THE INTERNATIONAL ATOMIC ENERGY AGENCY

AND THE SAFEGUARDING PROCESS

CHARLES DENYER

Table of Contents

Chapter 1

The International Atomic Energy Agency (IAEA) serves as the world's nuclear regulatory mechanism and enforcer of the Treaty on the Non-Proliferation of Nuclear Weapons, or NPT, and considers itself the "center of the world's cooperation in the nuclear field."[1] We find the roots of the IAEA within the "Atoms for Peace" speech President Dwight D. Eisenhower gave to the United Nations in 1953. Eisenhower sought to establish a body that would channel the pursuit of nuclear technology into an endeavor that would provide more than martial benefit to mankind. In 1957 this "Atoms for Peace" agency, as the IAEA calls itself, was created. Due to the Cold War, the IAEA had difficulty carrying out its mission because of the ongoing arms race between the United States and Soviet Union. Finally, with the advent of the 1962 Cuban Missile Crisis, the superpowers began to cooperate on proliferation issues.[2] As it became clear that nuclear technology, and its military applications, were spreading with the successful testing of nuclear weapons by France and the People's Republic of China, the world saw a need to stem the tide of nuclear development and determined the IAEA's current limitations to be inadequate. Thus, the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) was drafted and voted into law in 1968. This froze the number of nuclear weapons states at five (5). Included in this club of sorts were the United States, Great Britain, France, China and the Soviet Union (subsequently Russia). The NPT concurrently banned all other signatories from developing nuclear materials and/or nuclear weapons. Since 1968, the primary objective of the IAEA has been to ensure the NPT's proper function in all signatory states.

---

[1] http://www.iaea.org/About/index.html.
[2] http://www.iaea.org/About/index.html.

The NPT, which significantly enhanced the role of the IAEA around the world, contains three main provisions to protect against the global spread of nuclear technology and equipment. First, with their agreement to the NPT, signatories "have undertaken not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over them, and not in any way to assist encourage or induce any non-nuclear-weapon state to manufacture or acquire such weapons or devices."[3] In addition, non-nuclear-weapons states "have pledged not to receive nuclear weapons or other nuclear explosive devices or control over them as well as not to manufacture them or receive assistance in their manufacture."[4] Second, those countries designated as Nuclear Weapons States must enact safeguards that "must be able to detect in a timely fashion the diversion of significant quantities of nuclear materials from peaceful nuclear activities to the manufacture of nuclear explosive devices as well as deter diversion by the risk of early detection."[5] Further, Nuclear Weapons States are required to work toward eventual disarmament and complete destruction of their nuclear arsenals. Lastly, in a principle that has spurred debate concerning The Islamic Republic of Iran, "the NPT affirms the right of the parties to develop and use nuclear energy for peaceful purposes and obligates the parties in a position to do so to contribute to such efforts in non-nuclear weapons states with due consideration for the needs of the developing areas of the world."[6]

---

[3] Goldblat, Jozef. *Arms Control: The New Guide to Negotiations and Agreements* (London: SAGE Publications, Ltd, 2002), 101-2.
[4] Ibid.
[5] Ibid., 103.
[6] Ibid., 105.

This report provides substantive information and analysis of the activities of the International Atomic Energy Agency (hereafter referred to as IAEA). The objective is to discuss the history, mission, and in particular, the successes and failures of the Department of Safeguards. This will be followed by a critical analysis and recommendations for improving the monitoring and evaluation process of the current safeguards system.

Chapter 2

The International Atomic Energy Agency (IAEA)

The U.N.-issued missions and mandates of the IAEA are manifold. These objectives are defined by the Statute of the IAEA and came into effect on July 29th, 1957. The first stated purpose of the IAEA is:

> To encourage and assist research on, and development and practical application of, atomic energy for peaceful uses throughout the world; and, if requested to do so, to act as an intermediary for the purposes of securing the performance of services or the supplying of materials, equipment, or facilities by one member of the Agency for another; and to perform any operation or service useful in research on, or development or practical application of, atomic energy for peaceful purposes.[7]

Most of the IAEA's stated objectives deal specifically with the monitored, sharing, and exchange of "scientific and technical information" and attempt to provide a trusted medium for the administration of "materials, services, equipment and facilities to meet the needs of research."[8] For the purpose of this report, the focus is on Article V of the statute, which covers Safeguards and regards the objective of safeguarding as:

> Establish[ing]and administer[ing] safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy.[9]

This statement begins the legal framework through which the IAEA asserts its rights to inspection and testing of nuclear sites and materials.

---

[7] http://www.iaea.org/About/statute.html.
[8] Ibid.
[9] Ibid.

The Departments of Safeguards is just one of the IAEA's many facets. There are six major departments within the Agency: The Department of Management, Technical Cooperation, Nuclear Energy, Nuclear Safety and Security, Nuclear Sciences and Applications, and Safeguards. In addition, four offices report directly to the Director General, Mohamed El Baradei. These offices include the Secretariat of Policy Making Organs (PMO), Office of Internal Oversight Services (OIOS), Office of External Relations and Policy Co-ordination (EXPO) and the Office of Legal Affairs (OLA).

The Department of Management is separated into five divisions. The Division of Budget and Finance "ensures the overall efficiency and effectiveness of financial services and systems." The staff ensures proper appropriation of agency funds and provides "transparency" in use of these funds. Other divisions within the Department of Management oversee personnel matters and facility management.

The Department of Technical Cooperation serves to "transfer nuclear and related technologies for peaceful uses to countries throughout the world."[10] The IAEA's technical cooperation programs spend nearly 70 million dollars (US) annually. This division provides educational opportunities to developing nations, with over 800 ongoing projects ranging from food and agriculture, to water resources and environmental protection, to nuclear power."[11]

Peaceful application of nuclear energy is the backbone of the atoms for peace program. Thus, one of the IAEA's foremost divisions is its Department of Nuclear Energy (DNE). The stated goal of the DNE is to "increase the capability of interested

[10] http://www-tc.iaea.org/tcweb/abouttc/default.asp.
[11] http://www-tc.iaea.org/tcweb/abouttc/default.asp.

Member States to implement and maintain competitive and sustainable nuclear power programmes and to develop and apply advanced nuclear technologies."[12] The IAEA accomplishes this mission through the training of localized personnel and by facilitating the construction of small- to medium-sized light-water reactors and power stations.

The Department of Nuclear Safety, while similar to Safeguards, focuses on protecting the people and environments that come into contact with radioactive materials and nuclear power stations. It monitors disposal and storage sites that contain spent nuclear fuel and provides training to member states in order to enhance their ability to meet Agency standards and regulations.

The Department of Nuclear Sciences and Applications conducts research and field experiments concerning the non-energy and military use of nuclear technology and equipment. Its primary focus is on "Nuclear Techniques for Development and Environmental Protection."[13] Further, this division has delved into researching applications of radiation therapy for certain types of cancer.

For the purposes of this report, the Department of Safeguards (DS) is the most important. It is the operational arm of the Director General as well as the most well-recognized and active sector within the IAEA. An in-depth discussion of the Department of Safeguards is presented later in this report, independent of the other departments.

These six departments assist the Director General in carrying out the IAEA's mission. The goal of the IAEA is to serve as "an independent intergovernmental, science

[12] http://www.iaea.org/worldatom/Programmes/Nuclear_Energy/NENP/.
[13] http://www-naweb.iaea.org/na/about/index.html.

and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear cooperation."[14] Through this mission the IAEA uses international resources to provide technical training and support to member states, especially those in the developing world. The Agency also includes in its mission the charge to create and codify the safety and security standards applied to nuclear facilities. It provides guidance on the proper use and storage of all radiological materials and devices. The IAEA characterizes its approach to fulfilling its mission as "cross-cutting…in which all Agency activities, regardless of organizational structure, programme location or sources of funding are integrated,"[15] into a cohesive and functional organization. The most visible part of the Agency's mission is to "[verify], through its inspection system, that States comply with their commitments, under the NPT and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes."[16]

As global concern grew over the possible spread of nuclear weapons. the Irish government submitted this draft to the General Assembly in 1961:

> All States, and in particular 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 from transmitting the information necessary for their 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.[17]

This draft formed the basis upon which the NPT was created, and the Department of Safeguards has its genesis in the NPT. Because all non-nuclear-weapons states that

[14] http://www.iaea.org/About/mission.html.
[15] Ibid.
[16] Ibid.
[17] http://disarmament.un.org/wmd/npt/nptbi.html

signed the treaty are required to allow inspection of their nuclear sites, materials and equipment, the Department of Safeguards was critically needed. In addition to ensuring non-nuclear-weapons states (NNWS) undertook do not receive assistance with acquiring nuclear weapons, the department is charged with enforcement of Article III of the treaty, which states:

> 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 Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices.[18]

However, the obligations for the five countries designated as nuclear-weapons states (NWS) are somewhat different. NWS are barred from sharing any nuclear material with a martial purpose yet are not themselves mandated to submit to safeguard regulations.

---

[18] http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc140.pdf.

Chapter 3

Department of Safeguards of IAEA

The history of the Department of Safeguards (DS) is short yet complicated. As stated previously, the DS has its genesis in the NPT. But it is not limited to the NPT alone. The treaty, and thus the mission of Safeguards, has been expanded through several treaties such as the Treaty for the Probition of Nuclear Weapons in Latin America, the African Nuclear Weapons Free Zone Treaty (Pelindaba Treaty) and the Guideline for Nuclear Transfers, 1993 Revision of the Nuclear Suppliers Group, just to name a few. The DS updates its provisions and regulations, usually on an annual basis, through what are called Information Circulars (INFCIRC), the most recent being INFCIRC 540, the Model Additional Protocol for the NPT, which sets out new guidelines and regulations to be adopted by member states.[19]

The DS is divided into five sections. At the head of the DS is the Deputy Director General for Safeguards, supervising the "Section for Safeguards Programme and Resources(SPR)." The SPR manages the DS, maintains control over its budget and direction, and makes recommendations with regard to inspection results.[20]

Similar to the IAEA as a whole, the DS has a Division of Technical Support that manages and keeps safeguards equipment operational and current. This division itself is consists of five sub-sections that manage different aspects of the safeguarding process. The Director of Technical Support "ensures the provision of training for inspectors…for personnel from member states…as well as analytical services associated with nuclear

---

[19] http://www.iaea.org/Publications/Documents/Treaties/index.html.
[20] http://www.iaea.org/About/Jobs/sg.html.

material and environmental inspection sample analysis."[21] The remaining sections within this division are well explained by their titles: Section for Installed Systems, Section for NDA Systems and Seals, Section for Common Technical Support and Section for Safeguard Training.

