate must be further processed in conversion plants to purify the raw material and convert it to the different forms needed for nuclear-fuel-cycle use.

From the non-proliferation perspective, the significance of natural U_3O_8 is that it can be converted into uranium metal and used in graphite-moderated, plutonium production reactors. Because of the high proportion of U-238 in natural uranium, graphite reactors of this type are excellent producers of plutonium. They were constructed in the United States as part of the Manhattan Project and provided the plutonium for the July 16, 1945 Trinity test at Alamogordo, New Mexico, and for the bomb that was dropped on Nagasaki on August 9, 1945. During the Cold War, France, the United Kingdom, and Russia also used graphite-moderated reactors in their nuclear-weapon programs. Starting in the 1980s, the DPRK used a graphite-moderated, natural uranium fueled reactor to produce plutonium for its nuclear-weapon program.

Without further enrichment, natural uranium can also be used along with heavy water as the moderator to build a nuclear reactor.²⁶⁴ Natural-uranium-fueled reactors form the basis for large-scale power production in a number of countries. The United Kingdom used metal fuel for its graphite-moderated MAGNOX (short for magnesium non-oxidizing) power reactors, although these have been phased out. Canada’s CANDU power reactors²⁶⁵ are moderated by heavy water rather than graphite and use fuel fabricated from natural uranium oxide. The many reactors in

²⁶³ World Nuclear Association Uranium Production Figures, <http://www.world-nuclear.org/information-library/facts-and-figures/uranium-production-figures.aspx> (accessed 20 March 2018)

²⁶⁴ Heavy water is ordinary water (H_2O) with atoms of heavy hydrogen (deuterium, $H-2$) substituted for ordinary hydrogen. It is required for natural uranium reactors because the ordinary hydrogen in light water absorbs too many neutrons and will not permit a chain reaction with natural uranium.

²⁶⁵ From Canadian-Deuterium-Uranium fuel cycle.

India that are based on the CANDU design are also fueled by natural uranium and moderated by heavy water.

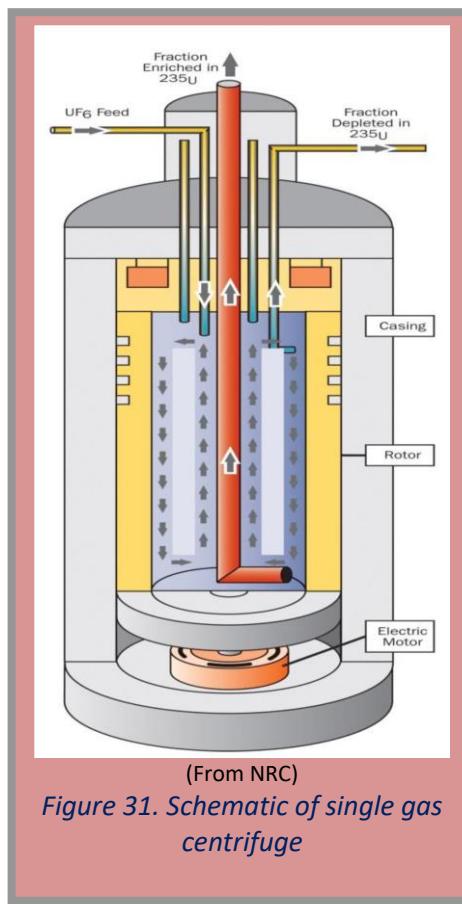
Alternatively, yellow cake can be converted into a form suitable for uranium enrichment. In this case, the chemical form of choice is uranium hexafluoride (UF_6). Conversion plants are generally large industrial facilities that handle a variety of chemical compounds of uranium in liquid and powder forms. The largest facilities process more than 10,000 tons of uranium annually. Different conversion processes are used, depending somewhat on the purity of the feed material. The scale and the complexity of conversion plants make safeguards implementation difficult. Measurement of flows may be easy only at the output of plants, and it may also be difficult to ensure that all outputs are known.

Safeguards at conversion facilities. The primary safeguards concern at conversion facilities is the diversion of purified natural uranium for use as feed to a clandestine enrichment plant. It may also provide fuel for a natural-uranium-fueled plutonium production reactor. INFCIRC/153 states that the starting point of safeguards is the point at which nuclear material is “suitable for fuel fabrication or for being isotopically enriched.” This generally occurs at the conversion plant, but the exact definition of this term has been the subject of ongoing discussion. Since the starting point may occur in the “middle” of the plant, one diversion strategy would be to produce more material at the starting point than is declared.

To address this, the IAEA may begin material accounting measures at an earlier process stage. Although safeguards at conversion facilities are based on nuclear material accounting,²⁶⁶ the safeguards approach for a specific facility may differ because of differences in the purity of the uranium ore concentrate feed or differences in the nature of the process.

6.4.4 Uranium enrichment

While CANDU reactors use natural uranium, most commercial power reactors require uranium enriched in U-235. Typical enrichment levels are between 3% and 5%. The chemical form of uranium used in all industrial-scale enrichment facilities today is uranium-hexafluoride (UF_6). UF_6 is a solid at room temperature but “sublimes”²⁶⁷ to a gas at only slightly elevated temperatures.



(From NRC)
Figure 31. Schematic of single gas centrifuge

²⁶⁶ B. Boyer, D. M. Gordon, L. G. Fishbone, and J. R. Lemley, “An International Safeguards Approach for Natural Uranium Conversion Plant,” Paper 424, *Proceedings of the 45th Annual Conference of the Institute of Nuclear Materials Management INMM*, July 18-22, 2004, Orlando, FL.

²⁶⁷ This means that as the solid UF_6 is heated, it changes from a solid to a gas without first becoming a liquid. Contrast this with water in the form of ice; it first melts and as more heat is added, the water boils and is changed to a gas. “Dry ice” is like UF_6 with respect to the direct transition from solid to gas.

In its gaseous form, it can be used in a number of enrichment techniques, most importantly gaseous diffusion and gas centrifugation. Many other uranium enrichment techniques have been shown to be feasible.²⁶⁸

Gaseous diffusion was one of the methods used to enrich the uranium for the nuclear weapon detonated over Hiroshima on August 6, 1945. After World War II, it became the primary enrichment method for the nuclear-weapon programs of the Soviet Union, the United Kingdom, and the United States. LEU produced by gaseous diffusion plants also served as the fuel for all of the world's LWRs through the early 1980s.

Centrifuge plants are in some ways more difficult to build and operate reliably than gaseous diffusion plants but are far more efficient. In particular, they use far less power²⁶⁹ and require much less area for equivalent outputs. Centrifuges are now the technology of choice for suppliers of commercial enrichment services (see **Error! Reference source not found.** and Figure 32). Gas centrifuge enrichment plants are basically the only enrichment plants where the IAEA applies safeguards today, although a few older, non-operational facilities of other types are listed by the IAEA as facilities subject to safeguards. (Table 5 lists the uranium enrichment facilities subject to safeguards by the IAEA in non-nuclear-weapon States.²⁷⁰)



(From USEC)

Figure 32. Gas centrifuges operated by the United States Enrichment Corporation are about 45 feet tall and several feet wide



(From IAEA Imagebank)

Figure 33. Gas-centrifuge enrichment plant

²⁶⁸ Most of the enrichment done for the Manhattan Project was done using electromagnetic processing equipment called calutrons, as was enrichment in Iraq around 1990. South Africa's nuclear-weapon program used an aerodynamic enrichment system, and atomic and molecular laser isotope separation processes have been demonstrated. At the end of 2011, a laser-based pilot plant was under construction in the United States.

²⁶⁹ Three large gaseous diffusion uranium enrichment plants were built by the United States in the 1940s and 1950s at Oak Ridge, TN, Paducah, KY, and Portsmouth, OH. They used a total of over 5,000 MW(e), about 10% of the electricity produced in the United States in the mid-1950s. From Highly Enriched Uranium: Striking a Balance - A Historical Report on The United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 Through September 30, 1996, U.S. Department Of Energy, National Nuclear Security Administration, January 2001, Revision 1. <https://www.Hsdl.Org/?View&Did=6962>. A gas centrifuge enrichment plant may use 25 times less electricity per SWU.

²⁷⁰ Data is drawn from "Profile of World Uranium Enrichment Programs—2009", April 2009, Prepared by M. D. Laughter, Oak Ridge National Laboratory, (ORNL/TM-2009/110).

<http://info.ornl.gov/sites/publications/files/Pub15166.pdf> (8 November 2011). Iran data is from IAEA reports.

Table 5. Uranium Enrichment Plants Subject to IAEA Safeguards Under NPT Safeguards Agreements

STATE	PLANT NAME/LOCATION	OWNER/OPERATOR	TYPE	STATUS	CAPACITY (IN SWU)
Argentina	Pilcaniyeu	CNEA	Gaseous diffusion	Standby/planned	20,000
Australia	Lucas Heights	AAEC	Centrifuge	Dismantled	Laboratory
Brazil	Aramar	Brazilian Navy/CNEN	Centrifuge	Operating	9,000
	Resende	INB	Centrifuge	Operating/under construction	120,000
Germany	Gronau	URENCO	Centrifuge	Operating	4,100,000
				Planned	2,300,000
Iran	Natanz Pilot Plant (PFEP)	AEOI	Centrifuge	Operating	Subject to JCPOA (Chapter 9)
	Natanz FEP	AEOI	Centrifuge	Operating/under construction	Subject to JCPOA
	Fordow FEP	AEOI	Centrifuge	Under construction	Subject to JCPOA
Japan	Ningyo-Toge Pilot & Demo	JAEA	Centrifuge	Shut down	250,000
	Rokkasho	JNFL	Centrifuge	Operating	150,000
Netherlands	Almelo	URENCO	Centrifuge	Operating	3,800,000
South Africa	Z-plant-Pelindaba	NECSA	Aerodynamic	Shutdown/dismantled	300,000
	Y-Plant Valindaba	NECSA	Aerodynamic	Shutdown/dismantled	10,000

A typical commercial centrifuge enrichment plant consists of identical centrifuges (at least hundreds and usually thousands) connected in an array called a *cascade*.²⁷¹ Figure 33 shows the cascade hall of such a plant. Each centrifuge can process only a very small quantity of material, and the increase in enrichment is modest. Many centrifuges must be connected in parallel in each *stage* of the cascade in order to process a large amount of material, and several stages must be connected in series to achieve the desired product enrichment.

In a typical commercial enrichment plant, the feed material is natural uranium, which has an enrichment level of around 0.71%, regardless of where it is mined. The product of a commercial plant is uranium with an enrichment level from 3-5%. Since the total amount of uranium and the total amount of U-235 that leave the plant must equal the amount that enters, except for very small

²⁷¹ For a full discussion of enrichment cascades see *Uranium Enrichment and Nuclear Weapons Proliferation* by Allan Krass, Peter Boskma, Boelie Elsen and Wim Smit (Taylor and Francis 1981). The book is out of print but is available on the web site of the Stockholm International Peace Research Institute (SIPRI):

http://books.sipri.org/product_info?c_product_id=286. For commercial uranium enrichment plants, the number of centrifuges can be hundreds of thousands.

amounts of hold-up and waste, the enriched product stream must be accompanied by another output stream that is lower in enrichment than the feed material. This is the “tails” stream, which is made up of depleted uranium, i.e., uranium with an enrichment level below natural uranium (~0.7%). The uranium in these streams is contained in steel cylinders (see Figure 34).

The capacity of an enrichment process to separate uranium isotopes is described by a quantity known as the “separative work unit.” The size of an enrichment plant or an individual plant element, such as a gas centrifuge, is measured in terms of the “separative work units” produced annually. A separative work unit (SWU) has the dimension of mass, typically characterized in kilograms (kg). Thus, the production capacity of a gas centrifuge plant is given generally as kg SWU per year. For large enrichment plants, capacities may be expressed in terms of tons. A single, crude centrifuge might have a separative capacity of one to five kg SWU per year, but modern centrifuges may range from tens to hundreds of kg SWU per year. A modern commercial facility may have a total separative capacity measured in millions of kg SWU per year. These sizes reflect the requirements of large power reactors, which need approximately 125,000 kg SWU per year to meet their annual fuel requirements.²⁷²

By contrast, the amount of separative work needed to create one significant quantity of 90% HEU starting from natural uranium is around 5,000 - 6,000 kg SWU. Safeguards at enrichment plants must be concerned not only with the diversion of uranium from the process, but also with the possibility that some part of the cascade might be reconfigured to produce HEU, perhaps using undeclared uranium as feed. The difficulty of such a reconfiguration depends on the details of the plant piping design, for example, whether there are electronically controlled valves that can change flow patterns.

A centrifuge enrichment plant consists of:

- Cylinder storage areas for natural, enriched and depleted uranium, where the material is in solid form;



Figure 34. Cylinder handling operations at a uranium enrichment plant



(Both images from D. Laughter, Oak Ridge National Laboratory)

Figure 35. Uranium hexafluoride cylinders containing tails in a storage yard

²⁷² A valuable introduction to uranium enrichment is available in Uranium Enrichment and Nuclear Weapon Proliferation by Allan S. Krass, Peter Boskma, Boelie Elzen and Wim A. Smit, ISBN 0-85066-219-2, which can be found at http://books.sipri.org/product_info?c_product_id=286#contents

- A cascade or process area where hundreds or thousands of centrifuges are connected in series and parallel arrangements to achieve the desired enrichment and throughput; and
- Feed and withdrawal areas. At the feed area, cylinders of natural UF₆ are heated, and the resulting gas is piped into the cascade. At the withdrawal area, the gas coming out of the cascade is cooled and withdrawn into similar cylinders. Two such streams exit the plant, the enriched product stream and the depleted “tails” stream.

INFIRC/153

105. "Enrichment" means the ratio of the combined weight of the isotopes uranium-233 and uranium-235 to that of the total uranium in question.

The product cylinders are shipped to fuel fabricators, but the tails cylinders generally remain stored on the plant site (see Figure 35). The product enrichment level is set by the fuel fabricators, while the tails enrichment is chosen by the provider of enrichment services based on economic considerations.²⁷³ The tails enrichment level is typically around 0.2%. There is no enrichment plant currently under safeguards that

is designed to produce HEU.

Safeguards objectives and concerns. The IAEA has identified three safeguards objectives for enrichment plants: (1) detection of diversion of LEU; (2) detection of production of HEU; and (3) detection of production of excess LEU from undeclared feed.²⁷⁴

Because gas centrifuge plants can produce weapon-grade HEU, the development of safeguards approaches for them is complicated by the fact that critical elements of the technology are sensitive from the non-proliferation perspective. In the United States, many details of enrichment plants and their technology are classified. Events have amply justified this sensitivity, especially with respect to centrifuge uranium enrichment.^{275,276}

Success in building and operating a gas centrifuge enrichment plant requires solving difficult design and engineering problems. Centrifuges spin very rapidly. To avoid catastrophic failures, they must be made of light, strong materials and built to extremely fine dimensional tolerances. Connecting them together in a complex cascade is also a difficult process that can require years of R&D to master. As a result, in addition to the non-proliferation sensitivity, there is also a great deal of commercial sensitivity about the way centrifuge plants are designed and operated.

²⁷³ If U-235 becomes more expensive, it is advantageous not to “waste” it in the depleted uranium, which is stored for years or decades. It is better to remove more of it from the tails stream, which is done by lowering the tails assay.

²⁷⁴ “Model safeguards approach for gas centrifuge enrichment plants,” W. Bush, D. Langlands, N. Tuley, J. Cooley, IAEA-CN-148/98; IAEA, 2007. Safeguards objectives and measures for centrifuge plants were originally set in the early 1980s by the Hexapartite Safeguards Project (Australia, Japan, Germany, Netherlands, United Kingdom, U.S., IAEA and Euratom participated). With changes in safeguards and centrifuge technology, these measures and objectives have been broadened.

²⁷⁵ The centrifuge technology stolen by A.Q. Khan from the URENCO facility in the Netherlands in 1974 served as the basis for Pakistan’s nuclear-weapon program. Khan then created a clandestine network to sell this technology. It was used with varying degrees of success in Libya, Iran, DPRK, and, perhaps, elsewhere. Iraq used electromagnetic isotope separation with some success before its nuclear-weapon program was terminated after the Gulf War in 1991.

²⁷⁶ David Albright, *Peddling Peril: How the Secret Arms Trade Arms America’s Enemies*, Simon & Shuster, 2010.

These factors make the design of a safeguards approach for centrifuge plants difficult, because inspector access to the cascade always involves restrictions. Also, each technology holder has its own view of what is sensitive and what measurements are acceptable. Verification of design information is complicated, and use is often made of the provision in INFCIRC/153 that allows the State to also keep some design information at the plant rather than transmit it to the IAEA in Vienna, which is the norm.²⁷⁷

Detection of diversion. Material accounting can be done with very high accuracy at centrifuge enrichment plants. Since the gas-phase uranium inventory of the cascade is small and the quantity is stable, it is generally ignored entirely. Since waste and scrap recycle streams are also typically very small, inspection effort is focused on verification of the contents of UF₆ cylinders. The amount of U-235 in a cylinder can be calculated as the product of three factors: mass; chemical form and concentration; and enrichment level. All three can be determined by very accurate means: weighing on the operator's accountability scale, chemical analysis, and mass spectroscopy.

It is not practical for the IAEA to use these highly accurate and precise methods to verify a large number of cylinders: it is too expensive and time-consuming for both the operator and the inspector to obtain the necessary samples from cylinders.²⁷⁸ In addition, the IAEA lacks resources to keep inspectors at plants handling LEU continuously in order to verify all the feed and product cylinders as they arrive and depart.

The first problem is overcome through the use of an “attribute/variables” approach. The Agency makes a large number of relatively easy and inexpensive but lower accuracy measurements and a smaller number of more accurate measurements.²⁷⁹ Lower accuracy measurements include portable multi-channel analyzers that measure gamma radiation and acoustic measurements; the latter are used in two different ways, to determine if cylinders are filled and to determine their wall thickness as an adjunct to the gamma measurement. Higher measurement accuracy is obtained by analysis of samples withdrawn from cylinders. The resource problem may be addressed by the SNRI strategy described above.

Detecting HEU production. It is generally assumed that a centrifuge enrichment plant designed to produce LEU could be reconfigured to produce HEU. The ease or difficulty and the time it would take to make such changes in the plant's operation depend on the details of the plant's design. From the non-proliferation perspective, it is important to remember that the separative capacity necessary to make a significant quantity of HEU is about 5,000 kg SWU, which is only a small

²⁷⁷ INFCIRC/153, paragraph 8: In examining design information, the Agency shall, at the request of the State, be prepared to examine on premises of the State design information which the State regards as being of particular sensitivity. Such information would not have to be physically transmitted to the Agency provided that it remained available for ready further examination by the Agency on premises of the State.

²⁷⁸ In order to do measure accurately purity and isotopic level, it is essential that sample of UF₆ from the cylinder be representative of its contents; in order to get a representative sample, a cylinder must be heated in order to homogenize its contents.

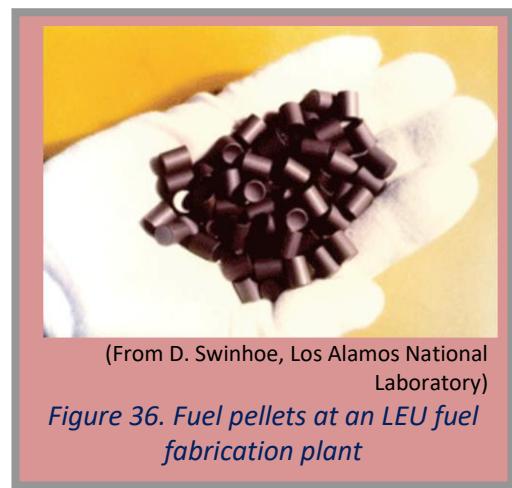
²⁷⁹ Large numbers of less accurate measurements detect a small number of large removals, while the smaller number of more accurate measurements detects a larger number of small removals. See J. Jaech, “Statistical Methods in Nuclear Material Control.”

fraction of the capacity of a large commercial facility, which could have a capacity of millions of SWU.²⁸⁰

There are a number of strategies for detection of HEU production. “Limited Frequency Unannounced Access” allows an inspector to make inspections on very short notice and enter the cascade to detect abnormal operations such as feed or withdrawal operations inside the cascade. Environmental sampling is now widely applied at enrichment plants, on the basis that any operations producing HEU might leave an environmental signature.²⁸¹ The IAEA also uses radiation measurement devices that can be applied to plant piping to detect higher-than-declared enrichments, but the acceptability and effectiveness of these devices is facility-dependent.

Detecting excess LEU production from undeclared feed. This is the most difficult scenario to detect, since it involves neither an HEU signature nor a diversion from the declared material balance. One must assure, for example, that only declared cylinders are attached to or detached from the cascade. Mailbox declarations and short-notice inspections could accomplish this. Instrumental measures could include unattended monitoring in the feed and withdrawal area; optical surveillance and load-cell monitoring of feed and withdrawal stations; and flow measurements at appropriate places in feed and withdrawal piping. While not a primary concern at the enrichment facility, utilization of undeclared LEU as the feed for a clandestine HEU enrichment facility can reduce its size significantly and, perhaps facilitate the concealment of a clandestine facility.

6.4.5 Uranium fuel fabrication



Uranium fuel fabrication facilities: These facilities receive feed material directly from a conversion facility. It is first converted to the required chemical and physical forms and then fabricated into the fuel elements to be used in reactors. The nuclear material in light water and CANDU power reactors is typically uranium oxide (UO_2). Some fuel fabrication plants receive uranium oxide produced elsewhere, while fabrication plants for LWRs typically receive uranium from enrichment plants in the form of uranium hexafluoride (UF_6). The UF_6 is then converted to uranium oxide at the fuel fabrication plants.

The uranium oxide powder, which is produced as a powder, is then compressed into pellets and heated to bond and fuse the powder together

²⁸⁰ Characteristics of the Gas Centrifuge for Uranium Enrichment and Their Relevance for Nuclear Weapon Proliferation (corrected), Alexander Glaser, *Science and Global Security*, 16:1–25, 2008, provides a very useful, albeit somewhat technical, description of the operation of centrifuges and centrifuge cascades. It also describes various breakout possibilities – i.e., HEU production strategies – and estimates the feasibility and time to utilize them.

²⁸¹ Field exercises in Europe have shown that uranium enrichment levels at a commercial plant can be tracked via environmental sampling. However, this does not necessarily mean that the same would be the case where a state made efforts to reduce or eliminate the release of particles.

(sintering).²⁸² The pellets are placed in metal tubes (called fuel rods or fuel pins), which are then combined into bundles called fuel assemblies.

The IAEA must be prepared to verify numerous forms of nuclear material:

- uranium powder, which poses a set of handling and measurement challenges;
- pellets (Figure 36), which are relatively easier to measure, but there are a very large number of them;
- fuel pins (Figure 37), in which the nuclear material is well-contained; and
- fuel assemblies (Figure 38), in which the nuclear material is well contained but they are difficult to measure because of their size and the self-shielding of radiation from fuel pins in the center by the pins near the outside of a fuel assembly.

Safeguards concerns at fuel fabrication facilities. Because enrichment levels are not changed at fuel fabrication plants, although more than one enrichment level might be used, there is only one safeguards objective: detection of diversion of uranium. The diversion of LEU is considered to be more of a non-proliferation concern than diversion of natural uranium. A clandestine enrichment plant using LEU feed would be smaller than one using natural uranium feed and could be more difficult to detect. However, diverted natural uranium could also serve as fuel for an undeclared production reactor to yield plutonium.

Safeguards methods at fuel fabrication facilities. Nuclear material is received at the fuel fabrication plant in bulk form and leaves in fresh fuel assemblies, many of which contain hundreds of fuel pins and thousands of fuel pellets. As a consequence, the measurement and verification methods change significantly as nuclear material passes through the plant. Moreover, the predominantly solid uranium inventory is very large, and there are significant waste and scrap recycle streams. Thus, verifying the material balance requires many forms of uranium to be measured. Both NDA equipment and sampling and DA must be used both at the annual PIT and at other times to verify plant flows of feed, product, and tails.

UF₆ feed and intermediate forms of uranium are amenable both to NDA and DA. Feed cylinders at a fabrication plant are treated in the same ways as at enrichment plants. For

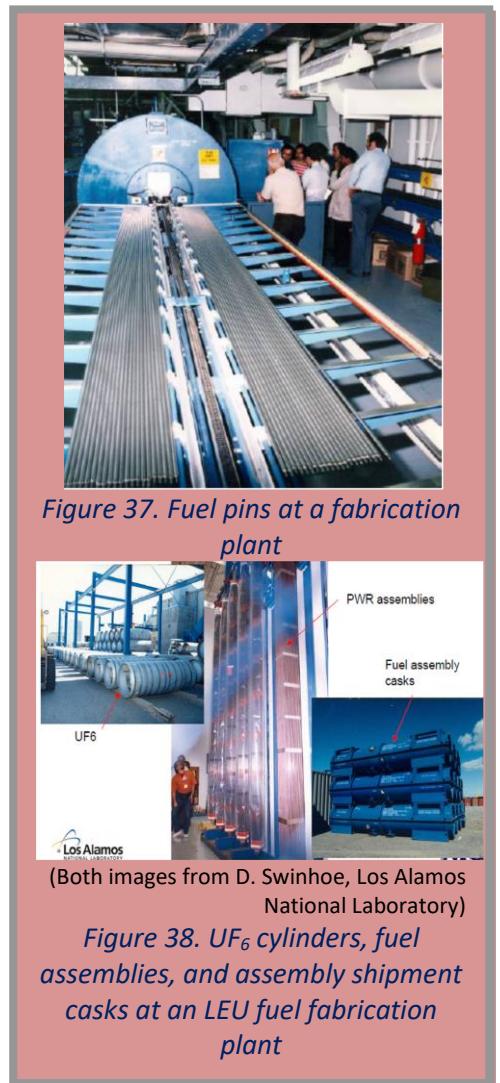


Figure 37. Fuel pins at a fabrication plant



(Both images from D. Swinhoe, Los Alamos

National Laboratory)

Figure 38. UF₆ cylinders, fuel assemblies, and assembly shipment casks at an LEU fuel fabrication plant

²⁸² Figures 36 37, and 38 are from a presentation by M.T. Swinhoe, Los Alamos National Laboratory on “Safeguards at LEU Fuel Fabrication Facilities” available at http://www.lanl.gov/orgs/ndo/n4/documents/leu_fuel_fab21.pdf.

the fuel pins and fabricated fuel assemblies, only NDA is possible through gamma spectroscopy or neutron coincidence counting.

These nuclear material inventories and flows are verified in accordance with the IAEA's standard statistical sampling schemes (see the "attributes/variables" strategy discussed in the last section). To address resource constraints, SNRIs can be used to verify flows. (The SNRI strategy was described in Section 6.3.²⁸³)

6.4.6 Nuclear reactors

There are four broad categories of reactors:

- *Research reactors* vary widely in design and power. Powers range from almost zero (called "critical assemblies"²⁸⁴) up to about 200 MWth.²⁸⁵ New research reactors use LEU fuel. While in the past, HEU fuel was typical, many of these research reactors have been converted to use LEU fuel and the HEU spent fuel has been returned to its supplier. This reduces the nuclear non-proliferation and nuclear security risks by minimizing both the flow and inventory of HEU fuel elements.²⁸⁶ About 150 research reactors and critical assemblies were under safeguards in 2016.²⁸⁷ Research reactors of about 25 MW thermal reactors can produce a significant quantity of plutonium per year, but most research reactors are smaller.
- *Naval reactors* propel nuclear-powered naval vessels, of which the largest number is military submarines. At this writing, no nuclear material has been withdrawn from safeguards for use in a naval reactor, which would be permitted by paragraph 14 of INCIRC/153. Safeguards are applied to a land-based naval reactor prototype in Brazil.
- *Production reactors* are designed specifically to produce plutonium for nuclear weapons. There are none under safeguards.
- *Power reactors* are designed to produce electricity. While there has historically been a wide range of sizes, a modern power reactor typically has a power output on the order of 3,000 MW thermal and an electrical power output of about 1,000

²⁸³ "Field Test of Short-Notice Random Inspections for Inventory Change Verification at a Low-Enriched-Uranium Fuel Fabrication Plant," Proceedings of the 17th ESARDA Symposium on Safeguards and Nuclear Material Management, ESARDA 27, p. 355 (1995); L. Fishbone, C. Sanders, D. Colwell, C. Joyner, M. Hosoya, P. Scott, G. Moussalli, J. Fager, G. Naegele, and P. Ikonomou.

²⁸⁴ Critical assemblies are used to investigate reactor core composition and geometry. They operate at very low power levels.

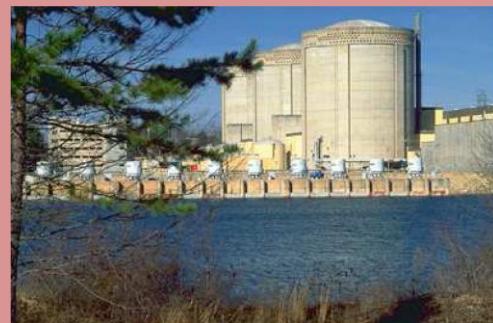
²⁸⁵ "Megawatt thermal" or MWth is a measure of the power of a reactor generated as heat. In a power reactor the electrical output is usually around a third of the thermal output.

²⁸⁶ There has been a long-standing interest in reducing the use of HEU for civil purposes. For example, the United States initiated a program in 1978 to convert research reactors using HEU to LEU fuels. The Reduced Enrichment for Research and Test Reactors (RERTR) Program develops technology necessary to enable the conversion of civilian facilities using HEU to LEU fuels and targets. See <http://www.rertr.anl.gov/>. One of the elements of the 2010 Communiqué of the Washington Nuclear Security Summit was an agreement to "encourage the conversion of reactors from highly enriched to low enriched uranium fuel and minimization of use of highly enriched uranium, where technically and economically feasible."

²⁸⁷ Lists of facilities under safeguards can be found in the Annex to IAEA Annual Reports.

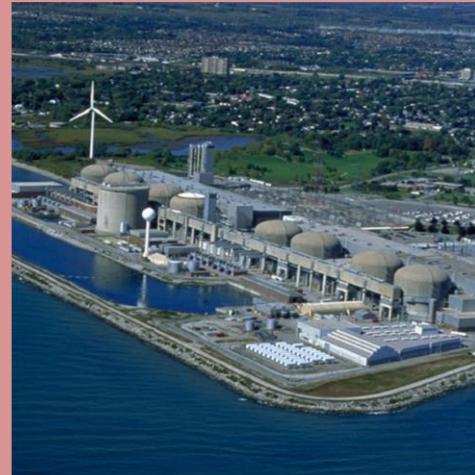
MW electric. LWRs of this size typically have about 100 tons of uranium in the core, and about 30 tons are replaced annually. The 30 tons of spent fuel removed each year contain about 200-300 kg of plutonium. About 250 power reactors were under IAEA safeguards in 2016. While there are many power reactor designs, the most important in terms of the application of safeguards are light-water and heavy-water reactors.

- *Light-water reactors* (LWR) are far and away the most common power reactors. A power station with LWRs appears in Figure 39. They use fuel enriched to 3% - 5% U-235 and shut down every one to two years to refuel. A few countries, most prominently France and Japan, have programs to use fuel containing a mixture of oxides of uranium and plutonium (MOX fuel). Nuclear material is contained in fuel assemblies made up of about sixty pins for boiling-water reactors to hundreds of pins for pressurized water reactors. They are approximately five meters long. It is difficult to verify irradiated fuel assemblies: core fuel is inaccessible during reactor operation; they are highly radioactive; and they are stored underwater in spent fuel pools after removal from reactor cores. Accurate measurement of the plutonium content can only be done using NDA techniques and is very difficult.
- *Heavy-water reactors* use natural uranium. The most prominent type is the CANDU reactor. A power station with eight CANDU reactors appears in Figure 40. The application of safeguards at heavy-water reactors must take into account their operating characteristics, which are very different from those of LWRs. In particular, they are refueled continually during power operation. This requires the IAEA to use special equipment to count the fuel assemblies being loaded and unloaded. In addition, CANDU fuel bundles are much smaller than LWR fuel assemblies and, as a consequence, there are many more of them in the core and in storage. In storage, CANDU reactor spent fuel bundles may also be placed in racks one upon another, which makes accessibility an issue.
- Breeder reactors are designed to “breed” extra plutonium from uranium while producing power; they would typically employ fuel assemblies that contain



(From <http://www.nrc.gov/infofinder/reactor/oco1.html>)

Figure 39. Pressurized light-water reactors at Oconee Nuclear Station, Seneca, South Carolina



(From Photo Library, Ontario Power Generation, <http://www.opg.com/news/photolibrary.asp>)

Figure 40. CANDU reactors at Pickering Nuclear Power Station, Ontario, Canada

large quantities of plutonium or HEU, and they may be surrounded by a blanket of natural or depleted uranium. This is an advanced design, and there are only a few of them, most of which are in Russia.

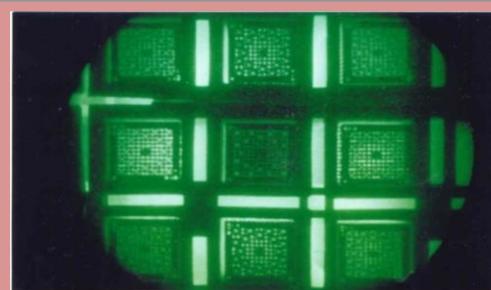
Because of their unique designs, safeguards at research reactors and breeder reactors require specialized treatments. This text will focus on safeguards at LWRs and CANDU reactors.

Light-water reactors

Safeguards concerns at LWRs. There are three safeguards concerns for LWRs. The first is diversion of fresh, unirradiated fuel assemblies or constituent pins to obtain LEU, or, much more importantly, plutonium if MOX assemblies are used. The second is diversion of irradiated fuel assemblies or constituent pins to obtain plutonium. The third is unreported production of plutonium by undeclared placement of uranium in the reactor core.

Safeguards methods at LWRs. Nuclear material at LWRs is handled predominantly in the form of assemblies. These are generally moved only during reactor refueling. To increase fuel efficiency, fuel assemblies are typically removed from the reactor during refueling periods and re-inserted in different locations. In some fuel designs, individual, defective fuel pins can be replaced in the fuel assembly. Thus, though safeguards approaches at LWRs rely heavily on C/S, the possible diversion of pins must be addressed. Surveillance is in place to observe the cover over the reactor core and the spent fuel pool, while a seal is placed on the reactor cover during power operation. The inspector is present during refueling, when all the fuel is visible, for the physical inventory verification. Temporary, additional surveillance cameras may be installed during the refueling process.

At physical inventory verification inspections, both fresh and irradiated fuel can be verified by counting, serial number identification, and NDA measurement.²⁸⁸ Irradiated fuel could also be verified by Cerenkov glow detection, an image of which is shown in Figure 41. Interim inspections



(From NRC.gov and Brian Boyer, Los Alamos National Laboratory)

Figure 41. Irradiated power reactor fuel seen from above with a Cerenkov-glow “night” vision device



(From CANTEACH
<http://canteach.candu.org/imagelib/37000-fuel-1.htm>)

Figure 42. CANDU fuel bundle (50x10 cm)

²⁸⁸ Cerenkov glow devices examine the ultraviolet light that appears in the water surrounding spent fuel. The light is results from energetic electrons that are generated in the spent fuel and are traveling faster than the speed of light in water. They emit light as the water slows them down.

occur between refueling; these may be randomly timed or periodic.²⁸⁹ If fresh MOX assemblies are present, there would be more frequent inspections to verify them in accordance with the current three-month timeliness goal. Finally, there would be additional inspections to verify transfers of partially filled spent fuel casks and transfers to dry storage.

CANDU reactors

Safeguards concerns at CANDU reactors. For CANDU heavy-water reactors, there are also three safeguards concerns: the diversion of fresh, unirradiated fuel bundles or pins (see Figure 42); diversion of spent fuel; or undeclared production of plutonium.

Safeguards methods at CANDU reactors. CANDU reactors are refueled while operating at full power. Since assemblies pass continually into and out of the reactor core, a quite different approach is implemented at CANDU reactors than at LWRs. Only fresh fuel and irradiated fuel outside of the reactor core are susceptible to direct verification. The former can be verified by NDA, but the latter cannot because of the storage conditions. Special unattended bundle counters are therefore used to monitor the flow of irradiated fuel leaving the reactor core as fuel bundles are moved to the spent fuel pond. This monitoring is combined with extensive surveillance of the irradiated fuel pathway and storage. In contrast to LWR fuel assemblies, CANDU fuel bundles are quite small, and in planning surveillance approaches this must be taken into account. (The reactors at Pickering, which are shown in the Figure 40, have 480 fuel channels in their cores and a total of 5760 fuel bundles when fully loaded.)

Under traditional safeguards, there would be quarterly interim inspections to meet the timeliness goal of three months. As will be described in Chapter 7, the IAEA has moved to a more flexible system under integrated safeguards, which is applicable in Canada. Under integrated safeguards, the quarterly inspections are not needed because the timeliness goal under integrated safeguards for spent fuel is one year. But there would be a scheme of unannounced inspections, particularly to cover transfers of irradiated fuel to dry storage.²⁹⁰

6.4.7 Spent fuel reprocessing

The steps of mining, milling, conversion, enrichment and fuel fabrication constitute the front end of the nuclear fuel cycle. After the fuel has been used for power production, it emerges into the back end of the cycle. At this point it is highly radioactive and must be handled entirely by remote control. If it is fuel from a production reactor and the plutonium is wanted for weapons, it will typically be reprocessed very quickly, which is possible because it has been irradiated relatively briefly in the reactor to prevent the buildup of undesirable isotopes.

Fuel from a power or research reactor may or may not be reprocessed. If fuel is not reprocessed, it remains intensely radioactive for many tens of thousands of years and must be secured against theft or release of radioactive materials to the environment. Immediately after discharge from the

²⁸⁹ The frequency and timing of interim LWR inspections will depend on whether the state has an additional protocol in force; see the discussion of the State Level Approach in Chapter 7.

²⁹⁰ Information driven safeguards: new concepts for implementing the State Level Integrated Safeguards Approach in Canada, E. Franklin Saburido, N. Whiting, J. Doo, IAEA-CN-184/257.

reactor, the used fuel is at its most radioactive and is cooled for a period of about five years before it is moved again.²⁹¹ At that point, it may be moved into heavily shielded dry casks or into another spent fuel pond at an interim storage facility. It may also be moved to a reprocessing plant to recover the uranium and plutonium from the fuel assembly in order to produce new reactor fuel.

As shown in Table 6, there are very few commercial reprocessing plants in operation today.²⁹² They share in common, the following basic process operations:

- a spent fuel pool to store incoming assemblies;
- cells for shearing the assemblies and dissolving them in an aqueous solution;
- a separations process in which the plutonium and uranium are separated from each other and from fission products. This process involves aqueous and organic liquids and consists of tanks, processing vessels, and piping;
- a process for converting the initial plutonium solutions to plutonium oxide powder. This part of the process mostly involves the processing of solids within glove-boxes. A plant may also be operated so that uranium and plutonium emerge in a single stream and the powder is a MOX that contains both elements;
- a process for converting the initial uranium solutions to a storable form;
- a product storage vault for cans of plutonium or MOX powder;
- a product storage area for uranium; and
- a waste storage area for the high-level waste, which may subsequently be immobilized in a glass-like matrix through a process called vitrification.

Table 6. Commercial Reprocessing Plants Worldwide

COUNTRY	FACILITY NAME	START	CAPACITY*
France	La Hague — UP2-800	1967	1,000.0
France	La Hague — UP3	1990	1,000.0
Russian Federation	RT-1, Combined Mayak	1971	400.0
United Kingdom	BNFL B205 Magnox Reprocessing	1964	1,500.0
United Kingdom	BNFL Thorp	1994	900.0

*Unit: t HM/year

A reprocessing plant will have both a large inventory and a large throughput of plutonium. The most important example, by far, of a reprocessing plant under safeguards is the Rokkasho Reprocessing Plant in Japan (See Figure 43). The Rokkasho plant is designed to process a

²⁹¹ Because some of the radiation produced by the spent fuel is absorbed within it – heating it - cooling refers both to the temperature of the spent fuel and the radiation escaping from it.

²⁹² IAEA-TECDOC-1613, Nuclear Fuel Cycle Information System, A Directory of Nuclear Fuel Cycle Facilities, 2009 Edition; the latest version of this information is at <https://infcis.iaea.org/NFCIS/Facilities>

maximum of 800 tons of irradiated power-reactor fuel per year (t HM/year). This contains about eight tons of plutonium. However, the scheduled completion date of the plant is 2021.²⁹³

It was recognized early that at large reprocessing plants the uncertainties in the yearly MUF would be much greater than a significant quantity. To address this limitation of conventional material balance accounting, the LASCAR (large-scale reprocessing) project was initiated.²⁹⁴ It developed a number of recommendations for safeguards at large-scale reprocessing plants. These ideas guided the development of the actual safeguards approach at the Rokkasho plant.²⁹⁵ It is the most ambitious safeguards system in the world, and its development and implementation were heavily assisted by Japan's safeguards support program, with further assistance from the United States. Safeguards for any future large-scale, aqueous reprocessing plant will likely be based on the Rokkasho model, so we will focus on that system here.

Safeguards objectives and concerns. The main safeguards objective is the detection of the diversion of plutonium, especially separated plutonium. A secondary consideration is that of detecting the diversion of uranium. The IAEA is also concerned with the possible misuse of the facility to process undeclared spent fuel, but this objective is covered by the measures undertaken to meet the other objectives. Finally, although not legally required by the safeguards agreement, the State and the IAEA may agree that the IAEA will use flow-sheet verification to confirm that the facility is not separating americium or neptunium. (Although they are not defined as special nuclear material, it is possible to use either americium or neptunium to manufacture a nuclear explosive device. As reprocessing capabilities grew, so too did concerns about this potential. Appendix Section A.2.1 describes the background and the steps taken by the Board of Governors that led to the flow-sheet verification approach.)

At facilities processing large amounts of separated plutonium (reprocessing plants and MOX fuel fabrication facilities) traditional material accounting verification encounters a number of problems. The timeliness goals are short, health issues prevent frequent human access to the nuclear material, and the uncertainty in the yearly plant MUF will be much larger than one significant quantity. As noted above, nominal annual output of the Rokkasho plant is eight tons of plutonium in the form of MOX and the storage capacity is 30 tons of plutonium. Measurement accuracies better than 1% on the liquid inputs and the powder form output are difficult to achieve. Finally, powders may become dispersed in unknown ways and the amount of plutonium in solution or as powder in certain process vessels (dissolvers, separation columns, evaporators) and other operational areas is difficult to measure.

Safeguards measures. The safeguards approach for the Rokkasho Reprocessing Plant is based on the following general elements:²⁹⁶

²⁹³ Japan Nuclear Fuels Limited, Extraordinary Press Conference, <http://www.jnfl.co.jp/en/release/president-talk/2017/201712.html> (accessed 21 March 2018)

²⁹⁴ The Large Scale Reprocessing Plant Safeguards forum met between 1987 and 1992. IAEA, "Report of the LASCAR Forum: Large Scale Reprocessing Plant Safeguards," IAEA, STI/PUB/922, Vienna, 1992

²⁹⁵ See S. Johnson, et. al., "Development of the Safeguards Approach for the Rokkasho Reprocessing Plant," IAEA-SM-367/8/01 01.

<http://www-pub.iaea.org/MTCD/publications/PDF/ss-2001/PDF%20files/Session%208/Paper%208-01.pdf>.

²⁹⁶ Technical status of safeguards at reprocessing plants is extensively reported in sessions 17 and 18 of the IAEA's October 2006 Safeguards Symposium "Addressing Verification Challenges," available on the IAEA's website. For example: "Extensive cooperation in establishment and installation of safeguards system at Rokkasho Reprocessing

- Intensive design verification activities during construction of the plant provide assurance that there are no hidden paths for the routing of nuclear material. This must cover more than twenty process buildings with 1700 km of pipes (700 km in the main process area). Figure 44, though for a different reprocessing plant, shows how a shipping container with fuel assemblies would be received.
- Hold-up is minimized through facility and process design.
- Inspector presence at the facility is continuous.
- C/S covers the assemblies from the spent fuel pool to the point where they are dissolved. C/S is also used in product storage areas. Figure 45, again for the other reprocessing plant, shows how the product storage area can be configured.
- Material accounting that relies on instrumentation installed within the process allows for closing material balances on a short-term basis without stopping the process for physical inventory verification. Three types of plutonium inventories must be measured: plutonium in solution, plutonium in the form of powder, and plutonium in waste streams. There is also, an annual physical inventory verification in which the process is shut down and cleaned out and inventories measured with maximum accuracy.
- Within the process area, material accounting is supplemented by process monitoring sensors that provide additional assurance that plant operations are occurring as declared.
- Extensive real-time information is provided by the plant operator regarding plant operations. This information is provided in the form of a read-only database that is shared by the IAEA and the Japanese safeguards authorities.
- An on-site IAEA laboratory allows for quick and accurate analysis of solution samples.



(Image from IAEA)

Figure 43. Reprocessing Plant in Rokkasho, Japan



(From IAEA Imagebank)

Figure 44. Spent fuel shipping container being received at the Sellafield Plant in the United Kingdom

Plant (RRP)," (IAEA-CN-148/109); and "The on-site laboratory for the Rokkasho Reprocessing Plant in Japan," (IAEA-CN-148/103).

Basic material accounting methods. The fundamental method for measuring the amount of plutonium in tanks during the separations process is to determine the volume of solution in a tank and its plutonium concentration. The volume is determined through verified pressure measurements that yield the liquid level and verified tank calibration that provides volume as a function of liquid level. The concentration of plutonium is determined by drawing multiple samples for laboratory analysis. To prevent sampling errors, it is important that the liquid in the tank be homogenized when the samples are taken and that the IAEA knows that the sample is authentic. For measuring the amount of plutonium in powder form, neutron measurements are used. NDA systems are also used to measure most types of waste streams.²⁹⁷

At the Rokkasho reprocessing plant, these elements are implemented by a number of integrated systems. Some of these were jointly developed by Japan, the United States, and the IAEA, and shared among the facility, the IAEA, and the Japanese safeguards authority:

- The Integrated Spent Fuel Verification System consists of surveillance cameras coupled with radiation sensors that watch the assemblies from the time they are placed in the spent fuel pool until they are chopped and dissolved.
- The Rokkasho Hulls Monitoring System is a neutron NDA system to estimate the residual plutonium in the waste “hulls” (chopped-up spent fuel assembly tubes).
- The Automatic Sampling Authentication System monitors the movement of liquid samples taken from the tanks for DA.
- The Solution Measurement and Monitoring System uses sensors (mostly pressure sensors that measure the level liquid in tanks) to estimate the inventories and transfers of nuclear material in solution form.
- The Plutonium Canister Assay System is a neutron coincidence system to determine the plutonium content of MOX powder in cans.



(From IAEA Imagebank)

Figure 45. Plutonium storage facility in Sellafield, United Kingdom



(From H. Menlove et al., Los Alamos National Laboratory.)

Figure 46. “Super glove box assay system” developed by Los Alamos National Laboratory for use in Japan

²⁹⁷ For a technical treatment of neutron measurement methods and other NDA techniques see Chapter 3a, “Nuclear Material Measurements” in *Nuclear Safeguards, Security, and Non-Proliferation*, James Doyle, Editor.

- The Plutonium Inventory Measurement System is a neutron assay system monitoring the plutonium powder content of glove-boxes.

Figure 46 is shows the “Super Glove Box Assay System,” in use at a glove box processing plutonium powder and is indicative of both the importance and the complexity of hold-up measurements.

There are other C/S systems covering storage areas, and other NDA systems to measure various waste streams. Sensors track the movement of nuclear material in real time or near-real time. The sensors, combined with results from sampling and analysis, enable short-period (five to fifteen days), sequential evaluations of MUF for various sections of the plant; these material accounting statistics have much smaller uncertainties than the overall plant yearly material balance and are timelier as well. Moreover, the large, continuous flow of information from the process area can provide very much increased confidence that the plant is operating as declared.

6.4.8 Spent fuel storage and disposition

The issues of radioactive waste disposal and whether or not to reprocess have been the subject of intense debate and go far beyond the scope of this book. They involve issues of economics, non-proliferation, safety, and inter-generational equities. Suffice it to say, a civilian nuclear fuel cycle does not, in principle, need to separate plutonium. It could operate indefinitely without “recycle” if there were sufficient (see Table 2), economically recoverable uranium to make nuclear electricity competitive with other energy sources without recycle. Many observers support this approach because of the perceived non-proliferation and nuclear security advantages of operating without producing separated plutonium.²⁹⁸ Many others believe that recycling is important and inevitable. They see advantages in managing radioactive waste, doubt the sustainability of uranium supply at competitive prices, and consider that the non-proliferation and security problems are manageable.^{299,300}

If spent fuel is not reprocessed it remains intensely radioactive for many thousands of years and must be stored safely and securely to prevent theft or diversion of nuclear material or release of radioactivity to the environment. The disposition of spent fuel that has accumulated from power reactor operations is a pervasive problem.

Interim solutions are:

- increasing the density of spent fuel in existing spent fuel pools;
- building additional “away-from-reactor” spent fuel pools; and

²⁹⁸ http://www.armscontrol.org/act/2008_04/LymanVonHippel, Reprocessing Revisited: The International Dimensions of the Global Nuclear Energy Partnership, Edward Lyman and Frank N. von Hippel.

²⁹⁹ <http://world-nuclear.org/info/inf69.html> World Nuclear Association, Processing of Used Nuclear Fuel, updated January 2011.

³⁰⁰ According to a 2008 Nuclear Energy Agency press communiqué, “There is enough uranium known to exist to fuel the world’s fleet of nuclear reactors at current consumption rates for at least a century, according to the latest edition of the world reference on uranium published today.” Many, however, foresee a significant growth in demand, although the consequences of the Japanese tsunami in 2011 may alter these predictions.

- increasing the use of dry storage in heavily shielded casks either at or away from reactors.

Permanent disposition of spent reactor fuel in underground geologic repositories has long been studied. Finland and Sweden have active programs, but permanent disposition remains an essentially unsolved problem for most States.

6.4.9 Mixed oxide plutonium fuel fabrication

The separated plutonium and uranium produced by a reprocessing plant can be recycled as reactor fuel (see Table 7 below). Japan, for example, recycles plutonium as MOX fuel for LWRs. There is a strong motivation to apply effective safeguards at such plants because both the plant inputs and outputs are direct-use material that is highly attractive from the proliferation perspective. Large plants pose a significant challenge because they may process tons of plutonium, and measurement uncertainties can lead to statistical uncertainties in the material balance much larger than one significant quantity of plutonium (8 kg).

Table 7. Mixed Oxide Plutonium Fuel Fabrication Facilities.

FACILITY	STATE	CAPACITY (T MOX/YR)	STATUS
PFFF	Japan	10	Operating
PFPPF	Japan	5	Operating
BN-MOX /FBFC-MOX	Belgium	40	Closed (2006)
Siemens MOX	Germany	35	Canceled
MELOX	France	195	Operating
Sellafield – MOX	United Kingdom	40	Operating
J-MOX	Japan	130	Planned
MFFF	US	n/a	Planned
Zheleznogorsk-MCC	Russia	60	Operating

(Data from J.B. Marlow, M. T. Swinhoe, and H. O. Menlove, Los Alamos National Laboratory and World Nuclear Association [<http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/mixed-oxide-fuel-mox.aspx>])

The input to the fabrication process is a mixture of MOX powder, which is then formed into ceramic pellets. The plutonium-bearing MOX powder and pellets that make up the fuel must be isolated in glove boxes; processing is largely done remotely to minimize radiation exposure to workers. For an LWR, the MOX pellets are put in pins that become part of a fuel assembly, similar to the fuel assembly shown in Figure 38.

Safeguards Concerns: The main concern is the diversion of separated plutonium. From the safeguards perspective, challenges include meeting a timeliness goal of one month for detecting the diversion of separated plutonium, which requires frequent inventory verification. In addition, nuclear material exists in many forms – powder, pellets, fuel pins, and fuel assemblies - and the number of items is very large. The safeguards issues for such facilities are similar to those at the final stages of reprocessing plants. In-process inventories may be large, and powder processing always has the potential for hold-up problems. Modern facilities involve remote processing for health and safety reasons, and material is difficult to access for measurements.

Safeguards measures. These conditions require advanced approaches involving considerable in-plant instrumentation roughly similar to those for reprocessing plants described above. (See also the description of sector approaches in Section 6.3.8.)

PART III

THE EVOLUTION OF IAEA SAFEGUARDS

CHAPTER 7. THE IAEA RESPONDS TO CHALLENGES

Introduction

Previous Chapters describe the safeguards system as it was applied up to the early 1990s. It was a mature system in which the Agency had developed model safeguards approaches for all facility types. Routine inspections were planned on the basis of safeguards criteria that spelled out what inspectors should do and how often. The criteria established timelines for the resolution of anomalies and inconsistencies.

In 1991-1992 events occurred that shocked the safeguards system into change and shaped how it would change. The first event was the discovery in 1991 that Iraq had pursued a nuclear-weapon program that was not known to the IAEA. Even worse, it had pursued part of its nuclear-weapon program in research centers to which IAEA inspectors had had access. Member states immediately perceived that the IAEA safeguards system needed to be strengthened, and a program of work to do so was initiated in 1991.

Another was the invitation by South Africa to the IAEA to verify the dismantlement of its nuclear-weapon program and its nuclear weapons. Although this exercise was carried out cooperatively, it gave the IAEA confidence that with access and information much broader than that available under INFIRC/153, it could verify all of a state's nuclear activities.

The Agency also detected significant non-compliance by the DPRK with its safeguards agreement in 1992. It gave the Secretariat confidence that new technical measures, such as environmental sampling combined with Headquarters analysis that took advantage of all available information, would allow it to detect undeclared nuclear activities.

In addition, in 1992, the Conference on Disarmament completed the negotiation of the Chemical Weapons Convention (CWC). Since the CWC represented the most recent example of verification approaches that were acceptable to the international community, many member states and the IAEA Secretariat turned to it for ideas that could be adopted by the IAEA to strengthen its safeguards system.

These experiences led to a five-year effort to strengthen safeguards. Some strengthening measures were adopted in very short order because they were within the scope of INFIRC/153. The Board of Governors decided that the IAEA needed additional authorities, and, as a result, it authorized the negotiation of a new safeguards agreement. The outcome of the negotiation was the "Model

Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards that was adopted by the Board in 1997.”³⁰¹

This Chapter describes the process of deciding what new authorities were needed and how the results were incorporated into the Model Protocol. Adoption of the Model Protocol, in turn, triggered another top-down review of how to strengthen the application of safeguards and make them more efficient. The new focus was on the detection of undeclared nuclear material and activities in a state in addition to detection of diversion of declared nuclear material.

7.1 Historical Background

7.1.1 South Africa

In 1989, South Africa decided to stop production of nuclear weapons.³⁰² By the end of 1990, it had dismantled them and removed all of the HEU from them. South Africa joined the NPT in July 1991, and in October 1991, it provided its initial nuclear material declaration to the IAEA. It had long been suspected that South Africa had had a nuclear-weapon program because it had operated a uranium enrichment facility without safeguards for many years. In addition, its initial declaration of nuclear material contained large quantities of HEU.

Given the circumstances, the Agency knew that a major challenge would be to ensure that it could account for all the nuclear material and facilities in South Africa. Fortunately, South Africa provided extensive cooperation and permitted use of environmental sampling. The IAEA obtained access to nuclear facilities and to many other locations used in South Africa’s nuclear-weapon program. It conducted comprehensive reviews and analysis of operating records, uranium mining activities, and imports of relevant equipment. Interviews with involved managers, scientists and technicians helped to provide the IAEA with a good picture of South Africa’s nuclear infrastructure. In 1992, the IAEA concluded that it had “no evidence that the inventory of nuclear material contained in [South Africa’s] Initial Report was incomplete.”³⁰³

At the time of this report, South Africa had not announced that it had had a nuclear-weapon program. This was not required by South Africa’s INFCIRC/153 safeguards agreement, which requires an initial report on “all nuclear material subject to safeguards.” However, significant public speculation led South Africa to announce in 1993 that it had manufactured and subsequently dismantled seven nuclear weapons.

The IAEA was now asked by the General Conference at its next meeting to verify the dismantlement of South Africa’s nuclear-weapon program. With the active cooperation of South

³⁰¹ Commonly known as the Model Additional Protocol or sometimes just the Model Protocol, the text of this agreement is published in INFCIRC/540 (Corrected).

³⁰² The rationale for South Africa to embark on a nuclear program that could produce nuclear weapons in the 1950s is complex, including national prestige, perception of threats from other African states and the Soviet Union, and energy independence. By 1989, threats were perceived to be lower; the actual utility of nuclear weapons had become more apparent; and, South Africa wanted to see “greater international integration to solve its political, energy, and social problems. See, “Revisiting South Africa’ Nuclear Weapons Program, David Albright with Andrea Stricker, June 2016.

³⁰³ GC(XXXVI)/1015, 4 September 1992. In IAEA General Conference archives at, http://www.iaea.org/About/Policy/GC/GC36/GC36Documents/English/gc36-1015_en.pdf.

Africa and the assistance of nuclear-weapon states, the IAEA was ultimately able to conclude that South Africa's nuclear-weapon program had been dismantled (see Figure 47). In its report, the IAEA stated that its teams had "found no indication to suggest that there remain any sensitive components of the nuclear-weapon programme which have not been either rendered useless or converted to commercial non-nuclear applications or peaceful nuclear usage."³⁰⁴

These two episodes – verification of South Africa's initial declaration and the dismantlement of its nuclear-weapon program – could only have been carried out with the cooperation of South Africa. It provided the IAEA with access to information and locations well beyond the requirements of INFCIRC/153. This imparted to the IAEA the conviction that with such information and access it would be able to draw conclusions in any state about the full range of the state's nuclear and nuclear-related activities.

7.1.2 DPRK

The Democratic People's Republic of Korea (DPRK) became a party to the NPT in 1985, but it did not conclude an NPT safeguards agreement with the IAEA until April 1992 (see Figure 48), well after the Treaty's requirement to do so within eighteen months. In the interim, North Korea operated an unsafeguarded reactor and reprocessed spent fuel.

Shortly after its safeguards agreement entered into force, the DPRK reported its initial inventory of nuclear material to the IAEA. The declaration included its 25 MW thermal reactor at Yongbyon and the reprocessing of a limited number of spent fuel rods. The declaration turned out to be false. IAEA analysis of plutonium and environmental samples indicated more extensive reprocessing than had been declared. The United States shared with the IAEA, and later with the Board of Governors, satellite imagery that showed two undeclared structures believed to be storage sites for reprocessing waste.

INFCIRC/153 contains a number of provisions to address "non-routine" implementation of safeguards.

There was no doubt that this was "non-routine." The IAEA promptly used all the authorities at its



(From the IAEA)

Figure 47. "Rendering harmless" the Kalahari test shafts in South Africa



(From the Institute for Science and International Security)

Figure 48. Dr. Hans Blix, Director General of the IAEA meeting with DPRK officials in 1992

³⁰⁴ A history of South Africa's nuclear-weapon program and the IAEA's role in verifying its dismantlement is contained in a report submitted to the IAEA General Conference in September 1993 entitled the "Denuclearization of Africa" (GC(XXXVII)/1075). It is found at http://www.iaea.org/About/Policy/GC/GC37/GC37Documents/English/gc37-1075_en.pdf.

disposal. In February 1993, relying on the 1992 Board decision that reaffirmed its right to do so, the IAEA requested a special inspection at the two locations that it suspected of containing nuclear waste in order to take samples to help to determine the extent of the DPRK's reprocessing program. The DPRK denied this request.



(From the Institute for Science and International Security [ISIS])

Figure 49. The Radiochemical Laboratory Complex at Yongbyon, North Korea showing no obvious signs of plutonium reprocessing

In March 1993, the Board decided that access was "essential and urgent" and called on the DPRK to cooperate and respond positively and without delay. One of the unique aspects of this process was the Board's reliance on the satellite photography shown to the Board by the United States. It made transparent the DPRK's efforts to conceal activities at the Yongbyon Research Center (Figure 49) and helped to convince the Board that urgent action was needed. Finally, in April 1993, the Board found the DPRK to be in non-compliance with its safeguards agreement. It used the authority in paragraph 19 of the safeguards agreement and Article XII.c of the Statute to report the DPRK's non-compliance to the United Nations Security Council.

Subsequent United Nations Security Council action did not give the IAEA additional authorities (as had been the case in Iraq). Rather, it encouraged all states to work with the DPRK to bring it into compliance with its safeguards agreement. After the DPRK announced its intention in 1993 to withdraw from the NPT, the United States and the DPRK entered into intensive negotiations. These led to the "Agreed Framework" under which the DPRK placed all of its declared facilities under an IAEA-supervised freeze.^{305,306} As noted in Section 4.2.4, the DPRK also suspended its withdrawal from the NPT on the 89th day after its announcement, one day before it would become effective.

This series of events in the early 1990s in South Africa, the DPRK and Iraq gave the IAEA a degree of confidence that it could successfully address verification of the correctness and completeness of a state's declarations, and with its new tools, detect omissions.

³⁰⁵ A short summary of this chronology is contained in a report of the IAEA Director General to the General Conference in 1993 called, "Implementation of the Agreement between the Agency and the Democratic People's Republic of Korea in connection with the Treaty on the Non-proliferation of Nuclear Weapons." See http://www.iaea.org/About/Policy/GC/GC37/GC37Documents/English/gc37-1084_en.pdf.

³⁰⁶ A thorough review and analysis of these episodes and subsequent events is contained in "Going Critical: The First North Korean Nuclear Crisis", Joel S. Wit, Daniel Poneman, Robert L. Gallucci, Brookings Institution Press, 2005. As U.S. government officials, Wit, Poneman, and Gallucci were deeply involved in these events.

7.1.3 Chemical Weapons Convention

Contemporaneously, the Chemical Weapon Convention was opened for signature.³⁰⁷ It contained approaches similar to those of the IAEA. It also contained innovative measures that were drawn upon later in elaborating IAEA safeguards-strengthening measures. The Chemical Weapon Convention contains an ambitious verification regime of comprehensive data reporting and detailed on-site inspections. Unlike INF CIRC/153, a State may take action under the Chemical Weapon Convention that requires the Organisation for the Prohibition of Chemical Weapons to act.³⁰⁸ In particular, a challenge inspection may be requested by any state party to the Chemical Weapon Convention at any location where prohibited activities are believed to be occurring. Because of heightened concerns about protecting proprietary or sensitive information, the Chemical Weapon Convention includes detailed provisions allowing the inspected state to “manage access” to sensitive locations. The Chemical Weapon Convention also had provisions requiring a state to provide designated inspectors with multi-year entry visas. If used by the IAEA, this approach would have provided a significant improvement in addressing a problem that had vexed the IAEA for years.

7.1.4 Iraq – A nuclear-weapon program is discovered

Prior to 1991 Iraq had pursued a clandestine nuclear-weapon program that was not detected by the IAEA. The nuclear-weapon program included enrichment activities both in buildings adjacent to facilities where the IAEA had routinely conducted inspections under INF CIRC/153 and at undeclared locations (Figure 50).³⁰⁹ This program was fully revealed after the first Gulf war.

As IAEA Director General Han Blix said in a statement to the U.S. Senate Foreign Relations Committee, “IAEA inspectors in Iraq have recently uncovered vast unknown, undeclared uranium enrichment programmes in the billion-dollar range and documentary evidence of an advanced nuclear-weapons development programme. This is a direct and flagrant violation of Iraq’s non-proliferation pledge.”³¹⁰ He went on to tell the Committee that “the IAEA safeguards inspection system should be given sharper teeth” and referred to the need to have enhanced access to locations as well as access to additional information, including “data obtained through national technical means, satellite cameras and other intelligence gathering activities.”

³⁰⁷ The Conference on Disarmament adopted the draft text of the Chemical Weapons Convention in September 1992.

³⁰⁸ The Organisation was established by the Treaty as its implementing body.

³⁰⁹ The image in Figure 50 of Tuwaitha is drawn from ISIS, Development of the Al-Tuwaitha Site: What If the Public or the IAEA Had Overhead Imagery? David Albright, Corey Gay, and Khidhir Hamza, April 26, 1999. <http://isis-online.org/isis-reports/detail/development-of-the-al-tuwaitha-site-what-if-the-public-or-the-iaea-had-over/9#images>.

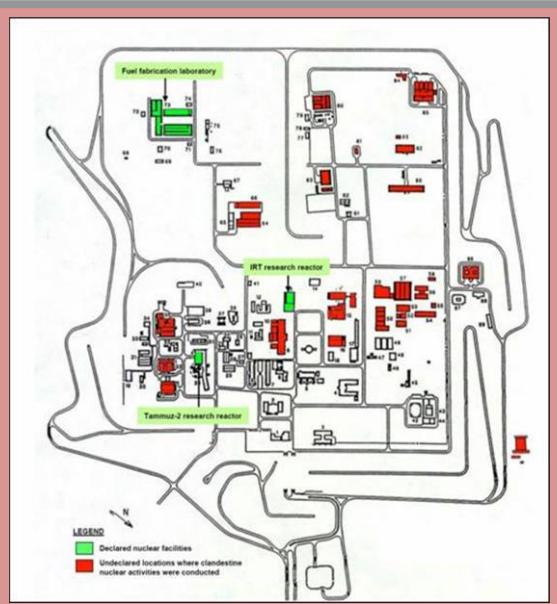
³¹⁰ From <http://www.fas.org/news/un/iraq/iaea/dgsp1991n06.html>.

The discovery also led to a series of United Nations Security Council Resolutions. The most significant from the perspective of nuclear non-proliferation and the IAEA was United Nations Security Council Resolution 687. This Resolution gave the IAEA unprecedented authority to destroy, remove, or render harmless any subsystems or components or any research, development, support or manufacturing facilities related to the acquisition or development of “nuclear weapons or nuclear-weapons-usable material.”³¹¹ The building in Figure 51 had been used for Iraq’s secret nuclear weapon program. The Resolution was adopted by the Security Council acting under Chapter VII of the United Nations Charter, which gives the Security Council the authority to use force and to decide what actions a state “shall” take. As a result, Iraq was required to cooperate with the IAEA in the fulfilment of the IAEA’s responsibilities.

It is important to keep in mind that the extensive and wide-ranging activities conducted by the IAEA in Iraq were conducted under the auspices of United Nations Security Council Resolution 687. They were not conducted under Iraq’s NPT safeguards agreement, which the reader may recall from Chapter 5 does not give the IAEA under any circumstances the right to destroy facilities or take related actions.

United Nations Security Council Resolution 687 gave the IAEA essentially unlimited access, allowing Agency inspectors to “go anywhere, anytime.” In reality, anywhere could not mean everywhere. There was a need to focus on specific sites. Sites with declared nuclear activities were an initial focus, but the IAEA needed assistance in identifying undeclared locations. The Agency routinely used information from third parties as the basis for these inspections.

As in the DPRK, the IAEA took good advantage of environmental sampling. To obtain a comprehensive picture of Iraq’s nuclear-weapon program, it investigated many nuclear-fuel-cycle and related activities not required to be reported by INFCIRC/153. These included uranium ore



(From ISIS)

Figure 50. Tuwaitha Research Center showing sites of declared activities in green and undeclared in red



(From Action Team 1991-1998/IAEA)

Figure 51. "Before and After": the destruction of a building at Al Atheer, Iraq in the summer of 1992 carried out under the supervision of an IAEA inspection team

³¹¹ S/Res/687 (1991) Iraq-Kuwait, United Security Council Resolution 8 April 1991. <http://www.fas.org/news/un/iraq/sres/sres0687.htm>.

mining and the manufacture or import of components that could be used for enrichment or reprocessing activities.

The map in Figure 52 shows the extent of Iraq's nuclear-weapon program.³¹² With the exception of the Tuwaitha Research Center, none of the facilities shown in the figure had been declared to the IAEA under Iraq's NPT safeguards agreement. (The reference in the header of the figure to "Declared Nuclear Facilities" refers to the facilities declared by Iraq to the IAEA Action Team as required by UN Security Council Resolution 687.)

As will be described below, even though the IAEA's actions in Iraq were not carried out under Iraq's INFCIRC/153 safeguards

agreement, the experience that the IAEA gained in Iraq assisted it in developing a plan of action to strengthen safeguards under INFCIRC/153

agreements. This led in 1997 to the adoption of a new safeguards

agreement that gave the IAEA authorities additional to those found in INFCIRC/153. This is described in the remainder of this Chapter.



7.2 Strengthening Safeguards

The discovery of Iraq's nuclear-weapon program highlighted limitations of INFCIRC/153 safeguards. Not only had Iraq pursued a clandestine nuclear-weapon program, but some of its clandestine activities were carried out "under the nose of inspectors" at the Tuwaitha Research

³¹² The map in Figure 52 of "Iraq: Declared Nuclear Facilities" is taken from an October 2002 CIA report entitled, "Iraq's Weapons of Mass Destruction Programs." See http://www.gritzie.com/PDFs/Iraq_womd_10_02.pdf.

Center where IAEA inspectors were present on a routine basis.³¹³ This happened because routine inspections gave access only to declared locations within the research center. Iraq had also pursued other nuclear-weapon-related activities involving nuclear material at undeclared locations entirely unknown to the IAEA. As Director General Blix emphasized, remedying these limitations would require enhanced access to information and locations.

7.2.1 Reviewing existing authority

One of the first things that the IAEA did to provide “sharper teeth” was to re-examine its existing legal authorities to determine whether they were being used to best advantage. Two areas were identified for early attention. One was the obligation in INFCIRC/153 that states provide design information and the other was the provision for the IAEA to carry out special inspections.

Early provision of design information

Under INFCIRC/153, states are required to provide design information “as early as possible before nuclear material is introduced into a new facility.” The ambiguity of the phrase “as early as possible” left it to be clarified in Subsidiary Arrangements. With ample room for interpretation, the IAEA standard before 1992 required a state to report design information for new facilities 60-90 days before nuclear material was introduced. Under this interpretation, the timing of reporting is left to the discretion of the state. It can decide when to introduce nuclear material. In this circumstance, a facility could be finished before reporting took place.

This is clearly too late to design a safeguards approach effectively. This interpretation would also permit a state to pursue many nuclear activities not involving nuclear material and have no obligation to report them to the IAEA. This could leave the IAEA “in the dark” about the specifics or even the fact of new nuclear facilities or the initiation of new nuclear-fuel-cycle programs, all in accordance with agreed arrangements.

To preclude this, the Board of Governors clarified the interpretation of “as early as possible” in early 1992. The new interpretation required states to begin reporting when the decision to build a facility was taken and to continue to report information about the facility until it was completed

INFCIRC/153 PARAGRAPH 42

Pursuant to paragraph 8 above, the Agreement should stipulate that design information in respect of existing facilities shall be provided to the Agency during the discussion of the Subsidiary Arrangements, and that the time limits for the provision of such information in respect of new facilities shall be specified in the Subsidiary Arrangements. It should further be stipulated that such information shall be provided as early as possible before nuclear material is introduced into a new facility.

³¹³ As recorded by the Director General in Annex 1 of the “Fourth consolidated report of the Director General of the International Atomic Energy Agency under paragraph 16 of Security Council Resolution 1051 (1996),” S/1997/779, 8 October 1997, these clandestine activities included: separation of plutonium from unreported irradiation of uranium targets; conversion of uranium oxide to U-metal, UF₄, UF₆, and UCl₄; fabrication, testing, and operation of electromagnetic isotope separation (EMIS) equipment and recovery of EMIS-enriched uranium; chemical enrichment research; neutron initiator development; and other activities.

and ready for operation. (The details of the new requirements for early reporting of design information are spelled out in Section 5.2.4.) The Board also called upon all states to incorporate this new interpretation in their Subsidiary Arrangements.

By early 2003, all states with nuclear activities had adopted the new interpretation and modified their Subsidiary Arrangements to implement the change.³¹⁴ This change has proven its worth. It provides the IAEA with complete pictures of states' nuclear-fuel-cycle plans and progress, and it provides a basis for the IAEA to conclude that a state is in non-compliance with its safeguards agreement when early, clandestine steps toward a potential nuclear-weapon program are revealed. This may be well before nuclear material is introduced and provide a means to halt or slow a suspected nuclear program well before it reaches the stage of production of nuclear material. It has been used to good effect in declaring the construction of clandestine facilities in Iran and Syria to be violations of their safeguards agreements.³¹⁵ These cases exemplify how safeguards strengthening measures initiated in 1991 have made it much harder for a state to come to the brink of operating a significant nuclear program in secret without being in violation of its safeguards obligations. (Although Iran's program was detected at an early time, demonstrating non-compliance with its safeguards agreement, this cannot be said to have slowed its nuclear program.)

Special Inspections

The IAEA Board of Governors also re-affirmed in February 1992 that IAEA safeguards apply to *all* nuclear material in *all* nuclear activities. This action confirmed the validity of safeguards approaches that are designed to detect the misuse of facilities to produce undeclared nuclear material. It also made clear that safeguards are applicable to states' nuclear activities anywhere.

The Board also decided at the same time to "urge the full exercise of *all* ... rights ... in NPT safeguards agreements," making an explicit reference to the Agency's right to undertake special inspections.

Despite the Board's reaffirmation of the Agency's right to undertake special inspections "when necessary and appropriate," it also expressed its anticipation that they would be rare. In practice they have been rare, in part because instances where they would be needed are unusual, but also because the IAEA has chosen to use informal approaches to gain access for investigations (as in Egypt, Iran, South Korea, and Syria). The Board's anticipation that special inspections would be rare could reflect two different perspectives. One is the expectation that non-compliance would be rare. Or it might be guidance to the Director General that he should not seek to undertake a special inspection except in the most egregious circumstances. (Recall, though, that the Board may also call for special inspections. It would be unusual for it to anticipate its own actions.) The ambiguous language may reflect a compromise between Board members holding these alternative views.

³¹⁴ Iran was the last such State to do so, although it later unilaterally announced that it would no longer implement it. The IAEA considers this to be a violation of its safeguards agreement.

³¹⁵ For Iran, see the report to the Board by the Director General, GOV/2010/46 at <https://www.iaea.org/sites/default/files/gov2010-46.pdf> (accessed 5 March 2019). For Syria, see IAEA Board Resolution adopted June 9, 2011, GOV/2011/41 at <https://www.iaea.org/sites/default/files/gov2011-41.pdf> (accessed 5 March 2019).

Director General Blix also proposed that the Board encourage states to provide intelligence information and to strengthen the ability of the IAEA to utilize it. The Board proved unwilling to speak to this issue explicitly. Even so, although the Board has never endorsed the use of third-party information, or rejected it, it has become commonplace. As noted above, it was used explicitly in the case of the DPRK.³¹⁶

Assurance of the absence of undeclared nuclear activities

In 1995, the Board further clarified the reach of INFCIRC/153. It decided that, in addition to detecting diversions, the safeguards system under comprehensive safeguards agreements should be designed to allow the IAEA to provide “credible assurance of the absence of undeclared nuclear activities” in the state as a whole.³¹⁷ This was an important step along the way toward negotiation of the Model Protocol because it cemented the need to enhance the authority of the IAEA in the ways needed to accomplish these objectives.

7.2.2 IAEA program to strengthen safeguards (Programme 93+2)

While the Board of Governors is the appropriate body to address legal issues related to the authorities of the IAEA, the Director General turned to his Standing Advisory Group on Safeguards Implementation (SAGSI) to look at possible strengthening measures that would have a strong technical component. SAGSI’s report in 1993, a summary of which was provided to the Board of Governors, proved to be influential. The report stated SAGSI’s “conviction that the Agency’s safeguards system must be strengthened so as to provide significant confidence that no undeclared nuclear activities of proliferation relevance are being carried out in states with comprehensive safeguards agreements....” It emphasized the importance of:

- Environmental sampling at facilities and at different ranges;
- Measures that would take advantage of the availability of information, including the analysis of publicly available information; information from member states reporting on import/export and production of nuclear and non-nuclear material and equipment; non-safeguards information; safeguards information; and information provided by member states; and;
- Development of a model of the arrangements to use for investigation of sites of possible undeclared facilities drawing on elements of the CWC.

The SAGSI report was followed by intensive discussions in the Secretariat and the Board of Governors. Afterwards, the Director General created a small unit within the Secretariat to examine the legal, financial and political implications of the various recommendations being considered. The target date for completion of this examination was 1995 and gave rise to the name “Programme 93 +2.” The work of this unit formalized a process that had already begun to divide the efforts to

³¹⁶ A more recent example is the September 2011 report of the IAEA to the Board of Governors on the implementation of safeguards in Iran. The report noted that, “The information available to the Agency in connection with these outstanding issues is extensive and comprehensive and has been acquired both from many member states and through its own efforts.” Quotation is from GOV/2011/54 at <https://www.iaea.org/sites/default/files/gov2011-54.pdf> (accessed 5 March 2019).

³¹⁷ GOV/Decisions 1994-1995, Decision 94-95/28.

strengthen safeguards into two phases. The first phase examined measures that could be implemented based on authority already contained in INFCIRC/153. The second phase focused on measures that would require new, specific authorities.

The Programme 93 + 2 staff started out with a list of potential improvements. It divided them between those available under existing legal authority and those that required new authority. Technical measures were assessed, and environmental sampling trials were conducted in a number of member states. The proposals discussed below were drawn from this work.³¹⁸

Existing and needed authorities

The experiences in Iraq and the DPRK demonstrated the value of environmental sampling. The Secretariat staff found that INFCIRC/153 contained the authority for using this technique wherever access was allowed.³¹⁹ The IAEA commissioned the construction of a clean laboratory for handling, screening, analyzing, and archiving environmental samples. In addition, a network of analytical laboratories in member states with capabilities to analyze environmental samples was created to supplement the IAEA's own clean lab.

In Iraq and the DPRK, information provided by third parties had been found to be very helpful. Taken together with information available to the Agency from its traditional safeguards activities, results from environment sampling, and information collected from open sources, this third-party information provided indications of undeclared nuclear activities in these states. Use of such information was found by the IAEA to be within the authority granted to the Agency by the Statute and INFCIRC/153.³²⁰

The IAEA also concluded that other measures were within existing legal authority. These included: requiring additional information from states about facilities in which nuclear material would be used or had been used; expanded use of unannounced inspections; and use of advanced technology to monitor remotely the movement of nuclear material. Monitoring could also include real time or near-real time data transmission to IAEA Headquarters, appropriately authenticated and encrypted.

7.3 Negotiation of the Model Protocol – INFCIRC/540

As noted above, during Programme 93+2, the Board identified strengthening measures that could be conducted within the authority of INFCIRC/153. However, the Agency and its member states agreed that greater authority was needed to permit the Agency to provide a meaningful assurance

³¹⁸ There have been extensive studies done on this topic; see E. Kuhn et al., "Environmental Sampling for IAEA Safeguards: A Five Year Review," IAEA-SM-367/10/01. In addition, the IAEA set up what it referred to as a 'wide area environmental monitoring programme' as part of the UNSCOM effort in Iraq.

³¹⁹ INFCIRC/153, paragraphs. 6, 74(d), 74(e), 676(a); see "IAEA Safeguards Serving Nuclear Non-Proliferation," p. 10, IAEA, 2015 at https://www.iaea.org/sites/default/files/safeguards_web_june_2015_1.pdf .

³²⁰ The Board's decision on reporting design information was reported in GC(XXXVI)/1017. Relevant information is also in GC(XXXVII)/1073, 6 September 1993.

http://www.iaea.org/About/Policy/GC/GC37/GC37Documents/English/gc37-1073_en.pdf. Annex 2 of Volume I of a Brookhaven National Laboratory review of the Negotiation of the Model Protocol contains the relevant portion of GOV/2554/Attachment 2/Rev.2. <http://www.bnl.gov/isd/documents/71012.pdf>.

about the absence of undeclared nuclear activities and materials. In order to capture these additional authorities, the Secretariat began to draft language that could serve as the basis for a new safeguards agreement. The Board of Governors provided a specific mandate to do so when it took the following decision in 1995:

The Board reiterates that the purpose of comprehensive safeguards agreements, where safeguards are applied to all nuclear material in all nuclear activities within the territory of a State party to such an agreement, under its jurisdiction or carried out under its control anywhere, is to verify that such material is not diverted to nuclear weapons or other nuclear explosive devices. To this end, the safeguards system for implementing comprehensive safeguards agreements should be designed to provide for verification by the Agency of the correctness and completeness of States' declarations, so that there is credible assurance of the non-diversion of nuclear material from declared activities and of the absence of undeclared nuclear activities.³²¹

Based on previous discussions within the Board of Governors, the Secretariat submitted to the Board a first draft of a Model Protocol. After further Board discussion, in 1996 the Secretariat submitted to the Board a revised draft of a Model Protocol that contained the additional authorities it believed were needed.³²² It operationalized the exhortation of Director General Blix to provide the safeguards system with "sharper teeth" and reflected the work of SAGSI, the subsequent discussions in the Board of Governors, and the program of work carried out in the context of Programme 93+2.

The two main features of this draft were the requirements for much broader reporting of information and for enhanced access. In particular, the draft reflected the view that had developed during the early 1990s that the IAEA needed information about the full range of a state's nuclear-fuel-cycle activities, not just those activities that employed nuclear material. The draft necessarily reflected compromises between the positions of different members of the Board of Governors. In order to complete the negotiations, the Board created a committee to agree upon a text containing those new authorities. It used this Secretariat draft as a basis for its negotiations. The committee was open to all member states. It was the 24th committee created by the Board and was called Committee 24.

It is important to remember that the Committee's charge was to draft a new agreement that would complement INFCIRC/153 but not replace it. It was expected that member states would be subject to both an INFCIRC/153 agreement and the new agreement. As a result, the Committee had to address how implementation of the two agreements would be harmonized and not be in conflict with each other. It also had to ensure that some activities that the IAEA was able to carry out under INFCIRC/153 agreements could also be carried out under the new agreement. (This would not be a new authority but rather maintaining an existing right, for example, the right to conduct environmental sampling, under new circumstances.)

³²¹ It is noteworthy that this decision gave explicit authority to design safeguards to make sure that there are no undeclared activities not only in the new system to be developed but also for the existing comprehensive safeguards agreements.

³²² GOV/2863, Annex III. The text of this draft is contained in Annex III of Volume II of the Brookhaven negotiating history of the Model Protocol cited earlier. <http://www.bnl.gov/isd/documents/71014.pdf>.

7.3.1 Negotiating dynamic

Among the approximately 80 countries participating in the negotiations, four major groups emerged. The first group, and the most active, consisted of countries with INFCIRC/153 safeguards agreements that had significant nuclear activities, particularly Germany, Japan, Spain, Belgium and Italy. Other active delegations within this first group were Argentina, Australia, Brazil, Canada and the Republic of Korea. By and large, these states often deferred to Germany.

These countries generally did not have major substantive problems with the Secretariat draft because prior discussions in the Board of Governors were reflected in the document. Their problems were primarily with procedures and process. Their views were colored, moreover, by the perspective that the implementation of a new legal instrument would add new burdens to the burden of INFCIRC/153 safeguards.³²³

To ensure that the new measures would not do so, two of their major objectives were “cost neutrality” and “safeguards neutrality.” That is, there would be no increase in the cost of safeguards in the IAEA budget and the implementation of new safeguards measures would be compensated by a reduction in other measures.

The second group was made up of countries that had INFCIRC/153 safeguards agreements but did not have significant nuclear programs. This group was the largest numerically, and their primary interest was ensuring that funds needed for safeguards did not take away from funds available to the Agency for technical assistance.

The third group consisted of the five countries with nuclear weapons recognized in the NPT. Views among the five varied, with China and to a lesser extent Russia preoccupied with ensuring that whatever new authorities were given to the IAEA would not be applied to them. France, the United Kingdom, and the United States were interested in ensuring that the Agency had as much authority as possible to detect undeclared nuclear activities, and they were generally supportive of the Secretariat draft.

During prior Board discussions, all nuclear-weapon states had indicated a willingness to accept some of the provisions of the Model Protocol, with the United States committed to accepting all of the provisions subject to exclusion for matters of “national security significance.”³²⁴ As with the negotiations of the NPT and INFCIRC/153, European countries, particularly Germany, were concerned about the potential for commercial disadvantage that would flow from implementation of the Model Protocol only in non-nuclear-weapon states. Some states also wanted to use the negotiation to further Article VI of the NPT, which called for the elimination of nuclear weapons. Universal application of safeguards was seen as a step in that direction. In order to assuage these

³²³ According to Meier, initial German support for strengthening safeguards could at best be characterized as very reluctant. “Germany at first tried to prevent such an initiative by dragging its feet in the negotiations and also opposing some of the measures. Once the political leadership had taken the initiative (it took a personal call from President Clinton to Chancellor Kohl to support a change of the German position), economic criticisms were overruled.” Oliver Meier, paper presented at the conference “Germany as a Civilian Power – Results of Recent Research,” Trier University, December 11-2, 1998. In March, 2009 found at <http://www.bits.de/public/articles/trier98.htm#fnverweis59>.

³²⁴ This would incorporate into any new U.S. safeguards agreement the same “national security exclusion” that was incorporated into the U.S. Voluntary-Offer Safeguards Agreement. This is described in Appendix D.

concerns, U.S. President Bill Clinton made a commitment in a letter to Germany's then Chancellor Helmut Kohl to accept all the provisions of the agreed protocol subject to the national security exclusion mentioned above.

The last group consisted of the four countries that were not parties to the NPT at that time: Cuba, India, Israel and Pakistan.³²⁵ The interests of these states were simply to ensure that whatever was negotiated did not apply to them. (Cuba joined the NPT in 2002.)

7.3.2 Major issues

From 1991 until the conclusion of the Model Protocol in 1997, efforts to strengthen safeguards focused on the two major themes that had been introduced by Director General Blix: enhanced access to information and locations and the need to make explicit the Agency's right and obligation to address the issue of undeclared nuclear material and activities. Details count. As a result, considerable effort was invested in defining what would be the scope of information to be provided to the IAEA. What would be the level of detail? What would the Agency do with the information? To which locations would the IAEA have access and under what circumstances? And what activities could be carried out during this access? The more important of these issues are addressed below.³²⁶

One area is omitted because of its detail and complexity. This is the use of the Model Protocol to provide the IAEA with more information about nuclear material than is available under INFCIRC/153. This includes information, for example, about mines and concentration plants (Article 2.a.(v)), information about material before the "starting point of safeguards" (Article 2.a.(vi)), and information about nuclear material exempted from safeguards (Article 2.a.(vii)).