Possibly the most active, and certainly the most well-known, division within the DS is the Division of Operation (SGO). The SGO has three teams of inspectors: A, B and C. These teams carry out the vital mission of verification of nuclear activities, or lack thereof. Their activities and responsibilities are broad in scope and range from the "implementation of safeguards inspections at nuclear facilities…verification of design information at declared facilities to confirm the completeness and adequacy of the design information provided by the state" to "tak[ing] nuclear material and environmental samples" and "analyz[ing], review[ing] and evaluat[ing] data collected from facility records, design information and other reports submitted by States, inspection results, databases and open sources." Inspection activities of the SGO are categorized as either field activities or activities at Headquarters. Both briefings and debriefings on inspection results are conducted at Headquarters.[22]

The fourth primary division is the Division of Safeguards Information Technology (SGIT), which distributes safeguards information throughout the entire DS. "This includes information from declarations by States, under safeguards agreements, the strengthened safeguards system and the Additional Protocol, from open sources,

[21] Ibid.
[22] http://www.iaea.org/About/Jobs/sg.html.

commercial satellite imagery and from any other source available to the Agency."[23] SGIT is subdivided into three sectors: Information Support Services, Systems Infrastructure Support, and Hardware and Software Services. These sectors assist in safeguards compliance confirmation, maintenance of databases and deployment, and maintenance of information technology services, respectively.

The Division of Concept and Planning (SGCP) is responsible for "strategic planning and for the development and standardization of safeguards concepts, approaches, procedures and practices in order to ensure effective and efficient application of safeguards." SGCP also ensures the quality of incoming data from safeguards evaluations.

The Department of Safeguards and the respective missions of its divisions are critical for continuing global stability and keeping nuclear weapons and technology from those who would utilize it for dubious means. At its core the DS has two vital components: To ensure the safe use of nuclear energy and to implement the NPT to stop the spread of nuclear weapons.[24] In fulfilling the first mission, the DS performs a public service and assures both member states and the general public that accidents like those at Chernobyl, Mayak, and Three Mile Island facilities won't occur again. The second mission—stopping the proliferation of nuclear weapons—has never been important as non-member states continue to acquire nuclear weapons. For example, Pakistan, which tested its first nuclear weapon a few decades ago, has been responsible for spreading, or attempting to spread, the technology and expertise involved in creating nuclear weapons

---

[23] Ibid.
[24] http://www.usun-vienna.rpo.at/_index.php?cmd=cmdFrontendInternationalOrganizations.

to other countries with hostile global aspirations. The scientist responsible, A.Q. Khan, admittedly expropriated technical know-how to Libya, Iran, and North Korea, which would use these weapons as tools of intimidation against other nations and as bargaining chips in negotiations with other nuclear-capable states. The success of the Department of Safeguards is essential, so that non-nuclear countries need not exist in a constant fear of a nuclear attack from a rogue state. If the DS is successful, the likelihood of a nuclear conflict decreases. The Safeguards system can aid global stability and lead to confidence-building measures among otherwise antagonistic states. Positive nuclear diplomacy improves the global standard of living. Nuclear safeguards, in turn, can fashion a world in which peaceful uses of nuclear energy are made available to nations who agree to comply with safeguards.

The IAEA, and the DS in particular, face several challenges in verifying that signatory states are in fact not abusing their nuclear materials and facilities. The most blatant examples of direct defiance of IAEA authority were discovered in Iraq following the 1991 Gulf War, when Saddam Hussein "undertook an extensive programme to develop the capability to produce weapons-usable nuclear materials." The facilities and materials Iraq disclosed to the IAEA were under inspection and safeguards, yet in the months leading up to the invasion, Iraq had been smuggling fissile material to secret facilities in the Iraqi desert. In discovering a clandestine nuclear program, the IAEA learned the limitations of its safeguard system. This experience created a "substantial strengthening of the IAEA safeguards system to provide assurance not only that declared material is not diverted, but also that undeclared nuclear activities are not taking place in

States which have signed comprehensive safeguards agreements."[25] Then, when South Africa renounced its pursuit of nuclear weapons and signed the NPT, it allowed the IAEA unfettered access to all its nuclear sites and nuclear material. This allowed the IAEA to verify what has come to be known as the "correctness" and "completeness" of South Africa's declarations. Unfortunately, there are some nations whose pursuit of nuclear technology and nuclear arms is undeterred by international pressure, the IAEA or the Safeguards system. One of the greatest problems facing the DS arises when inspectors are expelled from member states and those states withdraw their NPT membership and choose to pursue nuclear arms. Two cases have come to light recently that may pose dire consequences for the future of the NPT and global stability. In one case, the Democratic People's Republic of Korea (DPRK) expelled IAEA inspectors and withdrew from the NPT. The North Korean nuclear program began in the 1960s, with Soviet help, with other countries like "China also provid[ing] various kinds of support over the next two decades…A milestone was reached with the construction of a 5-megawatt electric reactor that began operating in 1986." In the early 1990s, the U.S. brokered an agreement under which "North Korea would freeze and eventually dismantle its nuclear program, which would be verified by the International Atomic Energy Agency (IAEA)."[26] But North Korea consistently evaded detection of its clandestine nuclear program and the DS failed to detect the inconsistencies in the DPRK's reporting. Prior to its withdrawal from the NPT, the DPRK received from Pakistan "high-speed centrifuges and how-to data on building and testing a uranium-triggered nuclear weapon." The DPRK became the first country to remove itself from the NPT. Most recently the events in Korea have caused

[25] http://www.iaea.org/Publications/Booklets/Safeguards2/part5.html.
[26] http://www.thebulletin.org/article_nn.php?art_ofn=ma03norris.

global alarm. On 8 October, 2006, North Korea detonated an explosive of a magnitude that indicated it was a nuclear weapon. The danger that the DPRK poses is manifold and has led, in part, to the fourth major challenge facing the IAEA: Iran.

Issues regarding the correctness and completeness of Iran's reporting arose in 2003 and the IAEA sent a team of inspectors to investigate. The IAEA, soon thereafter, passed a resolution censuring Iran for its nuclear program and calling for Iran to suspend enrichment and allow for tougher inspection criteria.[27] Matters worsened in 2005 when Iran resumed uranium enrichment and was found by the IAEA to be in violation of its treaty obligations. The situation further deteriorated in February 2006 when the IAEA referred Iran to the U.N. Security Council and Tehran continued its enrichment. Since then negotiations have stalled, with the Security Council demanding Iran halt enrichment and Iran patently refusing. These challenges make it difficult to enforce the NPT and raise fears that highly-enriched uranium (HEU and/or U-235 or higher) and nuclear technology will be sold to those with evil intentions.

[27] http://news.bbc.co.uk/1/hi/world/europe/2645741.stm.

Chapter 4

The Safeguards System and its Functions

The IAEA Safeguards system has its background in the voluntary acceptance of safeguards by signatory states. The actual system itself is defined in the Information Circulars (INFCIRC) disbursed by the IAEA. The specific arrangement between the state parties and the IAEA is details what regulation states are willing to accept. The nuclear weapons states (NWS) have arrangements that differ in several respects from those of the non-nuclear weapons states (NNWS), and that's a significant point of contention between the two groups. In some cases, NWS such as the United States and France have allowed access only to civilian reactors and not military reactors. Naturally, countries with only civilian reactors resent this as a double standard.

In order to determine whether a state is in accord with its obligations under the NPT, the IAEA uses its principles of "correctness" and "completeness." In verifying the "correctness" issue, the IAEA assesses the accuracy of a state's declared nuclear resources, including the location of storage facilities, the type and amount of material stored, and the type of equipment used. In order to verify completeness, the IAEA uses a variety of means such as satellite imagery and, more notably, inspection teams. Usually the "completeness" issue surfaces when there are inconsistencies or glaring inaccuracies in the country's report. Until the early 1990s:

> Verification measures actually implemented under comprehensive safeguards agreements were focused primarily on the "correctness" of a State's declarations…the safeguards system was able to provide meaningful assurance only in relation to the non-diversion of nuclear material that had been declared to the Agency.

After the revelation of the clandestine program in Iraq, the IAEA shifted its focus to an "ability to verify the completeness of a State's declarations so that the safeguards system would also be able to provide credible assurance of the absence of undeclared nuclear material and activities in a State with a comprehensive safeguards agreement."[28] In order to strengthen its role in stopping the spread of nuclear material, the IAEA chose to expand its role in verifying "completeness."

Although the primary legal framework of the safeguards system had been worked out in the NPT, the question arose as how to expand the Agency's role without offending notions of national sovereignty and national security. The legal basis for safeguards was found in the original INCIRCS and was expanded to fit the changing international situation. The original Safeguards agreement had been constructed as INFCIRC 153, which, deemed to be inadequate from the perspective of completeness, resulted in more legislation. Expansion of the safeguards system was outlined in INFCIRC 540, also called the Model Additional Protocol, which filled in the areas that INFCIRC 153 was lacking. This protocol differed from the original in several respects, but most critically in its combining the correctness and completeness aspects. The Model Additional Protocol provides a solid legal foundation for inspections, collection of material and information, and verification of completeness. It accomplishes these goals by requiring countries to submit materials concerning "nuclear fuel cycle-related research and development activities," which includes the operational and output status of uranium mines. They also inquire as to the amount of fissionable materials, especially HEU and plutonium, and demand the names and qualifications of those who will be working with the material.

---

[28]www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf#search=%22legal%20basis%20for%20IAEA%20safeguards%22.