Relationship to NPT comprehensive safeguards agreements

The form of the new agreement and its relationship with INFCIRC/153 was one of the first issues addressed. The Committee decided to follow the model of INFCIRC/153. Each state would use the new model in negotiating its own bilateral agreement with the IAEA. Some treaties, the NPT, for example, enter into force after a specified number of states adhere to the treaty. This model

³²⁵ Since 1997, Cuba has joined the NPT, and the DPRK has announced its withdrawal from the Treaty.

³²⁶ Readers interested in detailed information about the negotiation of the Model Protocol should refer to the detailed study done by Brookhaven National Laboratory, which covered both the background and the negotiation of the Model Protocol. The result, "Review of the Negotiation of the Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected)" was published in January 2010, in three volumes, BNL-90962-2010, BNL-90964-2010, and BNL-90965-2010. Volume I, "Setting the Stage: 1991-1996" covers the period during which strengthening measures were reviewed and ends when the Board created Committee 24. It was prepared by: Michael D. Rosenthal, Lisa L. Saum-Manning, Frank Houck, and George Anzelon; Volume II, "IAEA Committee 24: Major Issues Underlying the Model Additional Protocol, (1996-1997)" examines the negotiations in Committee 24 issue-by-issue and was prepared by Michael D. Rosenthal, Lisa Saum-Manning, and Frank Houck; and Volume III, "IAEA Committee 24: Development of INFCIRC/540, Article-by-Article Review (1996-1997)," which examines the negotiations in detail, was prepared by Michael D. Rosenthal and Frank Houck. The three volumes are available respectively at www.bnl.gov/isd/documents/71012.pdf, www.bnl.gov/isd/documents/71014.pdf; and www.bnl.gov/isd/documents/71015.pdf.

was rejected because it could not take account of the different status of non-nuclear-weapon states, nuclear-weapon states, and parties and non-parties to the NPT.

The resulting treaty would be brought into force for each state in accordance with its domestic requirements. But then, how could an outcome be avoided where non-nuclear-weapon states would negotiate different versions of the agreement, and how would “universality” be achieved?

A Foreword to the Model Protocol was adopted to address these issues. It established the Model Protocol as the standard to be used in bilateral agreements by countries with comprehensive safeguards agreements. The Foreword also requested the Director General to negotiate additional protocols with NPT nuclear-weapon states and with other countries not party to the NPT, which could contain a subset of the provisions of the Model Protocol.

The Committee also needed to address the question of what would happen if there were a conflict between the provisions of the Model Protocol and a safeguards agreement to which it was “Additional.” The solution was to have the provisions of the Model Protocol take precedence. In addition, an important distinction is made in the Model Protocol that might appear nomenclatural, but which is extremely important. It is the use of the term “access” and “complementary access” to characterize the IAEA’s activities under the Model Protocol. Since the ground rules of INFCIRC/153 generally govern “inspections” and the ground rules of the Model Protocol govern “access,” there could be no conflict between them.

MODEL PROTOCOL ARTICLE 1

The provisions of the Safeguards Agreement shall apply to this Protocol to the extent that they are relevant to and compatible with the provisions of this Protocol. In case of conflict between the provisions of the Safeguards Agreement and those of this Protocol, the provisions of this Protocol shall apply.

Constitutional and legal limitations

Two broad objectives were at the core of the negotiations: enhanced access to information and to locations. Heavily debated throughout the negotiations in Committee 24 were what types of limitations and qualifications should there be on the Agency’s ability to seek this enhanced access to information and locations. The corollary—the obligation of states to provide it—was also debated. Constitutional and legal issues underlay this debate. The important distinctions to keep in mind are between “heavily regulated” activities, such as those involving nuclear and other radioactive material, and other industrial activities; and between public and private activities. In “heavily regulated” activities, there is an expectation of licensing and extensive regulatory requirements that make the provision of information about them and inspection of them readily, legally available. In the latter category, information about publicly financed activities should be straightforwardly available, while information about private activities may be just that, “private.”

A common proposal to avoid these dilemmas was to make the provision of information and access “subject to the laws and constitution of the state.” However, there was widespread agreement that a broad exception for laws and constitutions would create real problems because in many states, enactment of laws or even modifications to the constitution are not difficult to achieve. The fear

was that accepting such a far-reaching limitation would eviscerate the authority the Agency was seeking.

The greatest debate involved reporting of nuclear R&D. Many were concerned that a state would not know about wholly private R&D. Moreover, states could find it difficult to convince legislatures to require reporting of such activities. The blanket qualification of “subject to the laws and constitution” of states was considered to be too sweeping. The Committee ended up dividing R&D activities into ones with government involvement and those without. For the former, there is an unqualified obligation to provide information (Article 2.a), but for activities where there is no government involvement, the obligation is for a state “to make every reasonable effort” to provide information regarding such activities (Article 2.b).

Access also raised the issue of whether to make it subject to states’ laws and constitution. There was ready agreement on a right of access unqualified by constitutional concerns for areas with nuclear material or at decommissioned facilities where nuclear material had been used. This agreement was possible because expectations of privacy diminish as state regulation increases, and such regulations are pervasive when nuclear material is present. (This is why the same issue was not raised during the negotiation of INFCIRC/153.)

Long discussion was required to reach agreement on how to provide access to areas where nuclear material was not present. Ultimately, limitations based on constitutional requirements were rejected. The Model Protocol requires a state to provide access where nuclear material is present (Article 5.a), but, where nuclear material is not present, a state is obligated to provide access. If it is unable to provide such access, it has an alternative: to “make every reasonable effort to satisfy Agency requirements, without delay, through other means” (Articles 5.b and 5.c).

Environmental sampling

The Agency, with Board concurrence, concluded that it had the right under INFCIRC/153 to carry out environmental sampling. What the Committee had to decide was how to frame the right of the Agency to conduct environmental sampling at locations where INFCIRC/153 did not provide access.³²⁷ In addition, a new way to implement environmental sampling was introduced. First proposed by SAGSI, it would permit routine environmental sampling anywhere in a state, not just at specific locations included in a state’s declaration to the IAEA under the Model Protocol. Such widespread environmental sampling would take advantage of its demonstrated capabilities to detect undeclared nuclear material processing anywhere in a state.

Eventually, two forms of environmental sampling, “location-specific” and “wide-area” environmental sampling, were included in the Model Protocol. Article 6 of the Model Protocol permits the collection of “location-specific” environmental samples whenever access is allowed. Wide-area environmental sampling raised different issues. Countries in Europe doubted the value of wide-area environmental sampling in areas where borders are close, rivers flow through several countries, and individual countries have differing levels of nuclear activities. This posed a risk that a country might be accused of conducting undeclared nuclear activities on the basis of nuclear

³²⁷ Of course, under special inspections, the IAEA potentially has the right to inspect anywhere in a State. The issue here was to secure the Agency’s rights during other situations.

material in an environmental sample that had been transported from another state, by wind or water, for example.

Even though field trials that the Agency had conducted showed the potential of this tool to disclose undeclared nuclear activities, there was a generalized concern that the technique had not been perfected, nor had the cost-effectiveness been demonstrated. As a result, the Model Protocol provides to the IAEA the right to conduct wide-area sampling, only after approval by the Board of Governors (Article 9). To date, the Board has not addressed this matter.

It is noteworthy that the definitions of both location-specific and wide-area environmental sampling make explicit that they are intended to assist the Agency in drawing conclusions about the absence of undeclared nuclear material or nuclear activities.

Specified equipment and non-nuclear material

Information about a state's capabilities to manufacture commodities that are related to the nuclear fuel cycle can provide insight into its potential to pursue undeclared nuclear activities. Information about imports or exports of nuclear-related equipment may also be indicative of a state's interest or capability to pursue nuclear activities. Efforts to purchase nuclear-related commodities in other countries, sometimes illegally, had already revealed that some countries had pursued clandestine nuclear activities.

Dealing with *imports and exports* was an easier task than dealing with *manufacture*. The Board of Governors had already established a voluntary reporting scheme for imports and exports of equipment in 1993. The equipment list for voluntary reporting was based on the NSG trigger list. The Secretariat proposed that the Model Protocol require states to report both imports and exports using the list agreed for the voluntary reporting arrangement. This list was adopted and is incorporated into the Model Protocol as Annex II. However, the Committee decided to require reporting only for exports. Information regarding imports would need to be supplied only "upon specific request by the Agency" (Article 2.a.(ix)). The rationale was based on grounds of efficiency to avoid "double counting."

Dealing with manufacture of specified equipment and non-nuclear material was more contentious. Initial proposals to use the list agreed for reporting imports encountered strong opposition. There was also opposition to detailed reporting about inventories, production, and production capabilities. Agreement was reached on reporting manufacturing capability, but only of items directly related to the operation of reactors and enrichment, fuel fabrication, and reprocessing plants. The agreed list is included in Annex I of the Model Protocol. According to the Model Protocol, states need to report on "scale of operations" for these fifteen items (Article 2.a.(iv)).

MODEL PROTOCOL

ARTICLE 9

..... shall provide the Agency with access to locations specified by the Agency to carry out wide-area environmental sampling provided that if is unable to provide such access it shall make every reasonable effort to satisfy Agency requirements at alternative locations. The Agency shall not seek such access until the use of wide-area environmental sampling and the procedural arrangements therefor have been approved by the Board and following consultations between the Agency and

While there was no agreement on precisely what “scale of operations” meant, there was agreement that it related more to capacity than to the precise number of items produced.

Administrative issues

The Secretariat draft addressed some long-standing administrative issues that had arisen in the implementation of INFCIRC/153. It drew upon approaches contained in the Chemical Weapon Convention. For example, under the Chemical Weapon Convention, states agree to provide inspectors with multi-entry visas that cover at least two years. For reasons never clearly explained, many states that had accepted the two-year period in the Chemical Weapon Convention insisted on one year for the Model Protocol, and that was the final outcome (Article 12).

The Model Protocol also addresses the issue of designation of inspectors (Article 11). The Committee accepted a simplified procedure that calls for the Director General to notify states when the Board of Governors approves an individual as an inspector. Designation is then assumed unless the state objects. This reverses the procedure provided for in INFCIRC/153 whereby designation requires a state to respond positively that it accepts an individual as an inspector (paragraph 85).

Further, the Model Protocol enhanced the ability of inspectors to communicate with IAEA Headquarters and to transmit to Vienna information generated by its safeguards equipment (Article 14). Concerns about confidentiality of sensitive information were addressed through requirements that the Agency maintain a stringent regime for the protection of such information and that the regime be periodically reviewed and approved by the Board of Governors.

INFCIRC/153 permits a form of managed access. A new provision was needed in the Model Protocol in view of the additional information and access that the Agency would be obtaining. The Committee needed to address what types of information could be protected by managed access. The outcome permits states to use managed access to “prevent the dissemination of proliferation sensitive information, to meet safety or physical protection requirements, or to protect proprietary or commercially sensitive information.” The Committee rejected proposals to include information related to national security of information that it considered to be classified, confidential, or restricted. These categories were rejected as too sweeping because they would potentially permit states to designate anything as falling in one of these categories.

The Committee also addressed the issue of how managed access could be used and still permit effective safeguards. The Model Protocol, accordingly, contains a broad interpretation that managed access could not preclude the Agency “from conducting activities necessary to determine the absence of undeclared nuclear material and activities or otherwise resolve any inconsistency.” This rejected a more limiting qualifier that referred only to precluding the Agency from conducting activities necessary to resolve any inconsistency.

Adoption of the Model Protocol

The Committee concluded its work on the Model Protocol after four meetings held in less than a year. At the end of its work, it sent the draft Model Protocol to the Board of Governors and recommended adoption. Many participants in the negotiation strongly favored “universal” application of the Model Protocol in the five NPT nuclear-weapon states. As a result, each of them

reads a statement at the Board indicating its intention to accept measures in the Model Protocol. With these statements in the official record, the Board adopted the Model Protocol in April 1997.

A key outcome of the negotiation of the Model Protocol is that it makes explicit the IAEA's obligation to provide assurance about the absence of undeclared nuclear material and activities. It provides new tools to accomplish this – enhanced access to information and locations – and it presumes that the IAEA will draw conclusions about the completeness and correctness of the information provided by a state.

As of December 2016, there were 181 states in which safeguards agreements were being implemented of which 127 had additional protocols in force. had both a comprehensive safeguards agreement and an Additional Protocol in force. Each NPT nuclear-weapon state also had an Additional Protocol in force. The following section reviews key provisions of the Model Protocol and provides an overview of how these provisions interact.

7.4 Key Features of the Model Protocol

Overview

The Model Protocol has a complex structure. The following sections clarify its elements and their relationship to comprehensive safeguards agreements. In light of the discussion above, the reader will not be surprised that the final text of the Model Protocol is complex. It necessarily reflects compromise language that satisfied participants with differing views on a wide range of topics.

In simplified form, the Model Protocol may be thought of as addressing three different realms. One is the realm of nuclear industry where nuclear material is used as a matter of course. This realm is highly regulated, and there is little or no expectation of privacy. Complementary access in this realm can be conducted with little or no notice, and the tools selected on the basis of safeguards effectiveness. An analogy to this realm is now found at airports, where the privacy rights of passengers as they enter the secure zone are markedly different than when they are driving to the airport or within the airport. In turn, these are dramatically different than when they are sitting at home reading this book!

The most significant result of the Model Protocol in this realm is the need for states to provide detailed information about “sites,” itself a new safeguards concept developed during the negotiation. On the site of a facility, the IAEA may obtain complementary access anywhere on the site on short notice to ensure the absence of undeclared nuclear activities. In addition, the

MODEL PROTOCOL ARTICLE 2

..... shall provide the Agency with a declaration containing:

a.iii. A general description of each building on each site, including its use and, if not apparent from that description, its contents. The description shall include a map of the site.

ARTICLE 18.

b. Site means that area delimited by in the relevant design information for a facility It shall also include all installations, co-located with the facility or location, for the provision or use of essential services, including: hot cells for processing irradiated materials not containing nuclear material; installations for the treatment, storage and disposal of waste; and buildings associated with specified activities identified by under Article 2.a.(iv) above.

Model Protocol also provides access to nuclear material in forms and circumstances under which INFCIRC/153 does not provide inspection rights. This includes circumstances where nuclear material is not subject to inspection because it is exempted; before the starting point of safeguards; or contained in waste. The Model Protocol closes these gaps in inspection coverage and gives the IAEA a more complete picture of states' nuclear programs and activities.

The second realm is new to the IAEA because it consists of nuclear-fuel-cycle related activities that support the nuclear fuel cycle but do not handle nuclear material. The Model Protocol specifies the fuel-cycle activities that need to be reported. Of course, these activities are regulated in many ways – for example, for health, safety, and economic reasons – but no license is needed to engage in the activities themselves. The manufacture of nuclear grade graphite or reactor control rods is an example. Since these activities are not regulated from the nuclear perspective, except sometimes for export control purposes, the conditions of complementary access are more stringent. In these cases, if the IAEA has a question or detects an inconsistency in the completeness or correctness of information about these activities, the IAEA must inform states in writing of the matter to be resolved before it requests access. Because the activities are not licensed, access is not necessarily assured. As a result, if the state is unable to provide access, it "shall make every reasonable effort to satisfy Agency requirements without delay, through other means" (Article 5.b).

In both of these realms, Article 6 of the Model Protocol allows the IAEA to use a full range of inspection activities.

The third realm consists of "the rest of the world." Access is provided for in the event that there is a question or inconsistency, but here even the State might find that obtaining access is difficult – it could be one's home. As a result, the only allowed inspection activity is environmental sampling, but if the question is not resolved, the IAEA may also use "radiation detection and other measurement devices" (Article 6.d). However, the state is also allowed, if obtaining access is not possible, to satisfy the IAEA's needs at "adjacent locations or through other means" (Article 5.c). (Recall that in such circumstances, the IAEA can also request special inspections under the authority of the INFCIRC/153 agreement.)

7.4.1 Enhanced access to information

Under the Model Protocol, states are required to provide nuclear-fuel-cycle information and information about nuclear material much broader than what is required under INFCIRC/153. The requirement is given in Article 2, and the required information has become known as the expanded declaration.

The expanded declaration provides a broad overview of a state's nuclear infrastructure and capabilities, focusing on activities such as enrichment and reprocessing, which are key technologies in the production of weapon usable nuclear material. But it also includes reporting on a broad range of nuclear-fuel-cycle R&D activities not involving nuclear material. The information provided falls into three basic categories. The first two are associated with locations where nuclear material is present and the third, where it is not:

- Information in addition to facility design information about each of the buildings on the site of a facility and whether the building has nuclear material or not;
- Expanded information about nuclear material that is not covered by INFCIRC/153; and
- Information about nuclear-fuel-cycle activities that do not normally utilize nuclear material.³²⁸

7.4.2 Enhanced access to locations

COMPLEMENTARY ACCESS
ARTICLE 4

The following shall apply in connection with the implementation of complementary access under Article 5 of this Protocol:

a. The Agency shall not mechanistically or systematically seek to verify the information referred to in Article 2; however, the Agency shall have access to: (i) Any location referred to in Article 5.a.(i) or (ii) on a selective basis in order to assure the absence of undeclared nuclear material and activities; (ii) Any location referred to in Article 5.b. or c. to resolve a question relating to the correctness and completeness of the information provided pursuant to Article 2 or to resolve an inconsistency relating to that information; (iii) Any location referred to in Article 5.a.(iii) to the extent necessary for the Agency to confirm, for safeguards purposes,'s declaration of the decommissioned status of a facility or of a location outside facilities where nuclear material was customarily used.

Under Article 4 of the Model Protocol, the IAEA is permitted to have access to any location associated with information provided in the expanded declaration. This term “complementary access” is used because it differs from the “inspections” called for in INFCIRC/153. The declaration requires general information on mining operations, source material before the starting point of INFCIRC/153 safeguards, and certain wastes on which safeguards have been terminated under INFCIRC/153 (Articles 2 a.(v), (vi)(a), and (vii)(b)).³²⁹ In all three cases, the Model Protocol does not require the state to maintain or provide “detailed nuclear accountancy” information. Thus, unlike the requirements of INFCIRC/153, there is no basis for the Agency to confirm the accuracy of that accounting. In addition, the Model Protocol specifies that the Agency “shall not mechanistically or systematically” seek to verify information in the expanded declaration. (Article 4.a)

Nonetheless, at locations where nuclear material is present, the explicit purpose of access is to assure the absence of undeclared nuclear material and activities (Article 4.a.(i)) and 4.a.(ii)). For other situations, including access to undeclared locations, complementary access is intended to resolve a question or an inconsistency related to both the correctness and the completeness of the information provided (Article 4.a.(iii) and Article 5.c.).

From a risk perspective, the nuclear material and facilities that are safeguarded under INFCIRC/153 pose more of an immediate proliferation threat than activities covered under the Model Protocol. The Model Protocol, though, can provide an indication of an undeclared attempt to acquire

³²⁸ These three categories are drawn from the twelve specific requirements in Article 2 of INFCIRC/540 (Corrected).

³²⁹ In this Chapter we will reference INFCIRC/540 text with [brackets]. This references Article 2, paragraph a. (v), (vi)(a), and (vii)(b), INFCIRC/540.

capabilities leading to the production of weapon-usable nuclear material at an early stage of development.

That complementary access is not to be “mechanistically or systematically” applied does not mean that it is not routinely used. Complementary access is built into the Agency’s safeguards approaches.³³⁰ It is used at the sites of nuclear facilities to assure the absence of undeclared nuclear material and activities. There is no requirement to justify such access, only to use it on a selective basis. Elsewhere it may be used to resolve an inconsistency or question. Complementary access may be used extensively after a state’s initial expanded declaration is submitted. In this case, the IAEA expects to draw a conclusion for the first time about the absence of undeclared nuclear material and activities in the state, a so-called broader conclusion. It wants to ensure that this initial conclusion is as sound as possible and will only do so if all questions and inconsistencies are resolved. This establishes a baseline, and subsequently complementary access will be used less frequently.

The following examines the three reporting categories identified above and describes what access rights the Agency has at each.

7.4.3 Sites with INFCIRC/153 facilities, including decommissioned facilities

Section 7.1.4 described how Iraq pursued its nuclear-weapon program at a research center where only some buildings were inspected. By co-locating undeclared nuclear activities close to declared activities, indicators of undeclared nuclear activities can be obscured by activities or emissions from the declared activities. To deal with this problem, the Model Protocol defined a new concept, called “site,” which if in effect in Iraq at the Tuwaitha facility would have permitted the IAEA to detect the undeclared nuclear activities conducted there. According to the definition, a “site” includes the “area delimited by [the state] in the relevant design information,” and “shall also include all installations, co-located with the facility or location, for the provision of essential services, including: hot cells for processing of irradiated materials not containing nuclear material; installations for treatment, storage and disposal of waste, and buildings associated with specified activities ...” (Article 18.b). An Additional Protocol party must provide a map of the site where a safeguarded facility is located with a general description of each building, including its use and, “if not apparent from that description, its contents” (Article 2.a.(iii)).

The Agency may seek complementary access to any place on the site, and the state must provide that access. As with all complementary access, notice of 24 hours is required with one exception. When the Agency is conducting INFCIRC/153 inspections on a site, only two-hour notice is needed, “but in exceptional circumstances, it may be less than two hours” (Articles 4. b).

There is no reporting requirement in the Model Protocol for decommissioned facilities since they are required to be reported under INFCIRC/153. To deal with the concern that such a facility might subsequently be used for undeclared nuclear activities, the Model Protocol provides a right of complementary access to confirm “for safeguards purposes” the state’s declaration of the decommissioned status (Article 4.a.(iii)). As with an INFCIRC/153 site, the state must provide access to decommissioned facilities if the Agency requests.

³³⁰ In 2015, the IAEA carried out 64 complementary accesses.

7.4.4 Locations with nuclear material not subject to INFCIRC/153 safeguards

In this category, states must report information on: uranium mines and concentration plants; (Article 2. a.(v)); specified quantities of nuclear material such as yellow cake before the starting point of safeguards (Article 2.a.(vi)); nuclear material exempted from safeguards, such as depleted uranium (Article 2. a. (vii)); and intermediate or high-level wastes containing plutonium or HEU. (These might be found in liquid wastes from reprocessing plants.) (Article 2.a.(viii))

Complementary access must be provided to these locations during which the Agency may carry out visual observation, environmental sampling, use of radiation detection and measurement devices and other measures approved by the Board. It may not use tamper-indicating devices. Because of the presence of nuclear material, the Agency may also conduct item counting, NDA measurements, and sampling, as well as examination of records relevant to the quantities, origin, and disposition of the nuclear material (Article 6.b). Notice must be given 24 hours in advance of complementary access (Article 4.b.(i)).

7.4.5 Locations with nuclear-fuel-cycle activities but no nuclear material

In this category are two sets of activities:

A. “Nuclear fuel cycle-related R&D activities:” If they are carried out *with* government involvement, all of them must be reported (Article 2.a.(i)). Where there is *no* government involvement, the scope of reporting is narrowed to enrichment, reprocessing, and processing of certain waste forms containing fissile material (Article 2.b.(i)). The obligation to report government-related R&D is unqualified, while that for R&D with no government involvement requires a state to “make every reasonable effort.”

B. Manufacturing activities: States “shall provide” a description of the scale of operations for activities in Annex I and information about exports and, upon request, imports of items in Annex II (Article 2.a. (iv) and Article 2.a. (ix)(b)).

Unlike the first two categories where nuclear material is present, the Model Protocol spells out a threshold for access: to resolve a question or inconsistency about the correctness or completeness

INFCIRC/540

ARTICLE 5

..... shall provide the Agency with access to:

a.(i) Any place on a site; (ii) Any location identified by under Article 2.a.(v)-(viii) [where nuclear material is located]; (iii) Any decommissioned facility or decommissioned location outside facilities where nuclear material was customarily used.

b. Any location identified by under Article 2.a.(i) [R&D], Article 2.a.(iv) [manufacturing of equipment], Article 2.a.(ix)(b) [imports] or Article 2.b [specified non-governmental R&D or identified by IAEA outside a site], other than those referred to in paragraph a.(i) above, provided that if is unable to provide such access, shall make every reasonable effort to satisfy Agency requirements, without delay, through other means.

c. Any location specified by the Agency, other than locations referred to in paragraphs a. and b. above, to carry out location-specific environmental sampling, provided that if is unable to provide such access, shall make every reasonable effort to satisfy Agency requirements, without delay, at adjacent locations or through other means.

of the information in the expanded declaration. A state's obligation to provide access is also qualified. The state shall provide access, but "if [the state] is unable to provide such access, [the state] shall make every reasonable effort to satisfy Agency requirements, without delay, through other means" (Article 5.b).

The presence of nuclear material brings with it a higher level of state control and, as a consequence, less expectation of privacy. Therefore, the likelihood of conflicts with states' constitutional requirements is small, and the unqualified requirement for Agency access is reasonable.

The same rationale does not apply to locations without nuclear material. But if domestic circumstances prevent a state from providing access, it must still make a "reasonable effort" to satisfy Agency requirements without delay (Article 5.b). If a state fails to do so, the Agency would have the obligation to report that to the Board. If other circumstances also raised proliferation concerns, the Board would be able to report the matter to the Security Council.

7.4.6 All other locations

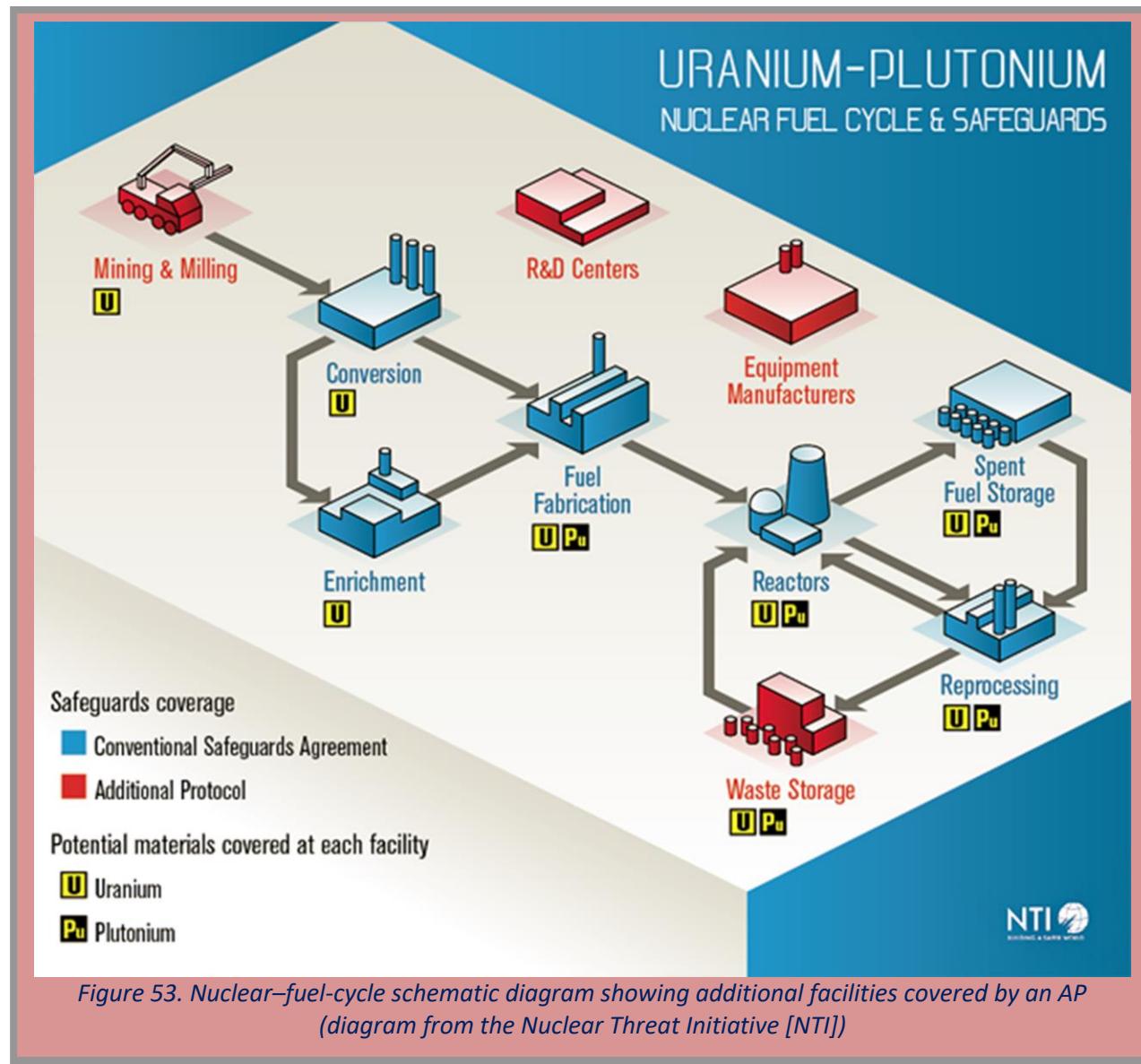
Article 5.c grants the Agency a sweeping authority. It specifies that the state shall grant the Agency access to "any location specified by the Agency." However, the grant is not unqualified. Unlike the three categories of locations that must be reported, this grant of access is for a very narrow purpose: access is granted so that the Agency "can carry out location-specific environmental sampling." However, "if [the state] is unable to provide such access, [it] shall make every reasonable effort to satisfy Agency requirements, without delay, at adjacent locations or through other means" (Article 5.c).

One reason for these qualifications is that the locations specified by the Agency could include private property. They might not prevent the Agency from fulfilling its objectives because the state could seek to satisfy the Agency's requirements by allowing it to take samples from vegetation or soils on public property near the private location. The Model Protocol recognizes that environmental sampling may not resolve the Agency's concerns and thus provides that the Agency can utilize "at that location" visual observation as well as radiation detection and measurement devices (Article 6.d). In circumstances that would lead to a request for complementary access to an undeclared location, the IAEA could also turn to the special inspection rights in INFCIRC/153, which do not limit the inspection measures that could be employed or provide for alternative locations.

7.5 The Impact of the Model Protocol

An Additional Protocol requires states to provide the IAEA with greater access and more information than under INFCIRC/153. It also provides the IAEA with new authorities. Figure

53 shows the differences between the coverage of a Comprehensive Safeguards Agreement versus the coverage of a Comprehensive Safeguards Agreement plus an Additional Protocol.



However, its impact has gone beyond adding new elements to the implementation of safeguards. The Model Protocol triggered a comprehensive review of the conceptual basis for safeguards. The review took into account the enhanced capability to detect undeclared activities and the need for the IAEA to draw conclusions about the absence of undeclared nuclear material and activities in a state as a whole. The IAEA also had to address how to balance the resources devoted to implementation of the new safeguards measures and those devoted to traditional measures.

In addition, the five-year process of developing a strengthened safeguards system, together with the IAEA's experiences in Iraq, the DPRK, and South Africa, had demonstrated the value of obtaining a comprehensive picture of a state's nuclear fuel cycle. Reporting under an additional protocol would provide such a perspective, but the IAEA also began to collect and analyze open-

source information. This was made easier by the very rapid pace of development of the internet and information technologies. The sections below trace and describe these changes.³³¹

³³¹ As noted in Chapter 5, states with little or no nuclear material could adopt small quantities protocols (SQP) that suspended most of the provisions of INFCIRC/153. With a new emphasis on detecting undeclared nuclear material and activities and given the importance of states providing early information about nuclear-fuel-cycle plans and development, the SQP that had been in use since 1971 was considered to be inadequate. Appendix E describes the SQP and the Board's decisions to revise it.

CHAPTER 8. STATE-LEVEL APPROACHES TO SAFEGUARDS IMPLEMENTATION

The Model Protocol strengthens the IAEA safeguards system, especially with respect to its ability to address undeclared nuclear material and activities. When implemented together with a comprehensive safeguards agreement, the Agency gains a much-enhanced ability to draw conclusions not only on the non-diversion of nuclear material from declared nuclear activities (the primary focus of safeguards implemented under a comprehensive safeguards agreement alone), but also on the absence of undeclared nuclear material and activities in the State as a whole. Previously, the implementation of safeguards and the evaluation of results had been done mainly on a facility-by-facility basis. Now, the focus of safeguards was broadened to include the State as a whole.

How was this to happen? For circumstances when both an additional protocol and a comprehensive safeguards agreement would be in force, the Agency developed a new framework for safeguards implementation. It characterized this framework as “integrated safeguards.” This framework provided the IAEA with the means to implement safeguards in a way that took full account of its new authorities as well as better account of a limited number of state-specific factors.

In turn, this led to investigation of whether there were other State-specific factors that would further strengthen the safeguards system. This was done over a number of years under the rubric of the development of a “State-level concept” for safeguards implementation.

These developments are described in sections 8.1 and 8.2 below.

8.1 Integrated Safeguards

8.1.1 Changes to the structure and philosophy of NPT safeguards

The Board of Governors approval of the Model Protocol in 1997 immediately led to a re-evaluation by the Secretariat of how best to apply safeguards when both a comprehensive safeguards agreement and an additional protocol were in force. This re-evaluation led to the adoption of a new conceptual framework called, ultimately, the State-level concept.

With its new authorities under the additional protocol, the Agency needed to review the way in which it conceptualized safeguards and drew conclusions. For example, when both a comprehensive safeguards agreement and an additional protocol are in force, the Agency is able to draw conclusions on the non-diversion of nuclear material from declared nuclear activities, as in the past. With the new authorities, it would now have a much-enhanced ability to draw conclusions about the absence of undeclared nuclear material and activities in the State as a whole.

Among the questions examined were, for example:

- If the capability to detect undeclared activities is increased, how should that affect the detection probability needed at declared facilities?

- What should be the timeliness goal at declared facilities if the IAEA could detect indications of undeclared facilities, perhaps well before they begin operations?
- What would be the basis for drawing a conclusion about the absence of undeclared nuclear material and activities in a State?

By its nature, a State-level conclusion differs from the conclusions drawn about individual material balance areas and facilities, even if these are combined to yield conclusions about a State.

The IAEA was also confronted quickly with the practical challenges of incorporating the new features of the Model Protocol into its safeguards system.³³² For example, it would be receiving information about States' nuclear fuel cycles and related nuclear R&D activities, voluminous for large fuel cycles, of types that had not been reported to it before. The Agency would need to organize, store and retrieve this information and then assess it and use it as a basis for planning field activities.

There were numerous questions to address:

- How would the IAEA conduct complementary access at sites? Which buildings should it examine and how would it do so?
- What format should States use to report the information required by an additional protocol?
- How would the IAEA store, retrieve and analyze the large amounts of data to be received?
- What would constitute a “question” or “inconsistency” that would trigger complementary access?
- What activities were to be performed if the IAEA obtained complementary access to locations where it had no experience, for example, uranium mines?

Moreover, the new measures would consume resources. In this respect, the IAEA confronted long-standing issues: the need for effective safeguards under budget constraints; traditional concerns by States about the “burden” of safeguards; and concerns that an additional protocol would compound this problem. The IAEA also anticipated significant growth of the number of nuclear facilities under safeguards and a corresponding increase in resources to the extent that safeguards continued to rely on the facility-based approaches already in use.³³³

³³² The first additional protocol entered into force in December 1997 (Australia). By the end of 2000, the Board of Governors had approved 71 agreements of which 18 were in force. By the end of 2017, 127 states had both a comprehensive safeguards agreement and an additional protocol in force, and 46 states had a comprehensive safeguards agreement in force but no additional protocols in force.

³³³ Growth in the nuclear industry anticipated in the late 1990s has been less than expected as a consequence of unforeseen factors such as the destruction of reactors in Japan following a tsunami and decreasing costs in energy production from other sources. Nevertheless, the number of facilities under safeguards grew by 15% from 1999 through 2016.

During the negotiation of the Model Protocol, non-nuclear-weapon States had made clear that new requirements should not simply be added to existing ones; they sought a new, integrated system where implementation of additional protocols would come with compensating benefits. The IAEA treated this expectation as a guideline in developing new approaches.

Another factor changed the way in which both the IAEA and Member States thought about safeguards, namely, the emergence of illicit trafficking in nuclear material, equipment, and technology, as well as clandestine nuclear programs in a number of States. This led to a generally held view that the Agency should shift emphasis so that inspectors should be “less like accountants and more like detectives.” They would need to ferret out undeclared activities. This would require not only putting more effort into field activities such as complementary access, but also placing more emphasis on Headquarters activities, especially the gathering of information and its analysis.

8.1.2 Development of integrated safeguards

The studies undertaken by the Agency to answer these questions resulted in the development of a “conceptual framework” for “integrated safeguards.”³³⁴ The IAEA intended for it to be more flexible and efficient without losing safeguards effectiveness. The “integrated safeguards” framework was reported to the IAEA Board of Governors and General Conference in 2001 and 2002.³³⁵

These reports introduced the following “State-specific features and characteristics” to be taken into account when developing integrated safeguards approaches:

- the nature and scope of the State’s nuclear fuel cycle and related activities;
- the possibility for the use of advanced technology in the State, given that the Model Additional Protocol has provisions that facilitate the use of advanced safeguards technology, e.g. the transmission of data from unattended C/S or measurement devices;
- the possibility of effectively using unannounced inspections in the State; and
- increased co-operation between the Agency and State or regional systems of accounting for and control of nuclear material.

In this context, the IAEA began to use the phrase “differentiation without discrimination.” This reflected the political requirement that safeguards not discriminate between States as well as the fact that States had numerous differences that could impact safeguards implementation.

Not all of these State-specific factors were new, and some had traditionally led to differences in safeguards implementation. For example, in one State, safeguards objectives might be met by short-notice random inspections, but, in another, such inspections might not be practicable.

³³⁴ “Integrated” because the framework integrated the requirements of INFCIRC/153 with those of the Model Protocol to produce a single approach.

³³⁵ The structure of integrated safeguards approaches was reported both to the Board of Governors and General Conference. Both reports are titled, “Strengthening the effectiveness and improving the efficiency of the safeguards system and application of the Model Additional Protocol.” Those sent to the General Conference are found in GC(44)/12, GC(45)/23 and GC(46)/6. They are available in the General Conference archives at <https://www.iaea.org/>. The Board of Governors “took note” of the framework for integrated safeguards as well as the Director General’s intention to implement it.

Contrast two situations: first, at a nuclear facility in the European Union, where inspectors can travel freely across borders of members of the European Union; and second, at a plant under safeguards in countries where the fact of inspector presence may be known well in advance as a result of border controls.

Under integrated safeguards, the Agency began the process of examining how to modify its safeguards planning assumptions in light of the enhanced ability provided by an additional protocol to detect undeclared nuclear material. Table 8 shows a comparison of the assumptions used before integrated safeguards and the changes under integrated safeguards that flowed from the Model Protocol.

<i>Table 8. Integrated Safeguards – Planning Assumptions</i>	
PLANNING ASSUMPTIONS WHEN ONLY AN INFIRC/153 AGREEMENT IS IN FORCE	PLANNING ASSUMPTIONS WHEN BOTH AN INFIRC/153 AGREEMENT AND AN ADDITIONAL PROTOCOL ARE IN FORCE
<i>The probability of diversion is not zero and each State is treated as if the probability were the same.</i>	<i>The probability of diversion is not zero, but a lower coverage of detection of diversion at some declared facilities is justified by enhanced coverage of the undeclared portion of an acquisition path. This is quantified in altered timeliness goals in some cases</i>
<i>Attempts to conceal diversions are plausible</i>	<i>No change</i>
<i>Subsequent use of diverted nuclear material to manufacture a nuclear explosive device is practicable</i>	<i>Subsequent use of diverted nuclear material to manufacture a nuclear explosive device is practicable</i>
<i>The safeguards conclusion relates only to declared activities and materials</i>	<i>An additional protocol enhances the IAEA's ability to detect undeclared nuclear material and activities.</i> <i>The safeguards conclusion refers to both declared and undeclared nuclear activities (the so-called "broader conclusion").</i>

8.1.3 Implementation of integrated safeguards

Planning

Using these changed assumptions, the IAEA revised the objectives for timeliness and detection probability for declared nuclear material when it was applying integrated safeguards. The basic idea is that the Agency's enhanced ability to detect the undeclared elements of acquisition paths – the possible means of acquiring nuclear-weapon-usable material - could result in relaxation in the intensity of safeguards on declared activities.

In particular, detection probabilities would be lowered, and timeliness goals would be extended. At reactors, the timeliness goal changed from three months to one year for irradiated fuel and, from one month to three months for fresh MOX fuel assemblies. The extension of timeliness goals at power reactors reduces field effort considerably, dropping the number of annual inspections (if there is no fresh MOX fuel present) from four to one.^{336,337} Another significant change was the expanded use of random selection. Under integrated safeguards, the IAEA would, for example, choose to inspect in a given year a random selection of facilities from a group of similar facilities. This replaced the system of inspecting all facilities every year.³³⁸

Drawing Conclusions

Integrated safeguards do not commence when an additional protocol enters into force. Rather, they begin when a State submits its initial additional protocol declaration and end when the IAEA concludes based on its inspection activities, examination of design information, and complementary access that the State's declaration was correct and complete.

As described by the IAEA, the information provided by the State in its expanded declarations is compared to and combined with all other relevant information available to the Agency in order to obtain as complete a picture as possible of a State's nuclear and nuclear-related activities.

It includes determinations that:

- the declared present and planned nuclear programme is internally consistent;
- the nuclear activities and types of nuclear material at declared locations are consistent with those declared (e.g. through the collection and analysis of environmental samples);

³³⁶ This is reflected in the change from 45% in 1999 to 25% in 2016 in the fraction of IAEA inspection effort devoted to power reactors.

³³⁷ These reductions were not made at enrichment or reprocessing facilities for two reasons. The first is their capability to produce quickly separated, unirradiated direct-use nuclear material; the second is the assumption that the likelihood of detecting facilities to manufacture nuclear weapons--in States with enrichment or reprocessing--would be too low to warrant such reductions.

³³⁸ Each facility is subject to inspection with a probability of less than 100%. As a result, conclusions about the selected facilities also apply to the entire set of facilities. IAEA GC(49)/9, Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System Including Implementation, contains a summary of the development of integrated safeguards through 2005. (<http://www.iaea.org/About/Policy/GC/GC49/Documents/gc49-9.pdf>.)

- overall production, imports and inventories of nuclear material are consistent with the utilization inferred from the declared programme;
- imports of specified equipment and non-nuclear material are consistent with the declared programme;
- the status of closed-down or decommissioned facilities and locations with very small amounts of nuclear material is in conformity with the State's declaration;
- nuclear fuel cycle R&D activities are generally consistent with declared plans for future development of the declared nuclear programme;
- the declared nuclear programme, research and related manufacturing activities are consistent with all information available to the Agency;
- all plausible acquisition pathways (including facility misuse) through which a State might acquire weapons-useable material have been identified and evaluated, and
- all inconsistencies or questions of significant safeguards concern have been resolved.³³⁹

When it is satisfied that these conditions are met, the IAEA draws a so-called “broader conclusion” and begins to implement integrated safeguards. The broader conclusion is based on the IAEA’s enhanced capability to detect undeclared nuclear material and activities under integrated safeguards, namely that “the Secretariat found no indication of the diversion of declared nuclear material from peaceful nuclear activities and no indication of undeclared nuclear material or activities. On this basis, the Secretariat concluded that, for these States, all nuclear material

³³⁹ https://www.jaea.go.jp/04/iscn/iscn_old/resource/safeguards%20system.pdf; see page 16

remained in peaceful activities.”³⁴⁰

The process of drawing conclusions is iterative and involves several steps that are part of a repeating cycle: the collection and analysis of all safeguards-relevant information; acquisition path analysis; the establishment and prioritization of technical objectives; the identification of applicable safeguards measures including the frequency and intensity of verification effort; development of State-level approaches and Annual Implementation Plans; the conduct of in-field and Headquarters safeguards activities; the evaluation of how effective those safeguards activities were in achieving the technical objectives; and drawing safeguards conclusions. Of course, safeguards relevant information includes the information obtained by inspectors in the field, for example, from verification of design information, and from analyses, such as environmental sample analysis, and other evaluations made in Vienna. Figure 54 illustrates how the IAEA describes its State evaluation process.³⁴¹

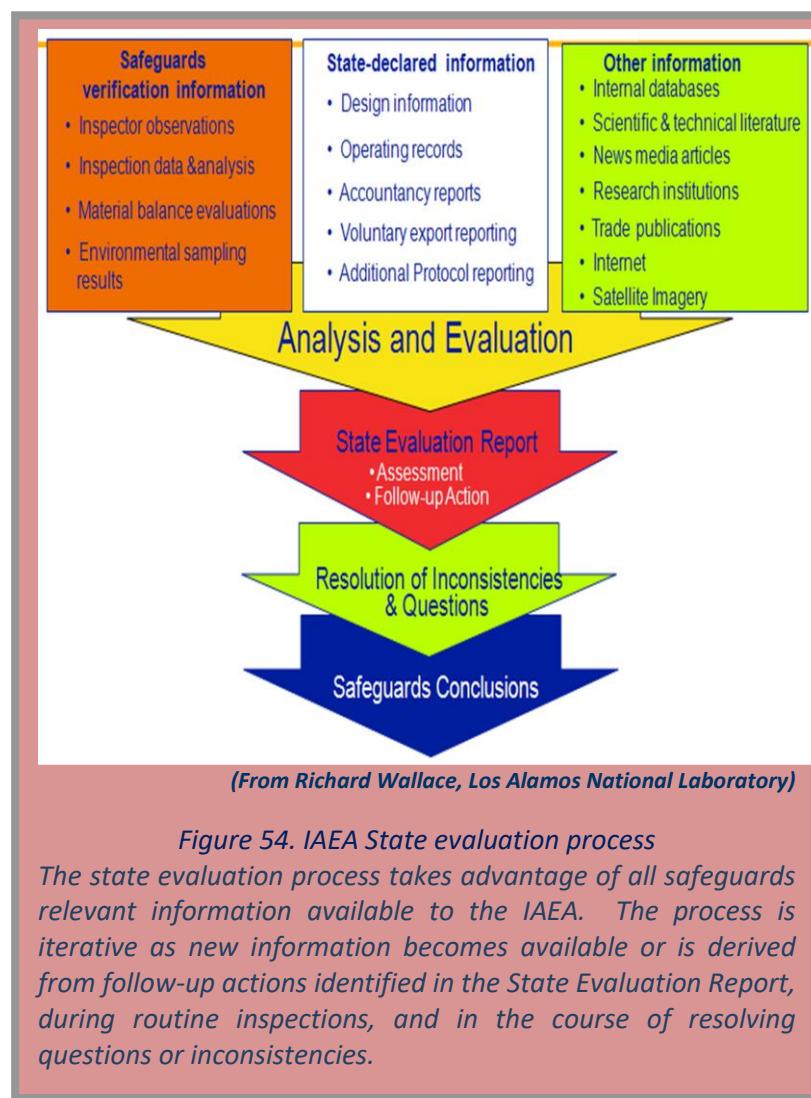


Figure 54. IAEA State evaluation process

The state evaluation process takes advantage of all safeguards relevant information available to the IAEA. The process is iterative as new information becomes available or is derived from follow-up actions identified in the State Evaluation Report, during routine inspections, and in the course of resolving questions or inconsistencies.

Although the Model Protocol triggered it, little in the process described above for integrated safeguards is unique to States with an additional protocol. However, where only an INFCIRC/153 safeguards agreement is in force, the declarations and the inspection tools that the IAEA has available differ. Absent an additional protocol, States do not provide to the IAEA information about, for example, plans for nuclear-fuel-cycle development; manufacturing activities; and R&D activities not involving nuclear material. Even if this information were available from public sources, the IAEA would not have access to relevant locations.

As a result, the IAEA does not draw the broader conclusion for these States (or when it has not yet completed its initial evaluation). For them, the conclusion refers only to nuclear

³⁴⁰ This language is found in the IAEA’s annual Safeguards Statement. See, e.g., <https://www.iaea.org/sites/default/files/18/06/statement-sir-2017.pdf>

³⁴¹ *Making the IAEA Safeguards System Fully Information Driven*, Bruce Moran, Jill Cooley, and Eric Pujol, ESARDA Symposium, May 2011.

material **declared** to the IAEA. In these circumstances, the IAEA limits its conclusion to a statement that, “for these States, declared nuclear material remained in peaceful activities.”

These conclusions are published by the IAEA in its annual “Safeguards Statement.”³⁴²

Resources

The deployment of safeguards resources changed considerably after the introduction of integrated safeguards. Since 2002, the application of integrated safeguards has reduced overall **field** inspection effort by roughly 40%.³⁴³ The largest part of this results from the aforementioned changes in the integrated safeguards approach to power reactors, the majority of inspected facilities. The enhanced use of random selection among a State’s similar reactors leads to additional reductions in field inspection effort.

The savings in field inspection effort has allowed the IAEA to increase activity at Headquarters. As a result, it is able to devote much more time to the collection and analysis for each State of safeguards relevant information and to assess whether it is internally consistent and also consistent with information provided by States. This is an important tool to provide enhanced confidence in its ability to provide assurances of the absence of undeclared nuclear material and activities.

8.2. The State-level concept

8.2.1 Going beyond integrated safeguards

The IAEA completed its review of applying safeguards at the State-level in 2002 and began to implement integrated safeguards where applicable. Integrated safeguards were a first step in implementing State-level approaches that reflected the strengthened ability of the IAEA to detect undeclared nuclear material and activities. It was also a first step in using safeguards relevant State-level factors to construct an integrated safeguards approach for a State. The Director General identified a number of factors to be used in developing integrated safeguards approaches, including the nature and scope of the State’s nuclear-fuel-cycle and related activities; the possibility for the use of advanced technology or of using effectively unannounced inspections; and increasing cooperation between State and regional systems of accounting and control of nuclear material.³⁴⁴

Nonetheless, under integrated safeguards, these factors were applied primarily using a facility-by-facility approach, and safeguards were applied uniformly by facility type. Of course, safeguards approaches continued to take into account nuclear material type (for example, whether or not HEU or plutonium are there) but used the revised safeguards criteria developed for integrated safeguards.

³⁴² Available at <https://www.iaea.org/publications/reports>

³⁴³ In States whose fuel cycles consist largely of power reactors and no sensitive facilities, the reduction can be considerably larger. For example, in Canada, the reduction in inspection effort is 70%.

³⁴⁴ These factors are closely related to INFCIRC/153. In paragraph 81, factors that are to be used to determine the “number, intensity, duration, timing, and mode of routine inspections” are listed, and in paragraph 84, provision is made for unannounced inspections. Factors that are State level include: effectiveness of a State’s SSAC; characteristics of the fuel cycle; and international interdependence.

The IAEA began to investigate whether it could further improve its ability to implement safeguards using a State-level concept intended to achieve both better effectiveness and efficiency and a better focus of safeguards resources on where they are needed most.

To this end, it studied what State-level factors could be used in addition to the ones cited above and embarked on a re-evaluation of the appropriate role of safeguards in the context of the international nuclear non-proliferation regime. Of course, it needed to respect fundamental boundary conditions of being non-discriminatory; provide coverage of all plausible acquisition paths; maintain safeguards effectiveness as a priority; and take full advantage of the Agency's legal authorities.

State-level factors

Many State-level factors were considered. For example, in 2009, an IAEA official cited the following as potentially relevant for planning implementation approaches:³⁴⁵

- (i) the State's nuclear-fuel-cycle infrastructure including facilities, types and quantities of nuclear material, and fuel cycle R&D activities;
- (ii) uranium/thorium deposits, mining and concentration;
- (iii) technological and industrial capabilities including manufacture of additional protocol Annex I items; and
- (iv) scientific and nuclear R&D.

Other State-specific factors were suggested for consideration when assessing the plausibility and risk associated with identified acquisition paths, including:

- (i) the dependence of the State's nuclear activities on other States (e.g. no indigenous supply of uranium; no indigenous fuel fabrication capabilities);
- (ii) the international interdependence of fuel cycle facilities (e.g. multinational ownership, management and operation); and
- (iii) the State's acceptance of and demonstrated commitment to non-proliferation norms.³⁴⁶

Such analysis was not limited to IAEA officials. Other observers suggested giving positive consideration to: a high level of cooperation between the State and the IAEA; a "State's

³⁴⁵ Jill N. Cooley, The State-level Approach to International Safeguards, *Journal of Nuclear Materials Management*, Summer 2009. Vol. XXXVII, No. 4. http://www.inmm.org/ScriptContent/JNMM_Archive_Files/Vol_37/V.37_4.pdf.

³⁴⁶ Ibid.

demonstrated commitment to non-proliferation”; a “prolonged pattern of consistent, appropriate behaviours;” the rationale for the State’s fuel cycle; and the transparency of its SSAC.^{347,348}

Such factors could be used to further refine the IAEA’s safeguards planning assumptions. For example, the IAEA could conclude that a State’s industrial capacity would make it difficult or practicably impossible for a State to build and operate a clandestine uranium enrichment plant. It might then make sense to reduce the intensity of safeguards on natural or low-enriched uranium.

But assessing the validity of the conclusion would have to take into account both the ability of a State to conceal such an enrichment program and a clandestine facility and the opportunities to acquire designs or technology from others. Unfortunately, both of these types of events have occurred.

In the context of “re-assessing traditional approaches to risk,” some suggested that State-level factors could be used to assess a State’s intentions rather than its capabilities. Perhaps, commitments to nuclear non-proliferation could be used to infer the absence of any intention to violate the terms of the NPT or an IAEA safeguards agreement in order to acquire a nuclear weapon. So too might a State’s history of cooperation and support of effective implementation of safeguards on its nuclear fuel cycle. If intention is considered to be lacking or absent, the rationale for a strong safeguards system would be diminished, and inspection effort could be reduced.

One dilemma in using these rationales is that intention is not measurable and can change quickly. As in the stock market, past performance may not predict future results. In addition, it is very unlikely that there could be a consensus among Member States on States’ intentions or a willingness to cede such evaluations to the IAEA.

Table 9 shows changes in planning assumptions that *might* be considered if the various factors described above were used to plan safeguards implementation under a State-level concept.

³⁴⁷ Transparency and other State-Specific Factors: Exploration of Ideas for Evolving the IAEA’s System of State-Evaluations and Safeguards Implementation, Craig Everton, Russell Leslie, Stephan Bayer, Michael East, ESARDA Bulletin, No.46 December 2011.

³⁴⁸ Implementing the State-level Approach: Moving Forward, James Casterton, Journal of Nuclear Materials Management, Summer 2009. Vol. XXXVII, No. 4.

Table 9. State-Level Concept – Planning Assumptions

PLANNING ASSUMPTIONS WHEN ONLY AN INFIRC/153 AGREEMENT IS IN FORCE	POSSIBLE CHANGES IN PLANNING ASSUMPTIONS WHEN BOTH AN INFIRC/153 AGREEMENT AND AN ADDITIONAL PROTOCOL ARE IN FORCE
<p><i>The probability of diversion is not zero and each State is treated as if the probability were the same.</i></p>	<p><i>State-level factors that are indicators of intention might reduce the likelihood of diversion to a very low value. In theory, the principle of non-discrimination would be respected if the same criteria were used everywhere to evaluate “intention.” 1</i></p>
<p><i>Attempts to conceal diversions are plausible</i></p>	<p><i>The IAEA may decide based on “all available information” that certain paths or concealments are less plausible in some States than others, resulting in a lower priority for safeguarding them.</i></p>
<p><i>Subsequent use of diverted nuclear material to manufacture a nuclear explosive device is practicable – that is, possibility of undeclared facilities is not precluded.</i></p> <p><i>All facilities of the same type (e.g., on-load heavy water power reactors) are safeguarded in essentially the same manner worldwide</i></p>	<p><i>State-level factors might indicate that one or more of the required skills or technical resources could be considered, for all practical purposes, as absent. The possibility of necessary undeclared facilities could be ruled out.</i></p> <p><i>Facilities may be safeguarded differently due to local technical factors or “State-level factors.”</i></p>

8.2.2 The State-level concept emerges

During this period, the IAEA continued to communicate with Member States and others the overall framework in which safeguards would be implemented under a State-level concept. The Deputy Director General for Safeguards outlined this in his keynote address at the INMM Annual Conference in July 2011. A key point that he made was that the State-level concept was “a natural continuation of a process that began in the early 1990s when strengthening measures were agreed through the Programme 93+2 and the subsequent introduction of the Additional Protocol. For the growing number of States under integrated safeguards, the State-level approach has already been developed and applied.” “The Agency is not,” he said, “changing the fundamental principles

underlying the safeguards system.”

In addition, he described the Agency’s rationales and overall objectives. He highlighted, in particular that:

- the implementation of safeguards should be more focused, less predictable and more adaptable; and that
- safeguards implementation should focus on the State as a whole and not just on the amount of nuclear material in the State and the sum of particular nuclear facilities, i.e., move away from such a heavy reliance on the routine verification of declarations and the formulaic application of generic criteria, in a “one size fits all” approach.

He also noted that, while the theory of the State-level concept was in place, in practice, the concept had not yet been fully implemented. Looking forward, he emphasized that the Agency needed “to fully embrace the State-level concept in practice and drive the process forward” but he stressed that “the Agency was not going to sacrifice effectiveness in order to save money. Indeed, quite the reverse.”

The Sections below describe how the Agency develops and implements safeguards approaches under the State-level concept.

8.2.3 Member State consideration of the State-level concept

DDG Nackaerts’ presentation highlighted the Agency’s objectives regarding the future development of the State-level concept. As the IAEA continued its work, its Member States focused more of their attention on the further development and utilization of the State-level concept. They wanted to know how safeguards would be planned, implemented, and evaluated under the State-level concept. This process had been reasonably well understood under the facility-by-facility approach, but Member States were unclear how it would work under the State-level concept.

As a result, at the June 2012 meeting of the Board of Governors, the further development of the State-level concept met resistance from a number of quarters. One concern was that some proposed factors would require the IAEA to make judgments that were considered to be subjective and outside the IAEA’s purview, for example, as noted above, intentions or “States’ commitments to non-proliferation.” Some States also raised concerns about the Agency’s use of open-source information and how, for example, it would verify it.

States with comprehensive safeguards agreements but not an additional protocol had a particular concern. They emphasized that adopting an additional protocol was a voluntary step and that a clear distinction had to be made between the legal obligations of Member States under their safeguards agreements and their voluntary undertakings. They wanted confidence that the

implementation of the State-level concept would not be used to slip in measures that were like those in the Model Protocol even though they had not adopted it.^{349,350}

In response, in 2013 the Director General submitted the first detailed report to the Board about the State-level concept entitled “Report on The Conceptualization and Development of Safeguards Implementation at the State Level.” However, it was not received well, and concerns noted above were reiterated. Although the Board deliberations are not available, States’ concerns can be identified by reviewing the 2013 Resolution on the implementation of safeguards adopted by the General Conference in September of that year.

Of relevance here are the elements of the Resolution that arose from concerns about implementation of the State-level concept. In particular, the Resolution stressed that safeguards:

- should remain non-discriminatory;
- only use objective factors to determine safeguards implementation; and
- exclude political or other extraneous considerations.

It also emphasized that there is a distinction between the legal obligations of States and voluntary measures aimed at facilitating and strengthening the implementation of safeguards.³⁵¹

The Resolution also noted the intention of the Director General to produce, after consulting with Member States, a document supplementary to the 2013 Report on The Conceptualization and Development of Safeguards Implementation at the State Level with the aim of further clarification.

The IAEA responded to these concerns with more details in a 2014 report to the Board on the conceptualization and development of safeguards implementation at the State level. Key elements of the report stressed that the IAEA’s State-level concept would:

- Consider a State’s nuclear and nuclear-related activities and capabilities as a whole, within the scope of the State’s safeguards agreement;
- Apply to all States with safeguards agreements in force (not just those under integrated safeguards) but strictly within the scope of each individual State’s safeguards agreement(s);

³⁴⁹ The IAEA’s State-Level Concept and the Law of Unintended Consequences, Laura Rockwood, Arms Control Today, Vol. 44, No. 7 (September 2014), pp. 25-30, Published by: Arms Control Association.

<https://www.jstor.org/stable/24336270>

³⁵⁰ These concerns were raised most forcefully by Russia, Brazil and Argentina. Although not necessarily so, Russia’s concerns may well have been exacerbated by its objections to previous actions by the Board of Governors that it considered to be politically motivated, for example, the Board’s report to the United Nations Security Council that Syria was in non-compliance with its safeguards agreement. Russia was also unhappy about the March 2011 bombing of Libya that led to Muammar Qaddafi’s demise as well as alleged U.S. efforts to stir up street protests in Russia during the parliamentary and presidential elections in late 2011 and early 2012.

³⁵¹ GC(57)/RES/13 Date: September 2013, Resolution adopted by the General Conference on Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards. “Voluntary measures” refers to the Additional Protocol. The General Conference is an annual event, and the agenda is generally the same from year-to-year, including always a resolution on safeguards. Unlike actions taken by the Board of Governors, resolutions adopted by the General Conference reflect the views of all Member States of the IAEA. They solidify their intentions about how, in this case, safeguards should be implemented and serve as guidance for the Secretariat.

- Not entail the introduction of any additional rights or obligations on the part of either States or the Agency;
- ... Develop State-level approaches and guide safeguards implementation in a consistent and non-discriminatory manner for all States with the same type of safeguards agreement;
- Continue to concentrate verification effort on sensitive stages of the nuclear fuel cycle;
- Improve safeguards effectiveness by enabling the Agency to be more focused on the attainment of technical objectives instead of mechanistically carrying out safeguards activities;
- Not be a substitute for the Additional Protocol.

Furthermore, the IAEA would only use State-specific factors that were objective and factual. The report specified an “exhaustive list of ... six objective State-specific factors” as follows:

- (i) the type of safeguards agreement in force for the State and the nature of the safeguards conclusion drawn by the Agency;
- (ii) the nuclear fuel cycle and related technical capabilities of the State;
- (iii) the technical capabilities of the State or regional system of accounting for and control of nuclear material (SSAC/RSAC);³⁵²
- (iv) the ability of the Agency to implement certain safeguards measures in the State;
- (v) the nature and scope of cooperation between the State and the Agency in the implementation of safeguards; and
- (vi) the Agency’s experience in implementing safeguards in the State.

The clarifications that were provided by the Secretariat were accepted by Member States and then recorded in the 2014 General Conference Resolution on Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards.³⁵³ The key paragraphs most relevant to the State-level concept in the Resolution are that the Conference:

23. Welcomes the clarifications and additional information provided by the Director General in the Supplementary Document to the Report on The Conceptualization and Development of Safeguards Implementation at the State Level (GOV/2014/41, and its Corrigenda), taken note of by the Board of Governors in September 2014, following the intensive consultation process undertaken over the past year;

24. Welcomes the important assurances contained in GOV/2014/41 and its Corrigenda, and in the statements by the Director General and the Secretariat as noted by the Board of Governors in its September 2014 session, including *inter alia*:

³⁵² SSAC stands for State system of accounting for and control of nuclear material and RSAC for regional system of accounting for and control of nuclear material.

³⁵³ GC(58)/RES/14 issued in September 2014.

- The State-level concept (SLC) does not, and will not, entail the introduction of any additional rights or obligations on the part of either States or the Agency, nor does it involve any modification in the interpretation of existing rights and obligations;
- The SLC is applicable to all States, but strictly within the scope of each individual State's safeguards agreement(s);
- The SLC is not a substitute for the Additional Protocol and is not designed as a means for the Agency to obtain from a State without an Additional Protocol the information and access provided for in the Additional Protocol;
- The development and implementation of State-level approaches requires close consultation with the State and/or regional authority, particularly in the implementation of in-field safeguards measures;
- Safeguards-relevant information is only used for the purpose of safeguards implementation pursuant to the safeguards agreement in force with a particular State – and not beyond it.³⁵⁴

Concerns did not completely abate, however. After the September 2014 Board meeting and General Conference, the State-level concept continued to meet resistance from a number of quarters, particularly from Russia and States with a comprehensive safeguards agreement without an additional protocol in force. In October 2014 during the IAEA Safeguards Symposium in Vienna, Russia made three main assertions critical of the State-level concept, which it has reiterated in subsequent years: 1) the Board of Governors and the General Conference should set “core parameters” of safeguards implementation rather than the Secretariat; 2) some of the proposed State-specific factors are based on subjective opinion, outside of the IAEA’s purview, are prone to politicization, and could lead to “collective biased thinking for political pressure against certain countries...” and 3) third-party information, used in State evaluations, cannot be guaranteed for accuracy and authenticity, its origin should be disclosed, and defended in open discussion at the Board of Governors.³⁵⁵ The debate over these issues has become less heated than during the 2012-2014 period, but still continues.

In 2015 and 2016, the Secretariat began to update State-level approaches for States under integrated safeguards. Subsequently, the Secretariat began the process of “progressively” updating or developing customized State-level approaches for all States with safeguards agreements in force.

³⁵⁴ The themes in the 2014 Resolution have been incorporated into the General Conference’s Safeguards Resolution each year since then.

³⁵⁵ Statement by Grigory Berdennikov, the head of the delegation of the Russia Federation, Ambassador-at-large, at the Symposium on International Safeguards: Linking Strategy, Implementation and People, Vienna, 20-24 October 2014, pages 3 and 6-8. According to Robert Einhorn, a former senior State Department official on nonproliferation issues in the Obama administration, “The Russians argue that overreliance on intelligence information has allowed the United States and its allies to dominate the IAEA and manipulate it to serve their own political agendas.”

8.2.4 Implementation of the State-level concept

SAFEGUARDS RELEVANT INFORMATION

Safeguards relevant information arises from a variety of sources: information required to be reported by States; the Agency's own activities, publicly available information, including commercial satellite imagery;¹ and information voluntarily supplied by Member States or others.

Open-source information is vast, in numerous languages and formats, and appears in news and media reports, scientific and technical literature, and databases. Its collection, the need to assess its reliability and importance, and the volume of information that needs to be stored, retrieved and analyzed poses severe logistical problems. Making proper use of this data required new software tools and new analytical skills. Acquiring them was a priority for the IAEA in the 2000s.¹

Overhead imagery is a particularly useful kind of open-source information. The IAEA has a Satellite Imagery Analysis Unit to review images that it acquired from commercial sources or from Internet resources such as Google Earth.¹ Overhead imagery is used to plan inspections to declared sites; to identify locations for complementary access; and to evaluate information routinely provided by States.

This section describes the way in which the IAEA implements the State-level concept taking into account the six agreed State-specific factors.

The IAEA uses an iterative process that involves several steps that are part of a repeating cycle:

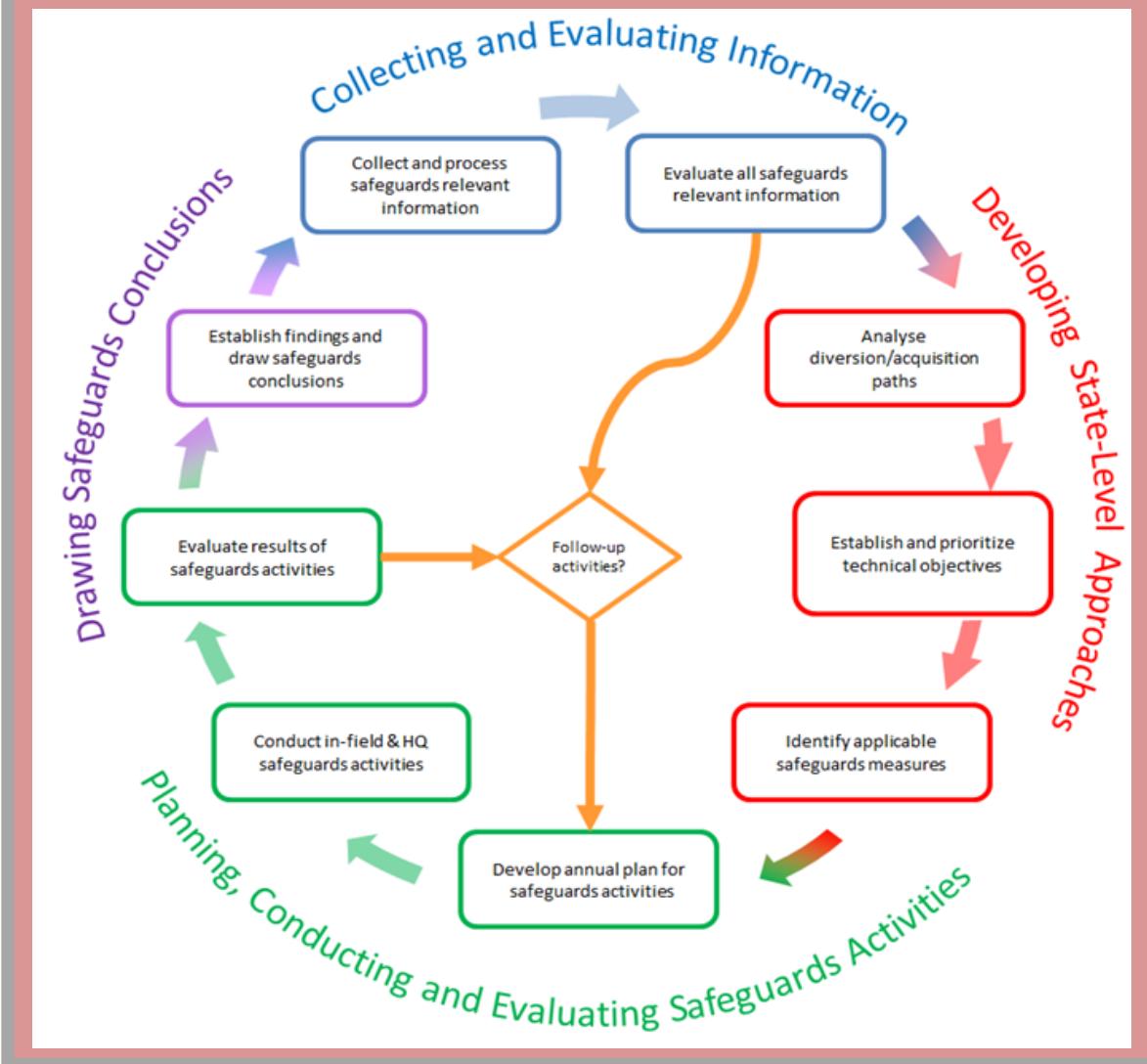
- (i) the collection and analysis of all safeguards-relevant information;
- (ii) acquisition path analysis;
- (iii) the establishment and prioritization of technical objectives;
- (iv) the identification of applicable safeguards measures including the frequency and intensity of verification effort;
- (v) development of State-level approaches and Annual Implementation Plans;
- (vi) the conduct of in-field and Headquarters safeguards activities;
- (vii) the evaluation of how effective those safeguards activities were in achieving the technical objectives; and drawing safeguards conclusions.

The flexibility of this process is intended to allow the IAEA to concentrate its resources where they are needed most to detect indications of undeclared activities or verify compliance.

Figure 55³⁵⁶ shows the Agency implementation process and illustrates its iterative character:

³⁵⁶ J. Cooley, "IAEA Strategies to Strengthen the Effectiveness and Improve the Efficiency of IAEA Safeguards," The 2014 International Forum on Nuclear Energy, Nuclear Non-Proliferation and National Security, Tokyo, Japan, 3 December 2014, at <https://www.jaea.go.jp/04/iscn/activity/2014-12-03/2014-12-03-06.pdf> (accessed 5 March 2019)

Figure 55. Iterative process for implementation of IAEA safeguards



Acquisition Path Analysis

To conduct acquisition path analysis, the IAEA analyzes the series of steps (declared and undeclared) along the nuclear fuel cycle that a State would need to take in order to acquire nuclear material suitable for nuclear weapons or other nuclear explosive devices. By identifying technically plausible paths for the acquisition of such material, the IAEA's State Evaluation Groups can determine and prioritize technical objectives specifically for individual states.

In addition to assessing the type of nuclear material and characteristics of a state's nuclear fuel cycle facilities, acquisition path analysis also considers the state's indigenous technical and industrial capabilities to build undeclared nuclear facilities, particularly enrichment and reprocessing plants.

One of the daunting aspects of these Agency assessments is that there are a number of steps that a State could take to undermine the Agency's conclusions. One is to find and take advantage of foreign supply of technology, equipment and materials; another is to use clandestine acquisition networks whereby equipment, material, and technology are acquired from well-known suppliers by falsifying documents to conceal, for example, the end use at the end-use location; yet another would be concealment by the State of ongoing activities, for example, concealing the location of and not publishing the results of research centers; or active measures to camouflage or otherwise conceal the location of a facility. Unfortunately, all too many States have pursued nuclear weapon programs using such techniques, for example, Iraq, Iran, South Africa (before it joined the NPT), Syria, and North Korea.

Establishment and Prioritization of Technical Objectives

In 2006, the IAEA established “generic objectives” for designing the implementation of safeguards for States with comprehensive safeguards agreements or with such an agreement and an additional protocol.³⁵⁷ The three generic objectives are the timely detection of:

1. diversion of declared nuclear material at declared nuclear facilities or other locations with very small amounts of nuclear material;
2. undeclared production or processing of nuclear material at facilities or other locations with very small amounts of nuclear material; and
3. undeclared material or activities in the State as a whole.³⁵⁸

To address the generic objectives for a State, the Secretariat establishes technical objectives through acquisition path analysis and state specific factors. These technical objectives guide the planning, conduct and evaluation of safeguards activities for a particular State. The technical objectives associated with an individual state form the basis for identifying safeguards measures and conducting safeguards activities for that State.

Technical objectives are at least one level more specific than the three generic objectives. For illustrative purposes, here are three examples of technical objectives: 1) detect diversion of spent fuel; 2) detect misuse of a declared reprocessing plant; and 3) detect undeclared construction of a reprocessing plant.

Technical objectives vary among different states depending on acquisition path analysis and state specific factors, such as different nuclear fuel cycle characteristics and capabilities. Safeguards activities aimed at meeting technical objectives can: involve inspections of multiple facilities; call for more than one type of safeguards measure; require an understanding of the relationship with other technical objectives along the same acquisition path (e.g., detection of undeclared production of UF6 and detection of misuse of gas centrifuge enrichment plants); and lead to adjustments from year-to-year.

The IAEA establishes and prioritizes technical objectives and then identifies safeguards measures for addressing those technical objectives. The priority of the technical objectives, along with State-

³⁵⁷ They are the same because an additional protocol provides the IAEA with more information and better tools; it does not change the fundamental objective of safeguards.

³⁵⁸ See J. N. Cooley, “The State-Level Approach to International Safeguards,” INMM Annual Conference, July 2009.

specific factors and acquisition path analysis assessments, determines the frequency and intensity of safeguards verification effort (in-field activities and Headquarters information analysis).³⁵⁹

Priorities are assigned taking into consideration the following:

- the State's nuclear fuel cycle (including the type, form and amount of material present in the State) and related technical capabilities
- the stage of the nuclear fuel cycle, especially "the proximity to sensitive parts of the nuclear fuel cycle involving nuclear material from which nuclear weapons or nuclear explosives could readily be made."
- the Agency's ability to address the technical objective effectively; and
- the number of paths covered by the technical objective.³⁶⁰

The intensity (or number of safeguards activities) is influenced by the priority of the technical objective. The frequency is influenced in particular by the assessed time to complete the acquisition path. For a high priority technical objective, the IAEA would plan and conduct an increased number of activities to provide high probability of detection.

8.2.5 Status of the State-level concept

As of the end of 2017, the Agency had updated or developed State-level safeguards approaches for States with a comprehensive safeguards agreement and an additional protocol in force as well as a broader conclusion. Of the 62 State-level safeguards approaches, 49 were for States with a small quantities protocol.³⁶¹

The Agency had also developed a State-level approach for two States with a comprehensive safeguards agreement and an additional protocol in force but without a broader conclusion; and for one State with a voluntary offer agreement and an additional protocol in force.³⁶² Indeed, the Agency plans to develop State-level approaches for all States, but it is not clear what that will entail for States without the broader conclusion.

The Agency has stated that the State-level concept is applicable to all States with safeguards agreements, but the State-level approach implementation would differ among States with five different types of agreement situations: States with a comprehensive safeguards agreement and an additional protocol with a broader conclusion, States with a comprehensive safeguards agreement and an additional protocol but without a broader conclusion, States with a comprehensive

³⁵⁹ Therese Renis, INMM Annual Conference, "Recent Progress in the Implementation of Safeguards at the State-Level," July 2017.

³⁶⁰ See the Supplemental Document, paragraph 84 for the list of considerations taken into account in prioritizing technical objectives.

³⁶¹ IAEA Annual Report 2017, pg.93. <https://www.iaea.org/sites/default/files/publications/reports/2017/gc62-3-nuclear-verification.pdf>.

³⁶² Based on the Nuclear Verification section of the Overview of the IAEA Annual Report for 2016, pg.16; see <https://www.iaea.org/sites/default/files/publications/reports/2016/gc61-3.pdf>

safeguards agreement but without an Additional Protocol, States with item-specific agreements, and States with voluntary-offer agreements.³⁶³

As described above, the introduction of integrated safeguards at the State level led to a sharp reduction in field inspection effort. Many expected that the further development of the application of safeguards at the State level would lead to savings in addition to those achieved under integrated safeguards. However, they have been disappointed. There has been a small reduction in the number of planned inspections and visits to verify design information, however, there has not been any overall reduction in cost. It remains to be seen whether meaningful reductions will be obtained in the future, but, if so, they are unlikely to result from implementation of the State-level concept as opposed, for example, to the deployment of new technologies.

³⁶³ Resolution adopted by the General Conference on 21 Sep 2017, “Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards.” GC(61)/RES/12; see paragraph 24.
https://www.iaea.org/About/Policy/GC/GC61/GC61Resolutions/English/gc61res-12_en.pdf

CHAPTER 9. IMPLEMENTATION OF SAFEGUARDS IN IRAN - THE JOINT COMPREHENSIVE PLAN OF ACTION

Preceding chapters have described how the IAEA implements safeguards under the NPT. In addition to this role, the IAEA has also assisted the international community by verifying and monitor other nuclear non-proliferation arrangements. In particular,

- At the request³⁶⁴ of the United Nations Security Council in 1991, the IAEA:
 - developed and implemented a plan for the “destruction, removal or rendering harmless” of almost all of Iraq’s nuclear fuel cycle activities;³⁶⁵
 - verified the freeze of nuclear facilities in the DPRK as called for in the 1994 DPRK-US Agreed Framework;³⁶⁶ and
- The IAEA verified the dismantlement of South Africa’s nuclear weapon program after President de Klerk reported in 1993 that South Africa had “develop[ed] a limited nuclear deterrent capability,” that it had been dismantled, and granted permission to the IAEA to confirm this.³⁶⁷

This Chapter describes another instance in which the IAEA was asked to play an important role that differs from the routine implementation of safeguards. In 2015, at the request of the United Nations Security Council, the IAEA undertook to verify and monitor Iran’s nuclear activities under the terms of an arrangement called the Joint Comprehensive Program of Action (JCPOA). This arrangement is intended to resolve international concerns that Iran’s nuclear fuel cycle activities were intended to obtain nuclear weapons.

9.1 Implementation of Safeguards in Iran

The JCPOA was negotiated by a group of States without the participation of the IAEA. However, it specifies that the IAEA would act to verify and monitor the voluntary commitments made by Iran in the JCPOA. The IAEA role under the JCPOA is a natural one because the JCPOA is a nuclear non-proliferation arrangement that resulted from long-term efforts by the IAEA to resolve Iran’s non-compliance with its NPT safeguards agreement. IAEA verification and monitoring

³⁶⁴ The IAEA is an autonomous international organization with its own governing bodies. In light of this, the Security Council “requests” the IAEA to act but cannot “instruct” it to act.

³⁶⁵ Specified activities related to medical uses were exempt from this requirement.

³⁶⁶ S/PRST/1994/64. “The Security Council notes with approval the DPRK decision in the Agreed Framework to freeze its graphite-moderated reactors and related facilities, which is a voluntary measure beyond what is required by the Treaty and the IAEA-DPRK Safeguards Agreement. "The Security Council, having received an oral report from the Director General of the IAEA, notes further that IAEA monitoring activities with respect to such a voluntary measure are within the scope of verification activities under the IAEA-DPRK Safeguards Agreement. "The Security Council requests the IAEA to take all steps it may deem necessary as a consequence of the Agreed Framework to monitor the freeze...."

³⁶⁷ Letter dated 22 April 1993 from the President of South Africa, Mr. F. W. de Klerk, to a joint session of Parliament on 24 March 1993. See

<http://digitalarchive.wilsoncenter.org/document/116789.pdf?v=c254c7fd2c4f6c4da62736d89b725760>

efforts under the JCPOA go well beyond, but build on and are complementary to, the IAEA's continuing implementation of safeguards under Iran's NPT safeguards agreement.³⁶⁸

9.2 Background to the Joint Comprehensive Program of Action

The origins of the JCPOA go back to 2002 when the IAEA was made aware of undeclared nuclear facilities in Iran. In subsequent years, the IAEA discovered other safeguards violations. Efforts by the IAEA to resolve compliance issues in Iran were intense and difficult. Others also engaged with Iran in efforts to resolve concerns that its nuclear program was intended to develop nuclear weapons.

Ultimately, in 2015, Iran and China, France, Germany, Russia, the United Kingdom, and the United States, with the High Representative of the European Union for Foreign Affairs and Security Policy, reached agreement on a complex plan of action to alleviate concerns about Iran's nuclear program. It was announced on 14 July 2015.³⁶⁹ To become effective, it required that the United Nations Security Council and the Board of Governors of the IAEA take important actions. On 20 July, the United Nations Security Council adopted Resolution 2231 (2015), which requests the IAEA to carry out the relevant verification and monitoring activities.³⁷⁰ In December, the IAEA Board of Governors agreed to this request.³⁷¹

The JCPOA places strict limits on Iran's nuclear capabilities for specified periods of time; calls for on-site verification and monitoring of these limits by the IAEA; and requires step-by-step removal of sanctions that were imposed on Iran for its prior failure to resolve concerns about its nuclear program. The JCPOA also includes provisions designed to resolve issues quickly if they arise, in a matter of weeks.

By the end of 2017, the JCPOA had been in force for more than two years, and important limitations on Iran's technical capacity to produce nuclear weapons remain in place. The IAEA continues to carry out its responsibilities under Iran's NPT safeguards agreement. The IAEA is also verifying Iran's additional protocol, which it agreed to implement on a provisional basis; and it is implementing the monitoring and verification activities assigned to it by the JCPOA. As of

³⁶⁸ INFCIRC/214, The Text of the Agreement between Iran and the Agency for the Application of Safeguards in connection with the Treaty on The Non-Proliferation of Nuclear Weapons. 13 December 1974, <https://www.iaea.org/sites/default/files/publications/documents/infcircs/1974/infcirc214.pdf> (accessed 17 October 2017)

³⁶⁹ In the United States in a Statement by President Obama on Iran, July 14, 2015. <https://obamawhitehouse.archives.gov/the-press-office/2015/07/14/statement-president-iran> (accessed 11 November 2017).

³⁷⁰ United Nations Security Council Resolution S/RES/2231 (2015), Annex A. https://www.iaea.org/sites/default/files/unsc_resolution2231-2015.pdf. (accessed 15 November 2017). The full text of the JCPOA is available in several places. It was published by the United Nations in S/2015/544 and by the IAEA in INFCIRC/877 (15 July 2015), <https://www.iaea.org/sites/default/files/infcirc877.pdf> (accessed 30 December 2017.)

³⁷¹ GOV/2015/72 "Joint Comprehensive Plan of Action implementation and verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015)" <https://www.iaea.org/sites/default/files/gov-2015-72.pdf> (accessed 11 November 2017)

this writing, the IAEA has reported positive conclusions with respect to its verification and monitoring activities.

The JCPOA illustrates the way in which the resolution of significant implementation problems may unfold under IAEA safeguards agreements. This Chapter describes the background and implementation of the JCPOA.

9.3 Origins of the Joint Comprehensive Program of Action - Iran's Non-Compliance with its NPT Safeguards Agreement

In 2002 an Iranian dissident group reported that Iran had a clandestine nuclear program involving the construction of an underground uranium enrichment facility at Natanz and a heavy-water-moderated research reactor at Arak.³⁷²

After visits to these sites, the Director General reported to the Board of Governors in 2003 that Iran had failed to meet many of its safeguards obligations under its 1974 NPT safeguards agreement. These included failures to declare imports of nuclear material, its subsequent processing and use, and the facilities where the nuclear material was stored and processed. He reported to the Board that the process of verifying the completeness and correctness of Iran's NPT safeguards agreement was continuing. The Director General also stated that the IAEA would seek clarification from Iran on the scope and extent of its nuclear program.³⁷³

One failure was that Iran had not implemented its obligation to provide design information concerning its enrichment program at an early time. Readers may recall from Sections 5.2.4 and 7.2.1 that the ground rules for providing design information were changed in 1992 to require States to begin reporting design information as early as when a decision to build a facility is made.³⁷⁴ These circumstances in Iran demonstrate the value of early reporting in bringing nuclear programs to light and allowing the IAEA to investigate a State's nuclear activities if it fails to do so. In that case, a State has violated its safeguards agreement, and the IAEA must resolve this violation.

In November 2003, the Director General reported to the Board of Governors that Iran had already dissembled in an effort to mislead the IAEA. Iran's dissembling would be repeated.³⁷⁵ He also

³⁷² <http://wwwiranwatch.org/library/ncni-new-information-top-secret-nuclear-projects-8-14-02> (accessed 8 December 2015)

³⁷³ GOV/2003/40 6 Jun 2003 "Implementation of the NPT safeguards agreement in the Islamic Republic of Iran." Report by the Director General. <https://www.iaea.org/sites/default/files/gov2003-40.pdf>

³⁷⁴ In this connection, one often reads, in reporting or analyses of the Iran nuclear program, the phrase, "violations of Code 3.1." This is because the requirements for early reporting of design information agreed by the Board in 1992 take effect only when incorporated into the general (as opposed to the facility-specific) part of a state's Subsidiary Arrangements, in particular through revision of Code 3.1, the section that addresses reporting of design information. Iran had made this revision.