The legal basis for safeguards inspections is found in Article 4: Complimentary Access. This article is broad in scope, stating what the IAEA can do and where it can go. The Agency reserves the right to conduct inspections at any time, providing it gives twenty-four hours notice to any facility that a member country is required to report upon. However, the Agency reserves the right for spot inspections in some cases: "For access to any place on a *site* that is sought in conjunction with design information verification visits or ad hoc or routine inspections on that *site*, the period of advance notice shall, if the Agency so requests, be at least two hours but, in exceptional circumstances, it may be less than two hours." Article VI of this agreement provides the framework for testing and sampling using both Destructive Assay (DA) and Non-Destructive Analysis (NDA) of declared nuclear materials. Articles VII-X concern the rights of the agency to conduct environmental sampling tests over larger areas to detect various illicit activities, the requirement of the signatory states to allow unfettered access to all locales in question and the promise of the agency to issue annual reports on its findings. The treaty also requires the signing party to issue visas to IAEA inspectors and personnel and to allow the inspectors to communicate with IAEA headquarters and other officials in that country. In return for good faith access and disclosure, the Agency guarantees the state party that it will not share commercial or technological secrets with other parties. This legal framework acquires force when all requirements of the protocol have been met and the agency has received a signed copy of the document. The legal framework defines all essential terms so there is no confusion as to what the Agency expects of the parties.[29]

[29]http://www.iaea.org/Publications/Documents/Infcircs/1998/infcirc540corrected.pdf#search=%22infcirc%20540%22.

The IAEA has set certain objectives it wishes to meet in order to fulfill its role as the international nuclear watchdog. According to the Agency, "the technical objectives of safeguards are the timely detection of the diversion of significant quantities of nuclear material from peaceful uses to the manufacture of nuclear weapons or other nuclear explosive devices or for purposes unknown; and the deterrence of such diversion by the risk of early detection." Secondarily, inspectors also attempt to discover undisclosed production and mining facilities. The theory behind this is that "a certain quantity of fissile nuclear material…is needed to manufacture a nuclear explosive device and that a certain length of time is required to convert that material" into a usable weapon. Another technical objective under the comprehensive safeguard agreements is to "pursue the detection of undeclared nuclear material and activities." For those states under the "safeguard agreements with additional protocols" the agency goals converge with the previously stated goals of "correctness" and "completeness."

> For INFCIRC/66-type safeguards agreements, the overall objective is to ensure that the nuclear material and items specified under the relevant agreements are not used for nuclear weapons or any other nuclear explosive device, or to further any military purpose. To achieve this, the Secretariat applies essentially the same technical safeguards objectives as those for comprehensive safeguards agreements. This is also the case for the nuclear material and/or facilities to which safeguards are being applied under the voluntary offer safeguards agreements with nuclear-weapon States.

The IAEA approaches its safeguarding systems from a facility-specific standpoint. Thus, the type and extent of safeguards depend on the location of the facility, who operates the facility, and the type of facility that is being monitored (i.e. light v. heavy water). The IAEA inspection team analyzes a facility, determines the possible means of misappropriating nuclear material specific to that site and applies the appropriate safeguards; the Agency also evaluates "the facility design features, including their suitability for the use of containment and surveillance; the form and accessibility of the nuclear material; and the measurement and analytical methods available to the Agency." The Agency also evaluates the likelihood, or lack thereof, of a state covertly producing and exporting nuclear products.[30] The reason for this approach is to detect both declared and undeclared material by identifying all possible ways and means of diversion.

The IAEA sets certain goals to be achieved during inspections. Inspections are designed to cover both the specific site and, from a wider perspective, determine if the country's facilities as a whole are in compliance. These inspections have a "quality component and a timeliness component." Concerning quality we look to the completeness of the inspection to determine that all possible approaches were covered. Regarding timeliness, the IAEA seeks to assess if the "periodic activities necessary to conclude that there has been no abrupt diversion during a calendar year" are present. So long as no more than 1 SQ (?) of nuclear material is not missing or unaccounted for, the IAEA considers the inspection a success. Secondly, the IAEA implements the "Zone Approach." With this approach the IAEA inspects all the facilities in a country at one time to prevent any misappropriation of resources. The Agency treats different sectors within a country as one entity for the purposes of enforcing the safeguards agreements. Within the inspections we focus on five components. First, the inspection must encompass all of the reactors/storage facilities in a given country and account for the type(s) of material produced there. Second, if there has been a transfer of nuclear

---

[30] http://72.14.203.104/search?q=cache:Z4seyWcbX-wJ:www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf+IAEA+safeguards+approaches&hl=en&gl=us&ct=clnk&cd=1.

material, it is necessary to verify that the receipt report and shipping report concur. The U.S. Department of Energy has guidelines on how to fill out reports on nuclear material transfers and has a model report to decrease the risk of errors. Non-nuclear materials and equipment linked to the nuclear fuel cycle must also be itemized and accounted for. Finally, for proper inspections, the IAEA must assure against the "borrowing" of nuclear material from one site to fill a vacancy in another. This part of the inspection process ensures all material is accounted for and requires that inspections take place simultaneously.[31]

Strengthening the Safeguards System has been an essential component of international nuclear security. There were two major safeguards milestones in the 1990s. First, North Korea, the DPRK, signed the NPT as a non-nuclear weapons state and opened its facilities to IAEA inspectors. Unfortunately, the DPRK recently withdrew from the treaty and has since claimed that it successfully tested a nuclear device. The other milestone was the renunciation of nuclear weapons by South Africa in 1991. With this development, the IAEA gained valuable insight into a secret nuclear program and learned how to enhance safeguards to better predict and detect a breach. Since the discovery of Iraq's clandestine program after the U.S.-led invasion, the IAEA has been called upon to augment its ability to safeguard nuclear material and prevent its diversion to unauthorized users. The Iraq case taught the IAEA that new and more effective means of completeness, correctness, and compliance were necessary for the Agency to receive respect and legitimacy. In 1991, some in the international community doubted the IAEA's effectiveness. However, after conducting inspections of Iraq's facilities without notification, and the IAEA discovered several generally applicable principals. "It is

[31] http://200.0.198.11/MenoriaT/Pi30.pdf.

possible for a nuclear verification body to provide the international community with an accurate estimate of the past and present situation provided that: the inspection team is technically strong and thorough, in particular in its analysis of documentation down to a detailed level and in its dealings with all relevant personnel; the team remains politically independent, i.e. relying on facts only, away from bending to political pressure; Member States are supportive of its action, both politically through the support of the Security Council and technically through the provision of information and expertise; the inspected State fulfils the verification body's requests."[32] Thus, following the exposure of Iraq's clandestine activities, the IAEA began to implement the Additional Protocol. In the words of Director General El Baradei, "A combination of sanctions and inspections disarmed Iraq."[33]

IAEA Safeguards are implemented and enforced in a variety of manners. First the Agency inspectors seek to verify the amount and quality of nuclear material possessed by a member state. Nuclear Material Verification focuses on the declared quantities reported by a state to the IAEA. The level of verification and type of inspections required depend on the kind of material produced and the type of safeguards agreement to which the IAEA and the country have agreed. It is important to note that not all material may be subject to safeguards and that the IAEA only has the right to inspect and verify those declarations made regarding the safeguarded material. Thus, "the Agency's ability to detect any undeclared nuclear material or activities in States without an additional protocol is limited."[34] Inspectors use the following techniques when verifying declared nuclear materials, "Examination of facility and accounting/operating records and

[32] http://www.iaea.org/Publications/Magazines/Bulletin/Bull461/article21.pdf.
[33] Ibid.
[34] http://www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf.

comparison of these records with accounting reports submitted by the State; □application of containment and surveillance measures; □verification of inventories of nuclear material and, under certain types of agreements, of non-nuclear material and equipment, and of inventory changes at a facility; □verification of nuclear material flows, including transfers between facilities and transfers within facilities; □confirmation of the absence of undeclared production or separation of direct-use material at reactors, reprocessing facilities, enrichment plants and installations with hot cells."[35] Thus, the process of nuclear material verification involves both technical and physical means of verification.

The additional protocol drafted following the discovery of Iraq's clandestine nuclear program called for allowing IAEA inspectors to visit nuclear facilities with little or no warning. Inspectors discovered the need for on-the-spot inspections after the Iraqi government used the time between notification and inspection to shuffle material and personnel from one place to another and deceive inspectors concerning activities conducted at the site. Under INFCIRC 540, those states that have signed the Model Additional Protocol must assent to inspections without notice. There are three main different types of inspections: Ad Hoc, Special, and Routine. *Ad Hoc* inspections are those carried out "to verify a State's initial report of nuclear material or reports on changes thereto, and to verify the nuclear material involved in international transfers."[36] *Special* inspections are carried out in unusual circumstances and used to supplement information provided by states when the IAEA deems that information inadequate. *Routine* inspections, those that by their very definition are the most common, are most limited in scope. These inspections occur at pre-designated sites and are usually

---

[36] http://www.uic.com.au/IAEAsafeguards.htm.

conducted with the knowledge of the host country. They are limited to those sites that are declared to contain or process nuclear material. Lastly, there are inspections to determine if the safeguards themselves are being appropriately constructed. These *Safeguards* inspections are conducted on a regular basis and with the permission of the host country.

Reports are issued yearly concerning compliance with the Safeguards implemented by the IAEA and the state. Because the nuclear fuel cycle involves several types of equipment and materials that are traceable if moved, there are several steps involved in issuing an accurate report on a state's activities. The report based upon "these features provides the basis for an assessment of, firstly, the internal consistency of the State's declarations to the Agency and, secondly, the consistency between the State's declarations and other information available to the Agency." Again, what the agency is confirming is completeness and correctness. The material evaluated by the IAEA comes from five main sources: Information submitted by the state, information obtained by the inspectors under the additional protocols, open source information, data from IAEA internal databases (such as comparisons of past and present amounts of nuclear material) and information from third parties.[37] More detailed reports can be made for those states that have enacted the additional protocols, allowing for integrated safeguards and complimentary access.[38] These reports are reviewed by an independent committee, which issues the final report along with any recommendations for follow-up inspections and/or other activities.

The Safeguards reports are issued at the end of each year after all inspections in a given state are completed. For states with comprehensive safeguards agreements, the

[37] http://www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf.
[38] http://www.iaea.org/NewsCenter/Statements/DDGs/2003/goldschmidt12022003.html.

ideal conclusion of a report would be that "all nuclear material within the territories of those States, under their jurisdiction or under their control anywhere had been placed under safeguards and remained in peaceful nuclear activities or was otherwise adequately accounted for." For those states without the additional protocol, the ideal statement would be that "…the nuclear material [and other items (INFCIRC/66 States only)] placed under safeguards remained in peaceful nuclear activities or was [were] otherwise adequately accounted for."[39] Those states without a safeguards agreement have no report issued regarding their activity because the IAEA has no legal right to review their activities (i.e. India, Pakistan, Israel, and DPRK). The IAEA, based on an evaluation of the safeguards in place, also issues a statement regarding the non-diversion of material and equipment. To conclude that safeguarded material has not been misused or misappropriated, the IAEA evaluates whether "nuclear material flows and inventories are as declared; the facility design is in accordance with the declared design and consistent with the corresponding safeguards approach; facility operations are as declared (e.g., though the review of surveillance records); facility material accountancy systems conform to prescribed standards; the facility operator's measurement systems perform to international standards and are in good statistical control over time; and that all anomalies are resolved or otherwise explained."[40]

One of the best examples of a successful integrated safeguards regime is that of Australia. In order to fall under the integrated safeguards standard, the country must first fall under the category of a state with "Strengthened" safeguards. The Strengthened safeguards program is voluntary (as is the integrated program) and allows the IAEA

[39] http://www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf.
[40] Ibid.

complimentary access to all sites it wishes with or without notice. It also involves an expanded declaration of materials by the member state. The integrated safeguards approach differs from the strengthened approach in that it involves the ratification of the additional protocol, a comprehensive state evaluation, the IAEA has complimentary access to all sites and the IAEA has concluded that there has been no diversion of nuclear material. Unannounced inspections are not uncommon with the integrated safeguards regime and are usually accompanied by remote monitoring equipment. However, now "the IAEA seems cautious about using remote monitoring because of problems related to reliability and cost."[41] While integrated safeguards come at a higher cost, they are more effective at preventing the spread of nuclear weapons, material and technology. But with fifty-four non-nuclear weapons states yet to sign a safeguards agreement, there is no way to assure all materials are accounted for. Integrated safeguards are only effective if they are implemented as a whole, in all countries with nuclear capabilities or aspirations.

[41] www.asno.dfat.gov.au/publications/intsafeguards_aust_viewexp.html.

Chapter 5

Nature of the Safeguards System

The nature of the safeguards system has changed drastically since the failures in Iraq in the early 1990s. The IAEA has created two "tests" for determining if the voluntary reporting of a member state is truthful and entails the entirety of its nuclear activities. These principles are aptly named "correctness" and "completeness." Completeness is addressed in three circumstances:

"The completeness of States' initial nuclear material declarations—for States with a significant nuclear program—upon entry-into-force of their comprehensive safeguards agreement with the IAEA; The completeness of States' nuclear material declarations as a continuing feature of the implementation of safeguards; and The completeness of States' declarations under circumstances where safeguards inspections are not carried out because of the small quantities of nuclear material involved."[42] After a state submits its report, the correctness of the report is verified and then the completeness element is addressed. Implementation of the safeguards is based on the assumption that the report is complete.

It helps to explain these principles in the context of a "problem" state. South Africa's renunciation of nuclear weapons was an example of correct and complete reporting. South Africa exhibited a high level of cooperation, which made a determination as painless as possible. Iran is an example of a report failing the correctness test. In June 2004, the Director General became concerned that Iran's reporting was inaccurate. The IAEA report concerning Iran "pointed to several key omissions or deceptions…[and] found that the Iranians have been experimenting with the

[42] http://www.iaea.org/Publications/Magazines/Bulletin/Bull451/article2.pdf.

production of polonium…Tehran has so far been unable to provide records or other evidence to support its explanation." Additionally, "the report also confirmed that Iran had been testing a much more advanced model of uranium centrifuge than previously admitted."[43] The IAEA was also concerned that Iran was purchasing nuclear technology on the black market via the A.Q. Khan network from Pakistan. Here the Iranians violated the correctness aspect of reporting because they falsified the type of centrifuges that they were using. They also failed the completeness test because they did not report that they had been experimenting with polonium. In summation, Iran failed correctness because it falsified information in its reporting and failed completeness because it did not disclose what it was required to disclose under its agreement with the IAEA.

Some of those countries that have ratified the Model Additional Protocol are experimenting with the integrated/comprehensive safeguards that the IAEA hopes to implement globally. Australia has chosen to implement the integrated safeguards program, which appears more cost effective and less invasive. Under the integrated safeguards regime, the IAEA and the Australian government have reduced inspection costs by 45%. This is accomplished through fewer inspections, plus remote monitoring techniques. There is one planned, announced inspection and one unplanned, unannounced inspection each year. Although there have been minor problems with remote monitoring, both parties believe they can be remedied with more advanced equipment. The Australian report notes that the integrated safeguards approach is beneficial and provides a "credible assurance" that there has not been a diversion of nuclear material. There were only minor problems with complimentary access as the government could not guarantee access at privately owned sites. A simple remedy would

[43] www.acronym.org.uk/dd/dd77/77iran.htm.

be legislation. Overall, integrated safeguards provide a more cost effective and simpler means of verifying that there has been no diversion.

Chapter 6

Safeguards Techniques and Equipment

Several new safeguards techniques and equipment for detecting diversion have developed in the past few decades, as the need arose. These measures of testing nuclear material have contributed to advances in several fields, especially medicine and environmental protection. When dealing with actual nuclear samples there are two general approaches: Non-Destructive Analysis (NDA) and Destructive Analysis (DA). The most prevalent NDA techniques include Gamma Ray, neutron counting and measurement of spent fuel. Destructive analysis involves elemental analysis, with isotopic analysis among several other techniques. Safeguards also involve monitoring of nuclear facilities (both actual power/research reactors and mining and storing equipment), remote monitoring of equipment, data security and tests on the environment surrounding the nuclear sites.

Within NDA, Gamma Ray detection is a simple and non-invasive way to test for radioactive materials. It can be accomplished with as little as a hand-held device that beeps as radioactive frequencies and PPM increase.[44] Recent developments have allowed these devices to be combined with cellular telephones, making Gamma Ray detection even easier.[45] Other products have been designed to increase the sensitivity of detection equipment. These advances by American scientists will allow "inspectors new capabilities, such as enabling them to determine the plutonium content of spent reactor fuel without handling the fuel or receiving reliable information from the reactor's

---

[44] http://www.radrisk.com/datasheets/PalmRad907_datasheet.pdf.
[45] http://www.llnl.gov/PAO/news/news_releases/2003/NR-03-04-06.html.

operators."[46] Gamma Ray tools are divided into two types, those with low resolution and those with high resolution. Low-resolution detectors are sensitive to low amounts of radiation but do not detect the entire spectrum. Conversely, high-resolution detectors sense the entire spectrum of radiation but will not always detect small amounts.

Neutron counting is also an effective means of NDA. This analysis ascertains the number of neutrons per sample and is effective when samples are taken directly from the reactor and placed immediately into a testing device. A special and accurate form of neutron counting is Delayed Neutron Counting (DNC), a rapid and sensitive technique developed in the United Kingdom.[47] Australia, a leader in the safeguards field, has developed a High Efficiency Passive Neutron Counter (HENC) that is highly accurate and conducts rapid analyses. There are several other types of neutron counters. Those developed by the Centtronic Corporation include Helium 3, BF_3 and Boron Lined Proportional Neutron Counters.[48]

Spent fuel measurement is a post-use means of determining the purpose and enrichment level of nuclear waste. Used nuclear fuel samples are delivered in what is called a "Large Sized Dry Spike." These analyses are conducted in IAEA laboratories by specially designed robots. Spent nuclear fuel is stored in indoor ponds (wet storage) or in a dry above-ground facility. There are five primary techniques involved in spent fuel measurement, as determined by the IAEA. Neutron emission and detection is an approach than involves "a detector which is basically insensitive to g rays. Another approach is to shield against the g rays while allowing neutrons to pass through the shield

---

[46] http://www.physorg.com/news11753.html.
[47] http://www.imperial-consultants.co.uk/example.php?id=58.
[48] http://www.centronic.co.uk/products_detectors_theory.asp.

into the neutron detector."[49] The IAEA also suggests gamma neutron and gamma ray detection, which is accomplished by testing "the ratio of the neutron to g ray data…combined with other…information" in order to "characterize a particular type of fuel assembly, giving information related to its neutron exposure in the reactor, its initial fissile fuel content and its irradiation history."[50] Other tests also include Gamma Ray Energy Spectral Analysis, Gamma Ray Intensity Scanning and Cerenkov Radiation Detection.

Another manner in which to test nuclear material is Destructive Analysis (DA). DA is broken down into Elemental Analysis, specifically of uranium and plutonium, and Isotopic Analysis. There are several types of Elemental Analysis that can be applied to plutonium, and the Department of Energy has compiled a list of recommended ways in which to test that have both a low cost and a high rate of accuracy. Controlled Potential Coulometry is one such test; it involves "Quantitative electrolytic oxidation of Pu(III) to Pu(IV) at an electrode maintained at a controlled potential with determination of the quantity of Pu from the quantity of electricity required for the complete oxidation." This is a precise and accurate test with a "medium" cost. A low-cost alternative is Ceric Tritration. This involves "Oxidimetric titration of Pu(III) to Pu(IV) using the oxidant Ce(IV) as titrant with spectrophotometric detection of the end point which is observed as a color change of the added ferroin indicator or potentiometric endpoint; the Pu in the initial sample is reduced prior to the titration using a lead reductor column." Another low-cost alternative is Amperometric Titration. This entails Reductimetric titration of Pu(VI) to Pu(IV) using the reductant Fe(II) as titrant with amperometric detection of the

[49] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.
[50] Ibid.

end point after preliminary oxidation of the Pu-to-Pu(VI) using excess Ag(II) oxide as an oxidant. Amperometric titration is based on observation of the change in current at a working electrode as titrant is added. In this titration the electrode responds to the Fe(II) titrant; when the end point is exceeded a current flow proportional to the excess Fe(II) is observed allowing detection and determination of the end point."[51]

Elemental Analysis is also an appropriate means of measuring the type and quantity of uranium. A low-cost means of analyzing uranium is Davies/Gray Titration. DG Titration consists of "Redox titration of U(IV) to U(VI) with potentiometric end point detection after chemical pretreatment of the sample solution to adjust the oxidation states of species present so that uranium is essentially the only substance titratable by the oxidant." One of the more technologically advanced means of elemental analysis is Laser Induced Kinetic Phosphorescence. This is a slow and simple method of analysis that is also low in cost. The basic principle is to utilize the "measurement of the intensity of the green phosphorescence of U which results from excitation with ultraviolet light from a pulsed nitrogen/dye laser. The phosphorescence of the UO2+2 is filtered, amplified, and measured by a computer which also calculates the result." Finally, a highly reliable, long-lasting and very fast method of analysis is Densitometry. In Densitometry, "a vibrating hollow U-shaped tube is caused to oscillate at a high frequency. The frequency squared of the tube oscillation is proportional to the mass of the tube. Filling the hollow tube with a liquid changes the mass of the tube and the tube oscillation. The density meter is calibrated by injection of two standards of different density into the hollow tube and measuring the tube oscillation for each standard. The