³⁷⁵ See, for example, GOV/2010/28, 31 May 2010, at <https://www.iaea.org/sites/default/files/gov2010-28.pdf>

(accessed 5 March 2019), which reports concealment of the construction of a new uranium enrichment plant near Qom, in violation of its reporting obligation under modified Code 3.1; also, GOV/2012/37, 1 August 2012, which reports efforts to modify a site to which the IAEA had requested access, Parchin, in ways that would disrupt verification, para.42. (<https://www.iaea.org/sites/default/files/gov2012-37.pdf>)

reported to the Board of Governors that Iran's nuclear activities practically spanned the "complete front end of a nuclear fuel cycle."³⁷⁶ Of particular concern was Iran's quest to master the two main pathways to nuclear weapons – the production of high-enriched uranium and the acquisition of weapon-grade plutonium, which require, respectively, uranium enrichment and reprocessing facilities.

Uranium enrichment plants are needed to produce HEU. For plutonium, the Arak reactor would be well designed to create weapon-grade plutonium. Both uranium enrichment and reprocessing programs are permitted under the NPT and Iran's NPT safeguards agreement. Under its safeguards agreement, however, Iran was obligated to declare them to the IAEA at an early time. As noted above, Iran had failed to do so. Iran also violated its safeguards obligations by not declaring information about imports of nuclear material as required by its NPT safeguards agreement. These safeguards violations were deliberate and heightened suspicions about its motives.³⁷⁷

In response to these violations, the Board of Governors adopted a series of resolutions that called on Iran to remedy its non-compliance and cooperate with the IAEA. The first Iran Resolution adopted by the IAEA Board of Governors in 2003 called on Iran to "to suspend all further uranium enrichment related activities and, as a confidence building measure, [and] any reprocessing activities"³⁷⁸ (As will be seen later, the pursuit by Iran of enrichment, reprocessing, and operation of its heavy-water moderated reactor are severely limited or prohibited by the JCPOA.³⁷⁹) In 2004, suspicions about Iran's motives in pursuing these nuclear activities were raised further. The IAEA reported then that it had begun to discuss with Iran indicators of activities in "the nuclear military area."^{380,381} It had requested access to "military workshops" in Iran, but

³⁷⁶ Implementation of the NPT Safeguards. Agreement in the Islamic Republic of Iran. Report by the Director General, GOV/2003/75, 10 November 2003. See paras.45-46. <https://www.iaea.org/sites/default/files/gov2003-75.pdf>

³⁷⁷ See, for example, GOV/2010/28, 31 May 2010, which reports concealment of the construction of a new uranium enrichment plant near Qom, in violation of its reporting obligation under modified Code 3.1 (<https://www.iaea.org/sites/default/files/gov2010-28.pdf>); also, GOV/2012/37, 30 August 2012, which reports efforts to modify a site to which the IAEA had requested access, Parchin, in ways that would disrupt verification, para.42. (<https://www.iaea.org/sites/default/files/gov2012-37.pdf>)

³⁷⁸ Implementation of the NPT Safeguards. Agreement in the Islamic Republic of Iran. Resolution adopted by the Board on 12 September 2003. GOV/2003/69, 12 September 2003, para. 3.

<https://www.iaea.org/sites/default/files/gov2003-69.pdf>

³⁷⁹ Iran also conducted experiments in the production of uranium metal, a key material in the manufacture of uranium-based nuclear weapons. Such production is also prohibited by the JCPOA.

³⁸⁰ Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran. GOV/2004/83: 15 November 2004. "Para. 104. In accordance with Agency practice in connection with its evaluation of other States' nuclear programmes, the Agency has discussed with the Iranian authorities open source information relating to dual use equipment and materials which have applications in the conventional military area and in the civilian sphere as well as in the nuclear military area." <https://www.iaea.org/sites/default/files/gov2004-83.pdf>

105. The acquisition of such equipment and materials by Iran was again discussed with Iranian officials in October 2004, at which time the Agency reiterated its request, in the interest of transparency, for a visit to a site located at Parchin, in order to provide assurance regarding the absence of undeclared nuclear material and activities at that site. In order to respond to Iran's concerns about such a transparency visit, the Agency sent on 25 October 2004 a note outlining modalities under which the visit could take place.

³⁸¹ Implementation of the NPT Safeguards. Agreement in the Islamic Republic of Iran. Report by the Director General. GOV/2005/67, 2 Sep 2005, Para 41: "The Agency has discussed with the Iranian authorities open source information relating to dual use equipment and materials which have applications in the conventional military area and in the civilian sphere as well as in the nuclear military area." (<https://www.iaea.org/sites/default/files/gov2005-67.pdf>)

these requests had not been answered satisfactorily. Access to these “military workshops” proved to be a matter of continuing disagreement between the IAEA and Iran.

In 2005, the Board of Governors made a finding of non-compliance by Iran with its safeguards agreement based, in part, on its failures to report nuclear material, facilities and activities.

9.4 Negotiations with Iran

Iran’s nuclear program and the IAEA’s findings raised significant nuclear non-proliferation issues. These issues, especially the concern that Iran was heading towards acquiring a nuclear weapon, led a number of Member States to open discussions with Iran in parallel with discussions between Iran and the IAEA. In particular, France, Germany and the United Kingdom, with the support of the High Representative of the European Union, reached agreement with Iran in 2004 in which it agreed to a voluntary suspension of its enrichment activities.³⁸² Of course, it was recognized that further discussions would be needed to reach a long-term agreement.

This suspension did not last long. In 2005 Iran resumed enrichment activities, which triggered a communication to the IAEA by the three that expressed their dismay and their intention to ask for a special meeting of the Board of Governors. The Board of Governors met in special session February of 2006 and adopted a Resolution (GOV/2006/14) in which it “deemed it necessary for Iran to:

- re-establish full and sustained suspension of all enrichment-related and reprocessing activities, including research and development, to be verified by the Agency;
- reconsider the construction of a research reactor moderated by heavy water;
- ratify promptly and implement in full the Additional Protocol;
- pending ratification, continue to act in accordance with the provisions of the Additional Protocol which Iran signed on 18 December 2003; and
- implement transparency measures ...[including] access to individuals, documentation relating to procurement, dual use equipment, certain military-owned workshops and research and development”³⁸³

In response to a report from the IAEA, the United Nations Security Council in July 2006 “called upon” Iran to take the steps required by the Board of Governors in this Resolution. However, it went one step further. Unlike the IAEA Board of Governors, the United Nations Security Council has the authority under the Charter of the United Nations to demand that Member States take action, i.e., to obligate States to act. In this case, it used its authority to demand that Iran “suspend all enrichment-related and reprocessing activities, including research and development.” The Security Council also expressed its intention, if Iran did not do so, to impose sanctions on Iran.³⁸⁴

³⁸² INFCIRC/637 26 November 2004, Communication dated 26 November 2004 received from the Permanent Representatives of France, Germany, the Islamic Republic of Iran and the United Kingdom concerning the agreement signed in Paris on 15 November 2004

<https://www.iaea.org/sites/default/files/publications/documents/infocircs/2004/infocirc637.pdf> (accessed 21 Mar 2018)

³⁸³ GOV/2006/14 Resolution adopted 4 February 2006 on Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran. (<https://www.iaea.org/sites/default/files/gov2006-14.pdf>.)

³⁸⁴ United Nations Security Council Resolution 1696 (2006), 31 July 2006

Iran did not comply with the demands of the Security Council. In turn, the Council imposed sanctions, and continued to do so through 2010, each time increasing their severity.³⁸⁵ (It should be noted that Iran frequently asserted that the engagement of the Security Council in Iran's nuclear program was unlawful.³⁸⁶)

This series of events is indicative of the way in which interactions with Iran would unfold during the nine-year period before the JCPOA was concluded in 2015. Important similarities include:

- On-going conclusions by the IAEA that it had not detected diversions from Iran's declared nuclear material;
- Persistent efforts by the IAEA to obtain credible assurance of the absence of undeclared nuclear activities and to resolve outstanding issues and reconstruct the history and nature of all aspects of Iran's past nuclear activities;
- Endorsement of these efforts by the Security Council and imposition on Iran of progressively more severe sanctions by the Security Council and by the United States and others;
- Rejection by Iran of these demands to curtail its nuclear program, and instead:
 - steadily increase in the size and capabilities of its uranium enrichment facilities; and
 - continue construction of the Arak reactor;
- Continued concerns about the possible military dimension of Iran's nuclear program;³⁸⁷
- Episodic cooperation by Iran with the IAEA but little or no cooperation with respect to clarifying the possible military dimension of its nuclear program; and
- Parallel discussions between Iran and other IAEA Member States for the purpose of reducing the nuclear non-proliferation risk posed by Iran's nuclear activities.

The most important of these parallel discussions proved to be those between Iran and China, France, Germany, Russia the United Kingdom, and the United States (the P5+1), referring to the five permanent members of the United Nations Security Council and Germany), with the High Representative for the European Union for Foreign Affairs and Security Policy. They began in 2006 with a proposal to Iran for a framework agreement. The proposal offered incentives to Iran

(https://www.iaea.org/sites/default/files/unsc_res1696-2006.pdf)

³⁸⁵ See: United Nations Security Council Resolution 1737 (2006), 27 December 2006, in which it decided that all states "shall" prevent transfers to Iran of items that could contribute to Iran's enrichment-related, reprocessing or heavy water-related activities; United Nations Security Council Resolution 1747 (2007) 24 March 2007, in which it forbade Iran to sell arms; United Nations Security Council Resolution 1803 (2008), 3 March 2008 in which it forbade states to provide item on NSG control lists; and United Nations Security Council Resolution 1929 (2010) 9 June 2010, which reaffirmed the previous resolutions and added numerous further demand on Iran.

³⁸⁶ An example of Iran's views is found in INFCIRC/724, 28 March 2008,

<https://www.iaea.org/sites/default/files/publications/documents/infcircs/2008/infcirc724.pdf> (August 28, 2017)

³⁸⁷ This conclusion is consistent with a statement by a U.S. spokesperson in 2012 that the conclusions of a U.S. National Intelligence Estimate released in 2007, which assessed with high confidence that Iran's nuclear weapon program had halted in 2003 and with moderate confidence that it had not restarted as of mid-2007. See "Iran: Nuclear Intentions and Capabilities, National Intelligence Estimate, November 2007,")

http://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/20071203_release.pdf
(accessed December 18, 2015)

in exchange for indefinite cessation of its enrichment program. Subsequent negotiations over almost a decade resulted in agreement by the P5+1 on the JCPOA.

It is noteworthy that the objectives of these discussions changed over time. The goal in 2006 was a suspension of Iran's sensitive nuclear activities. However, between 2006 and 2015, when agreement on the JCPOA was reached, the size and scale of Iran's nuclear program increased significantly. In 2006, it was operating one small enrichment cascade and had another being installed; an enrichment plant was under construction at Natanz; and the Arak reactor was under construction.

By 2015, Iran operated 19,000 centrifuges at Natanz and also an enrichment site inside a mountain at Fordow.³⁸⁸ The Arak heavy-water reactor was complete. Iran had demonstrated the capability to produce high-enriched uranium. As a result, a key objective of the negotiations with Iran on the JCPOA was to eliminate both the uranium route and the plutonium route to acquiring nuclear weapons.

This meant seeking an outcome that: (1) significantly diminished Iran's enrichment capabilities, including its stockpile of low-enriched uranium; and (2) eliminated the capability of the Arak reactor to produce significant amounts of weapon-grade plutonium. From the perspective of the P5+1, one measure of success in curtailing Iran's nuclear activities was the estimated time that it would take Iran to produce very high-enriched uranium, the so-called "breakout time" after it made a decision to do so. The JCPOA was designed to increase the breakout time considerably if it were fully implemented but then Iran decided to abandon the JCPOA.

Two other potential difficulties are also addressed in the JCPOA. One is the need to address compliance issues quickly. The decade-long saga of addressing these issues in the IAEA and the United Nations Security Council demonstrated the need for an alternative, more rapid mechanism. As described below, the JCPOA includes such a mechanism.

In addition to speedy resolution of issues, the JCPOA also includes a means to ensure that if a finding of non-compliance were made, action by the Security Council to restore sanctions could not be blocked by the veto power of a permanent Member of the Security Council.

Of course, Iran desired compensating measures, especially sanctions relief.

The next section describes the JCPOA, focusing on elements that relate directly to nuclear non-proliferation issues.

³⁸⁸ The Iran Nuclear Deal, by the Numbers, Graham Allison, Harvard University, Belfer Center for Science and International Affairs, April 4, 2015. (<https://www.belfercenter.org/publication/iran-nuclear-deal-numbers-0>, accessed April 11, 2018)

9.5 Joint Comprehensive Program of Action

The JCPOA is a complex interlocking arrangement intended to achieve nuclear non-proliferation objectives.³⁸⁹ It includes:

- political commitments by Iran that its nuclear program will be exclusively for peaceful purposes and that it will never seek, develop or acquire any nuclear weapons;
- strict restrictions on Iran's technical capacities, with on-site verification and monitoring by the IAEA of these restrictions;
- an implementation plan with milestones; and
- progressive lifting of sanctions as milestones are met.

The JCPOA foresees a time when Iran could “fully enjoy” its rights under the NPT to pursue peaceful nuclear activities, and if fully implemented, a “comprehensive lifting of all … sanctions … related to Iran’s nuclear programme.”

The JCPOA is much too complex and detailed to describe fully here. In brief, it covers: reciprocal legal and political commitments; strict limits on Iran’s nuclear activities; IAEA verification and monitoring; and progressive lifting of sanctions as benchmarks are met, some of which are linked to the IAEA’s reaching the broader conclusion; procedures to resolve concerns in a timely fashion; and a mechanism for sanctions to be quickly restored if concerns are not resolved in a satisfactory fashion.

The following elaborates on these core nuclear non-proliferation elements of the JCPOA:

A. Reciprocal legal and political commitments;

These include commitments by Iran never to seek, develop or acquire any nuclear explosive devices and not to engage in specified activities involving uranium or plutonium that could contribute to their development; provisional application of the additional protocol and its ratification eight years after the JCPOA became effective (October 18, 2015, which is called Adoption Day in the JCPOA) or the IAEA reaches the broader conclusion (see Chapter 7), whichever comes first; and implementation of the Board-approved rules for early reporting of design information (Code 3.1). The JCPOA also calls for the progressive lifting of sanctions as agreed milestones are met.

B. The implementation of the JCPOA is monitored by a Joint Commission of the contracting parties, which also has the responsibility to carry out the functions provided for in the JCPOA and to address issues arising from its implementation.

C. Limitations on Iran’s technical capacity to acquire nuclear weapon-usable high-enriched uranium or plutonium;

³⁸⁹ The full text of the JCPOA has been published by the IAEA in INFCIRC/887 at <https://www.iaea.org/sites/default/files/infirc887.pdf> (accessed November 30, 2017.)

Nuclear weapons use either high-enriched uranium or plutonium. Iran had developed nuclear fuel-cycle capabilities that could, if pursued, use either pathway: produce nuclear weapon-usable high-enriched uranium via centrifuge enrichment; or produce plutonium by reprocessing fuel irradiated in the Arak reactor. The JCPOA is designed to eliminate both of these pathways.

The former is addressed by strict limits, including restrictions on the locations where enrichment activities can be pursued, the nature of these activities, and their capacity. The quantity of enriched uranium and uranium-235 enrichment levels are also limited. Limitations are also imposed on Iran's development of advanced centrifuges and by the requirement that Iran permit the IAEA to monitor stored centrifuges.

The latter is addressed by requiring that the Arak heavy-water moderated reactor be converted so that it uses enriched uranium fuel rather than natural uranium. This reduces the quantity of plutonium produced and, in normal operation, makes that plutonium less useful for nuclear weapons. Limits are also placed on Iran's holdings and production of heavy water. Pursuit of reprocessing is prohibited.³⁹⁰

D. IAEA verification and monitoring;

The IAEA continues to implement safeguards under Iran's NPT safeguards agreement and also implements the additional protocol that Iran has brought into force on a provisional basis.

The Preamble to the JCPOA assigns a very broad role to the IAEA. It states that, "The International Atomic Energy Agency (IAEA) will be requested to monitor and verify the voluntary nuclear-related measures as detailed in this JCPOA." These voluntary measures relate to matters not covered by the NPT (except with respect to exports of especially designed and prepared equipment and materials) or NPT safeguards agreements.

These measures include, for example:

- monitoring nuclear material before the starting point of safeguards under NPT safeguards agreements (uranium ore concentrate);
- restrictions on R&D without nuclear material;
- limits on the stockpiles and production of heavy water;
- verification and monitoring of the disablement and reconstruction of the Arak reactor;
- ceilings on the holdings and enrichment levels of low-enriched uranium;
- numerous constraints on Iran's centrifuge-related activities; and
- other constraints on the location, character and size of nuclear activities.

Annex I to the JCPOA describes these measures in detail. For example, it specifies that the IAEA is allowed continuous monitoring to ensure that stored centrifuges remain in storage, except to

³⁹⁰ One exception is the production of radioisotopes for medicine or industry.

replace failed or damaged centrifuges. This is achieved by daily IAEA access to relevant buildings at the Natanz uranium enrichment facility.

E. The JCPOA specifies procedures to resolve concerns in a timely fashion and a mechanism for sanctions to be quickly restored if concerns are not resolved in a satisfactory fashion by the aforementioned Joint Commission. This mechanism involves actions by the United Nations Security Council. Since the Security Council's prior decisions had obligated States to apply sanctions, only the Security Council can lift these obligations or re-impose them. A mechanism was developed for the JCPOA that prevents Security Council members with a veto from using it to thwart the intentions of the JCPOA.

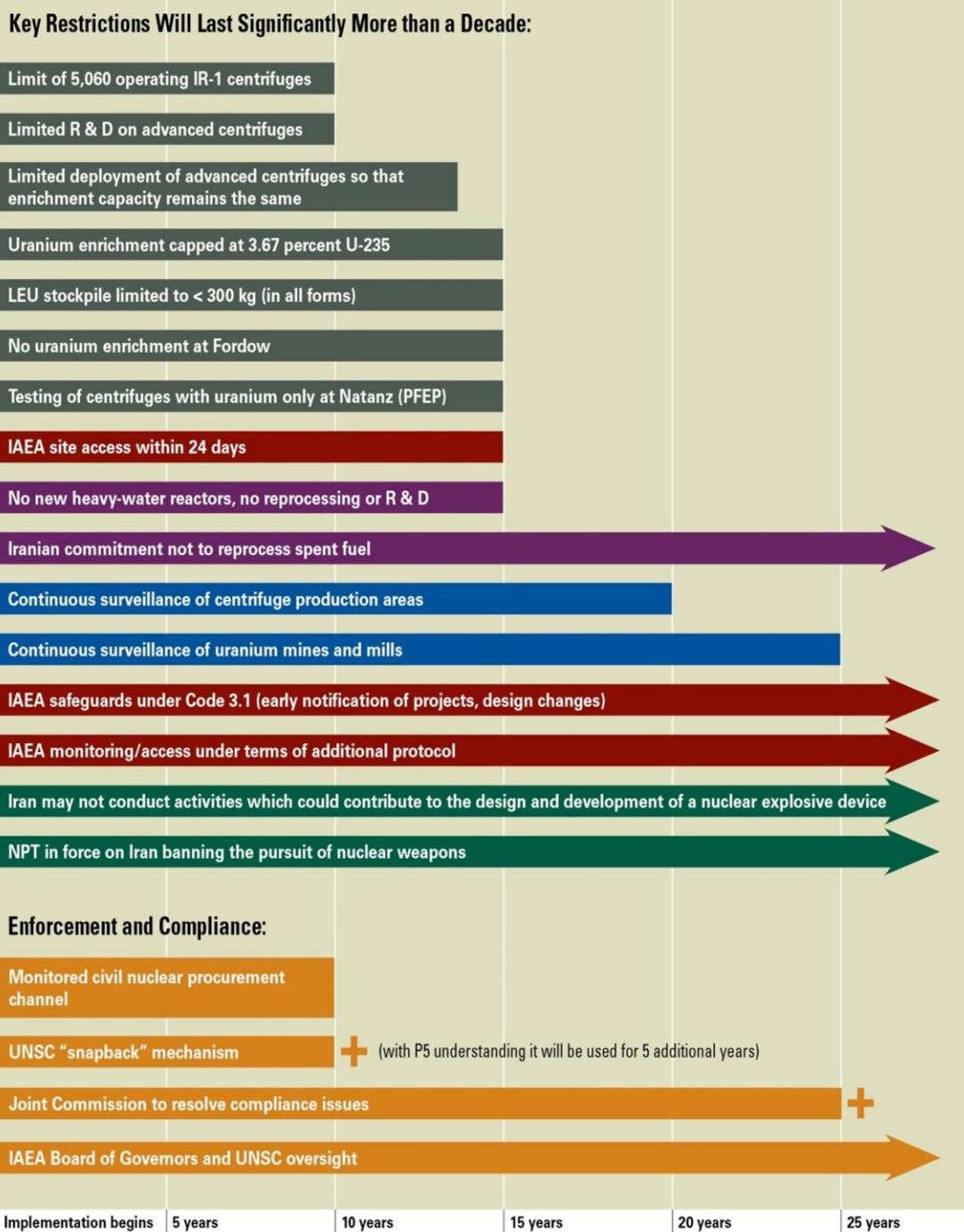
F. In addition, the JCPOA specifies:

- Early termination of provisions of United Nations Resolutions that had required Iran to limit its nuclear activities;³⁹¹
- Establishment of a Procurement Working Group, which reviews proposals to supply Iran with items on the control lists of the Nuclear Suppliers Group. Iran's ratification of the additional protocol 8 years from Adoption Day or when the IAEA reaches the broader conclusion, whichever comes first;³⁹²
- Iran's agreement to accept IAEA monitoring using advanced technology and equipment;
- IAEA verification and monitoring, including of:
 - disablement and reconstruction of the Arak reactor and continuous monitoring of fuel for the Arak reactor;
 - the quantity and production of heavy water;
 - storage of excess centrifuges and infrastructure; newly produced centrifuges; the use of specialized equipment for production of centrifuge rotor tubes;
 - uranium ore concentrates;
 - non-production of LEU by advanced centrifuge testing;
- Progressive lifting of sanctions as milestones are met, which are specified as “[N] years after Adoption Day or when the IAEA has reached the broader conclusion that all nuclear material in Iran remains in peaceful activities, whichever is earlier.” N is variously 5, 8, or 10 years for matters related to, for example, the Procurement Channel noted above; freezing of funds; limitations on arms sales and ballistic missile cooperation;
- Termination of limits specified in the JCPOA on Iran's centrifuge-related activities at times specified in the JCPOA. Figure 56 illustrates this;
- Procedures to monitor implementation of the JCPOA, address implementation issues and resolve concerns in a timely fashion as well as a mechanism for sanctions to be restored if concerns are not resolved in a satisfactory fashion.

³⁹¹ United Nations Security Council Resolutions 1696 (2006), 1737 (2006), 1747 (2007), 1803 (2008), 1835 (2008), 1929 (2010) and 2224 (2015)

³⁹² Adoption day was October 18, 2015.

JOINT COMPREHENSIVE PLAN OF ACTION



Sources: JCPOA, IAEA, UNSCR 2231, Arms Control Association

Figure 56. Key restrictions on Iran's nuclear activities under the JCPOA including their duration

One of the most important elements of Security Council Resolution 2231 (2015) relates to what happens if concerns are raised about implementation of the JCPOA. The JCPOA outlines two

processes for addressing concerns. One is the Dispute Resolution Mechanism in paragraphs 36 and 37 of the JCPOA. This mechanism specifies the procedures to be followed if any participant believes that commitments under the JCPOA are not being met. At the end of the process, if the issue is not resolved and the “complaining participant deems the issue to be significant non-performance,” the complainant has several options: treat it as grounds to “cease performing its commitments under the JCPOA in whole or in part, and/or notify the United Nations Security Council that it believes the issue to be significant non-performance.”

The second process, in paragraphs 74-78 of JCPOA Annex I, relates to an instance where the IAEA has concerns “regarding undeclared nuclear materials or activities, or activities inconsistent with the JCPOA” at undeclared locations. If concerns are not resolved by discussions between Iran and the IAEA, the IAEA may request access to such locations. If arrangements cannot be agreed or the IAEA remains unable to allay its concerns, the issue would be brought to the Joint Commission. Ultimately, barring resolution, Iran “would implement the necessary means,” to resolve the issue as agreed by the Joint Commission (the elapsed time for this process cannot exceed 24 days).³⁹³

In either case, if a JCPOA party notifies the Security Council of a significant non-performance of a commitment under the JCPOA, the Council “shall vote” on a resolution to *continue* the terminations of sanctions cited in paragraph 7(a) of the Resolution. Thus, only an affirmative action, adoption of the Resolution, will maintain sanctions relief.

If the Resolution is not adopted, the terminations do not “continue,” and the sanctions in the earlier relevant resolutions are restored as if they had never been terminated, i.e., they “snap back.” Thus, any permanent member of the Security Council, by using its veto, can ensure that sanctions “snap back.”

The issue of the “possible military dimension” of Iran’s nuclear program consumed a great deal of time and energy in the lead-up to the adoption of United Nations Security Council Resolution 2231 (2015) and the JCPOA. It was put aside by IAEA action. In particular, United Nations Security Council Resolution 2231 (2015) asked the Director General of the IAEA to submit a report to the Board of Governors that included his “final assessment of all past and present outstanding issues, as set out in the Director General’s report in November 2011 contained in GOV/2011/65³⁹⁴.”³⁹⁴

He did so, after which the Board adopted a Resolution on 15 December 2015 in which it stated that, “all the activities in the Road-map for the clarification of past and present outstanding issues regarding Iran’s nuclear programme were implemented in accordance with the agreed schedule and further notes that *this closes the Board’s consideration of this item*” [emphasis added].³⁹⁵

³⁹³ Under NPT safeguards agreements, no fixed times are specified for resolving concerns. This has the advantage of providing the IAEA with flexibility, but it has the disadvantage of allowing States to delay, perhaps for a long time. In the case of Iran, the JCPOA was agreed more than 13 years after the first discovery of Iran’s undeclared nuclear activities.

³⁹⁴ GOV/2011/65, Implementation of the NPT Safeguards Agreement and relevant provisions of the Security Council resolutions in the Islamic Republic of Iran,” is at <https://www.iaea.org/sites/default/files/gov2011-65.pdf>

³⁹⁵ Joint Comprehensive Plan of Action implementation and verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council Resolution 2231 (2015); Resolution adopted by the Board of Governors on 15 December 2015, GOV/2015/72.

Nonetheless, Iran has an incentive to clarify this issue further in cooperation with the IAEA in order to allow the IAEA to reach the broader conclusion, which, as seen above, is linked to sanctions relief.

As of mid 2018, the IAEA continued its monitoring and verification activities under the JCPOA, Iran's NPT safeguards agreement, and the additional protocol, which, at that time was being implemented by Iran on a provisional basis. As of then, the IAEA had not reported any implementation difficulties. On 30 August 2018, the IAEA Director General reported to the Board of Governors that:

The Agency continues to verify the non-diversion of declared nuclear material at the nuclear facilities and locations outside facilities where nuclear material is customarily used (LOFs) declared by Iran under its Safeguards Agreement. Evaluations regarding the absence of undeclared nuclear material and activities for Iran remained ongoing.

Since Implementation Day, the Agency has been verifying and monitoring the implementation by Iran of its nuclear-related commitments under the JCPOA.³⁹⁶

Regardless of the status of implementation in 2018, the JCPOA has been subject to criticism. For one, assurances that Iran is respecting the terms of the JCPOA can never be 100%, first because IAEA verification and monitoring cannot reach this level at declared locations and, second, because its access to other locations is circumscribed. In addition, key limitations on Iran's centrifuge program lapse after ten years. Thereafter, the time it would take for Iran to manufacture a nuclear weapon will lessen. Doing so would of course be in contravention of its basic non-proliferation commitment, unless it denounced the NPT.

On May 8, 2018, President Donald Trump announced that the United States will "end its participation in the JCPOA" and "re-impose all United States sanctions lifted or waived in connection with the JCPOA." This decision was based in part on the temporary nature of some of the JCPOA provisions and on Iran's continuing military support for activities in certain other Middle Eastern countries.³⁹⁷ ³⁹⁸ (In making this decision, the U.S. did not invoke the dispute-resolution mechanisms of the JCPOA.) U.S. sanctions were re-imposed as of August 6.³⁹⁹ As of this writing, the other parties to the JCPOA continue to abide by it, and, as indicated above, IAEA verifications in Iran continue.

<https://www.iaea.org/sites/default/files/gov-2015-72-derestricted.pdf>

³⁹⁶ Verification and monitoring in the Islamic Republic of Iran in light of United Nations Security Council resolution 2231 (2015), Report by the Director General, GOV/2018/33 Date: 30 August 2018, <https://www.iaea.org/sites/default/files/18/09/gov2018-33.pdf> (accessed 16 October 2018).

³⁹⁷ Ceasing U.S. Participation in the JCPOA and Taking Additional Action to Counter Iran's Malign Influence and Deny Iran All Paths to a Nuclear Weapon, Presidential Memorandum, May 8, 2018.

³⁹⁸ See also U.S. Decision to Cease Implementing the Iran Nuclear Agreement, K. Katzman, P. Kerr and V. Heitshusen, May 9, 2018, <https://crsreports.congress.gov/product/pdf/R/R44942> (accessed 16 October 2018).

³⁹⁹ Reimposing Certain Sanctions With Respect to Iran, Executive Order 13846, August 6, 2018, <https://www.federalregister.gov/documents/2018/08/07/2018-17068/reimposing-certain-sanctions-with-respect-to-iran> (accessed 16 October 2018).

CHAPTER 10. LOOKING TOWARD THE FUTURE

Introduction

The scope of NPT safeguards and the IAEA's ability to implement them have made significant progress since 1970. The NPT was extended indefinitely in 1995 and has a global reach. Only five countries stand outside the NPT: DPRK, India, Israel, Pakistan and South Sudan. As of the end of 2016, IAEA comprehensive safeguards agreements were in force for 172 of the 185 non-nuclear-weapon States parties to the NPT. IAEA safeguards are routinely applied in all non-nuclear-weapon States that have nuclear activities.⁴⁰⁰ As of the end of 2016, 124 States had both a comprehensive safeguards agreement and an additional protocol in force. In addition, six States without comprehensive safeguards agreements had additional protocols in force: China, France, India, Russia, the United Kingdom, and the United States. During 2016, integrated safeguards were implemented for 57 States.

The process of creating and implementing the Model Protocol served as the basis for establishing both a new legal and a new conceptual basis for safeguards, one that is more ambitious and more complex than safeguards applied under INFCIRC/153 alone.

IAEA safeguards have matured both conceptually and technologically. Examples include: short-notice random inspections to carry out flow verification soundly and efficiently; State-level approaches based on all-source information collection and analysis; and taking better advantage of States systems of accounting for and control of nuclear material (SSACs).

Technologically, the IAEA has also been effective in supporting the development and deployment of new technology. Examples include: widespread use of environmental sampling at facilities and sites; acquisition and analysis of numerous satellite images; deployment, as described above, of about 160 unattended monitoring systems, and 900 video surveillance systems; and remote transmission of data to IAEA Headquarters from about 120 facilities; introduction of a new generation of optical surveillance systems; application of new methods for process monitoring and data authentication; and introduction of new systems for the collection, analysis, and retrieval of information.

This is by no means a basis for complacency. Technology changes rapidly, especially in information technology and communications – witness the rapid and widespread introduction of smart phones and tablet computing. There will be a continuing need to take advantage of new technologies, deploy them, and ensure that the staff is well-trained to take advantage of them.

The IAEA will also have to address higher expectations about its ability to provide assurance of the absence of undeclared nuclear material and activities. The tools and authorities of the IAEA to do so have improved. This is especially so on the sites of facilities. However, the challenges of providing assurances about the absence of undeclared nuclear material and activities elsewhere are formidable. The absence of any significant diversion or misuse of declared facilities under NPT safeguards agreements, coupled with experiences in Iran, Libya, and Syria, demonstrates why

⁴⁰⁰ There are 13 NPT non-nuclear-weapon States that have yet to bring an NPT safeguards agreement into force. Most of them are not members of the IAEA. None of them has any nuclear activity.

many believe that dealing with undeclared activities at undeclared locations is the most important mission of the IAEA. However, recent experiences demonstrate the difficulty of meeting the challenge. Institutionally, the IAEA will need to manage these expectations.

Regardless of its missions, the Agency will be confronted with limited resources and will need to identify areas for potential savings and allocate resources wisely. It is the Board of Governors, though, that decides on the budget and how it is allocated among the IAEA's departments.

The IAEA may also be called upon to carry out verification activities under arrangements other than the NPT. These could relate to a Fissile Material Cutoff Treaty (FMCT) or to bilateral strategic arms reduction arrangements. The following sections address challenges that will confront the IAEA as it seeks to further improve the safeguards regime and those it may face in supporting other arms control efforts.⁴⁰¹

10.1 Technical Challenges

10.1.1 Detecting undeclared nuclear activities

The new authorities contained in the Model Protocol provide the IAEA with a new, important tool – enhanced access to information and to locations. Its goal is to provide the IAEA with a firmer basis to provide assurance of the absence of undeclared nuclear material and activities. How well can the IAEA do that? The following sections address this question from two perspectives: one relates to locations subject to routine inspection – declared facilities – and the other relates to everywhere else in a State.

Detecting undeclared activities at the site of a declared facility

At declared facilities, an additional protocol gives the IAEA enhanced access to both the facility and the “site” of the facility. Inspectors may go anywhere on the site with new, explicit authority to look for undeclared activities. The inspector also has information about all of the buildings on a site. The combination of access on short notice and inspection tools such as environmental sampling gives the inspector a good basis for detecting undeclared activities at a site (an additional protocol also gives the IAEA the ability to seek access to a location near a site if it considers that it might be functionally related to the site (Article 2.b (ii)).

The sites of some facilities are large and complex, and proliferation-sensitive activities related to reprocessing and enrichment can be conducted on a small scale. The efficacy of complementary access at sites to detect undeclared nuclear activities must be assessed taking into account both their scale and the concealment methods that might be used by a State.

The IAEA research and development (R&D) program includes the development of field-deployable technology that could assist in detecting undeclared activities. If combined with a

⁴⁰¹ Ways to improve the nuclear non-proliferation regime and a useful summary of the roles that the IAEA can play in this regard are in: Strengthening the Nuclear Nonproliferation Regime, Paul Lettow, Council on Foreign Relations Special Report No. 54, April 2010. See also, Priority Steps to Strengthen the Nonproliferation Regime, Pierre Goldschmidt, Carnegie Endowment for International Peace, Policy Outlook, February 2007.

http://www.carnegieendowment.org/files/goldschmidt_priority_steps_final.pdf (March 15, 2012).

systematic assessment of site characteristics and concealment methods, the fruits of this R&D program could buttress confidence or point the way toward the need for new tools.

Enhanced access is a major improvement. Present capability is likely to deter a State that might be considering the pursuit of undeclared activities from doing so at or near sites. As a consequence of pursuing undeclared nuclear activities elsewhere, a State cannot take advantage of the signatures associated with the operation of declared nuclear facilities to conceal undeclared nuclear activities at a site or nearby. This may provide advantages to both the IAEA and others in detecting undeclared nuclear activities.

Detecting undeclared activities at undeclared locations

The ability to uncover undeclared activities in the remainder of a State is a challenge that even the international community finds difficult to meet. Many States have large territories, there are technical constraints on obtaining the knowledge required, and the resources needed to deploy effective systems (e.g., satellite surveillance systems) worldwide is enormous compared to the Agency's resources.

Moreover, some methods of acquiring weapon-usable material do not leave easily detectable signatures, and an adversary determined to cheat will seek to understand detection technologies and the means to circumvent them. It is common knowledge that any facility built in the open can be seen by satellite systems, and adversaries will plan accordingly.

However, advances in technology in one area might provide the IAEA with the ability to carry out wide-area environmental sampling. The IAEA's right to do this is contained in the Model Protocol, but exercise of the right is contingent on prior approval of the Board of Governors. As of the end of 2017, this had not been given. A major reason for this is the cost.

The emergence of drone technology might change this. In particular, it appears to be feasible for drones to scan wide areas and take environmental samples themselves, when instructed to do so. If also cost-effective, this could reduce the cost of sample collection dramatically. Of course, there are many other system costs, including sample analysis, that might still make wide-area environmental sampling not cost-effective.

Concealment and the spread of technology

Images released by the U.S. Central Intelligence Agency (CIA) in early 2008 demonstrate the lengths to which a State went to conceal clandestine activities, as seen in Figures 57 and 58.⁴⁰² One shows the clandestine Syrian reactor under construction; the other after it was camouflaged. Not only is a significant portion of the facility underground, but the visible section has been altered so that it does not display any of the characteristics of a reactor.

The picture of the reactor under construction illustrates another factor that can complicate the ability of the IAEA and others to detect clandestine nuclear activities. It is very similar in appearance to the 25 MW thermal reactor at the Yongbyon research center in the DPRK. Together with other evidence, these similarities led the CIA to conclude that the Syrian reactor was built with the cooperation of the DPRK and used its designs. The implication of this is that even an accurate assessment of the indigenous capabilities of a State to pursue a nuclear-weapon program may lead to the wrong conclusion about whether it is doing so if the State is able to take advantage of technology available elsewhere.

This case is indicative of one route to acquiring weapon-useable material: acquiring plutonium by using a natural uranium-fueled reactor and a reprocessing facility. To acquire a meaningful amount of plutonium means that the reactor must have a minimum power level, and its heat and means of cooling may provide detectable signatures.⁴⁰³ The case of Syria indicates that the technology utilized need not be new or sophisticated. Graphite-moderated reactors of this size were built during the 1940s as plutonium production reactors. Also, a reprocessing plant will emit a noble gas such as xenon, which is potentially detectable.

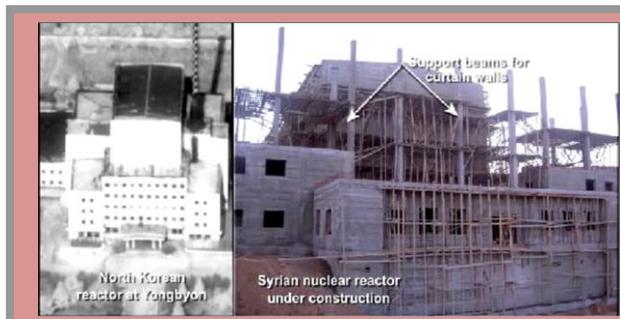


Figure 57. Clandestine Syrian reactor under construction



Figure 58. Camouflaged Syrian reactor

⁴⁰² See press release of April 24, 2008 by CIA Director Hayden, <https://www.cia.gov/news-information/press-releases-statements/press-release-archive-2008/cia-director-hayden-announces-findings-on-covert-syrian-reactor.html>.

⁴⁰³ The plutonium generated in a reactor is approximately proportional to energy output; it needs to be in the range of 40 MWth to produce a significant quantity of plutonium yearly. Reactors may also be concealed underground: a 25 MW thermal reactor was built 98' underground in Norway. See, "Underground Nuclear Power Plant Citing, by M. B. Watson, et., al., Aerospace Corporation, Sept. 1972; <http://caltecheq.library.caltech.edu/36/01/EQLReport6.pdf>.



(From AP/Iranian President's office)

Figure 59. Iran centrifuge facility being inspected by President Mahmoud Ahmadinejad

In this context, the spread of uranium gas-centrifuge enrichment technology⁴⁰⁴ is troublesome. It affords a path to acquiring nuclear-weapon-usable high-enriched uranium (HEU) that is particularly hard to detect. A State would need a source of uranium, a means to convert it to pure uranium hexafluoride, and a centrifuge plant.

While INFCIRC/153 and the Model Protocol contain some reporting requirements for uranium ore concentrate, it is not subject to safeguards inspection, so it is not tracked quantitatively by the IAEA. Uranium is mined widely around the world, and many countries have indigenous sources. There are also unconventional sources of uranium: for example, it can

be produced as a byproduct of phosphate production or, at great expense, from seawater.⁴⁰⁵ Thus natural uranium may not be difficult to obtain, and it is not subject to the same scrutiny as safeguarded material. Conversion of the impure forms of uranium to uranium hexafluoride that is suitable for enrichment is not difficult or expensive.

Gaseous diffusion plants, the first enrichment plants, were physically large and required very large amounts of energy (and cooling), but a centrifuge plant (see **Error! Reference source not found.**) requires much more modest amounts. It requires no special structures and could be built underground, as demonstrated by Iran's plant at Natanz.⁴⁰⁶ Unlike graphite-moderated reactors, development of a centrifuge enrichment capability has been considered to require a high level of industrial development. However, it has been demonstrated that even States with relatively poor industrial infrastructures may be able to pursue centrifuge enrichment programs on the basis of technology made available through clandestine trade networks.⁴⁰⁷ The DPRK has displayed a modern centrifuge enrichment plant. It is worrisome that the DPRK might become a new supplier of centrifuge equipment and technology.⁴⁰⁸

⁴⁰⁴ Centrifuge programs are known to exist or have existed in Brazil, the DPRK, China, France, India, Iran, Japan, Libya, Pakistan, Russia, the United Kingdom, and the United States.

⁴⁰⁵ The case of Syria demonstrates that this is not hypothetical. See Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic, *Report by the Director General*, GOV/2011/30, 24 May 2011.

<http://www.iaea.org/Publications/Documents/Board/2011/gov2011-30.pdf>.

⁴⁰⁶ "Verification of Dismantlement of Nuclear Warheads and Controls on Nuclear Material," JSR-92-331 (Jason Report), Mitre Corporation, Jan. 1993, page 77: "Unfortunately, both centrifuge and laser isotope separation methods seem to be much less amenable to remote detection. There are no known remotely observable signatures for either separation method, barring an accidental release."

⁴⁰⁷ Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies, David Albright, Free Press, March 2010 and Unraveling the A. Q. Khan and Future Proliferation Networks, David Albright and Corey Hinderstein, *The Washington Quarterly*, 28:2 pp. 111–128, Spring 2005. http://www.twq.com/05spring/docs/05spring_albright.pdf. (As of April 29, 2011).

⁴⁰⁸ What I found in Yongbyon and why it matters, Siegfried S. Hecker, American Physical Society site, <http://www.aps.org/publications/apsnews/201103/backpage.cfm>.

Whether or not centrifuge enrichment or plutonium production through reprocessing is the more difficult route, the factors cited above demonstrate that the IAEA must be sensitive to both routes and that it cannot necessarily use industrial status or nuclear development as an indicator of risk.

The IAEA's success in carrying out this mission will hinge on its capability to evaluate the declarations made by States for completeness, correctness, and consistency in order to detect possible indications of undeclared nuclear material and activities. Three elements go into this evaluation:

- assessment of the internal consistency of a State's declaration and comparison of it to information gathered by IAEA inspectors on the basis of their access to the locations, facilities, sites, personnel, and documents disclosed in States' declarations;
- comparison of States' declarations with other information available to the IAEA, for example, from scientific and technical literature and databases, trade journals, and media reports; and
- ability to archive, retrieve, organize, and analyze all available information for indications of potential undeclared nuclear material and activities.

In addition, inspectors in the field and Headquarters staff will need to be able to recognize such indications, define appropriate follow-up actions, and request States to provide further information and access in order to investigate and clarify any questions or inconsistencies.