[51] http://64.233.167.104/u/IaeaORG?q=cache:5zQBfZpY-68J:www.eh.doe.gov/techstds/tsdrafts/sans0001/sans0001.pdf+destructive+assay,+elemental+analysis&hl=en&gl=us&ct=clnk&cd=4&ie=UTF-8.

density of an unknown sample is determined by relating the tube oscillation of the sample to the tube oscillation of the standards. Temperature is controlled either with a constant temperature bath or Peltier cooler."[52]

Destructive Assay also presents itself in the form of Isotopic Analysis. Thermal Ionization Mass Spectrometry is a widely accepted and accurate means of Isotopic Analysis. This method is most effective because it utilizes "a dual uranium/plutonium spike isotope dilution technique…to allow rapid analysis of uranium/plutonium content and isotopics. A single UTEVA Resin column is utilized to simultaneously separate both uranium and plutonium from the sample matrix. The plutonium and uranium can be rapidly removed from the column separately or eluted together for analysis. This new method combines sample preparation into a single, effective separation step that significantly reduces sample preparation time and costs."[53] Another means of Isotopic Analysis lies in X-Ray Fluorescence. This helps to identify different elements as "high energy x-ray photons produced in the x-ray tube bombard the sample causing the ejection of electrons from their orbitals. Fluorescence occurs when energy is given off as outer shell electrons drop down to replace inner shell electrons that have been ejected. The amount of energy lost as a result of each such electron transition, along with its related wavelength, are specific to each particular element." This is especially helpful in identifying and differentiating LEU from HEU.

Containment and Surveillance are vital to verifying correctness and completeness without the expense of constant inspection. The IAEA has developed three types of

[52] http://64.233.167.104/u/IaeaORG?q=cache:5zQBfZpY-68J:www.eh.doe.gov/techstds/tsdrafts/sans0001/sans0001.pdf+destructive+assay,+elemental+analysis&hl=en&gl=us&ct=clnk&cd=4&ie=UTF-8.
[53] http://sti.srs.gov/fulltext/ms2001155/ms2001155.html.

single camera systems that will work in combination with what is described as the Next Generation Surveillance System (NGSS). A prime example of a true single camera system is the Digital Single Camera Optical Surveillance System (DSOS). This is a "single camera digital surveillance unit that has been developed to replace aging film and videotape surveillance systems for difficult to access locations where the camera must be located away from the recording unit." An adaptation of this system for larger facilities is the Server Digital Image Surveillance System (SDIS). SDIS "is a multicamera digital surveillance system developed for remote and unattended operation with limited multiple camera capability. Able to support up to six cameras, SDIS can also be used to replace single camera systems where they can be combined efficiently." Lastly the Digital Multi-camera Optical Surveillance System (DMOS) "is a multiple camera digital surveillance system developed for new installations and to replace aging videotape based multiple camera systems supporting between 6 and 16 cameras each." All three of these programs are already under way worldwide in nearly fifty facilities.[54] These systems will drastically reduce the cost of monitoring and the invasiveness of the inspections, and allow for unadulterated data transmission directly from the surveillance site to IAEA headquarters. Underwater television cameras are another means of monitoring nuclear sites and are especially helpful when viewing wet-storage facilities holding Uranium and Plutonium. These two systems alone cannot fulfill the IAEA verification mission. The element that makes remote monitoring possible is surveillance software. Surveillance software and its applications will be discussed in depth in the next section.

---

[54] http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html.

Additional unattended and remote monitoring practices continue to assist in reducing inspection costs. The IAEA defines remote monitoring as “the transmission of images and data off-site to IAEA headquarters, or to an IAEA regional office or field office.”[55] Remote monitoring promotes efficient use of time and resources by reducing the amount of time needed in the field and by saving money on inspections. Remote monitoring also has another context. “Information regarding the status of the monitoring equipment is transmitted,” thus “allow[ing] the IAEA to remotely monitor the performance of an instrument...Currently, the IAEA has five unattended monitoring systems in two countries providing remote ‘state of health’ data.”[56]

Because of the sensitive nature of the information and technology used in the nuclear facilities and the transfer of information concerning those facilities, the IAEA places a high priority on data security. Data security assuages fears that technological secrets vital to national security will be compromised. The Agency wants to ensure that nuclear technology or information about the transport of nuclear materials does not fall into the wrong hands. Information protection requirements depend on the material’s level of sensitivity and the length of time for which it must be encrypted. Data are divided into three categories: that used by inspectors during safeguarding activities, technical data used in review by IAEA technical staff, and control data “used for the real time control of the equipment” involved in remote monitoring activities or during maintenance.[57]

---

[55] http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#remotemonitoring.
[56] Ibid.

[57] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.

To protect information transferred by Safeguards Systems from member state-owned sites, the IAEA anticipates little difficulty; it is usually stored on-site and runs a minimal risk of interception because the remote monitoring systems will usually be operated by a closed-circuit or intranet system. The IAEA does not anticipate using satellite systems to transmit data because they are more easily intercepted. The IAEA states that "encryption should be applied during data transmission, as agreed with the State. Transmitted data shall be treated and stored as 'Safeguards Confidential' information." Surprisingly "the detailed safeguards information from the Agency equipment should not be made available to the States" yet IAEA will, at times allow the "sharing of certain data as part of the cooperation arrangements."[58] The IAEA also requires that member states act to ensure their own information security. Member states are responsible for "ensuring that adequate protection is provided for data links between sensors and collect computers if not otherwise protected by physical boundaries provided by member states and [e]nsuring adequate protection of the data stored on transportable media."[58]

Environmental sampling is one of the more recent safeguards added to the IAEA's arsenal. This technique, together with other NDA methods, allows inspectors to obtain a complete picture of the activities at a nuclear site through a "collection of swipe samples inside enrichment plants." Samples are analyzed and tested in either bulk or by particles. Bulk analysis requires testing of the entire sample while particle analysis "relies on the detection and analysis of individual particles in the micrometre size range

[58] Ibid.

and provides as results the U and Pu content."[59] Laboratory Safeguards are designed to ensure anonymous tests of the samples provided by member states. The samples are usually measured with gamma radiation, with certain samples being "chosen for measurement in the Clean Laboratory by isotope dilution thermal ionization mass spectrometry, using a highly sensitive instrument equipped with pulse counting detection." The environmental samples are tested by three main processes. Low-Level Gamma Ray Spectrometry is accomplished by placing samples "on a 90% efficient coaxial Ge detector enclosed in a high purity lead shield of 10 cm thickness." The samples are then "placed in a 15 position sample changer and counted for 1 h each to provide a g ray spectrum in the energy range from 5 keV to 3 MeV." X ray fluorescence spectrometry is used to "detect microgram amounts of U, Pu or other elements of interest on the surface of swipe samples." Similar to other tests, robots are used to conduct the analyses. The test "is performed for 4–5 hours and the spectra are then evaluated to determine the amount of the element present as well as its spatial distribution." Lastly, the IAEA uses Alpha/beta counting. Alpha/beta counting uses "a gridded ionization chamber counting system…to screen radioactive swipe samples for the presence of a or b emitting isotopes."[60] This is a highly sensitive and accurate system.

The IAEA also utilizes a form of Isotopic and elemental analysis in testing environmental samples. Again, "thermal ionization mass spectrometry is used to measure U and Pu concentrations and isotopic compositions." The thermal ionization test used in environmental testing is more sensitive than that used in Destructive Analysis. This is accomplished by "the use of special sample treatment procedures, drop

---

[59] Ibid.
[60] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.

deposition of the sample elements onto the mass spectrometer filament and use of a pulse counting detection system with high detection efficiency. The accuracy and precision of this technique are about 1–10% for a U or Pu concentration in the 10-9 g range and for the ratios of the major isotopes in the sample."[61]

The IAEA utilizes a substantial variety of equipment systems in conducting its safeguard activities in order to conduct the most effective and efficient tests. Within Non-Destructive Assay the IAEA uses different types of equipment for the three primary means of verification. Gamma Ray Spectrometry can be done with a hand-held detection device, the HM-5(fieldSPEC). This is a "modern, handheld, digital gamma spectrometer combining various functions such as dose rate measurement, source search, isotope identification, active length determination for fuel rods and assemblies, and Pu/U attribute verification." This device also has law enforcement and customs service applications in that it can be used to detect radiological devices at border crossings. The IAEA employs two types of multi-channel devices. The IMCA (InSpector2000) "can be combined with the various types of detector that are now used for inspection purposes, namely HpGe, CdZnTe and NaI, allowing high, medium and low resolution spectrometry." The diverse capabilities of this device and its ease of use allow the IAEA to pair it with basic software and provide accurate and reliable field data. There are high-resolution models of this equipment that provide for "the determination of the isotopic composition of plutonium…. Isotopic determination of plutonium is used to verify the nature of the material. The recently developed…TARGA software provides a user-friendly environment with the MGA code to determine the isotopic composition of

[61] Ibid.

plutonium samples. The combination of the I-2000 system with TARGA software replaces the previously used MediumCount Rate System combined with PUIS software."

Neutron counting devices include twenty-two different devices currently in use. The IAEA primarily uses the High-Level Neutron Coincidence Counter (HLNC), the Inventory Sample Counter (INCC), the Active-Well Coincidence Counter (AWCC) and the Uranium Neutron Coincidence Collar (UNCL). This equipment is used in "verification of Pu in 20–2000g canned samples (pellets, powders, scrap);" "Verification of Pu in 0.1–300 g samples. Modified version can be attached to gloveboxes;" "Verification of 235U in high-enriched U samples;" and "Verification of 235U in low enriched U fuel assemblies; a variety of collar configurations are available," respectively.