Each of these steps will require a continuing effort by the IAEA to train inspectors in new skills; to attract staff talented in collecting, organizing and analyzing large data sets; and to develop and acquire the information-handling systems needed to make this feasible.

The Model Protocol may be imperfect, but it does not stand alone. The Agency obtains information from States' declarations, satellite imagery, and from third parties. If the information raises concerns, the Model Protocol gives the Agency a right to ask questions or request access. The IAEA may also use the special inspection authority contained in INFCIRC/153.

Any statement by the IAEA that a country does not have undeclared nuclear material or activities cannot be presumed to be definitive. Such a statement is based on the IAEA's own activities and the information available to it. Others, for example, might have different information. As noted above and in the previous chapter, events in Syria and Iran demonstrate the lengths to which States will go to conceal clandestine nuclear activities. Whether or not an additional protocol is in force, any judgments about the strength of conclusions by the IAEA must take such concealment measures into account.

Despite progress made, the daunting nature of the challenge makes it hard to be completely sanguine about the Agency's ability to provide robust assurances about the absence of undeclared nuclear material and activities at undeclared locations despite its best preparations.

Investigation

The judgment made above about the effectiveness of the Agency's capabilities to address undeclared activities at undeclared locations needs to be placed in context. It is not a judgment

about the IAEA. The constraints placed on it need to be taken into account. For example, the Board of Governors has not approved the use of wide-area environmental sampling;⁴⁰⁹ it is not legally or politically acceptable for the Agency to operate in a covert manner; and credible information about undeclared locations is more likely to come from other sources whose resources are far greater than the IAEA's. Third parties are much more likely to detect undeclared nuclear activities than the IAEA can be expected to. Its search is limited to identification of inconsistencies or questions based on declared or publicly available information or information shared with it.⁴¹⁰

The IAEA is, nonetheless, in a unique position. It has independent sources of information on a State's nuclear fuel cycle that may not be available to States or may be greater than any State alone might have. This includes information related to its technical cooperation activities, information provided by States routinely under INFCIRC/153 or under an additional protocol, inspectors' observations, and third-party information shared only with the IAEA. The IAEA also has unique access to locations. For example, the IAEA sent inspectors to numerous sites in Iran, Libya, and Syria to investigate the extent of their nuclear programs.

These factors give the IAEA a unique capability to investigate concerns about undeclared nuclear activities, and this investigative function may be the primary value of the Model Protocol in the context of State-level approaches.

Once on-site, the Agency can interview people, review records, and employ location-specific environmental sampling. When inconsistencies are discovered, the Agency is in a position to report these to the international community and demand answers. In addition, the IAEA can place the information it receives this way in a richer context than others may be able to. States may be willing to share information with it that they do not choose to share with one another. These synergies are an important step forward. They highlight the fact that the IAEA safeguards system is just one element of the non-proliferation regime and that it complements and reinforces other elements.

Should a State under investigation refuse to answer questions or provide the requested access, the Board of Governors has the right to consider that refusal in determining whether to report it to the United Nations Security Council. Moreover, a violation of an additional protocol could occur at a much earlier stage of development than a violation of a comprehensive safeguards agreement. On the other hand, the non-proliferation significance of activities well before the production of nuclear material might be considered more of a technical than a meaningful safeguards violation. For example, failure to report government-sponsored R&D on uranium enrichment not involving nuclear material would be a violation of an additional protocol but not an INFCIRC/153 safeguards

⁴⁰⁹ A multi-nation support program study concluded that atmospheric sampling for detecting clandestine reprocessing was the wide-area technique with the greatest potential, but that even under the best conditions the cost of wide area techniques could be high; see E. Kuhn et. al., "Environmental Sampling for IAEA Safeguards: A Five Year Review," IAEA-SM-367/10/01.

⁴¹⁰ The capabilities of the intelligence agencies are beyond the scope of this text, but a few points should be noted. States will not always choose to share their information with the IAEA or they may choose other means to address non-proliferation problems. Israel has chosen direct military action in two instances, bombing the Osirak reactor in Iraq in 1981 and a Syrian reactor in 2007. Governments will always consider whether providing information (or detection technology) to the IAEA will compromise methods and sources and will balance the advantages of bringing information to the IAEA against the potential costs to them of disrupting the flow of information.

agreement. Thus, the international community could have more time to prevent the violator from acquiring nuclear weapons.

The issue of improving transparency to make undeclared nuclear activities more detectable is likely to be a continuing concern to the non-proliferation community and to the IAEA. Although there are no ready answers, proposed solutions include new detection technology, more aggressive use of current IAEA authorities (including those in the Model Protocol and the special inspection provision of INF CIRC/153), improved voluntary transparency,⁴¹¹ broader use of available information, and expanded authorities.

10.1.2 Safeguards at declared facilities

Fuel cycle growth

Looking ahead, growth of the nuclear fuel cycle might be significant, but most new facilities in the near future will be similar to facilities now deployed – for example, additional light-water reactors. For safeguards at these facilities, the IAEA may not need innovative technologies, since present techniques may suffice, but it will need to have the appropriate level of resources. Although the introduction of integrated safeguards and State-level approaches means that the inspection resources required would not grow at the same rate as the number of new reactors or other facilities, more resources will be needed unless compensated for by achieving higher efficiency.

Unfortunately, reliable forecasts may not be available. On the one hand, nuclear growth has always been difficult to predict, and the severe accident in 2012 at the Fukushima Daiichi reactor station in Japan has added uncertainty to present forecasts. On the other hand, required safeguards resources do not depend primarily on overall growth, but on an increase in the number of facilities with separated plutonium, especially processing facilities. Because of the material’s sensitivity and relatively short timeliness goals, such facilities absorb inspection resources disproportionately. Also significant, but to a somewhat lesser degree, would be an increase in the number of uranium enrichment plants.

Novel and larger facilities

New facilities might also pose safeguards challenges to the IAEA. One challenge would be to develop effective safeguards approaches for facilities that employ technologies with which it has no experience. Facilities may also become so large that present safeguards approaches become less effective. For example, uranium enrichment plants are already much larger than planned for under the Hexapartite Safeguards Project (HSP), and sizes might grow further. Newer enrichment plants may also incorporate electronic switching that can change a plant’s configuration with no visible signs. Electrochemical reprocessing and pyro-processing technology might be pursued on

⁴¹¹ The Report of the Commission of Eminent Persons on the Future of the Agency suggests: “All states should adopt the principle and practice of transparency in their civil nuclear activities, providing the IAEA with access to any information, locations, and individuals in their countries that may help it carry out its mission. states that engage in sensitive nuclear activities, in particular, should offer full transparency concerning all aspects of their civilian nuclear activities, to build international confidence.” GOV/2008/22-GC(52)/INF/4, 23 May 2008.

a large scale. If developed further, they would involve forms of nuclear material different from those subject to safeguards to date. New measurement techniques would be needed.

The IAEA will also be faced with applying safeguards to new types of enrichment facilities. A consortium of General Electric and Hitachi in the United States plan to build a uranium enrichment pilot plant based on lasers (the technology is called SILEX and was developed in Australia). As with gas centrifuge plants, the development of a safeguards approach to such a facility will need to accommodate States' requirements to protect classified and commercially and non-proliferation sensitive information.

Another facility type that would be new to the IAEA is a geological repository, where large amounts of spent fuel would be buried and become inaccessible indefinitely.⁴¹² Since there is no possibility of future measurement, this places a premium on ensuring that no nuclear material is removed from spent fuel assemblies before they become inaccessible. In this case, the safeguards approach needs to ensure that assemblies placed in the repository are not dummies used to conceal the diversion of real assemblies. At spent fuel ponds, reverification can detect such concealments, but at the repository, this may not be possible. Such facilities will pose long-term problems since they will be active for many years before they are sealed. A cost-effective approach must be developed both for the time during which the repository is being filled and when it is closed. R&D on this issue has been pursued for some time.

Fortunately, Agency safeguards have a history of dealing successfully with such problems. Safeguards developers have taken advantage of the long lead times associated with the design and construction of nuclear facilities to develop new safeguards approaches as needed. This has been primarily due to the support provided by Member States through safeguards support programs. In this regard, the IAEA receives significant support from Canada, Euratom, Germany, Japan, Sweden (including with respect to repositories), the United Kingdom, the United States, and others. (See Appendix C, Section C.2.1)

Two historical examples stand out. The commercialization of gas centrifuge technology in the 1970s engendered the Hexapartite Safeguards Project, a collaboration of inspection Agencies and technology holders that reached agreement on the objectives and methods of centrifuge facility safeguards.⁴¹³ Safeguards approaches had to be developed that would be effective in detecting the undeclared production of HEU or the diversion of low-enriched uranium (LEU). In addition, though, the safeguards approaches needed to take into account restrictions on inspector access that flowed from States' concerns about revealing sensitive information to the IAEA.

An analogous effort called the LASCAR project was undertaken to address the safeguards issues at large-scale reprocessing plants created by the combination of large throughput, measurement uncertainties, and short timeliness goal.⁴¹⁴ The result was the development of new and innovative in-line instrumentation. Other types of facilities where technical hurdles have been overcome include fast breeder reactors, where plutonium-based fuel is largely inaccessible, and CANDU

⁴¹² Finland and Sweden have projects for such repositories that would begin operation around 2020.

⁴¹³ The HSP consisted of a series of meetings during 1980-83, whose participants were the United States, Japan, Australia, the IAEA, Euratom, and the URENCO partners (Germany, the UK, and the Netherlands). "The Hexapartite Safeguards Project, a Review by the Chairman," by F. Brown, IAEA-SM-260/57, Vienna (1983).

⁴¹⁴ The Large Scale Reprocessing Plant Safeguards forum met between 1987 and 1992. IAEA, "Report of the LASCAR Forum: Large Scale Reprocessing Plant Safeguards," IAEA, STI/PUB/922, Vienna, 1992.

reactors, where the operations are continuous, fuel assemblies are small, and there is a potential for undeclared movement of fuel into and out of the core to make weapon-grade plutonium.

In light of its sparse resources and R&D capabilities, success by the Agency in developing and implementing solutions to such problems will require both early and consistent cooperation with the IAEA by technology holders and their governments, and by Member-State safeguards support programs that focus their efforts on such issues. Both are important since the IAEA does not have an internal R&D program of significance and must rely on Member States for technology development and transfer.

States and industry should also cooperate with the IAEA to ensure that new facilities reflect the implementation of “safeguards by design.” If this is done, from the beginning, new facilities will incorporate features that facilitate the application of safeguards. For example, by providing space for the installation of IAEA measurement equipment; by enabling the use of shared instrumentation; and by reducing the amount of hard-to-measure inventories. By accommodating safeguards requirements while avoiding retrofits, safeguards by design would be valuable in terms of both effectiveness and efficiency. Safeguards by design has a considerable potential to reduce safeguards costs. Costs to the IAEA could be further reduced if the cost and upkeep of the designed-in features were borne by the State, facility, or the regional or State system of accounting and control.

The importance of early incorporation of safeguards into the design of nuclear facilities has long been recognized. It would require very early, active coordination between industry, State regulatory authorities, and the IAEA. These ideas have studied by the Department of Energy’s Next Generation Safeguards Initiative, and at this writing, the IAEA also has initiated a project to provide design guidance.^{415,416} For new and large, complex facilities, cooperation between the State and IAEA could be a prerequisite for effective and efficient safeguards. Historically, such cooperation has occurred for reasons of policy, and not because it is required by a safeguards agreement.⁴¹⁷

Improvements in efficiency

There will be continuing pressures on the regular budget of the IAEA as well as continuing pressure to reduce inspection effort at declared facilities. The challenge for Member States and the IAEA is to implement safeguards effectively while taking these concerns into account.⁴¹⁸ To date,

⁴¹⁵ Final Report, Third International Meeting on Next Generation Safeguards: Safeguards by Design, December 14-15, 2010, Washington, D.C.

⁴¹⁶ Institutionalizing Safeguards-by-Design: High-level Framework, Volume 1 of 2, Revision 1, Trond Bjornard et. al. February 2009, Idaho National Laboratory, Idaho Falls, Idaho 83415, INL/EXT-14777. <http://www.inl.gov/technicalpublications/Documents/4539403.pdf> (March 15, 2012).

⁴¹⁷ INFCIRC/153 does require that the “Agreement should provide that the Agency and the State shall co-operate to facilitate the implementation of the safeguards provided for therein,” but also speaks of ‘avoid[ing] undue interference in the State’s peaceful nuclear activities, and in particular in the operation of facilities.’ These passages have never been interpreted as allowing the IAEA to dictate facility design.

⁴¹⁸ Not all observers think that the right balance has been achieved. For example, The Report of the Commission of Eminent Persons on the Future of the Agency, GOV/2008/22-GC(52)/INF/4, 23 May 2008, states that “[...] ‘zero real growth’ [...] has long ago cut into the Agency’s ability to carry out its most critical missions ...” See http://www.iaea.org/About/Policy/GC/GC52/GC52InfDocuments/English/gc52inf-4_en.pdf

the latter objective has been accomplished through means such as: remote or unattended monitoring; randomization; sharing work with the SSAC or RSAC; shared instrumentation; and regional offices. The introduction of the Model Protocol and “integrated safeguards” also led to a significant diminution of field effort by relaxation of certain inspection goals.

Some of these are successful because they shift costs from the regular budget of the IAEA to Member States. Another important example is the purchase of safeguards equipment using States’ voluntary contributions. Member States have also funded large capital costs for safeguards infrastructure outside the regular budget, for example, the Agency’s analytical laboratories.

As described above, the IAEA reduces the level of field inspection effort when States have an additional protocol and integrated safeguards in place because of the relaxation in facility goals. While there is not much room for further reductions due to the application of integrated safeguards, the further development of the State-level concept and the implementation of more sophisticated State-level approaches may identify and yield additional efficiencies.

Technical efficiencies will also be important. Efficiencies result from new approaches, techniques, and technology. Data collection, storage, and transmission costs will continue to drop, and the IAEA may be able to increase its reliance on in-field instrumentation that is monitored from Vienna. One concept under investigation is using a more extreme version of its remote-monitoring strategies.⁴¹⁹

Burden-sharing with other nuclear inspectorates has also proven to be an important tool for improving the efficiency of the IAEA’s safeguards implementation. The IAEA has long had inspection-sharing arrangements with RSACs.⁴²⁰ This includes IAEA use of equipment owned and maintained by these organizations and shared inspection duties. Many observers have suggested having regional systems (or even State systems) that assume more of the IAEA’s job. These ideas raise two concerns: one, that the IAEA might give up so much responsibility and presence that its ability to draw independent conclusions is lost; and two, that budgets and policies established by partner organizations will not be stable.⁴²¹

10.2 Safeguards Effectiveness

Improvements in technology or system design do not themselves indicate whether the system is effective. The record to date of the IAEA safeguards system speaks to its effectiveness: no NPT non-nuclear-weapon State subject to safeguards has diverted any meaningful amount of declared nuclear material or significantly misused a safeguarded nuclear facility.⁴²² This speaks well of the IAEA’s abilities and the effectiveness of the comprehensive safeguards system at detecting – or at least deterring – diversions of nuclear material and undeclared activities at declared facilities. This

⁴¹⁹ “Remote inspections” involve a combination of remote monitoring, random short-notice inspections, and the burden-sharing concepts of the next text paragraph. See I. Tsvetkov, et. al., “Remote Safeguards Inspections: Concept and Practicalities,” IAEA-CN-184/211.

⁴²⁰ Euratom and the Brazilian-Argentine Agency for Accounting and Control of Nuclear material (ABACC).

⁴²¹ For example, in the mid-2000s, the European Commission recast the responsibilities and structure of its nuclear inspectorate, causing some conflict with both the IAEA and members of the European Union.

⁴²² Romania reported that it had used a research reactor to produce a few milligrams of plutonium that it had not previously reported to the IAEA. The DPRK failed to make a complete report of its initial inventory of plutonium when its NPT safeguards agreement entered into force.

may be why NPT non-nuclear-weapon States that have sought to pursue unsafeguarded nuclear activities have generally done so through parallel, clandestine programs, not linked to declared activities.

Moreover, the IAEA detected non-compliance in the DPRK, and it used its program of open-source information collection and analysis to detect instances in which two States had failed to report nuclear activities involving nuclear material, albeit small quantities. Even where it did not initially detect safeguards violations in Iraq, Iran, and Syria, the IAEA has proven its value in investigating their undeclared programs and helping to reveal the scope and extent of their nuclear programs.

One might ask, though, whether the measures of success cited above are meaningful. After all, States do not join the NPT and accept comprehensive safeguards in order to deter themselves from diverting.⁴²³ If States do not seek to divert nuclear material or pursue undeclared nuclear programs, and this is certainly true of the vast majority of NPT non-nuclear-weapon States, what is there for the IAEA to find? The absence of IAEA detection of diversion confirms what many observers would think is self-evident: very few non-nuclear-weapon States parties to the NPT seek nuclear weapons.

It is worth re-emphasizing what has been stated elsewhere: IAEA safeguards provide States with confidence that others are adhering to their safeguards commitments. This promotes regional and international stability and facilitates nuclear cooperation. However, it must be recognized that IAEA safeguards are just one element of the nuclear non-proliferation regime. Other elements of the nuclear non-proliferation regime deter the development of clandestine nuclear programs, slow them down, and have, ultimately, detected them. Whether this was made any easier by these States' decisions to avoid safeguards and pursue entirely clandestine programs is not readily answered, but it remains the case that the effectiveness of the IAEA safeguards system should be judged in the context of the performance of the overall system.

With this in mind, is the progress cited above is enough? What should we expect of the IAEA safeguards system in decades to come? During the early years of the IAEA, safeguards were required primarily as a condition of nuclear commerce. In that era, safeguards were only applied to the items transferred under an Agreement for Cooperation, and nuclear cooperation at that time was permitted without any assurances that the recipient would not pursue nuclear weapons. As a result, the level of reassurance that safeguards needed to provide -- that States were not using imported commodities for a nuclear-weapon program -- was relatively low. In addition, it was easy to arrive at a State-level assessment that the financial and technological resources necessary for a nuclear-weapon effort were simply not available to the great majority of States. In any case, Cold War politics made any such ventures even less plausible.

Today, with several developing countries having already embarked on nuclear-weapon programs, it is clear that such an assessment is outdated. Looking to the future, we need to turn the calculation on its head. The high technological and cost barriers have been lowered considerably, and information and sophisticated equipment are widely available. The constraints and security

⁴²³ However, if the domestic politics model, which is described in Sagan's Why Do States Build Nuclear Weapons, is valid, then, the statement above may be literally correct, but the outcome is driven by internal coalitions. He cites Argentina and Brazil as examples of nuclear restraint that emerged in this way.

provided by Cold War alliances have diminished, and the Cold War political structure has been replaced by a multi-polar world afflicted by regional tensions.

The IAEA's technical job becomes larger with the spread of nuclear activities and technology; at the same time, suspicions that States may be moving toward nuclear weapons could feed a self-sustaining calculus that nuclear weapons are achievable and perhaps necessary.⁴²⁴ In this context the level of reassurance that States expect of the safeguards system has risen and might rise further. Thus, the role of safeguards in reducing regional and international tensions could become more significant.

10.3 Political Challenges

10.3.1 Non-compliance

One of the challenges that the IAEA must be prepared for is the discovery of a significant diversion of nuclear material or the discovery of significant undeclared nuclear activities in a State where the Agency had recently made the “broader conclusion” about non-diversion of declared nuclear material and the absence of undeclared nuclear material and activities. To date, no such diversions have been detected, and where undeclared nuclear activities have been discovered, the States in question were not parties to an additional protocol. In 1991, when Iraq’s clandestine nuclear-weapon program was discovered, criticism of the Agency was muted because of its prompt efforts to strengthen the safeguards system and because of the perception that any failures were on the part of Iraq. The IAEA, it was generally agreed, lacked the authority to detect Iraq’s secret program.

This may not be the case today, depending, of course, on the nature of the diversion and the extent to which the non-compliant activities took place in the context of declared activities or were entirely unconnected. Reactions may also depend on the extent to which the IAEA is clear about the basis for its conclusions and does not overstate their strength.

If such events were to occur, though, caveats made about the Agency’s findings might be of little value to the public perception that the Agency had failed. While such a result would be harmful to the Agency, the key consideration would be whether Member States understand, and find reasonable, why the Agency did not detect non-compliance. In addition, the Agency would have to be seen as having a credible plan to address needed changes.

Another concern related to non-compliance is that the IAEA as an institution is ill-suited to deal with it promptly and effectively. For example, Iran’s undeclared program was revealed in 2002, but it was not referred to the United Nations Security Council until 2006 (see United Nations Security Council Resolution 1696). It then took another ten years before agreement was reached on an arrangement, the JCPOA, that rolled back Iran’s nuclear capabilities and made it more difficult for it to acquire a nuclear weapon in the near term.

⁴²⁴ Op. cit., Commission of Eminent Persons (2008); it warned, quoting the United Nations High-level Panel on Threats, Challenges, and Change, “We are approaching the point at which the erosion of the non-proliferation regime could become irreversible and result in a cascade of proliferation.”

Clearly, the founders of the IAEA safeguards system did not foresee how the complicated interactions, including technical and political, between the inspectors and the Director General, the IAEA Board of Governors, the United Nations Security Council and Member States would lead to such protracted discussions. The fact that the Board was unable to reach a consensus and had to vote on resolutions concerning Iran's non-compliance may also contribute to the perception of the IAEA's political ineffectiveness. However, the IAEA is playing an important role in implementation of the JCPOA, as described above. This is indicative of States' confidence in both the technical competence of the IAEA and its unbiased approach to verification.

Non-compliance by Syria illustrates a similar pattern. Israel destroyed its clandestine reactor 2007, one that Syria had failed to report to the IAEA. Syria then delayed giving the IAEA access to the site. Afterwards, the Director General reported to the Board of Governors that Syria was in breach of its safeguards obligations. Nonetheless, the decision by the Board of Governors to find Syria in non-compliance and report it to the United Nations Security Council was taken by a vote of seventeen in favor with six against and eleven abstentions. As of mid-2017, Syria has been able to put off IAEA efforts to satisfactorily resolve Agency concerns about the reactor.^{425,426}

Both cases illustrate how the transformation of the political dynamic in Vienna referred to in Chapter 3 has made it difficult to obtain what might seem to be a straightforward outcome: that safeguards violations be uniformly condemned and every effort be made to convince States to come into compliance. Of course, the same inability to act firmly may also be seen within the United Nations Security Council, so these difficulties should not be considered as indicative of a particular failing of the IAEA. Nonetheless, the IAEA is considered to be a technical agency, and the United Nations Security Council is by its nature a political body, thus leading, perhaps, to more criticism of the Agency for the same factors. There are no simple or easy answers to the lack of political will.

10.3.2 Middle East

As in other international forums, meetings of the IAEA serve as a platform for criticism of Israel by States in the Middle East. In this context, the fact that Israel is not a party to the NPT, whereas all other States in the Middle East are, provides a salience to the criticism that might otherwise be lacking.⁴²⁷ On the other hand, Israel is not the only member of the IAEA that is not a party to the NPT. India and Pakistan are not NPT parties, but criticism of these States is conspicuously absent. Israel's unwillingness to accept full-scope safeguards is also cited, by Egypt especially, as a reason not to adopt additional safeguards requirements, for example, the Model Protocol.

While States inside the region are inclined to focus publically on Israel's failure to join the NPT, many Arab States might well feel more threatened by the fact of a nuclear-weapon program in Iran

⁴²⁵ The IAEA Board of Governors found Syria to be in non-compliance with its safeguards agreement in June 2011. The text of the Resolution, GOV/2011/41, is at

<http://www.iaea.org/Publications/Documents/Board/2011/gov2011-41.pdf>.

⁴²⁶ Despite the unrest in Syria, the IAEA has been able to conclude that declared nuclear material has not been diverted. Its conclusions are based on Syria's cooperation in providing information and access for inspections, as feasible.

⁴²⁷ Israel has a safeguards agreement with the IAEA that covers a small research reactor.

than they do by Israel. Not surprisingly, States outside the region are more likely to focus on continuing issues surrounding safeguards violations by Iran and Syria.

The impact of the “Arab spring” that began in 2011 is difficult to anticipate. It might lead to some lessening of these criticisms, but it might well be otherwise. For most States in the Middle East their belief that Israel possesses nuclear weapons, even if not a violation of any of Israel’s obligations, is likely to remain an important feature of their public diplomacy.

10.4 Beyond Safeguards

The future may hold new verification roles for the IAEA, some more challenging than others. The 20/20 Report⁴²⁸ notes that the Statute “directs the Agency to conduct its activities ‘in conformity with policies of the United Nations furthering the establishment of safeguarded worldwide disarmament.’” It goes on to say that the Agency may be called on to assist in the verification aspects of nuclear disarmament. The bilateral agreements that have typified nuclear reductions to date will, over time, need to include other nuclear-weapon States and require multilateral verification arrangements. The subsequent “Eminent Persons Report” has as one of its recommendations: “Verification of nuclear arms reductions should be international, to give all States, not just the United States and Russia, confidence that reductions are being carried out as agreed.”⁴²⁹ Both reports mention a potential IAEA role in verification of excess material, the Trilateral Initiative, and the Fissile Material Cutoff Treaty. To this list should be added the Plutonium Management and Disposition Agreement.

10.4.1 IAEA verification of material unilaterally declared excess to weapon programs by nuclear-weapon States

Provided that the legal and financial aspects of the activity can be resolved and provided the material in question is not in classified forms, there is no real difficulty for the IAEA in monitoring excess nuclear-weapon material. In fact, the IAEA does this currently in the United States, where a large quantity of plutonium that came from the U.S. nuclear-weapon program is under IAEA containment and surveillance at the Savannah River Site in South Carolina. The United States covers the cost of this through its voluntary contributions to the IAEA. However, the legal framework for this activity is the U.S.-IAEA voluntary-offer safeguards agreement, which gives the United States the legal right to withdraw this material from safeguards.⁴³⁰

10.4.2 The Trilateral Initiative

The Trilateral Initiative was launched in 1996 by the United States, the Russian Federation, and the IAEA.⁴³¹ The key technical question was how to provide IAEA inspectors with confidence in the nature of the material being submitted without revealing *classified* information. Any conventional measurement technique, such as gamma spectroscopy, would in fact reveal such

⁴²⁸ “20/20 Vision for the Future,” IAEA, February 2008; available as annex to the next cited document.

⁴²⁹ Op. cit., Commission of Eminent Persons (2008) May

⁴³⁰ INFCIRC/288 (1980).

⁴³¹ T. Shea, “Report on the Trilateral Initiative,” IAEA Bulletin, 43/4/2001.

information. The approach taken was to identify certain *unclassified* attributes of the material and create a measurement device incorporating an “information barrier” that would reveal only those attributes to an inspector. The task of creating such a device in which both sides, simultaneously, have confidence (the inspector that the device is producing valid answers, and the State that the device cannot reveal classified information) is very difficult, but prototype devices were built and tested, and considerable progress was made. Despite this progress, the parties did not move forward to conclude a legal framework, build IAEA-approved instruments, or place material under IAEA monitoring.

The parties’ work concluded in 2002. The IAEA press release 2002/13 at the close of the exercise stated, “The parties concluded that the task entrusted to the Trilateral Initiative Working Group in 1996 has been fulfilled. The work completed has demonstrated practical approaches for IAEA verification of weapon-origin fissile material designated as released from defense programs in classified forms or at certain sensitive facilities. The work included the examination of technical, legal and financial issues associated with such verification.” The work was aimed at establishing a framework under which the United States and Russia could place weapon-origin material under irreversible monitoring without having to take the potentially time-consuming and expensive processing steps that eliminate all classified information from the material.

10.4.3 The Fissile Material Cutoff Treaty

A fissile material cutoff treaty (FMCT) was proposed by then President William Clinton in a United Nations General Assembly speech in 1993. The most widely accepted description of such a treaty is contained in a report to the Conference on Disarmament by Canadian Ambassador Gerald Shannon in 1995.⁴³² It describes “a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices.” Since then, there has been widespread international support for the negotiation of such a treaty, including repeated endorsement of such negotiations by NPT review conferences. However, for over 15 years the Conference on Disarmament has been unable to reach the consensus necessary to begin formal negotiations on an FMCT.⁴³³ The best that can be said at this writing is that the prospects for beginning, or completing, an FMCT are dim.

There is thus no agreed text of an FMCT, and there is a wide divergence of views internationally on the basic definitions; on whether the FMCT should address pre-existing stocks of fissile material or only future production; and on exactly what role the IAEA would play in verifying an FMCT.⁴³⁴

It is clear that most versions of an FMCT would require, at a minimum, a verification regime - very much resembling IAEA safeguards - to assure that newly produced fissile material is not

⁴³² Report of Ambassador Gerald E. Shannon of Canada on Consultations on the Most Appropriate Arrangement to Negotiate a Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices, CD/1299, 24 March 1995.

⁴³³ Negotiations did take place for about two weeks in 1998, the year that economic sanctions were imposed on India and Pakistan after they tested nuclear weapons. The most recent roadblock has been the refusal of Pakistan to join consensus on any program of work containing such negotiations.

⁴³⁴ A good review of the issues may be found at <http://www.fas.org/programs/ssp/nukes/armscontrol/bragin.pdf>.

diverted to use in weapons. The IAEA is the most likely candidate for that role.⁴³⁵ If this were to come to pass, the impact on the IAEA would be considerable. The FMCT verification task has been estimated as being comparable to or even considerably larger than the NPT safeguards task.⁴³⁶

⁴³⁷ For non-nuclear-weapon States, existing safeguards would likely be considered adequate, but safeguards are not applied generally to the extensive fissile-material production facilities of nuclear-weapon States, whereas FMCT verifications would be.

As noted above, the IAEA has historically had the luxury of being able to increase its safeguards effort and introduce new technology gradually, in line with the predictable growth of fuel cycle facilities in the non-nuclear-weapon States; the FMCT task would hit all at once. Whereas NPT safeguards have in many instances been designed into large processing facilities, FMCT verification for many production facilities in the five nuclear-weapon States plus the de facto weapon States would have to be retrofitted.

Aside from inspection challenges, an FMCT would require solving a number of institutional questions regarding the relationship of the IAEA to the new treaty regime. The FMCT might well require, for example, a separate FMCT budget, or an executive organization (comparable to the Organization for the Prohibition of Chemical Weapons or the Comprehensive Test Ban Organization) to set policy and address issues of non-compliance. It is unclear how that organization would relate to the Board of Governors (to whom the Secretariat reports) or how the FMCT budget could be incorporated into the IAEA budget. Whatever the solution, the resulting IAEA would be a much larger, and more complex institution.

10.4.4 The Plutonium Management and Disposition Agreement

The U.S.-Russia Plutonium Management and Disposition Agreement (PMDA) from the year 2000 commits each side to the disposition (e.g., burning in reactors) of at least 34 metric tons of surplus weapons plutonium.⁴³⁸ The PMDA was significantly modified by a 2010 protocol, which allows Russia to use fast-neutron reactors instead of LWRs to burn the plutonium. The United States planned to make mixed oxide fuel at the Savannah River site in South Carolina and burn the plutonium in LWRs. However, construction of the plant has been delayed, and, according to a

⁴³⁵ For an example of such a regime see: V. Bragin, and J. Carlson, "An Introduction to Focused Approach to Verification under FMCT," JNMM, Winter 2000. In addition, a valuable discussion of verification alternatives and the way the structure of an FMCT could impact verification arrangements is found in, J. Carlson Defining the safeguards mission, Paper presented to IAEA Safeguards Symposium, Vienna, 16-20 October 2006.

⁴³⁶ See 'A Cut-off Treaty and Associated Costs: An IAEA Secretariat Working Paper on Different Alternatives for the Verification of a Fissile Material Production Cut-off Treaty and Preliminary Cost Estimates Required for the Verification of These Alternatives,' presented at the Workshop on a Cut-Off Treaty, Toronto, Canada, 17-18 January 1995.

⁴³⁷ Dougherty, et al., Routine Inspection Effort Required for Verification of a Nuclear Material Production Cutoff Convention, Brookhaven National Laboratory Report BNL-63744, SSN-96-14, 1996, <http://www.ost1.gov/bridge/servlets/purl/434426-5ZaqAm/webviewable/434426.pdf>.

⁴³⁸ See, for example,

<http://www.state.gov/r/pa/prs/ps/2010/04/140097.htm> and <http://dtirp.dtra.mil/tic/synopses/pmda.aspx>.

2016 report by the Department of Energy, the total project cost was estimated at \$17.17 billion with a projected completion date of 2048.⁴³⁹

The PMDA has verification provisions to provide confidence that the subject plutonium is being disposed of as called for in the Agreement. While these can be bilateral, the 2010 protocol states that the sides “shall begin consultations with the International Atomic Energy Agency (IAEA) at an early date and undertake all other necessary steps to conclude appropriate agreements with the IAEA to allow it to implement verification measures with respect to each Party’s disposition program.” In August 2010, the United States and the Russian Federation made this request to the IAEA Director General. Such a verification agreement has not been concluded. In October 2016, Russia’s President Putin suspended implementation of the agreement citing, among other factors, “the unfriendly actions of the United States toward the Russian Federation” and the “inability” of the United States to fulfill its plutonium disposition.”⁴⁴⁰

⁴³⁹ 2016 Updated Performance Baseline for the Mixed Oxide Fuel Fabrication Facility at the Savannah River Site https://nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/2016_updated_performance_baseline_for_mox.pdf (accessed 21 Mar 2018)

⁴⁴⁰ International Panel on Fissile Materials, http://fissilematerials.org/blog/2016/10/russia_suspend_implement.html (accessed 21 Mar 2018)

APPENDIX A. Technical Basis for Nuclear Explosions

This Appendix describes the technical basis for nuclear weapons. Why do they work and what are they made from? Section A.1 notes that all nuclear weapons currently deployed are manufactured from highly enriched uranium (HEU)⁴⁴¹ or weapon-grade plutonium that has high levels of the isotope Pu-239.⁴⁴² From the perspective of IAEA safeguards, this clearly makes these materials the most significant, especially when they are in forms from which nuclear weapons can most readily and quickly be made. They have the shortest timeliness goals and the highest detection goals. (The forms of uranium or plutonium separated from fission products are called by the IAEA “unirradiated direct-use material.” When the same materials are contained in reactor fuel that has been irradiated, they are called, “irradiated direct-use material.”)

Two issues about the technical basis for nuclear weapons are addressed in Section A.2.

The first issue is whether there are elements other than uranium and plutonium that could be used to manufacture a nuclear weapon? If so, then how should the safeguards system respond to what might be a proliferation threat that is not covered by IAEA safeguards? It turns out that the answer to the first question is yes. Materials other than nuclear material (uranium and plutonium) can form the basis for the manufacture of nuclear explosive devices. The relevant materials are americium and neptunium. Section A.2.1 describes how the risk of an emerging proliferation threat from these elements was addressed by the IAEA.

With respect to the NPT, itself, the issue is primarily a verification issue. The NPT requires safeguards only on nuclear material, but if a non-nuclear material could be used to make nuclear weapons, the non-proliferation obligations in the Treaty still apply. For example, Treaty obligations that prohibit non-nuclear-weapon States from manufacturing – or nuclear-weapon States from transferring – nuclear weapons and other nuclear explosive devices prohibit these activities regardless of whether or not the nuclear weapon or nuclear explosive device is made from nuclear material.

The second issue relates to whether the isotopic form of plutonium affects the ability to use it for the manufacture of a nuclear weapon. Since States with nuclear weapons have all chosen to use weapon-grade plutonium, perhaps the plutonium created in power reactors that is not weapon-grade could not be used in a nuclear weapon. If this were so, then the safeguards significance of these forms of plutonium might be lower than for weapon-grade material. Many observers have argued that this should be so.

This issue is addressed in Section A.2.2. This section quotes from a U.S. Department of Energy document, “Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material

⁴⁴¹ Uranium is defined as high enriched uranium by the IAEA when the ratio of the isotope U-235 to the isotope U-238 is greater than or equal to 20%. In the context of nuclear weapons, the phrase “highly enriched uranium” is often used to describe uranium where the U-235 fraction is 80% or more.

⁴⁴² Weapon-grade plutonium has less than 7% of the isotope Pu-240; fuel-grade plutonium between 7% and 19% Pu-240, and power reactor-grade plutonium has 19% or more Pu-240. See, DOE/PP-0137 (196) Plutonium: The First 50 Years. United States Plutonium Production, Acquisition, and Utilization from 1944 to 1994.

<http://www.doeal.gov/SWEIS/DOEDocuments/004%20DOE-DP-0137%20Plutonium%2050%20Years.pdf>.

Storage and Excess Plutonium Disposition Alternatives.”⁴⁴³ Its conclusion is, “Virtually any combination of plutonium isotopes – the different forms of an element having different numbers of neutrons in their nuclei – can be used to make a nuclear weapon. Not all combinations, however, are equally convenient or efficient.”

As a result of this conclusion, the implementation of IAEA safeguards is the same for all combinations of plutonium isotopes except where the concentration of Pu-238 exceeds 80%. Plutonium with this combination of isotopes is exempted from safeguards because of the judgment that its very high rate of neutron emission and heat generation makes its use for nuclear weapons implausible.

A.1 What makes a nuclear weapon?

The essential and the most difficult step in making a nuclear weapon is to acquire the materials necessary to create a nuclear explosion. These so called *fissile materials*⁴⁴⁴ are defined by their ability to sustain a nuclear *chain reaction*, which is the mechanism by which the explosion’s energy is generated. The two fissile materials used in all nuclear weapons currently deployed⁴⁴⁵ are HEU and weapon-grade plutonium. In this section we will explain why these two materials have the properties they do, how they are used in weapons, and the nuclear fuel cycle in which they are produced.⁴⁴⁶

Atoms, nuclei and isotopes

The subject of fissile materials begins with the neutron, which was discovered by the British physicist James Chadwick in 1932. Physicists had suspected for some years that such a particle must exist in order to explain the properties of the atomic nucleus. Since 1914, they had understood that virtually all the mass and positive charge of an atom is concentrated in a tiny volume at the atom’s center, with the very light electrons occupying various “orbits” in the space around the nucleus. The simplest atom is hydrogen, of which the nucleus is a single positively charged particle, a proton; a single negatively charged particle, an electron, occupies the space around the proton. It was the simplicity of this atom that allowed Niels Bohr to make the first successful use of quantum mechanics to compute the energy levels of the hydrogen atom.⁴⁴⁷

⁴⁴³ This document, DOE/NN-0007 of January 1997, is at <http://www.osti.gov/bridge/servlets/purl/425259-CXr7Qn/webviewable/>.

⁴⁴⁴ Isotopes that undergo fission by neutrons of all energies, including slow (thermal) neutrons, are usually referred to as fissile materials or fissile isotopes. For example, isotopes U-233, U-235, Pu-239, and Pu-241 are referred to as both fissionable and fissile, while U-238 and Pu-240 are fissionable but not fissile.

⁴⁴⁵ We will discuss only weapons based on nuclear fission in this section. Another class of weapons, based on nuclear fusion – usually called “hydrogen bombs” – are extremely important. But they are far more technically sophisticated and difficult to make than fission weapons, and they have always been second or third generation designs that depend on mastering the manufacture of fission weapons. Therefore, from the point of view of non-proliferation and safeguards, fission weapons are far more important.

⁴⁴⁶ Since this is not a physics textbook, it does not provide references for the original works cited here about the underlying nuclear physics.

⁴⁴⁷ A good description of the people and the history of the creation of nuclear weapons is *The Making of the Atomic Bomb*, by Richard Rhodes (Simon & Schuster, 1986).

Physicists knew that there were protons in all nuclei, and the chemical properties of the elements as displayed in the periodic table made it clear that atoms -- helium, lithium, beryllium, etc., all the way up to uranium -- have integral numbers of protons and electrons -- two for helium, three for lithium, four for beryllium, etc., up to 92 for uranium. What was not clear was what holds the nucleus together and what makes up the masses of the nuclei, which do not match the mass of the protons alone. For example, the mass of the helium atom is not twice the mass of hydrogen, but four times as much. The heaviest element then known, uranium, has 238 times the mass of hydrogen. It was clear that there had to be something else in the nucleus that is at least as massive as the protons.

Another reason to believe that there had to be other components of the nucleus was the remarkable fact that so much electric charge is packed into such a small volume. All protons have positive charge, and positive charges repel each other with a force that is inversely proportional to the square of the distance between them. It was known that the diameter of the nucleus is approximately 10,000 times smaller than the diameter of the atom⁴⁴⁸, which would make the average repulsive force between protons about 100 million times stronger than the attractive forces holding the electrons in orbit. What holds all those protons together so tightly?

So, Chadwick did not just stumble on the neutron – he was looking for it. What he found was a particle that has a mass roughly equal to that of the proton but no electric charge. Physicists immediately inferred that the neutron must be a constituent of the nucleus and that there must be a previously unknown, and very strong, attractive force between protons and neutrons. Now they could explain both the atomic masses and why atomic nuclei are stable. For example, helium must have two neutrons as well as two protons, which explains why it is four times as heavy as hydrogen; lithium must have four neutrons holding together its three protons to give it an atomic mass of seven; and so forth up to uranium, which must have 146 neutrons holding together its 92 protons.

The neutron also helped to explain other puzzling features of atoms. One was that atomic masses were not always simple integer multiples of the hydrogen atomic mass. For example, the atomic mass of iron is 55.85 times the mass of hydrogen, and copper's atomic mass is 63.55 times that of hydrogen. The most reasonable way to explain this (without postulating fractional neutrons) is to suggest that nuclei of a given element can be stable as different *isotopes*, of which the chemical properties (determined by the number of protons and electrons) are very similar, but such that the nuclei of different isotopes contain different numbers of neutrons. For example, copper (29 protons) exists in nature as two stable isotopes: 69.2% Cu-63 (34 neutrons) and 30.8% Cu-65 (36 neutrons). Most important for our purposes is the element uranium, which is found in nature in two major isotopic forms: 0.71% U-235 (143 neutrons), and 99.29% U-238 (146 neutrons).⁴⁴⁹

But the existence of isotopes explains only part of the atomic mass puzzle. The other part is explained by the equivalence between mass and energy as expressed in Albert Einstein's famous equation $E=mc^2$. To see how this enters into the atomic-mass calculation, imagine that we could

⁴⁴⁸ The volume of the nucleus is only one trillionth (10^{-12}) the volume of the atom. Their relationship has been compared to that of a fly in a cathedral. (Brian Cathcart, *The Fly in the Cathedral: How a Group of Cambridge Scientists Won the International Race to Split the Atom*, Farrar, Straus and Giroux, 2004).

⁴⁴⁹ Natural uranium also contains a very small amount of U-234, 0.0054%, but this isotope has no weapons or energy significance.

take a U-238 nucleus completely apart into individual protons and neutrons and move all of the particles far away from one another so that they no longer feel one another's forces. The total mass of the configuration would now be just the sum of the masses of all 238 constituents. Now let us start moving the particles closer together to reassemble the nucleus. As the protons approach one another their mutually repulsive electric forces cause the potential energy of the assembly to increase, just as applying a force to lift a rock off the ground increases its potential energy. But as the neutrons come together they exert a strong, mutually attractive nuclear force which lowers the potential energy of the assembly, just as letting the earth pull the rock back down lowers its potential energy. (Here and in the next section we are oversimplifying the actual situation to ease understanding. In fact, the protons all contribute to the mutually attractive nuclear force as well.)

The net effect of these two energy changes will not be exactly zero; in fact, if the nucleus is to be stable the negative potential energy created by the attractive forces must be greater in magnitude than the positive potential energy created by the repulsive forces. In other words, the net potential energy of a stable nucleus will be less than zero, i.e., less than what it was when the particles were all infinitely far apart. This negative potential energy results in a "mass defect," defect because the mass of the assembled nucleus is smaller than the sum of the masses of the separated particles. In general, the mass of a stable nucleus will always be slightly less than the sum of the masses of its constituents. This difference is typically quite small in percentage terms; in the case of U-238 it amounts to a difference of less than two proton masses out of 238, i.e., less than one percent of the nuclear mass.

But two proton masses multiplied by the square of the speed of light using Einstein's formula $E=mc^2$, is an enormous amount of energy compared to the energy changes made by electrons in chemical reactions. The large amounts of energy associated with the nucleus had already been noticed in the study of **radioactivity**, which is energy released when atomic nuclei emit particles and undergo structural rearrangements. From the very beginning of the study of radioactivity, physicists were struck by the huge difference between chemical and nuclear energy releases, and many began to wonder how such enormous energy releases might be controlled and used for either peaceful or military purposes. In 1914, long before the discovery of the neutron and nuclear physics, H.G. Wells wrote a novel called *The World Set Free* in which he imagined the creation of "atomic bombs" and the effect these might have on war between great powers. Twenty-one years later, after the discovery of the neutron, the Hungarian physicist Leo Szilard was inspired by Wells's novel to imagine and then patent (secretly) the concept of a nuclear chain reaction, which might be the foundation for a nuclear bomb. Szilard's idea was to find a nuclear reaction in which a nucleus absorbs one neutron and then releases energy and two neutrons. At the time he did not have a particular mechanism in mind, but the discovery of **nuclear fission** late in 1938 made plausible that Szilard's idea could, in fact, be realized.

Nuclear fission

In 1936, Niels Bohr formulated the first working theoretical model of a nucleus containing protons and neutrons. Bohr looked at a heavy nucleus in which the number of protons and neutrons is large and noted that it should behave very much like a drop of liquid in which an attractive force keeps the molecules close together. Bohr's **liquid drop model** was quite successful in accounting for many of the measurable properties of nuclei, such as their mass and size.

When nuclear fission was discovered in December of 1938, Bohr was shocked and embarrassed that he had not predicted it. As soon as he learned about fission he realized that the liquid drop model was the perfect tool for understanding it, and, in collaboration with the American physicist John Wheeler, he wrote two important papers using his model to explain fission. The key to understanding the mechanism of fission is that the attractive force provided by the neutrons and protons, while stronger than the repulsive electric force between the protons, is of much shorter range. So, each proton is repelled by all the other protons in the nucleus but attracted by the neutrons and other protons in its immediate vicinity. This is why the ratio of neutron number to proton number must increase as nuclei get larger. Only a limited number of neutrons and protons can be within a short distance of a given proton, so as the nucleus gets bigger the repulsive force of all the other protons begins to approach the attractive force of the few neighboring neutrons. When the nucleus is large enough, in particular when it is uranium, the attractive and repulsive forces are very nearly balanced and the addition of only a small amount of energy can cause the nucleus to become unstable and break apart.

This is what happens in nuclear fission. The absorption of a single neutron into the uranium nucleus adds just enough energy to create oscillations of the liquid drop, just as dropping a small pebble into a glass of water causes ripples on the surface of the water. On the surface of a drop, these ripples appear as distortions of the shape of the drop, and these distortions upset the delicate balance between the short-range attractive forces and the long-range repulsive forces. The nucleus becomes unstable and breaks up into two (occasionally more than two) large pieces. These pieces then repel each other with tremendous force because the mutual repulsion of the protons is no longer balanced by the attractive force of the neutrons and protons. The two pieces (called *fission fragments*) fly apart with great kinetic energy. It is this kinetic energy that constitutes the major portion of the energy released by nuclear fission.

Because the fragments have so much electric charge (each one has approximately half the charge of the uranium nucleus), and because they start out so close together (remember that the original nucleus is 10,000 times smaller than an atom) the kinetic energy released in fission is roughly 20 million times what is released in a typical chemical reaction. So, the fissioning of a kilogram of uranium (about the size of a golf ball) releases as much energy as the detonation of 20 million kilograms (20 kilotons) of high explosives (about 200 rail cars packed with TNT).⁴⁵⁰

Besides creating two very energetic fission fragments, nuclear fission also liberates a number of free neutrons, making it the perfect answer to the question originally posed by Szilard. In the months after the announcement of the discovery of fission in early 1939, physicists all over the world understood the significance of this fact and began to think about how energy might be generated by creating a nuclear chain reaction, in which a single fission creates more fissions and the energy release grows exponentially. More experiments established that the average number of neutrons released in a uranium fission reaction is about 2.3. So, in principle, the reaction can more than double itself in each “generation,”⁴⁵¹ leading to a very rapidly (exponentially) growing energy release, i.e., an explosion. It was also clear that if one could somehow control the neutrons so that

⁴⁵⁰ The mass of a single uranium atom is approximately equal to the mass of a TNT (tri-nitro toluene) molecule.

⁴⁵¹ A generation is defined as the elapsed time between the fissioning of a nucleus and the absorption of a neutron created in that fission by another nucleus.

only one of the neutrons created in each generation led to a fission in the next generation, one could create a controlled, steady release of energy, i.e., a nuclear reactor.

Two other important discoveries were made shortly after the discovery of fission. One was Bohr's insight that it was the U-235 isotope that fissioned on absorption of a neutron and not the U-238 isotope. But, as noted above, U-235 makes up only about 0.7% (one atom out of 140) of naturally occurring uranium. U-238 makes up the other 99.3% but is not easily fissioned. This meant that if one wanted to create a chain reaction, especially a rapid explosive one, it would be necessary to separate the two isotopes and substantially concentrate the U-235. But separating isotopes is very difficult, especially in large quantities, and scientists realized that it could be achieved only with a major industrial effort.

Such an effort during wartime (World War II started in September 1939) seemed to many (in Germany, Japan, the Soviet Union and Great Britain in particular) to be out of the question. Only the United States, with its substantial financial and scientific resources and its safety from aerial attack, could consider undertaking such an effort. The United States succeeded in enriching just enough uranium to about 80% U-235 to make the bomb that destroyed Hiroshima. But this required the construction of a huge industrial facility near Oak Ridge, Tennessee that cost well over a billion dollars (a lot of money in 1945!). By the end of World War II, it was using more than 10% of all the electricity generated in the United States.

The other discovery was made primarily by Glenn Seaborg's group at the University of Chicago, namely that when U-238 absorbs a neutron, it becomes U-239, and the U-239 undergoes a relatively rapid radioactive transformation in which a neutron transforms into a proton, releasing an electron. This process is called ***beta decay*** and it occurs in many radioactive nuclei. When it happens in U-239, the product is a new element (atomic number 93) that the physicists called neptunium after Neptune, the next planet beyond Uranus (for which uranium was named when it was first discovered in 1789).

But neptunium-239 (Np-239) also undergoes a rapid beta decay and becomes another new element (atomic number 94), named, not surprisingly, plutonium. The Bohr-Wheeler model, along with some other subtler properties of large nuclei, predicted that Pu-239 (which is nearly stable and does not rapidly decay) should behave very much like U-235 when it absorbs a neutron. This suggested that there might be another path to a nuclear bomb: the extra fission neutrons in a reactor fueled by natural uranium could be used to produce plutonium, which, because it is a different element with a different chemistry from uranium, should be relatively easy to separate from uranium.

In summary, from the earliest stages of the U.S. atomic bomb project, it was understood that for this purpose, there were two priority paths for producing fissile material: one was to concentrate the U-235 isotope from natural uranium (***enrichment***) and the other was to irradiate natural uranium in a reactor to produce Pu-239 and then chemically separate the plutonium from the

irradiated fuel (*reprocessing*). It remains the case, 70 years later, that these two choices have been the only ones selected by other States as the practical basis for a nuclear-weapon program.^{452,453}

The chain reaction and nuclear weapons

To create a nuclear explosion, one must rapidly assemble a ***critical mass*** of fissile material and ***initiate*** the chain reaction with a burst of neutrons.⁴⁵⁴ Both of these things are difficult to do and will typically take a country several years to master. Yet they are still easier to accomplish than it is to produce the fissile materials themselves.

Just how rapidly one must assemble the critical mass can be seen by examining a model chain reaction. Suppose that each fission produces two neutrons that cause fissions in the next generation. These neutrons travel at high speeds (on the order of one-tenth the speed of light), and the density of fissile material is very large, so the neutrons will usually encounter another fissile nucleus in a very short time (typically about ten nanoseconds or one hundred millionth of a second). To fission a kilogram of uranium or plutonium requires about 80 generations (2^{80} or 10^{24} fissions), which takes a total time of about 800 nanoseconds, or just under a microsecond.

In other words, the entire reaction, which can release an energy equivalent to twenty thousand tons of TNT, is started and completed in less than a millionth of a second. The critical mass must be held together at least as long as this, and the initiating burst of neutrons must be generated at precisely the time when the density is maximum with a tolerance of a small fraction of a microsecond. The result is the release of energy equivalent to that in 200 freight cars full of high explosives in a volume about the size of a grapefruit in a time less than a microsecond. The resulting temperature inside the volume is hundreds of millions of degrees, much hotter than the interior of the sun, and the pressure reaches tens of billions of atmospheres. The principal effects of the explosion are therefore an intense burst of electromagnetic energy (mainly light and heat) and a powerful shock wave. The combination of heat and shock can level buildings out to more than a mile and set fire to anything flammable well beyond that range.

The designers of the first nuclear weapons thought of two ways of rapidly assembling the critical mass. One is to put two subcritical pieces of fissile material inside a gun barrel and fire one of them into the other just like a shell is fired from a cannon. This so-called ***gun-type*** weapon was

⁴⁵² There are other possibilities because elements or isotopes other than U-235 and Pu-239 could be used to make a nuclear explosive device, e.g. U-233, neptunium, and americium. (See “Advanced Emerging Nuclear Measurements – Sensitivity Analysis, Safeguards Problems and Proliferation Risk,” Jared S. Dreicer, Los Alamos National Laboratory at <http://www.osti.gov/bridge/servlets/purl/759168-VdrFoj/webviewable/759168.pdf>.) But each of these elements poses difficulties for use in a nuclear-weapon program, either because of its relatively high radioactivity or its difficulty of production.

⁴⁵³ Jungmin Kang and Frank N. von Hippel, U-232 and the Proliferation-Resistance of U-233 in Spent Fuel, *Science & Global Security*, Volume 9 pp 1-32, March 2001. http://www.torium.se/res/Documents/9_1kang.pdf.

⁴⁵⁴ According to the Federation of American Scientists, “The minimum mass of fissile material that can sustain a nuclear chain reaction is called a critical mass and depends on the density, shape, and type of fissile material, as well as the effectiveness of any surrounding material (called a reflector or tamper) at reflecting neutrons back into the fissioning mass. Critical masses in spherical geometry for weapon-grade materials are as follows:

	Uranium-235	Plutonium-239
Bare sphere:	56 kg	11 kg
Thick Tamper:	15 kg	5 kg”

<http://www.fas.org/nuke/intro/nuke/design.htm>.

the type dropped on Hiroshima. Another way to assemble a critical mass is to surround a spherical mass of fissile material with a symmetrical array of high explosives, so that when the explosives are detonated a spherically symmetric converging shock wave is generated (*implosion*) that squeezes the fissile material into a much smaller sphere with much higher density. Since the shock wave travels even faster than an artillery shell, and since the critical mass is smaller in the implosion design than in the gun-type design, the assembly of the critical mass is much faster, and implosion weapons are typically much more efficient (i.e., they use less fissile material) than gun-type weapons. The Manhattan Project discovered that because some isotopes of plutonium undergo *spontaneous fission* (i.e., they can fission even without absorbing a neutron), the gun-type assembly is too slow for plutonium and only works for uranium. Implosion works for both materials but is more difficult to design and accomplish successfully. It was an implosion design using plutonium that was first tested near Alamogordo, New Mexico in July 1945 and dropped on Nagasaki in August.⁴⁵⁵ These two basic designs of fission weapons remain the only ones in use today.

A.2 What material can be used to make a nuclear weapon?

A.2.1 *Proliferation potential of americium and neptunium*

In the late 1990s, the IAEA Board of Governors was confronted with an emerging nuclear proliferation issue. Board Members had been aware for some time that the manufacture of a nuclear explosive device from the elements neptunium (Np) and americium (Am) posed a potential proliferation risk.⁴⁵⁶ Any risk of proliferation using these materials was mitigated because they were available only in spent fuel or otherwise only in very small amounts. Almost all of it existed in spent fuel from power reactors. Even where the fuel was reprocessed to separate the plutonium and uranium, essentially all of the Np and Am remained in waste and was disposed of. By the 1990s, though, consideration was being given in a number of places to separation of these elements from the waste in order to improve waste management.⁴⁵⁷

This posed the problem that nuclear-weapon-usable materials would become available in the civil nuclear fuel cycle without controls. If a non-nuclear-weapon State used them to manufacture a nuclear explosive device, it would be a violation of the NPT. Yet these materials were outside the scope of safeguards. Why? Because the NPT calls for safeguards to be applied by the IAEA with respect to “source or special fissionable material;” and INFCIRC/153 safeguards agreements relied

⁴⁵⁵ The gun-type Hiroshima design was not tested, and it is generally assumed today that this design does not require testing to be reliable. But, as already noted, it requires substantially more fissile material than an implosion design and can only work with uranium enriched to high levels.

⁴⁵⁶ See for example, re neptunium, Proliferation-Resistant Fuel Cycles, D.O. Campbell and E.H. Gift, 1976 <https://www.osti.gov/servlets/purl/6743129>

⁴⁵⁷ David Albright and Kimberly Kramer, Neptunium 237 and Americium: World Inventories and Proliferation Concerns, June 10, 2005, Revised August 22, 2005. http://isis-online.org/uploads/isis-reports/documents/np_237_and_americium.pdf.

on the definitions in the IAEA Statute of that phrase, definitions that included only uranium, plutonium, and thorium.^{458,459}

Faced with this situation, the IAEA Board identified three options to respond to this proliferation potential:

- (a) define Np and Am as special fissionable materials and place them under safeguards;
- (b) monitor international transfers of separated Np and Am to non-nuclear-weapon States and any activity to produce separated Np and Am in States with comprehensive safeguards agreements; or,
- (c) conclude that Np or Am or both do not currently pose a sufficient proliferation risk to warrant any short-term action.

In the context of making a decision, the Board was informed that most existing inventories of Np and Am were contained in spent nuclear reactor fuel in unseparated form. Information available to the Secretariat at the time of preparation of the Board paper suggested that quantities of separated Np and Am appeared to be small in States which had a comprehensive safeguards agreement with the Agency.

The Secretariat recommended the flow-sheet verification approach identified in Option (b) above as a cost-effective means of providing assurance that quantities of separated Np and Am in States that had, or are obliged to have, a comprehensive safeguards agreement remain insufficient to pose a proliferation risk.

As it stood, if Option (b) were fully implemented, it would address all possible routes whereby a State with a comprehensive safeguards agreement could accumulate quantities of separated Np or Am. While the implementation of Option (b) would require the cooperation and participation of all relevant States in reporting exports of separated Np and Am, including States without comprehensive safeguards agreements, the monitoring approach as a whole would focus on States with comprehensive safeguards agreements in light of the nature of their non-proliferation obligations.

⁴⁵⁸ IAEA Statute, Article XX. The term "special fissionable material" means plutonium-239; uranium- 233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine; but the term "special fissionable material" does not include source material. The term "source material" means uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing in such concentration as the Board of Governors shall from time to time determine; and such other material as the Board of Governors shall from time to time determine.

⁴⁵⁹ Np and Am were not the only elements examined for their proliferation potential. However, the results of an extensive survey of the isotopes of transuranic elements that are not under international control, conveyed to the Secretariat by nuclear-weapon states, led to the conclusion that no elements other than Np and Am were likely to pose a proliferation potential for at least several decades. Although other transuramics formed in fuel during the operation of a nuclear reactor (e.g., curium, berkelium and californium) also have fissionable isotopes, their limited availability, high thermal output, short half-lives and other nuclear properties make them unsuitable for use in the foreseeable future in nuclear explosive devices.

No member of the Board supported either Option (a) or Option (c). The former was not supported because defining Np and Am as special fissionable material and placing them under safeguards would entail substantial costs and appeared to be premature given the assessed low proliferation risk of these materials. The latter was not supported because taking no short-term action appeared imprudent at a time when the nuclear industry appeared poised to take steps that looked likely to result in an increase in the amount of separated Np and Am.

As a result of this decision, the IAEA developed and began to implement a flow-sheet verification technique at reprocessing plants subject to IAEA safeguards. It was designed to provide confidence that separated neptunium or americium was not produced. At the same time, States in a position to do so, including the nuclear-weapon States, would report on a voluntary basis past exports of Np and Am to States which had, or were obligated to have, comprehensive safeguards agreements, as well as future exports on an annual basis.

A.2.2 Reactor-grade and weapon-grade plutonium in nuclear explosives

Power reactors are designed and operated for the economic production of electricity. To maximize production, reactor shut downs are minimized and fuel assemblies remain in a power reactor as long as possible. The result is long irradiation times so that almost all of the production of plutonium is reactor grade.

In contrast, reactors intended to produce weapon-grade plutonium are designed otherwise. The primary design criterion is to optimize the production of plutonium that is well suited for use in a nuclear-weapon program. Production of electricity, if any, is of secondary importance. To achieve this goal requires the uranium fuel to be irradiated for only a short time and then removed from the reactor.

There has been considerable discussion of whether a different set of safeguards goals and objectives should be applied to reactor-grade plutonium as opposed to weapon-grade plutonium. If the characteristics of reactor-grade plutonium make it very difficult or practicably impossible to use for the manufacture of a nuclear explosive device, this would carry considerable weight in deciding whether to treat reactor-grade and weapon-grade plutonium in the same fashion or to change the IAEA safeguards arrangements for reactor-grade plutonium.⁴⁶⁰

Drawing conclusions in this regard depends on considerable insight into the design of nuclear weapons. Since almost none of this insight is available to the authors of this textbook and is, in any case, classified information in the United States, an independent analysis of this issue is impossible here. It is relevant, however, that the U.S. Department of Energy has released the fact that, “A successful test was conducted in 1962, which used reactor-grade plutonium in the nuclear explosive in place of weapon-grade plutonium,” and that, “The yield was less than 20 kilotons.”⁴⁶¹

Additional insights into the arguments involved and conclusions drawn by the United States Government about this issue are contained in the aforementioned “Nonproliferation and Arms

⁴⁶⁰ John Carlson, John Bardsley, Victor Bragin, and John Hill, Plutonium Isotopes - Non-Proliferation and Safeguards Issues, IAEA-SM-351/64 (1997), http://www.fas.org/nuke/intro/nuke/O_9705.htm.

⁴⁶¹ <https://www.osti.gov/opennet/forms.jsp?formurl=document/press/pc29.html#ZZ6> (August 2012).

Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives," pages 37-39.

In order to make this analysis and its conclusions available to readers of this textbook, the following is quoted verbatim from this document:

"Virtually any combination of plutonium isotopes—the different forms of an element having different numbers of neutrons in their nuclei—can be used to make a nuclear weapon. Not all combinations, however, are equally convenient or efficient.

The most common isotope, Pu-239, is produced when the most common isotope of uranium, U-238, absorbs a neutron and then quickly decays to plutonium. It is this plutonium isotope that is most useful in making nuclear weapons, and it is produced in varying quantities in virtually all operating nuclear reactors. As fuel in a reactor is exposed to longer and longer periods of neutron irradiation, higher isotopes of plutonium build up as some of the plutonium absorbs additional neutrons, creating Pu-240, Pu-241, and so on. Pu-238 also builds up from a chain of neutron absorptions and radioactive decays starting from U-235.

These other isotopes create some difficulties for design and fabrication of nuclear weapons. First and most important, Pu-240 has a high rate of spontaneous fission, meaning that the plutonium in the device will continually produce many background neutrons, which have the potential to reduce weapon yield by starting the chain reaction prematurely. Second, the isotope Pu-238 decays relatively rapidly, thereby significantly increasing the rate of heat generation in the material. Third, the isotope Americium-241 (which results from the 14-year half-life decay of Pu-241 and hence builds up in reactor-grade plutonium over time) emits highly penetrating gamma rays, increasing the radioactive exposure of any personnel handling the material.

Because of the preference for relatively pure Pu-239 for weapons purposes, when a reactor is used specifically for creating weapons plutonium, the fuel rods are removed, and the plutonium is separated from them after relatively brief irradiation (at low "burn-up"). The resulting "weapons-grade plutonium" is typically about 93 percent Pu-239. Such brief irradiation is quite inefficient for power production, so in power reactors the fuel is left in the reactor much longer, resulting in a mix that includes more of the higher isotopes of plutonium. In the United States, plutonium containing between 80 and 93 percent Pu-239 is referred to as "fuel-grade" plutonium, while plutonium with less than 80 percent Pu-239 -- typical of plutonium in the spent fuel of light-water and CANDU reactors at normal irradiation -- is referred to as "reactor-grade" plutonium.

All of these grades of plutonium can be used to make nuclear weapons. The only isotopic mix of plutonium which cannot realistically be used for nuclear weapons is nearly pure Pu-238, which generates so much heat that the weapon would not be stable. (International rules require equal levels of safeguards for all grades of plutonium except plutonium containing more than 80% Pu-238, which need not be safeguarded.)

Designing and building an effective nuclear weapon using reactor-grade plutonium is less convenient than using weapon-grade plutonium, for several reasons. Some nuclear weapons are typically designed so that a pulse of neutrons will start the nuclear chain reaction at the optimum moment for maximum yield; background neutrons from Pu-240 can set off the reaction prematurely, and with reactor-grade plutonium the probability of such "pre-initiation" is large.

Pre-initiation can substantially reduce the explosive yield, since the weapon may blow itself apart and thereby cut short the chain reaction that releases the energy. Nevertheless, even if pre-initiation occurs at the worst possible moment (when the material first becomes compressed enough to sustain a chain reaction), the explosive yield of even a relatively simple first-generation nuclear device would be of the order of one or a few kilotons. While this yield is referred to as the “fizzle yield,” a 1-kiloton bomb would still have a radius of destruction roughly one-third that of the Hiroshima weapon, making it a potentially fearsome explosive. Regardless of how high the concentration of troublesome isotopes is, the yield would not be less.

Dealing with the second problem with reactor-grade plutonium, the heat generated by Pu-238 and Pu-240, requires careful management of the heat in the device. There are well developed means for addressing these problems and they are not considered a significant hurdle to the production of nuclear weapons, even for developing states or sub-national groups. The radiation from Americium-241 means that more shielding and greater precautions to protect personnel might be necessary when building and handling nuclear explosives made from reactor-grade plutonium. But these difficulties are not prohibitive. While reactor-grade plutonium has a slightly larger critical mass than weapon-grade plutonium (meaning that somewhat more material would be needed for a bomb), this would not be a major impediment for design of either crude or sophisticated nuclear weapons.

*The degree to which these obstacles can be overcome depends on the sophistication of the state or group attempting to produce a nuclear weapon. At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation nuclear weapons could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that). At the other end of the spectrum, advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapon-grade plutonium. The greater radioactivity would mean increased radiation doses to workers fabricating such weapons, and military personnel spending long periods of time in close proximity to them, and the greater heat and radiation generated from reactor-grade plutonium might result in a need to replace certain weapon components more frequently. Proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device. **

Every state which has built nuclear weapons from plutonium to date has chosen to produce weapons-grade plutonium for that purpose. States have been willing to make large investments in some cases to acquire weapon-grade rather than reactor-grade plutonium: the United States, for example, in the 1980s, considered spending billions of dollars on the Special Isotope Separation facility to enrich reactor-grade plutonium to weapon-grade. The disadvantage of reactor-grade plutonium is not so much in the effectiveness of the nuclear weapons that can be made from it as in the increased complexity in designing, fabricating, and handling them. The possibility that either a state or a sub-national group would choose to use reactor-grade plutonium, should sufficient stocks of weapon-grade plutonium not be readily available, cannot be discounted.

In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states. Theft of separated plutonium, whether weapon-grade or reactor-grade, would pose a grave security risk.”

**See W. G. Sutcliffe and T.J. Trapp, eds., Extraction and Utility of Reactor-Grade Plutonium for Weapons, Lawrence Livermore National Laboratory, UCRL-LR-115542, 1994 (S/RD).*

The Pu-240 content even in weapons-grade plutonium is sufficiently large that very rapid assembly is necessary to prevent pre-initiation. Hence the simplest type of nuclear explosive, a “gun type,” in which the optimum critical configuration is assembled more slowly than in an “implosion type” device, cannot be made with plutonium, but only with highly enriched uranium, in which spontaneous fission is rare. This makes HEU an even more attractive material than plutonium for potential proliferators with limited access to sophisticated technology. Either material can be used in an implosion device.

APPENDIX B. Creation of Euratom

In 1957, an international organization, the IAEA, was created with the objective of both promoting and controlling peaceful uses of nuclear energy. The same year saw the creation of a European organization that had the same purposes, namely, the European Atomic Energy Community, known as Euratom.

The predicate for the establishment of Euratom was far different from that of the IAEA. Following World War II, leading statesmen sought a way to diminish and restrain the rivalries, especially between France and Germany, that had divided Europe for centuries and had led to two World Wars in the twentieth century alone. Their approach, designated European integration, was to create “communities” with supranational powers tying together key sectors of the European economy. The selection of nuclear energy as the basis of one of the new European Communities was indicative of the high promise with which nuclear power was viewed in the world. It was especially important in Europe because of the Suez crisis unfolding at the time. In October 1956, the Suez Canal, through which much of Europe’s oil supply was delivered, was closed as a result of hostilities between Egypt on one side and Israel, France and the United Kingdom on the other. The canal remained closed until April 1957, giving a powerful impetus to the negotiation of the Euratom treaty.

Euratom was given legal ownership of special fissionable material within the Community. It was also given the right of inspection and control of all civil nuclear materials to ensure that they were not diverted from the use declared by the State to other purposes, especially military purposes. This stands in contrast to IAEA safeguards, where the IAEA is not charged with making any judgments about the use to which nuclear material is being put.

Euratom safeguards also cover all civil nuclear material regardless of whether it is acquired from an outside supplier or is of domestic origin. At the time, this was an important difference from the rights of the IAEA, whose safeguards extended only to projects where it acted as a supplier or where it was requested by a State or States to apply its safeguards.

Euratom inspectors have access at all times to all places and data and to all persons who, by reason of their occupation, deal with materials, equipment or installations subject to the safeguards. This access authority matches the safeguards authority in the IAEA Statute, but it is broader than the access actually permitted to the IAEA under NPT safeguards agreements.⁴⁶²

The Euratom treaty is not strictly a non-proliferation instrument since it includes a mechanism allowing France (and the United Kingdom, following its entry into the Community) to develop nuclear weapons outside of Euratom and its controls. The treaty works to prohibit nuclear weapons elsewhere in the Community. In the mid 1950s, when Nazi crimes and the results of World War II remained starkly apparent, this was of particular significance in relation to Germany.

⁴⁶² A good description of the evolution and coverage of the Euratom safeguards system is found in The EURATOM Regional Safeguards System, Piotr Szymanski1, Director, Directorate for Nuclear Safeguards, Directorate General for Energy, European Commission, Luxembourg at <http://www.iaea.org/newscenter/focus/iaeanwfz/euratom211111.pdf>. (September 14, 2012).

The United States strongly supported the move toward European integration. As a result, the United States developed a close relationship with Euratom, and a joint program designed to support the creation of a nuclear power industry in the Community was negotiated. This unique program included several important financial benefits and guarantees by the United States. It was the subject of a special Agreement for Cooperation that included several provisions favoring Euratom and not found in any other U.S. Agreement for Cooperation. In particular, rather than providing for safeguards applied by U.S. inspectors, the Agreement delegated the safeguards authority to Euratom. This delegation gave support to European integration and reflected the U.S. view that Euratom was an international organization in its own right with a strong interest in assuring that nuclear material under its safeguards was not misused.

When the IAEA safeguards system became operational in the early 1960s, the United States adopted the policy of making its nuclear cooperation, except in the case of Euratom, contingent on the application of IAEA safeguards. Agreements for Cooperation already in effect and calling only for bilateral safeguards were amended as their terms expired or additional nuclear material was needed. This made both past and future bilateral supply subject to Agency safeguards. The Agency's safeguards responsibilities were spelled out in "safeguards transfer agreements" that suspended the inspection rights of the United States as long as the IAEA was applying safeguards.

In the case of Euratom, though, this U.S. policy of preference for IAEA safeguards was not applied, and it had an impact on the content of Article III in the NPT. The concession made to Euratom countries was the reference in Article III that the requirement to conclude a safeguards agreement with the IAEA could be done "either individually or together with other States."

The members of Euratom did, in fact, negotiate the required NPT safeguards agreement collectively, and the IAEA-Euratom safeguards agreement (INFCIRC/193) came into force in 1973. It is based on INFCIRC/153 but includes a Protocol that reflects a unique arrangement between the Euratom and the IAEA inspectorates.

The original members were Belgium, Denmark, the Federal Republic of Germany, Ireland, Italy, Luxembourg, the Netherlands, the European Atomic Energy Community and the IAEA. Each new member of the European Union has been obliged to be an NPT party and to accede to INFCIRC/193.

APPENDIX C. IAEA – The Institution

Introduction

IAEA safeguards are implemented by the Department of Safeguards, one of six departments in the IAEA Secretariat. It is the largest, taking up about 40% of the total IAEA regular budget. Necessarily, its operations are affected by Agency-wide institutional constraints, which can affect hiring practices and budget resources. And, of course, the decisions of the Board of Governors and the General Conference must be taken into account.

The discussion below focuses on a variety of constraints that have confronted the Agency, many of which continue. Because some of the constraints can be ameliorated by actions taken by the United States through voluntary contributions, attention is also paid to its programs in this area. The United States plays an important role in helping to ensure that the Department of Safeguards has well-trained staff with the right skills and tools to measure nuclear material and to detect undeclared activities.⁴⁶³ As the largest contributor to the IAEA, both in terms of the regular budget and in terms of voluntary contributions, U.S. approaches to the budget and to technical support for the IAEA can have a significant impact.

C.1 Board of Governors

The IAEA Board of Governors is the governing body of the IAEA. Two issues have arisen that are related to its own operation. One is its decision-making. The other is its size.

C.1.1 Board decision making

For decades, most Board decisions were taken by consensus because:

- the Agency addressed primarily technical issues;
- the United States and the Soviet Union, while in opposition on many issues, had similar views on the importance of non-proliferation, and they were able to influence or impose on members of the Board their own views; and
- the Board in the past was more compact in size and more homogeneous in its views.

Over time, it has become increasingly more difficult to find that consensus.

Regarding the first point, the nature of the problems confronted by the Board has shifted from issues that are primarily technical toward issues that are highly political. For example, Iran is in non-compliance with its NPT safeguards agreement, and the Board has addressed this politically charged issue since 2003. It represents an issue that is clearly not just technical. Does Iran have a nuclear-weapon program or not? The answer to that question is not entirely, perhaps not even primarily, a technical issue. However, the answer will sway members of the Board to support or oppose measures that affect Iran negatively. This is an example that highlights the importance of

⁴⁶³ The United States is by no means the only state that does so. As of February 2016, twenty-one states had safeguards support programs.

the IAEA Director General, whose expressed view on such matters carries considerable technical and political weight.

The dissolution of the Soviet Union in December 1991 altered the second point. This had two effects. One was to shift the balance of influence within the Board toward the West, which tends to isolate Russia; and the second was to further reduce the influence that both the Soviet Union and the United States had been able to exert on others during the Cold War.

The third point, intertwined with the first two, relates to the size of the Board, which has increased from its original 22 members to 35 members today.⁴⁶⁴ (Further expansion of the Board is addressed in Section C.1.2 below.) This has made the Board more heterogeneous and has increased representation from Board members who are also members of the non-aligned movement (NAM). When the NAM opened an office in Vienna in 2003, this made coordination between NAM Board members more feasible and more likely. It introduced further into the Board a perspective consolidated from the views of States with generally little or no interest in nuclear power and substituted for inputs from some Board members previously expressed on the basis of regional groupings.⁴⁶⁵

Finally, the significance of China's decision to join the Agency in 1984 should be mentioned. Acting in its own words as "a Group of One," China brings to international forums a perspective that reflects its own history and sense of international status. Its perspective may sometimes be at odds with many others, and it often aligns itself with the non-aligned. This is also seen clearly in its actions in the United Nations Security Council. The perspective of China on nuclear non-proliferation has changed, and it is increasingly likely to give more weight in its decision making to actions that promote a strong non-proliferation regime.

In such an environment, obtaining consensus on many issues will simply be less likely. The necessary alternative is for the Board to use the voting mechanism that is provided in the IAEA Statute, which means that Member States must not only be prepared to abandon the search for consensus when it is clearly not attainable, but they must also be willing to forward findings of serious non-compliance to the Security Council even when there is no consensus in the Board of Governors.

C.1.2 Size and composition of the Board

The Board had 22 members in 1957. It reached its present size of 35 members in 1984.⁴⁶⁶ Pressures to increase the size of the Board stem from increases in the Agency's total membership and from a desire among new members to obtain more equitable geographic representation.⁴⁶⁷ In addition, some States that have developed significant nuclear programs want to expand the size of

⁴⁶⁴ The size of the Board increased from 22 to 24 in 1961; to 34 in 1973; and to 35 in 1984.

⁴⁶⁵ For a useful analysis of the role of the Non-aligned Movement with respect to the IAEA, see Yew, Yvonne. "Diplomacy and Nuclear Non-Proliferation: Navigating the Non-Aligned Movement" Discussion Paper 2011-07, Cambridge, Mass.: The Future of Diplomacy Project, Belfer Center for Science and International Affairs, Harvard University, June 2011. (<https://www.hsl.org/?view&did=4319>, March 16, 2012).

⁴⁶⁶ The Members States on the Board of Governors is published by the IAEA at <https://www.iaea.org/about/governance/board-of-governors>. (Accessed 17 Mar 2018)

⁴⁶⁷ For IAEA purposes, the geographical categorization of Member States is found in <https://www.iaea.org/OurWork/ST/NE/Pess/rds-1/RDS1-23scr.pdf>. (Accessed 13 April 2018)

Board in order that they could be members at all times rather than on a rotating basis. The Republic of Korea (South Korea) is in this category.

It has a strong and growing nuclear program but remains in the category of States that are elected and, thus, are not always on the Board. Not surprisingly, South Korea has expressed the desire to be considered among the most advanced nuclear States, which would entitle it to a “permanent” seat, or to have the Board expanded to increase the number of States in this category on the reasonable assumption that it would be included.

As a result of this pressure, in 1999 the IAEA adopted an amendment to the IAEA Statute that would increase the size of the Board by eight members. The amendment will take effect when: (a) it is ratified by two-thirds of IAEA members in accordance with Article XVIII.C of the Statute; and (b) when ninety percent of Member States present and voting at the General Conference confirm a list of all IAEA Member States, whereby each Member State is allotted to one of the geographic regions as defined in Article VI.A of the Statute.

Neither of these requirements has been met to date. The former condition reflects a statutory requirement. The latter condition will be difficult to achieve even if the former is met because of the unwillingness to date of States in the Middle East and South Asia region to recognize Israel as a member.

C.2 Funding International Safeguards⁴⁶⁸

C.2.1 Safeguards financing issues

Adequate funding is a prerequisite for effective implementation of IAEA safeguards. As nuclear fuel cycles have grown, and safeguards have expanded in scope and complexity, the question of how to provide sufficient funding for safeguards has been raised repeatedly and, at times, with considerable urgency.

The issue of funding safeguards is multifaceted. The total cost of IAEA safeguards is one concern. Cost requirements are driven by such factors as the choice of safeguards approaches at nuclear facilities; the degree of effectiveness sought; the extent to which integrated safeguards are adopted; the resource requirements at Headquarters devoted to State evaluations and the collection and analysis of open-source information; and the cost of safeguards equipment and infrastructure.

A second issue is the allocation of safeguards costs among IAEA Member States. For example, in many developing countries safeguards are not applied – they have no nuclear programs. They often assert that as a result they should not pay, or not pay much, to support safeguards. Some non-nuclear-weapon States argue that the nuclear-weapon States should bear the expense of safeguards required under the NPT since the Treaty does not require safeguards in nuclear-weapon States.

A recent and important issue is how the IAEA will strike the balance between the resources it devotes to traditional safeguards measures at declared facilities versus the resources it spends on activities designed to detect undeclared nuclear activities. In addition, there is the question of how

⁴⁶⁸ The authors wish to thank Ms. Sarah E. Cross for conducting the research that forms the basis for this section.

to fund implementation of safeguards in nuclear-weapon States pursuant to their voluntary-offer agreements (see Appendix D).

Finally, there is the important issue of how to provide the IAEA with the specialized instrumentation and measurement equipment it needs to do its job and, in turn, how to train inspectors to operate these instruments correctly. Finding answers to these and other issues related to safeguards funding will remain a challenge.

How safeguards are funded

When the IAEA came into existence in 1957, the concept of a safeguards system was included in its Statute, but no operating system existed. As noted by a former IAEA Deputy Director General for Safeguards, “The IAEA had to develop the theory and practice of international safeguards from scratch. In 1958 a small division of safeguards was established. In 1959 it consisted of five professionals and two secretaries. It had no separate budget, no safeguards agreements in force or under negotiation, no inspectors, and no facilities to safeguard.”⁴⁶⁹ Two inspectors conducted the IAEA’s first safeguards inspection at the Nora research reactor in Norway in 1962. This modest start marked the beginning of a constant and dynamic evolution and expansion of the safeguards system that continues to this day. From its modest beginning in 1962, the safeguards system has expanded significantly: As of 30 June 2017, 182 States had safeguards agreements in force with the Agency, 129 of which (including 123 States with comprehensive safeguards agreements) also had additional protocols in force.⁴⁷⁰

The IAEA Statute specifies that the Agency will have its own budget and that the costs of implementing safeguards will be covered by the regular budget. Each year the regular budget is billed to IAEA Member States according to a Scale of Assessments. This Scale is based on the United Nations Scale of Assessments but is modified to reflect the differences in membership in the two organizations. For allocating the costs of safeguards, there is an additional modification, which is described in the next section.

Funding for the safeguards portion of the regular budget –

Shielding

As mentioned above, the financing of the Department of Safeguards represents approximately 40% of the IAEA’s regular budget. All IAEA Member States are obliged to contribute to the IAEA’s regular budget, but that budget is broken into two parts, one for safeguards and one for the remainder of the Agency’s budget. For the safeguards portion of the regular budget, a large majority of the Agency’s Member States are “shielded” from paying their full assessment. The policy of shielding was introduced in the 1970s when Member States began concluding NPT safeguards agreements and safeguards costs began to rise rapidly.⁴⁷¹ As a result, under pressure

⁴⁶⁹ H. Gruemm, “IAEA Safeguards: Milestones in development & implementation,” IAEA Bulletin 3/1987, p. 29.

⁴⁷⁰ “Strengthening the effectiveness and improving the efficiency of the safeguards system and application of the Model Additional Protocol.” Report by the Director General. GC(61)/16. 26 July 2017.

⁴⁷¹ See “Assessments of Members’ Contributions Towards the Agency’s Administrative Expenses: Resolution Adopted During the 150th Plenary Meeting on 27 September 1971,” GC(XV)/Res/283, October 1971, http://www.iaea.org/About/Policy/GC/GC15/GC15Resolutions/English/gc15res-283_en.pdf.

from developing countries, the General Conference decided to distinguish between safeguards costs and non-safeguards costs and created distinctions between “shielded” Member States and others.

Shielding was introduced to protect lower income States from paying the full amount of their assessed contribution or base rate of assessment for the safeguards component of the regular budget.⁴⁷² Originally, in order for a State to be shielded it had to have a per capita net national income of less than one third of the average of the ten Member States with the highest per capita net national income. If this were the case, the Member State in question would pay less than its full share of the safeguards component of the budget. The assessment of the unshielded Member States was then raised to compensate for the loss of funds from the shielded countries.

The shielding formula has changed over time.⁴⁷³ In 1976, the shielding amount was changed, and then, following a decision made by the General Conference in 1980, in order to qualify for shielding, States had to have a per capita net national product of less than the one-third the average of the fifteen Member States with the highest net national product.⁴⁷⁴ Finally, in 2000 the concept of “de-shielding” was introduced. Accordingly, all States would be moved gradually out of the shielded category toward financing at their full base rate of assessment, and incoming members to the Agency, after 2003, would no longer be eligible for shielding even if they met the original economic qualifications.⁴⁷⁵

Funding from voluntary contributions

The Statute also allows for voluntary or “extrabudgetary” funding. It is funding provided by States in addition to what they pay for the regular budget. Voluntary funds are often contributed for specific programs or purposes of priority to the donors and may come from Member States or individual institutions or private citizens.

While States are obligated to pay their assessed contributions to the regular budget to remain a member in good standing of the IAEA, there is no obligation to provide voluntary funding. Voluntary contributions play a major role in a number of IAEA programs and the total amount is significant. The IAEA’s budget for 2016 totaled €500.6 million of which €359.7 million was in the regular budget; €45.9 million of voluntary contributions; and €90.7 million in the Technical Cooperation Fund.⁴⁷⁶

⁴⁷² A good introduction to the history of IAEA financing can be found in a note to all Member States in 2009 entitled, “Note by the Secretariat: Informal and Open Ended Process to Discuss ‘the Future of the Agency,’” 2009/Note 57.