Spent Fuel Analysis is conducted by four primary methods, each using a different equipment system. Gross neutron and Gamma Ray detection is conducted using a Fork Detector Irradiated Fuel Measuring System. This device accomplishes both Gamma Ray and neutron detection in one unit in addition to a portable computer. The purpose of this device is to detect highly radioactive wet-storage areas in underwater ponds. Gamma Ray energy spectral analysis is performed by the Spent Fuel Attribute Tester (SFAT). The SFAT serves to verifies the presence of spent fuel through detection of particular fission product g rays — either from 137Cs (662 keV) for fuel that has cooled for longer than four years or from short lived fission products such as 144Pr (2182 keV) for fuel with short cooling times—and performs tests that Cerenkov detectors cannot.[62] However, Cerenkov radiation detection is a vital element of spent fuel analysis and is done through the Cerenkov Viewing Device and the Digital Cernkov Viewing Device.

[62] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.

These products are "sensitive to the ultraviolet radiation in the water surrounding spent fuel assemblies" and are capable of operating in poor lighting conditions.

Unattended radiation monitoring is the key component to the Unattended and Remote Monitoring Segment of the Safeguards Protocols. This safeguards system has been integrated with easy to use software such as Microsoft's Windows NT edition in order to simplify the safeguarding process.[63] There are three main systems the IAEA has deployed with regard to Unattended Radiation Monitoring: VXI Integrated Fuel Monitor CANDU Bundle Counter (VFIB), the VXI Integrated Fuel Monitor CANDU Core Discharge Monitor (VFIC) and the Advanced Thermo-Hydraulic Power Monitor (ATPM). The VIFB is a "specialized unattended radiation monitoring system developed to replace aging spent fuel bundle counters in CANDU reactors." The system has already been installed at seventeen installations.[64] In order to better monitor the core fuel delivery monitor in CANDU reactors, the IAEA deployed the VFIC, which has installed 19 systems with six more to be introduced in the near future. Lastly, the ATMP system is designed to provide a "process based measure of reactor power for research reactor based safeguards." Only one of this system is in place; the IAEA plans to install seven more in coming years.[65]

As stated previously, the Containment and Surveillance aspect of the comprehensive safeguards regime helps prevent diversion of nuclear material, confirms correctness and completeness and lowers the costs and frequency of inspections. The IAEA has implemented a series of comprehensive systems in order to accomplish these

---

[63] Ibid.
[64]http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#unattendedradiationmoniori n.
[65] www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#unattendedradiationmonioring.

goals. The All-in-one System (ALIS) is a single digital video surveillance device that provides real-time and constant access to locations. Installation of these devices and replacement of the obsolete ones was scheduled to be completed in 2003.[66] Secondly, the IAEA has utilized the All-in-one Portable System (ALIP). ALIP is a device specifically designed to be used temporarily to monitor specific activities. IAEA has also implemented the Digital Single Camera Optical Surveillance System (DSOS), which is designed for difficult-to-access areas within facilities where the camera and recording unit must be located away from each another. Several multiple camera systems have also been employed in the surveillance domain. The Server Digital Image Surveillance System (SDIS) is "a multi-camera…system developed for remote and unattended operation." This system can support six independently functioning cameras. Finally, there is the Digital Multi-Camera Optical Surveillance System (DMOS). This digital system will replace video-tape systems and support between six and sixteen cameras per system; it is being installed with the intent of replacing all aging and/or obsolete systems.

To accommodate the advancing surveillance systems, the IAEA has introduced software designed "specifically for the review of all the digital image surveillance records." This program, designated General Advanced Review Station Software or GARS, allows the IAEA to provide the most accurate reports and keeps inspectors up to date on all monitoring activities.[67]

Sealing technology is a simple yet reliable means of verifying that various parts of nuclear facilities and equipment have not been tampered with. Seals have been used in the past with limited success in Iraq and North Korea. There are two primary methods of

---

[66] Ibid.

[67] http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#surveillance.

sealing in use today; the Variable Coding Sealing System (VCOS) and the Improved Adhesive Seal (VOID). The VCOS is "an *in situ* readable electronic seal" that has recently been upgraded. The VOID is a paper seal that is used in the traditional sense of forbidding access to certain facilities and equipment.[68] There are more advanced sealing measures such as the Ultrasonic Seal and the Ultrasonic Sealing Bolt. Both of these devices effectively secure "underwater applications of CANDU fuels bundles or for bolts closing shipment and storage containers of LWR spent fuel assemblies."[69]

The IAEA also uses a series of remote monitoring systems in its comprehensive safeguards regime. Remote monitoring significantly cuts the cost of verifying completeness and correctness while also reducing the need for repeat inspections. Within the world of safeguards, remote monitoring is "generally considered to mean the transmission of images and data off-site to IAEA headquarters." Remote monitoring allows inspectors to evaluate the "state of health" of the system itself without having to perform routine inspections.[70] The IAEA's primary system for collecting field data is the Server Digital Image Surveillance system or SDIS. This device provides information security and encryption of sensitive materials for transmission to field offices or headquarters and allows for integration of remote monitoring systems.[71]

---

[68] http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#sealing.
[69] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.
[70] http://www.iaea.org/Publications/Booklets/TeamingInspectors/applying.html#remotemonitoring.
[71] http://www-pub.iaea.org/MTCD/publications/PDF/NVS1-2003_web.pdf.

Chapter 7

Recent developments in troubled areas of the world have heightened the need for the global community to move toward comprehensive safeguards agreements. In order for lesser-developed countries to agree to the additional protocols, leading nations need be in the vanguard of the safeguarding process. The IAEA has begun an admirable upgrade program in several countries, but the states that have implemented an integrated safeguards regime are not those posing a significant risk of proliferation. In order to truly test the integrated safeguards programs described above, it needs to be applied in a state which poses a threat of proliferation (as a proven or suspected proliferant). In order for the IAEA to fulfill its mission, several things are required, according to Deputy Director General for Safeguards Pellaud. First, the IAEA needs to mandate those verification activities required under INFCIRC/153 and INFCIRC66. Second, it is essential that non-nuclear weapons states ratify the model additional protocol containing the integrated safeguards requirements with complimentary access; third, nuclear weapons states need to allow complimentary access, too. This will help ensure non-diversion, correctness and completeness, and set an example for non-nuclear weapons states on compliance standards.[72] Director Pellaud also advocates increased cooperation between states and the IAEA; modification/elimination of redundant measures; judicious use of resources and revision of technical and temporal parameters; less predictability regarding inspections and more sophisticated use of advanced safeguards equipment.[73] Should the IAEA succeed in its drive to employ the model additional protocols and have those agreements

[72] http://www.iaea.org/Publications/Magazines/Bulletin/Bull394/pellaud.html.
[73] Ibid.

ratified and enforced, the risk of diversion and proliferation will drastically decrease along with budget expenditures.

However, there are major concerns about the future of safeguards and the goals of non-proliferation. They stem from two big problem areas. First, there is the consistent and troubling lack of international will to enforce the safeguards agreements. Second, there are still major nuclear players that are not parties to the NPT.

There are two major cases in which states have totally disregarded the international safeguards community: Iran and North Korea. The Iranians have consistently and systematically defied their obligations under the NPT. Iran has also openly defied the IAEA and the UN. If the international community cannot prevent a rogue state from disabling its safeguards equipment and suspending inspections, then the efficacy of safeguards is nil. The Iranians have removed seals and monitoring equipment in addition to successfully enriching uranium. While the Iranians claim that their nuclear program is for peaceful energy purposes only, President Ahmadinejad's fiery rhetoric suggests otherwise. The full nature of Iran's program remains to be seen. But Iran's example may inspire other nations to defy international law and acquire enrichment equipment on their own. Sadly, some members of the Security Council give economic concerns higher priority than global security and non-proliferation. It is troubling and dangerous that the United Nations Security Council, the most powerful countries in the world, could not persuade, either by diplomacy or threat of sanction, Iran to relinquish its illegal nuclear program. Should Iran continue its enrichment work it may result in either a) a proliferation nightmare or b) an environmental disaster, or both.

It is also of great concern that some nuclear powers are not under any internationally recognized method of safeguarding. India, Pakistan, and North Korea (DPRK) have all successfully tested a nuclear device of one form or another, and they've either negated their safeguards arrangement or never enacted one. These countries have shown it is entirely possible to flout international convention and use the Atoms for Peace program or donated civilian reactors to build a home-grown nuclear cycle complete with nuclear weapons. Pakistan and the DPRK have been implicated in assisting each other and Iran with nuclear equipment design, specifications and missile/warhead technology. If these networks continue to grow and prosper, the consequences for relations in Asia and the Middle East could be apocalyptic.

For the safeguards regime to succeed long-term, member states must cooperate with the needs of the Agency. The IAEA needs accurate reporting, ratification of the Model Additional Protocol and increased support from the Security Council. By providing correct and complete information, member states reduce the inspection frequency and intensity, saving both time and money that can be used to create more advanced safeguards. That time and money also would be better spent in states prone to proliferation. When member states ratify the Model Additional Protocol, they increase the efficacy of the IAEA in the international community and promote acting in accordance with its treaties as a matter of international law. Without increased support from the UN Security Council, the IAEA will be unable to fulfill its mission as the international nuclear watchdog because it will be forced to rely entirely on the goodwill of nations, which often turns into a matter of convenience for some states.

We are seeing a growing demand for nuclear power, as well as increasing proliferation and nuclear waste. As global energy prices continue on their steady upward trend, many states are considering building their own nuclear power systems. As the demand for nuclear power grows, so will the need for safeguards, inspectors and, unavoidably, increased funding. However, if more member states ratify the Model Additional Protocol, thus implementing comprehensive and integrated safeguards systems, it is possible that the number of inspectors may need to rise only slightly. With a globally integrated safeguards system in force, the strain upon personnel and budget would be significantly reduced. The IAEA should be at the forefront of developing reactors that can used only for peaceful purposes, and it should enact and enforce agreements concerning the storage and maintenance of enriched and spent nuclear fuel.

As the number of reactors increases worldwide, so does the threat of more nations developing their own nuclear weapons capability. And those weapons could be sold on the black market. The world has historical evidence of what can happen when one country illicitly acquires nuclear weapons and technology: it sells them to the highest bidder. Pakistan and its scientist A.Q. Khan have sold nuclear technology, and equipment, and thus created a serious proliferation risk, to countries such as Libya, Iran, and North Korea. Had safeguards been in place, it is unclear what would have happened. However, one may surmise that had safeguards been in place in other nations, the advances in centrifuge technology (Iran) and other enrichment techniques could have been detected by remote monitoring, sealing, and/or digital surveillance. Comprehensive safeguards in *all* nuclear facilities are essential to prevent these information and equipment breaches in the future. Non-proliferation is a grave concern in Russia and the

NIS. With vast resources and borders, and struggling economies, these countries are a great proliferation risk and a potential arsenal for terrorists. In the name of nuclear security, the IAEA could implement its digital surveillance systems at these storage facilities and along the borders. This would provide ample opportunity to test the new remote monitoring and surveillance systems and software in a constructive and, more importantly, necessary manner that promotes non-invasive global nuclear security. A practical way to control the spread of nuclear weapons is to vest more power and authority in a number of the global export control regimes, specifically the Missile Technology Control Regime (MTCR) and the Nuclear Suppliers Group (NSG).