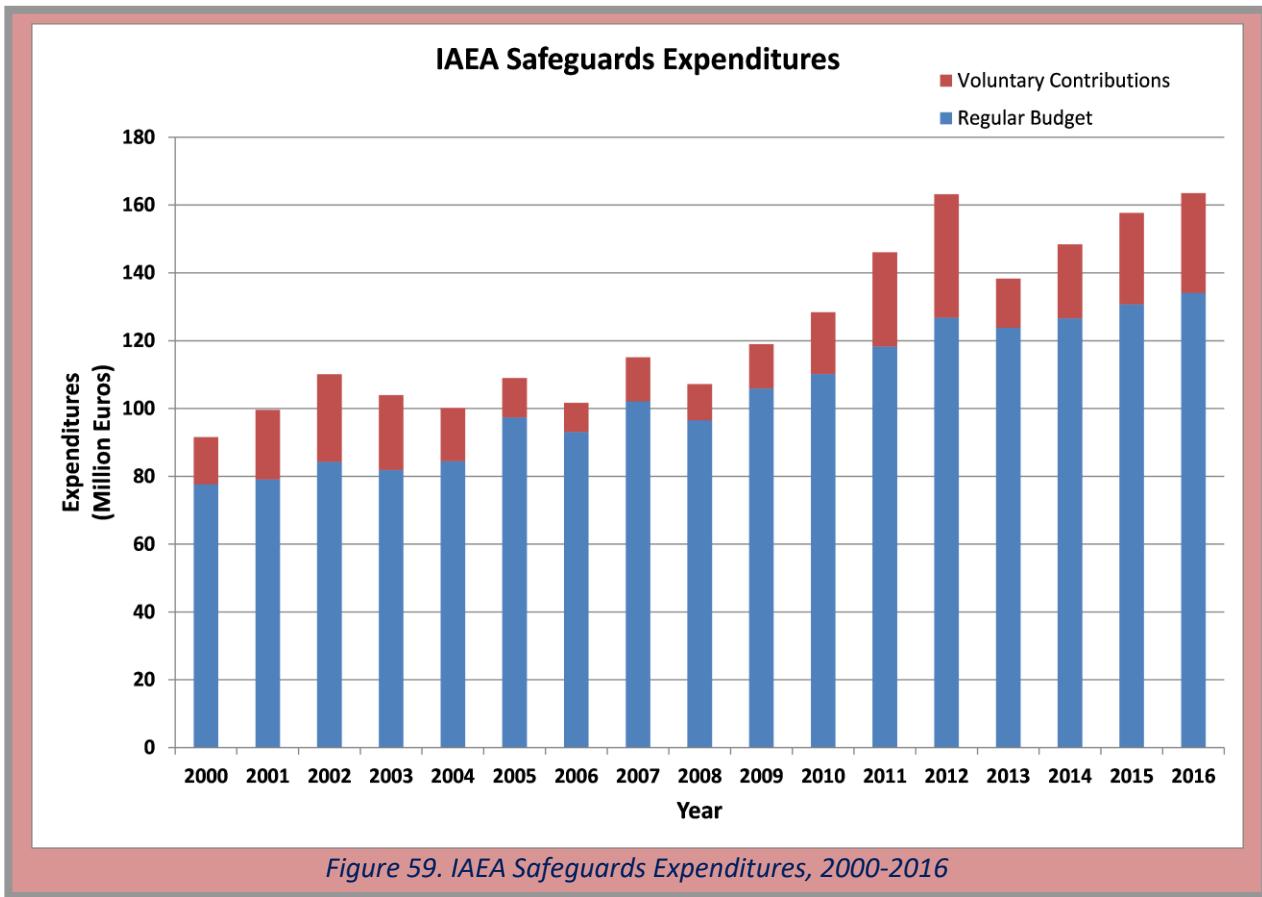
⁴⁷³ See “Assessment of Members’ Contributions Towards the Agency’s regular budget: Resolution Adopted During the 191st Plenary Meeting on 28 September 1976,” GC(XX)/RES/341, November 1976, http://www.iaea.org/About/Policy/GC/GC20/GC20Resolutions/English/gc20res-341_en.pdf.

⁴⁷⁴ See “The Financing of Safeguards: Resolution Adopted During the 220th Plenary Meeting on 26 September 1980,” GC(XXIV)/RES/376, October 1980, http://www.iaea.org/About/Policy/GC/GC24/GC24Resolutions/English/gc24res-376_en.pdf.

⁴⁷⁵ See “The Financing of Safeguards: Revised Arrangements for the Assessment of members’ Contributions Towards the Safeguards Component of the Agency’s regular budget,” GC(44)/RES/9, September 2000, <http://www.iaea.org/About/Policy/GC/GC44/Resolutions/gc44res9.pdf>.

⁴⁷⁶ <https://www.iaea.org/about/overview/budget>

One program that relies significantly on voluntary contributions is the IAEA Technical Cooperation (TC) program. This program is intended to enhance States' abilities to take advantage of the benefits of peaceful uses of nuclear science, with a primary goal of doing so in developing countries. The management of the program is funded through the IAEA's regular budget for the Department of Technical Cooperation, while technical support for the program comes from the Department of Nuclear Sciences and Applications. Funding to support TC projects in Member States, though, comes from a TC fund, which is obtained entirely from voluntary contributions. Despite the voluntary nature of the funding, a target level is agreed at the annual IAEA General Conference and "invoices" are sent to Member States to contribute to the fund using the same scale of assessment as for the IAEA regular budget. The U.S. share, for example, is 25%. The TC fund target for 2016 was 84.5 million Euros.



Voluntary contributions also play a significant role in supporting IAEA safeguards implementation. Figure 60 shows IAEA safeguards expenditures over time and the portion of it that results from voluntary contributions. As can be seen, in 2010, expenditures from voluntary contributions added about 15% to expenditures from the regular budget. This total does not reflect all of the voluntary contributions made to support safeguards. Many States have a safeguards support program that funds the development or purchase of safeguards equipment. Japan and Canada have made significant contributions in this way.

U.S. voluntary funding for IAEA safeguards

The United States has a safeguards support program called the U.S. Program of Technical Assistance to Agency Safeguards (POTAS). Funded at \$16 million in 2017, POTAS was established in 1977 by Congress with an authorization for \$5 million, to be spent over a period of five years, for R&D activities to support the Department of Safeguards.⁴⁷⁷ Since its creation, POTAS has expanded greatly (see Figure 61) and led to the development of the U.S. Support Program to IAEA Safeguards (USSP), which is managed by the International Safeguards Project Office at Brookhaven National Laboratory in Upton, New York. Over the years as the Agency's mission and mandate have expanded, the Department of Safeguards has become increasingly reliant on extrabudgetary contributions and Member States' support programs to meet their resource needs. As of February 2016, there were twenty-one Member State safeguards support programs and one multinational support program (that of the European Commission).

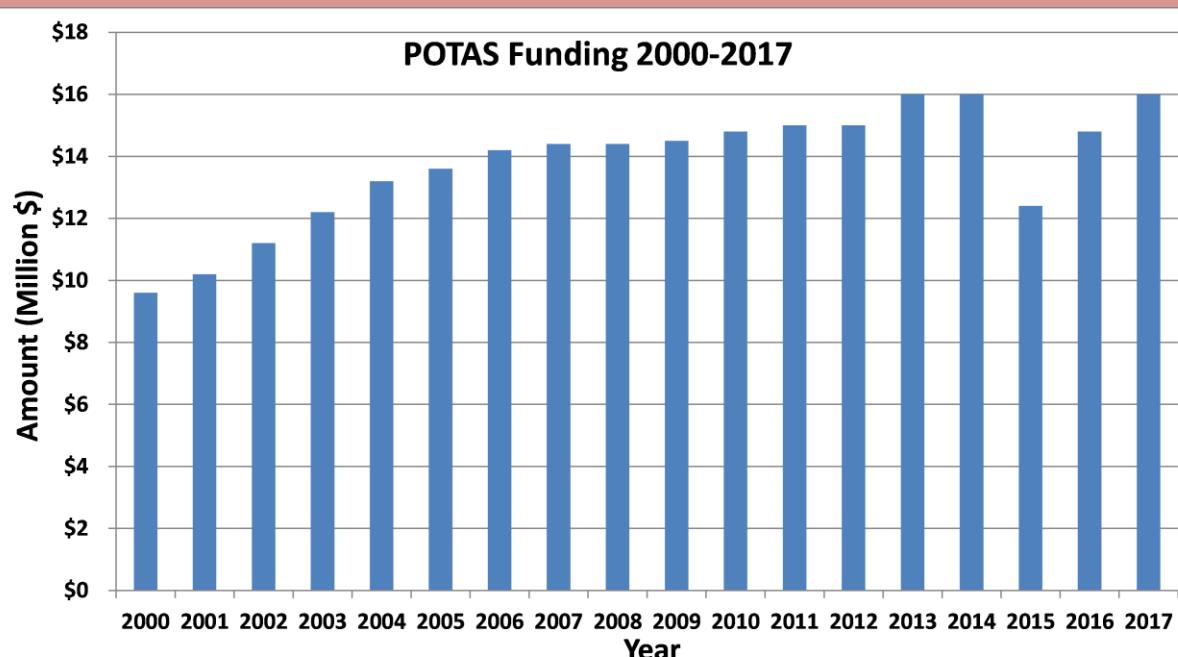


Figure 60. U.S. Program of Technical Assistance to Agency Safeguards funding, 1977-2017

In addition to support programs for IAEA safeguards, the IAEA relies in a significant fashion on extrabudgetary support for on-going activities in nuclear safety and security and when it is called upon in special cases such as monitoring arrangements in Iraq and the DPRK.

⁴⁷⁷ Brookhaven National Laboratory, "The U.S. Support Program to IAEA Safeguards," updated 17 June 2017, <https://www.bnl.gov/ispo/docs/PS1-USSP-Task-Req.pdf> (accessed 5 March 2019).

C.2.2 The IAEA budget process

The IAEA's regular budget is prepared and adopted in a lengthy process. Each year following the September meeting of the annual General Conference, an initial draft of the proposed budget for the following two years is prepared by the IAEA Secretariat (this draft formerly covered one year, but the IAEA moved to a biennial budget in 2002-2003). This draft is presented to IAEA Member States, usually by December, and comments from them are incorporated into the draft to the extent possible. In May the IAEA's Program and Budget Committee (a committee of the Board of Governors) meets and makes recommendations regarding the budget for consideration at the June meeting of the Board of Governors.

In June the Board meets and typically agrees to submit the budget to the annual General Conference with its recommendation for final approval by the General Conference, usually a formality. Generally, this process is more automatic and less problematic in the second year of a biennial budget because budget issues have been agreed during the consideration of the budget for the first year of the two-year cycle.

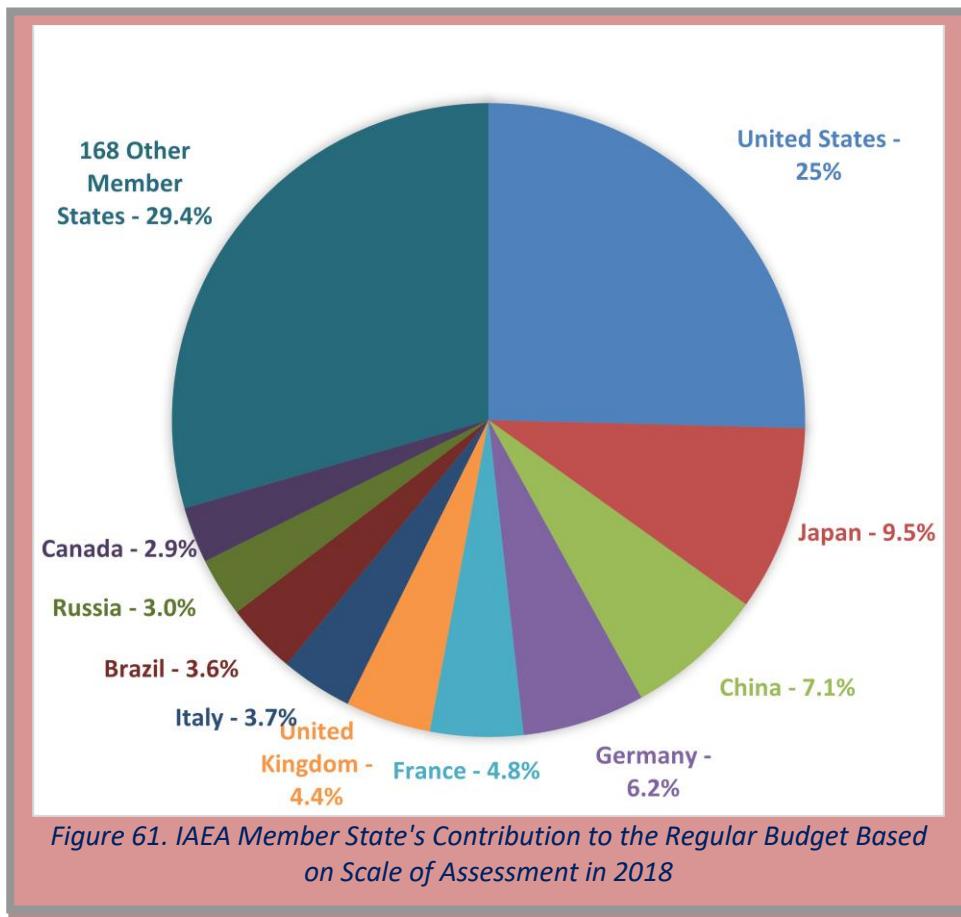
The budget preparation process is reasonably predictable in that there is intense pressure from many States to retain a zero-real-growth policy (see the next section). This can generate considerable controversy when the budget proposed by the Secretariat includes real increases, or when a Member State seeks a real increase in a program area that it finds of special interest. The United States, for example, has proposed real increases in the safeguards budget on several occasions.

The budget process can also generate controversy in other, sometimes unpredictable, ways. As membership in the IAEA has increased over time, each new Member State enters the Agency with its own views and priorities. With 169 IAEA Member States as of November 2017, the IAEA Secretariat staff in charge of moving the budget process along can now anticipate many and often conflicting views on any proposed budget. While not all Member States engage actively on budget issues, many choose to, depending on the issues and their interests at the time. For many developing Member States, a continuing priority is maintaining a "balance" in funding for safeguards and for the Agency's promotional programs, particularly the size of the Technical Cooperation Fund and the work of the Technical Cooperation Department. While adequate safeguards funding may be a priority for some developed States, most developing countries support peaceful nuclear cooperation through IAEA TC projects as their priority in the IAEA.

Table 10. IAEA Budget Share of the Top Ten Contributing Member States

RANK	COUNTRY	PERCENT
1	U.S.	25.41
2	Japan	9.47
3	China	7.01
4	Germany	6.25
5	France	4.75
6	United Kingdom	4.37
7	Italy	3.67
8	Brazil	3.62
9	Russian Federation	3.02
10	Canada	2.85
	TOTAL	70.50%

The United States has consistently been the single largest contributor to the IAEA. The United States funds the IAEA in two major ways, payment of the annual U.S. assessment for the IAEA's regular budget and an annual voluntary contribution. (The United States may also provide additional ad hoc funding or other support for specific IAEA activities of particular concern to it.) For the first two decades of the Agency's existence, the United States provided almost one-third of its regular budget. It now contributes a little over 25 percent of the regular budget. Table 10 shows the United States' current contribution in addition to that of the other top ten contributing nations.



Zero real growth

From the first IAEA safeguards budget until the early 1980s, funding for safeguards grew modestly, reaching about \$31 million by 1985. At that time, the IAEA major donors decided that budgets of the major international organizations in the United Nations system, including the IAEA, should be held to "zero real growth (ZRG)." Originally, this group, called the Geneva Group, was comprised of the fourteen largest donors to the United Nations system, including the United States, Japan and several States in Europe; currently, there are sixteen members of the Geneva Group. Under the policy of ZRG, budgets were allowed to increase only for non-discretionary costs such as inflation or exchange rate fluctuations but not for new or expanded programs. With few exceptions this policy remains in effect to this day. Figure 62 shows IAEA Member States' contributions in 2011 as a percentage of the IAEA's regular budget. (The contribution made by

each State is based on the United Nations scale of assessment adapted to the IAEA, where the United States pay 25% rather than 22% and by focusing the costs of safeguards on developed countries.)

This has particular relevance for the Department of Safeguards because its activities are not discretionary. They are treaty-driven. According to the terms of NPT safeguards agreements, the IAEA is obligated to apply safeguards. Thus, as there are increases in the number of nuclear facilities, the amounts of nuclear material, and the number of countries where safeguards must be applied, the safeguards obligations of the IAEA increase. These increases suggest that budgets should also increase, although at times increases may be offset by savings due to efficiency gains. Alternatively, without other sources of income, safeguards effectiveness would likely diminish. While voluntary contributions have been essential to meet key program needs, they may be unpredictable, which can make program planning and execution more difficult.

IAEA safeguards budgets

One exception to ZRG resulted from a U.S. decision in 2002 to press for an increase of \$30 million in the IAEA's regular budget, all for safeguards. This decision reflected deep concern among senior U.S. officials dealing with nuclear issues about the escalating demands on the safeguards system, the lack of funding available to meet these demands, and a concomitant loss of effectiveness. In response to the U.S. initiative, IAEA Member States agreed to phase in an increase of \$25 million in the IAEA's regular budget, with \$20 million dedicated to safeguards. This phase-in began in 2003 and ended in 2007. As a result of these increases the safeguards share of the total budget grew from 36% to 40%.⁴⁷⁸ A second exception to the "zero real growth" policy came in 2009 when IAEA members agreed to a 2.7% real increase for the IAEA's 2010 regular budget. A third exception was made for the IAEA's 2012 regular budget, which grew in real terms by 2.2%.

Despite these exceptions, major donors to the United Nations system continue to support the ZRG policy. Indeed since 1995 the Geneva Group has often supported an even more stringent policy of "zero nominal growth" which does not provide for any increases in the budgets of these United Nations organizations for any reason. With very few exceptions the policy of zero nominal growth has not applied to the IAEA.

U.S. deferred payment policy

As the Geneva Group was imposing its ZRG policy in the mid 1980s, the United States unilaterally adopted a policy of "deferred payment" for its assessed contributions to the budgets of the largest international organizations affiliated with the United Nations system, including the United Nations and the IAEA. To understand the impact of this policy it is important to recall that the IAEA operates on a calendar year budget (from January 1 to December 31) while the U.S. Government operates on a fiscal year budget that runs from October 1 to September 30. Each year the U.S.

⁴⁷⁸ Data is from IAEA budget documents available at www.iaea.org in the General Conference archives. It should be noted that at the time the U.S. was seeking a real IAEA safeguards budget increase, it was also seeking a decrease in its maximum regular budget assessment from 25% to 22% in all international organizations. To enhance prospects to secure a real increase in IAEA's budget, the U.S. set aside efforts to achieve this decrease in the IAEA.

assessed contribution to the IAEA is due on January 1. Under the U.S. deferred payment policy, however, the request to Congress for funding for U.S. assessed contributions to the major international organizations is deferred to the *next* fiscal year.

In practice this means that U.S. funding for these organizations is deferred to at least October 1, which is the start of the *next* U.S. fiscal year but the tenth month of the IAEA fiscal year. Since Congress rarely approves a new budget by the beginning of the fiscal year, funds for U.S. assessed contributions may not become available until well into October or beyond. In some years funding does not become available until well into the *next* calendar year.

Under the IAEA calendar-year budget schedule this means the United States can be at least one year in arrears in its assessed payment to the Agency. As other IAEA Member States became aware of the U.S. deferred payment policy, some of them opted to emulate this policy, notably Japan, the IAEA's second largest donor. As a result, the IAEA found itself increasingly strapped for the cash necessary to pay its staff and continue its operations. Furthermore, when the Soviet Union dissolved, several of the constituent States, including the Russian Federation, were unable to pay their IAEA assessments for some time.

Repeatedly over the past two decades the IAEA has experienced a cash-flow crisis that brought it close to closing its doors and shutting down its programs. In each instance a crisis was narrowly averted as requisite funds were made available in different ways.

C.3 Safeguards Funding Today: Status and Prospects

As in the past the overall costs of IAEA safeguards will continue to be driven by many factors, including the overall number, size and complexity of nuclear facilities worldwide, the amounts and types of nuclear material subject to safeguards, the specific requirements embodied in the different types of safeguards agreements, specific events of proliferation concern resulting in IAEA involvement, unique cases such as India, the nature and character of safeguards approaches for facilities, and the application of integrated safeguards and the State Level Concept.

The United States has consistently confirmed its support for the international safeguards system and has sought to ensure that it is funded at an appropriate level. As described above, beginning in 1986, the United States and others began to insist on an approach to funding international organization of ZRG for their regular budgets, augmenting shortfalls, especially in safeguards, by extrabudgetary contributions, and in one instance in 2003, a real increase in the IAEA regular budget. Such an increase was also made in 2017 in the amount of 1.9%, and the biennial budget for 2018 and 2019 is expected to increase by 1.2%, reflecting, in part, the Agency's verification and monitoring activities in Iran under the JCPOA.

Much of the support from the United States for the IAEA safeguards program comes from the National Nuclear Security Administration. It is focused primarily on the technical and manpower needs of safeguards. Meanwhile opportunities to obtain additional funding for safeguards remain limited as a result of meeting the requirements of the Statute as well as satisfying the often, conflicting goals of Member States and the need, as a consequence, to retain balance in IAEA funding between safeguards and development-oriented activities. Absent a major initiative such as guaranteed funding from non-governmental sources or a dedicated departure from ZRG for the IAEA by major Member States, with a corresponding dedicated effort to secure significant real

growth in regular budget funding for safeguards, funding safeguards at adequate levels will remain challenging.

C.4 Staffing the Safeguards System

Geographic distribution

Among the many challenges facing the safeguards system is the need to recruit, train and retain qualified IAEA safeguards inspectors and other experts required to implement effective safeguards in the future. When the safeguards system was first created in the early 1960s and for several decades thereafter, most safeguards personnel were hired by the IAEA from the United States, Western Europe and Japan. This reflected the reality at the time that these countries had

the most advanced nuclear programs and cadres of experienced and knowledgeable technical nuclear experts.

The United States in particular sent a steady stream of American nuclear experts to the IAEA to work in the Safeguards Department. In many ways, the United States had a competitive advantage because it was able to draw on its large and continuing investment in its nuclear-weapon program and in the national laboratory system. The United States was also a leader in the civil nuclear industry and developed many advanced nuclear technologies. Furthermore, many experts from outside the United States were trained in the United States.

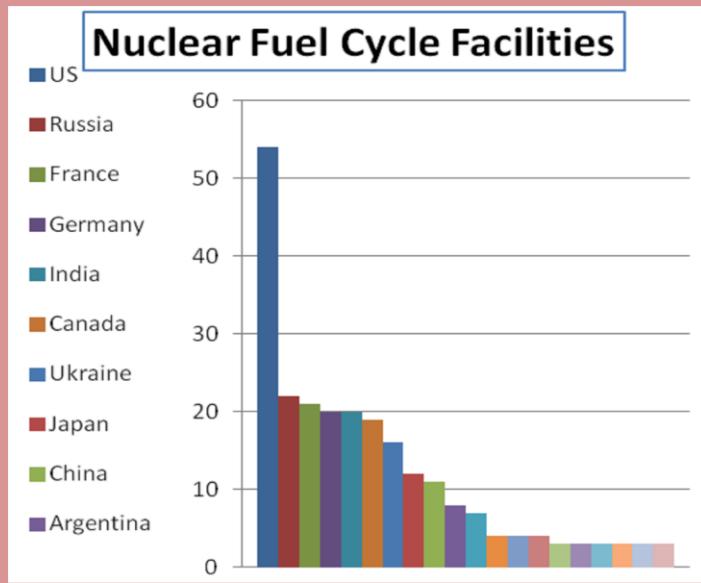


Figure 62. Nuclear fuel cycle facilities by country

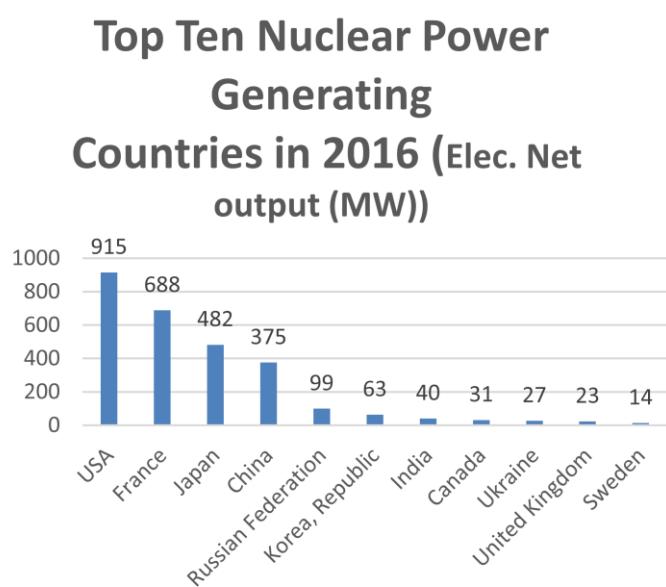


Figure 63. Top 10 nuclear power generating countries, 2016

As membership in the IAEA increased, there was mounting pressure for the IAEA to expand the geographic scope of its recruitment efforts to include the new Member States of the Agency. However, many of these new Member States were developing countries with few if any well-trained and experienced nuclear personnel. IAEA recruitment efforts were increasingly caught between requirements in the IAEA Statute that on the one hand, “The paramount consideration in the recruitment and employment of the staff and in the determination of the conditions of service shall be to secure employees of the highest standards of efficiency, technical competence, and integrity,” but that on the other hand, “Subject to this consideration, due regard shall be paid to the contributions of members to the Agency and to the importance

of recruiting the staff on as wide a geographical basis as possible.”⁴⁷⁹ These provisions have led to a recurrent dilemma of how best to recruit safeguards expertise from the developing world.

Over time the character of the international nuclear community changed. Countries in South America, Asia and elsewhere developed increasingly advanced nuclear programs. Some States in Western Europe like France retained a strong nuclear program while other States in Eastern Europe developed their own nuclear programs. Some developing countries initiated nuclear programs. In short, the breadth of nuclear programs worldwide made it easier to comply with the Statute’s mandate to recruit safeguards personnel on a wide geographic basis, but the training and skills of the recruited individuals tended to vary considerably.

At the same time, nuclear power lost favor in the United States, and the growth of its nuclear industry has stopped. Many of the U.S. universities that had had a variety of programs in nuclear engineering and nuclear science terminated these programs. As U.S. influence in nuclear issues ebbed, the number of well-qualified Americans looking for positions in the IAEA dwindled and the percentage of Americans in the Department of Safeguards (and the Agency as a whole) dropped.

Regardless of the growth in nuclear programs outside the most advanced countries, the nuclear industry remains concentrated. Figure 63 and Figure 64 show that there are only nine countries with more than ten nuclear-fuel-cycle facilities and that a similar situation exists with respect to nuclear power generation.^{480,481} As a result of this concentration, there remains a continuing tension for the IAEA between the goal of hiring staff with the highest technical competence and achieving a more balanced geographic distribution.

Challenge of aging

This tension is compounded today by the demographics of the nuclear profession. International safeguards did not exist as a profession until the 1960s, but it was only in the late 1970s and early 1980s that the IAEA inspectorate grew in response to both the rapidly increasing membership in the NPT and the expansion of the worldwide nuclear industry. The increase in the size of the professional safeguards staff soon led to a second dilemma. On the one hand the IAEA Statute specifies that: “The Agency shall be guided by the principle that its permanent staff shall be kept to a minimum.”⁴⁸² On the other hand, the unique training and skills required for an effective safeguards professional argue in favor of retaining these professionals beyond the normal terms of the standard IAEA professional contract (generally seven years). In practice many of these professionals were granted long-term contracts, which raised concerns in other Departments of the IAEA Secretariat that sought similar exemptions for some of their own staff.

⁴⁷⁹ IAEA Statute. Article VII.D. 1957 as amended.

⁴⁸⁰ Data is taken from IAEA Tecdoc-1613, Nuclear Fuel Cycle Facilities, 2009,

http://www-pub.iaea.org/MTCD/publications/PDF/te_1613_web.pdf. The facilities listed included are: uranium production, conversion, enrichment, fuel fabrication, spent fuel storage, and spent fuel reprocessing. Omitted from the table are 10 countries with fewer than 3 facilities.

⁴⁸¹ Nuclear Energy Institute, “Top 10 Nuclear Generating Countries (2010),”

<http://www.nei.org/resourcesandstats/documentlibrary/reliableandaffordableenergy/graphicsandcharts/top10nucleargeneratingcountries/>.

⁴⁸² IAEA Statute. Article VII.C. 1957 as amended.

By the early 2000s, this group of safeguards experts that started in the late 1970s and early 1980s was nearing retirement. In 2008 an IAEA study reported that fewer than 20 percent of the IAEA's safeguards inspectors were under the age of 40. According to this report, "The IAEA also faces an incipient crisis in staffing. Much needs to be done to ensure that the IAEA is able to attract and retain the top-quality professionals it needs to carry out its multiple missions. Because of its participation in the United Nations Common System, the Agency has a retirement age of 62 years for most staff and only 60 years for a quarter of the staff. Half of its top management and its senior (safeguards) inspectors are expected to reach this limit and retire in the next five years."⁴⁸³ By 2011 more than one-third of senior IAEA staff was expected to retire and more than one-half by 2013 according to another 2008 report.⁴⁸⁴

The replacement of these experts will be a continuing challenge for the IAEA. If the nuclear industry grows, it will compete with the IAEA for staff, and if it does not, the number of well-qualified professionals may not be sufficient. To the extent that the disastrous accident in Japan at Fukushima led to a retreat from nuclear power in some countries, as is taking place in Germany for other reasons and could in Japan itself, the Agency will be forced to look elsewhere for staff.

In the United States the situation is similar. Fewer young people are pursuing degrees in nuclear engineering while at the same time many in the existing workforce in the U.S. government and U.S. nuclear industry who deal with safeguards have or will soon retire. With the support of the Department of Energy and NNSA, U.S. experts are currently working to develop a new generation of safeguards experts in the United States and also to encourage other countries to cultivate the expertise essential to the future of a credible international safeguards system.

Challenge of meeting new safeguards objectives

It is now clearly expected of the IAEA that it will detect diversion of nuclear material and provide assurances about the absence of undeclared nuclear material and activities. As described in Chapters 7 and 8, the latter objective has led the Agency toward a more qualitative approach that requires evaluations at the level of a State while taking into account State-level factors. It also takes into account all available information. This leads to the expectation that inspectors should be "less like accountants and more like detectives."

Accordingly, the Secretariat and inspectors needs to have additional skills beyond those needed to perform nuclear material measurements and draw conclusions based on nuclear material accountancy. There is today a much greater focus on all-source information analysis, which requires inspectors to have new analytical skills and much greater knowledge about nuclear-fuel-cycle technologies and indicators. New sources of information, such as satellite photographs, also place new demands on the staff of the Secretariat. Photo interpretation, for example, is a specialized skill, and there are a limited number of qualified individuals. The infrastructure for IAEA data collection, storage, retrieval and analysis also needs to be upgraded as the volume and types of information grow.

⁴⁸³ Report of the Commission of Eminent Persons (CEP) on the Future of the Agency, GOV/2008/22-GC(52) INF/4,23 May 2008.

⁴⁸⁴ Jill N. Cooley, IAEA, "Building Safeguards Expertise: Projected IAEA Needs," Next Generation Safeguards Initiative Workshop, Washington, D.C., 11-12 September 2008.

Overall, these trends have led to new requirements for training inspectors, for recruitment approaches, and for information technology expertise. To date these requirements have been met in large part by relying on support from Member States. Over time, though, the IAEA will have to develop internal organizational and staffing practices that reflect these requirements.

APPENDIX D. IAEA Safeguards in NPT Nuclear-Weapon States

As of December 2016, the IAEA had safeguards agreements in force with over 181 States. Almost all of these are INFCIRC/153 safeguards agreements concluded by non-nuclear-weapon States parties to the NPT. In addition, there are item-specific agreements, sometimes called INFCIRC/66 agreements that are in force with three States not party to the NPT, India, Israel, and Pakistan.

Although not required by the NPT, each of the five NPT nuclear-weapon States has also concluded a safeguards agreement with the IAEA. Because they are not required, they have become known as voluntary-offer agreements. Note that they are entered into voluntarily, but once in force, they are obligatory. For example, the United States voluntary-offer agreement, INFCIRC/288, has the status of a treaty and was treated legislatively like other treaties.

Voluntary-Offer Safeguards Agreements – IAEA “NPT” safeguards in NPT nuclear-weapon States

At the time of the negotiation of the NPT, there was widespread concern that the absence of IAEA safeguards in nuclear-weapon States would place non-nuclear-weapon States at a commercial and industrial disadvantage in developing nuclear energy. Non-nuclear-weapon States had two areas of concern: one was the potential interference with efficient operation of their commercial activities, and the other was compromise of industrial and trade secrets by IAEA inspectors.

These concerns led Japan and the non-nuclear-weapon States of the European Community to oppose, during preliminary NPT negotiations, an NPT provision that would require only non-nuclear-weapon States to accept IAEA safeguards. One solution would have been a requirement for all States to accept safeguards, but efforts to devise acceptable Treaty provisions for IAEA safeguards in nuclear-weapon States were unsuccessful. By late 1967, the safeguards issue had become a serious obstacle to acceptance of the NPT by major industrialized non-nuclear-weapon States.

In an effort to break that impasse, President Lyndon B. Johnson on December 2, 1967 stated that the United States was not asking any country to accept safeguards that the United States was unwilling to accept. He went on to say that, “when such safeguards are applied under the Treaty, the United States will permit the International Atomic Energy Agency to apply its safeguards to all nuclear activities in the United States -- excluding only those with direct national security significance.”⁴⁸⁵ The United Kingdom announced a similar offer on December 4, 1967. These two offers were instrumental in gaining acceptance of the NPT by key industrialized countries, and their importance was emphasized in public statements by the Federal Republic of Germany, Japan, and others. The U.S. offer would be delineated in a separate, formal agreement to be concluded with the IAEA.⁴⁸⁶ That agreement was signed in 1977, the same year that the safeguards

⁴⁸⁵ Address by President Lyndon B. Johnson on the occasion of the twenty-fifth anniversary of the first nuclear reactor, December 2, 1967. In *Public Papers of the Presidents of the United States: Lyndon B. Johnson, 1967, Book II*, pp. 1083–1085. Text of speech is also at

<http://www.presidency.ucsb.edu/ws/index.php?pid=28578&st=&st1=#axzz1WcvPylCo>.

⁴⁸⁶ For a useful review of the background and implementation of the United States Voluntary-offer safeguards agreement, including its text, see http://www.nt1.org/c_press/treaties_8.pdf, “Special Non-Proliferation Treaty

agreements of Euratom and Japan entered into force, and it was submitted to the U.S. Senate in 1978. The U.S. agreement entered into force in 1980.

Ultimately, this dynamic led each of the NPT nuclear-weapon States to conclude a safeguards agreement with the IAEA. Although the agreements are modeled on INFCIRC/153 and have almost the same text, the few differences make them fundamentally different in concept and coverage.

The key difference in concept is that INFCIRC/153 obligates a State to accept safeguards and also obligates the IAEA to apply safeguards. However, the voluntary-offer safeguards agreements with nuclear-weapon States have only “half” of this. They obligate the nuclear-weapon States to accept safeguards, but there is no obligation on the IAEA to apply safeguards.

The key difference in coverage is that the voluntary-offer agreements are not comprehensive. They all exclude military facilities and permit safeguards at a set of facilities that are identified to the IAEA, sometimes called the eligible list. Subject to available resources, the IAEA may select facilities from the list where it will apply safeguards. It is not obligated to pick any facility, although there are political pressures to pick some.

The coverage of the five nuclear-weapon State voluntary-offer agreements differs significantly, not only from INFCIRC/153, but also from one another. For example, under its agreement, the United States is obligated to provide the IAEA with a list of all nuclear facilities in the United States except only those “associated with activities of direct national security significance to the United States.” Under this requirement, in 2017, the United States listed about 300 facilities. In total, the five nuclear-weapon States have designated about 400 facilities to be eligible for the application of safeguards.

Table 11 compares the safeguards coverage of the five nuclear-weapon State voluntary offer safeguards agreements. In the Annex to its 2016 Annual Report, the IAEA reported that under these agreements, it applied safeguards to: a power reactor, a research reactor, and an enrichment plant in China; a fuel fabrication facility, a reprocessing plant, and an enrichment plant in France; a separate storage facility in Russia; one enrichment plant and two separate storage facilities in the United Kingdom; and one separate storage facility in the United States.

Safeguards Agreements.” This paper also includes the texts of the safeguards agreements with Euratom and with Argentina and Brazil.

Table 11. Safeguards for NPT Nuclear-Weapon States

NPT NUCLEAR-WEAPON STATES	SAFEGUARDS COVERAGE UNDER VOLUNTARY-OFFER SAFEGUARDS AGREEMENT
United States	All nuclear material in all facilities within the United States excluding only those facilities associated with activities of direct national security significance to the United States
United Kingdom	All nuclear material in facilities or parts thereof within the UK, subject to exclusions for national security reasons only
France	Nuclear material designated by France in facilities or parts thereof in France.
Russia	All nuclear material in peaceful nuclear facilities to be designated by Russia.
China	All nuclear material in peaceful nuclear facilities to be designated by China.

As described in Chapter 7, during the negotiation of the Model Protocol, non-nuclear-weapon States raised the same concerns that had arisen during the negotiation of the NPT: the desire for universal safeguards coverage and avoidance of placing them at a commercial or industrial disadvantage. It became clear that there would be no agreement on the Model Protocol without commitments by the nuclear-weapon States to conclude additional protocols themselves. As a result, the five NPT nuclear-weapon States made commitments to do so.⁴⁸⁷ Each of them now has an additional protocol in force.

⁴⁸⁷ The five Voluntary-Offer Agreements have been published by the IAEA as information circulars: United Kingdom, INFCIRC/263 (1977); United States, INFCIRC/288 (1980); France, INFCIRC/290 (1981); Russia, INFCIRC/327 (1985); and China, INFCIRC/369 (1989). The texts can be found at

<https://www.iaea.org/publications/documents/infcircs>. The texts of the five additional protocols are published as additions to these Information Circulars.

APPENDIX E. Small Quantities Protocol

As described in Chapter 5, INFCIRC/153 places a number of obligations on States, such as the establishment of a State System of Accounting for and Control of nuclear material that, strictly speaking, may not be relevant for States without nuclear programs. This was noticed almost immediately after the NPT entered into force, because more than forty non-nuclear-weapon States ratified the Treaty, which triggered their obligation to negotiate safeguards agreements with the IAEA. They had 180 days to start negotiations and eighteen months after that to bring their agreements into force. (Although eighteen months may seem like a long time, for States where entry into force depends on parliamentary, or in the case of the U.S., Senate advice and consent, it may not seem so long.)

Among the forty, there were many States, such as Iceland, Nepal, and San Marino, that had no nuclear material and no nuclear activities. Since it seemed unnecessary to require them to implement many of the provisions of INFCIRC/153, the Secretariat prepared a protocol to INFCIRC/153 that suspended the implementation of many of its provisions.⁴⁸⁸ States were eligible for this so-called “Small Quantities Protocol” (SQP) if they had only small quantities of nuclear material (less than the amount that could be exempted from safeguards under the terms of INFCIRC/153) and no nuclear material in a nuclear facility (as facility is defined by the IAEA).

Under the SQP, eligible States did not have to report these small quantities or give the IAEA advance notice of plans to build nuclear facilities. The SQP also suspended the IAEA rights of inspection, even special inspections. Thus, even if the Secretariat suspected a State with an SQP was no longer eligible for it, the IAEA’s rights to pursue this suspicion were, as a legal matter, extremely limited.

As the emphasis on detecting undeclared nuclear material and activities grew starting in the early 1990s, the limitations of the SQP became increasingly at odds with the safeguards-strengthening measures that had been put in place to improve the IAEA’s ability to address undeclared activities. As a result, in 2005 the Secretariat launched an initiative to revise the SQP, and later that year, the Board agreed on a modification that corrected the defects described above.⁴⁸⁹

Specifically, the modified version of the SQP includes requirements that States provide initial reports to the IAEA on all of their nuclear material and early design information for any planned nuclear facilities. It also reinstated the Agency’s right to conduct ad hoc and special inspections. The Board decided to approve in the future only the modified text, and it called on each State with an SQP to modify it or to rescind it. As of the end of 2017, some 100 States had concluded an SQP with the Agency.

⁴⁸⁸ The Small Quantities Protocol appears to have been drafted by the Secretariat and not approved by the Board prior to its use. The text of the Small Quantities Protocol used from 1971 to 2005, together with the text of INFCIRC/153 was published in GOV/INF/276 in 1974. (<https://ola.iaea.org/ola/documents/GINF276.pdf>.)

⁴⁸⁹ Small Quantities Protocol (SQP), Standard Text of the IAEA Small Quantities Protocol as revised in 2005, GOV/INF/276/Mod.1, 21 February 2006. (<https://ola.iaea.org/ola/documents/ginf276mod1.pdf>.)

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IX. Additional Resources

Journals, Periodical Reports

JNMM (Journal of the Institute of Nuclear Materials Management) and Annual Meeting and other Conference Proceedings, INMM; available at <https://www.inmm.org/>

ESARDA Bulletin and Symposium Proceedings, ESARDA, European Commission Joint Research Centre, Ispra, Italy; available at <https://esarda.jrc.ec.europa.eu/>

Arms Control Today, Arms Control Association, Washington DC, USA.

Nonproliferation Review, Monterey Institute of International Studies, Monterey, CA, USA.

Disarmament Diplomacy, Acronym Institute for Disarmament Diplomacy, London, United Kingdom.

IAEA Documents

Many of the technical papers referenced can be found by searching at the IAEA INIS website:

[http://www.iaea.org/inis.](http://www.iaea.org/inis)

IAEA General Conference documents are contained in its General Conference Archive.

Documents for the 55th General Conference (2011) may be found at:

<http://www.iaea.org/About/Policy/GC/GC55/Documents/>.

This is also a starting point for finding documents from earlier sessions of the General Conference.

IAEA Information Circular (INFCIRC) documents are at:

<https://www.iaea.org/publications/documents/infcircs>

The texts of the NPT and IAEA related treaties are at:

<https://www.iaea.org/publications/documents/treaties/npt>

A useful collection of definition of terms and guiding legal documents are at:

Nuclear Safeguards Education Portal, TAMU, <http://nsspi.tamu.edu/nsep/reference-modules>.

Proceedings of the Annual Meetings of the Institute of Nuclear Materials Management. Institute of Nuclear Materials Management, Deerfield, Illinois, published annually (now issued as CD-ROMs).

Proceedings of Symposia on International Safeguards. Vienna: International Atomic Energy Agency, published quadrennially (now issued as CD-ROMs).

2006 Symposium papers are available at:

http://www-pub.iaea.org/MTCD/Publications/PDF/P1298_webstart.pdf.

2010 Symposium papers are available at:

<http://www.iaea.org/OurWork/SV/Safeguards/Symposium/2010/Home.htm>.

Web Resources

Nuclear Threat Initiative.

(<http://www.nti.org/index.php>)

The Institute for Science and International Security (ISIS) is a non-profit, non-partisan institution that, in its words, is “dedicated to informing the public about science and policy issues affecting international security. Its primary focus is on stopping the spread of nuclear weapons and related technology to other nations and terrorists, bringing about greater transparency of nuclear activities worldwide, strengthening the international non-proliferation regime, and achieving deep cuts in nuclear arsenals.” It has detailed analyses of nuclear programs and compliance issues in countries of concern.

(<http://www.isis-online.org>)

The Center for Strategic and International Security (CSIS) regularly adds to its compilation of Essential Readings, which is part of its Proliferation Prevention Program.

CSIS: <http://csis.org>

Proliferation Prevention Program: <http://csis.org/program/proliferation-prevention>

The Homeland Security Digital Library is composed of homeland security related documents collected from a wide variety of sources. These include federal, state, tribal, and local government agencies, professional organizations, think tanks, academic institutions, and international governing bodies. It contains a large number of items related to IAEA safeguards and nuclear proliferation.

(<http://www.hsdl.org>)

Nuclear data graphs and diagrams relevant to safeguards measurement techniques are available from several sources. Two are

<http://www.nndc.bnl.gov/>

http://www.radiochemistry.org/periodictable/gamma_spectra/