A familiar, yet pressing question presented to both the IAEA and those thirty countries with active nuclear power stations is: What to do with the waste? It is necessary to provide safeguards to the byproducts of nuclear energy so that terrorists do not acquire it in an attempt to create a radiological weapon. Currently, nuclear fuel rods, the most radioactive of all nuclear waste, have no active permanent disposal site. This waste is stored either in the boric acid pools inside the power station or in “dry storage” containers above ground, also near the power station. Currently, the U.S. Government is drilling into Yucca Mountain, Nevada, in order to establish a permanent waste disposal site. While Yucca Mountain’s environment (lack of ground water, no active fault lines and a dry climate) provides an optimal atmosphere for nuclear waste disposal, there is intense political opposition to this plan as no citizen wants nuclear waste near his or her home and water supply. Yet this waste must be stored somewhere, somehow; the most efficient and safe method to dispose of waste would be under the auspices of an international authority. This authority would create uniform methods and obligations for all those that make use of the nuclear fuel cycle.

In conclusion, we find that the role of the IAEA is fundamental in enforcing safeguards, promoting responsible growth of nuclear power and ensuring stability in troubled areas of the world. The Agency's core mission for the next fifteen years should be to enact, implement, and enforce the Model Additional Protocol and integrated safeguards regime in all states with nuclear reactors. Additionally, the IAEA should require, via the UN and international law, that all new reactors be built in accord with the Model Additional Protocol and be monitored in accordance with a comprehensive safeguards agreement. Global stability, especially in the Middle East and Asia, depends on the Agency's ability to determine that all nuclear activities in non-nuclear-weapons states are for peaceful purposes alone. If Iran were to acquire a nuclear device and the means of delivery, the entire Middle East could erupt in an arms race and an eventual nuclear conflict between the Arab world and Israel, or along the Sunni-Shia religious divide. We may see a similar scenario develop due to the activities of the DPRK. However, the IAEA cannot accomplish these goals alone. The international community must demonstrate the will to enforce the safeguards agreements that are designed to keep the world safe from nuclear proliferation.

References

Publications

Bier, Vicki, James Joosten, David Glyer, and Jennifer Tracey. *Effects of Deregulation on Safety: Implications Drawn from the Aviation, Rail, and United Kingdom Nuclear Power Industries*. Springer, 2006.

Murray, Raymond. *Nuclear Energy, An Introduction to the Concepts, Systems and Applications of Nuclear Processes.* Butterworth-Heinemann, 2001.

Naosuke, Itoigawa, Babette Fahlbruch, and Bernhard Wilpert. *Emerging Demands for the Safety of Nuclear Power Operations: Challenge and Response*. CRC, 2004.

Petrangeli, Gianni. *Nuclear Safety*. Butterworth-Heinemann, 2006.

Sagan, Scott. *The Spread of Nuclear Weapons: A Debate Renewed*. W.W. Norton & Company, 2002.

Schelling, Thomas. *Arms and Influence (The Henry Stimson Lectures Series).*, Yale University Press, 1967.

Smoke, Richard. *National Security and the Nuclear Dilemma*. McGraw-Hill, 1992.

Snow, Donald. *National Security for a New Era*. Longman Publishing, 2006.

Selected Documents and Reports

"Iran's Nuclear Policy and the IAEA: An Evaluation of Program" (Military Research Paper, No. 3), Washington Institute for Near East Policy, May 2002.

Nuclear Forensics Support Technical Guidance. (IAEA Nuclear Security) (Paperback). International Atomic Energy Agency, June 30, 2006.

"IRAN - Sept. 12 - IAEA Gives Tehran Till End-Oct." *APS Diplomat Recorder* (Newsletter), September 2003.

The Criticality Accident in Sarov. (IAEA Safety Standards) (Paperback), International Atomic Energy Agency (January 2001)

Operation of Spent Fuel Storage Facilities (IAEA Safety Series) (Paperback), International Atomic Energy Agency, February 1995.

Regulatory and Management Approaches for the Control of Environmental Residues Containing Naturally Occurring Radioactive Material (Norm). (IAEA Tecdoc Series) (Paperback), International Atomic Energy Agency; 1st edition, February 28, 2006.

Appraisal for France Of The Safety Of The Transport Of Radioactive Material: IAEA Safety Standards Applications - Transas-6. (IAEA Safety Standards Applications) (Paperback), International Atomic Energy Agency, September 20, 2004.

Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material: Safety Guide. (IAEA Safety Standards Series) (Paperback), International Atomic Energy Agency, Rev. Ed, January 2002.

Internet Sites

The International Atomic Energy Agency. www.iaea.org.

Nuclear Threat Initiative. www.nti.org.

Center for Defense Information. www.cdi.org.

Alliance for Nuclear Accountability. www.ananuclear.org.

Carnegie Endowment for International Peace. www.carnegieendowment.org.

National Nuclear Security Administration. www.nnsa.doe.gov.

Stockholm International Peace Research Institute. www.sipri.org.

Wisconsin Project on Nuclear Arms Control. www.wisconsinproject.org.

British American Security Information Council. www.basicint.org.

Arms Control Association. www.armscontrol.org.

Global Security Institute. www.gsinstitute.org.

World Nuclear Association-www.world-nuclear.org.

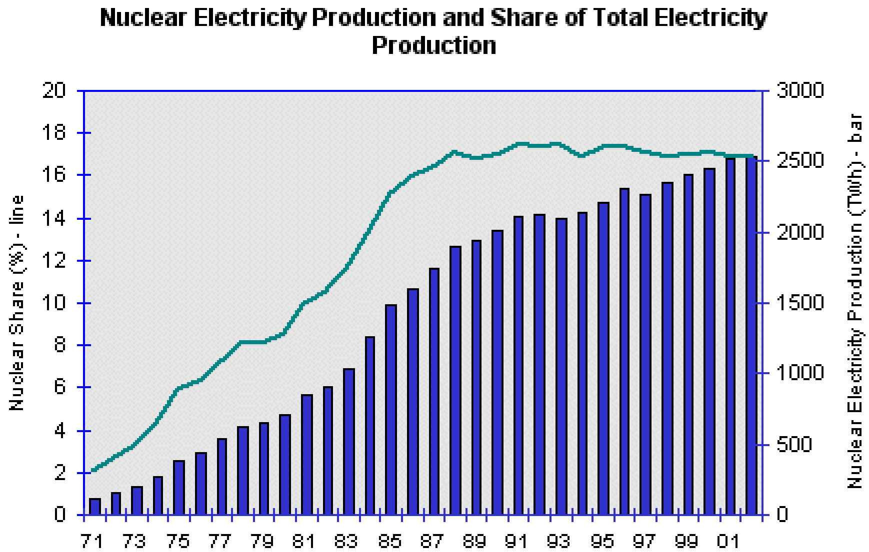
Nuclear Energy Institute. www.nei.org.

Appendix 1: Listing of Nuclear Reactors around the globe as of May 2007. Source: World Nuclear Association.

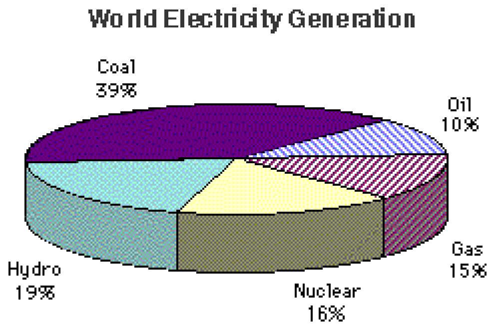
	NUCLEAR ELECTRICITY GENERATION 2006		REACTORS OPERABLE May 2007		REACTORS UNDER CONSTRUCTION May 2007		REACTORS PLANNED May 2007		REACTORS PROPOSED May 2007		URANIUM REQUIRED 2007
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
Argentina	7.2	6.9	2	935	1	692	0	0	1	700	135
Armenia	2.4	42	1	376	0	0	0	0	1	1000	51
Belgium	44.3	54	7	5728	0	0	0	0	0	0	1079
Brazil	13.0	3.3	2	1901	0	0	1	1245	4	4000	338
Bulgaria	18.1	44	2	1906	0	0	2	1900	0	0	255
Canada*	92.4	16	18	12595	2	1540	4	4000	0	0	1836
China	51.8	1.9	11	8587	4	3170	23	24500	54	42000	1454
Czech Republic	24.5	31	6	3472	0	0	0	0	2	1900	550
Egypt	0	0	0	0	0	0	0	0	1	600	0
Finland	22.0	28	4	2696	1	1600	0	0	0	0	472
France	428.7	78	59	63473	0	0	1	1630	1	1600	10368
Germany	158.7	32	17	20303	0	0	0	0	0	0	3486
Hungary	12.5	38	4	1773	0	0	0	0	0	0	254
India	15.6	2.6	17	3779	6	2976	4	2800	15	11100	491
Indonesia	0	0	0	0	0	0	0	0	4	4000	0
Iran	0	0	0	0	1	915	2	1900	3	2850	143
Israel	0	0	0	0	0	0	0	0	1	1200	0
Japan	291.5	30	55	47577	2	2285	11	14945	1	1100	8872
Kazakhstan	0	0	0	0	0	0	0	0	1	300	0
Korea DPR (North)	0	0	0	0	0	0	1	950	0	0	0
Korea RO (South)	141.2	39	20	17533	1	950	7	8250	0	0	3037
Lithuania	8.0	69	1	1185	0	0	0	0	1	1000	134
Mexico	10.4	4.9	2	1310	0	0	0	0	2	2000	257
Netherlands	3.3	3.5	1	485	0	0	0	0	0	0	112
Pakistan	2.6	2.7	2	400	1	300	2	600	2	2000	64
Romania	5.2	9.0	1	655	1	655	0	0	3	1995	92
Russia	144.3	16	31	21743	5	2720	8	9600	18	21600	3777
Slovakia	16.6	57	5	2064	2	840	0	0	0	0	299
Slovenia	5.3	40	1	696	0	0	0	0	1	1000	145
South Africa	10.1	4.4	2	1842	0	0	1	165	24	4000	332
Spain	57.4	20	8	7442	0	0	0	0	0	0	1473
Sweden	65.1	48	10	9076	0	0	0	0	0	0	1468
Switzerland	26.4	37	5	3220	0	0	0	0	0	0	575
Turkey	0	0	0	0	0	0	3	4500	0	0	0
Ukraine	84.8	48	15	13168	0	0	2	1900	20	21000	2003
United Kingdom	69.2	18	19	10982	0	0	0	0	0	0	2021
USA	787.2	19	103	98254	1	1155	2	2716	21	24000	20050
Vietnam	0	0	0	0	0	0	0	0	2	2000	0
WORLD**	**2658**	**16**	**437**	**370,040**	**30**	**22,398**	**74**	**81,601**	**182**	**151,345**	**66,529**
	billion	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U

	NUCLEAR ELECTRICITY GENERATION 2006		REACTORS OPERABLE May 2007		REACTORS UNDER CONSTRUCTION May 2007		REACTORS PLANNED May 2007		REACTORS PROPOSED May 2007		URANIUM REQUIRED 2007
	billion kWh	% e	No.	MWe	No.	MWe	No.	MWe	No.	MWe	tonnes U
	kWh										
	NUCLEAR ELECTRICITY GENERATION 2006		REACTORS OPERATING		REACTORS BUILDING		ON ORDER or PLANNED		PROPOSED		URANIUM REQUIRED

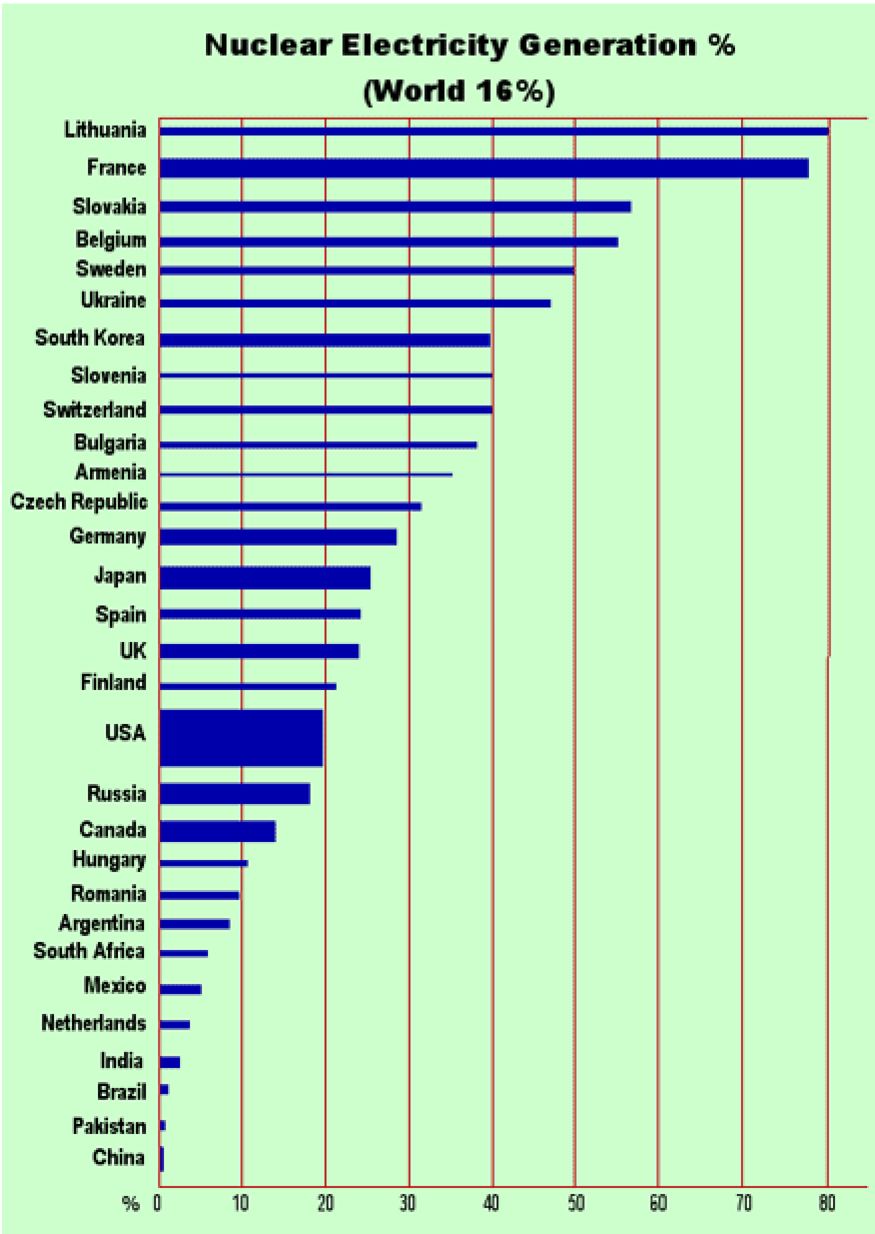
Appendix 2: Nuclear Electricity Production and Relevant percentages. Source: World Nuclear Association.



Appendix 3: World Electricity Production Percentages. Source: World Nuclear Association.



Appendix 4: Nuclear Production by Countries. Source: World Nuclear Association.



Appendix 5: Nuclear Power Plants in Commercial Operation in 2007. Source: Nuclear Engineering International Handbook 2007.

Reactor type	Main Countries	Number	GWe	Fuel	Coolant	Moderator
Pressurized Water Reactor (PWR)	US, France, Japan, Russia	264	250.5	enriched UO_2	water	water
Boiling Water Reactor (BWR)	US, Japan, Sweden	94	86.4	enriched UO_2	water	water
Pressurized Heavy Water Reactor 'CANDU' (PHWR)	Canada	43	23.6	natural UO_2	heavy water	heavy water
Gas-cooled Reactor (AGR & Magnox)	UK	18	10.8	natural U (metal), enriched UO_2	CO_2	graphite
Light Water Graphite Reactor (RBMK)	Russia	12	12.3	enriched UO_2	water	graphite
Fast Neutron Reactor (FBR)	Japan, France, Russia	4	1.0	PuO_2 and UO_2	liquid sodium	none
Other	Russia	4	0.05	enriched UO_2	water	graphite
	TOTAL	**439**	**384.6**			

GWe = capacity in thousands of megawatts (gross)

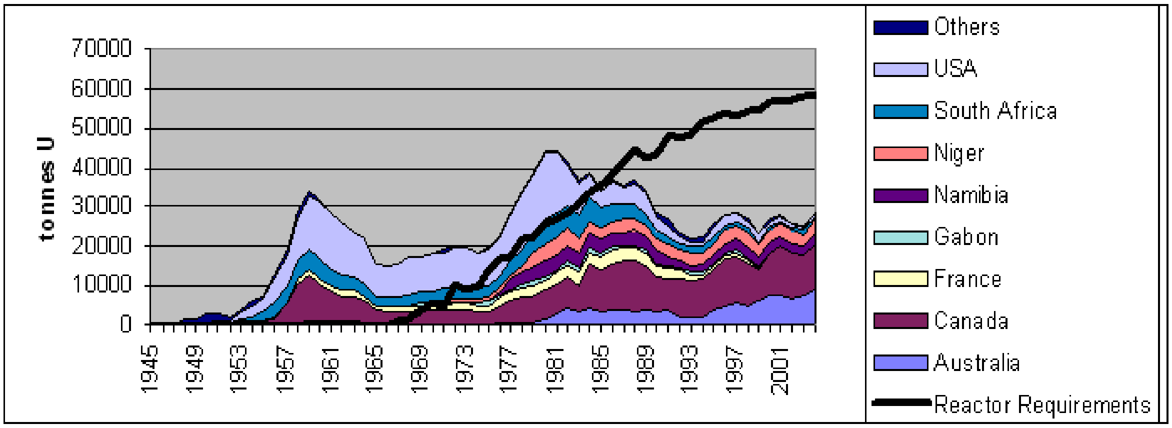
Appendix 6: World Uranium Mining and Production. Source: World Nuclear Association.

Country	2002	2003	2004	2005	2006
Canada	11604	10457	11597	11628	9862
Australia	6854	7572	8982	9516	7593
Kazakhstan	2800	3300	3719	4357	5279
Niger	3075	3143	3282	3093	3434
Russia (est)	2900	3150	3200	3431	3262
Namibia	2333	2036	3038	3147	3067
Uzbekistan	1860	1598	2016	2300	2260
USA	919	779	878	1039	1672
Ukraine (est)	800	800	800	800	800
China (est)	730	750	750	750	750
South Africa	824	758	755	674	534
Czech Repub.	465	452	412	408	359
India (est)	230	230	230	230	177
Brazil	270	310	300	110	190
Romania (est)	90	90	90	90	90
Germany	212	150	150	77	50
Pakistan (est)	38	45	45	45	45
France	20	0	7	7	5
Total world	**36 063**	**35 613**	**40 251**	**41 702**	**39 429**
tonnes U_3O_8	**42 529**	**41 998**	**47 468**	**49 179**	**46 499**

Appendix 7: Largest Uranium Production Mines. Source: World Nuclear Association.

Mine	Country	Main owner	Type	Production (tU)	% of world
McArthur River	Canada	Cameco	underground	7200	18.3
Ranger	Australia	ERA (Rio Tinto 68%)	open pit	4026	10.2
Rossing	Namibia	Rio Tinto (69%)	open pit	3067	7.8
Krazbokamensk	Russia	TVEL	underground	2900	7.4
Olympic Dam	Australia	BHP Billiton	by-product/ underground	2868	7.3
Rabbit Lake	Canada	Cameco	underground	1972	5.0
Akouta	Niger	Areva/Onarem	underground	1869	4.7
Arlit	Niger	Areva/Onarem	open pit	1565	4.0
Akdala	Kazakhstan	Uranium One	ISL	1000	2.5
Highland - Smith Ranch	USA	Cameco	ISL	786	2.0
Beverley	Australia	Heathgate	ISL	699	1.7
McClean Lake	Canada	Cogema	open pit	690	1.7
Top 12 total				**28,642**	**72.6%**

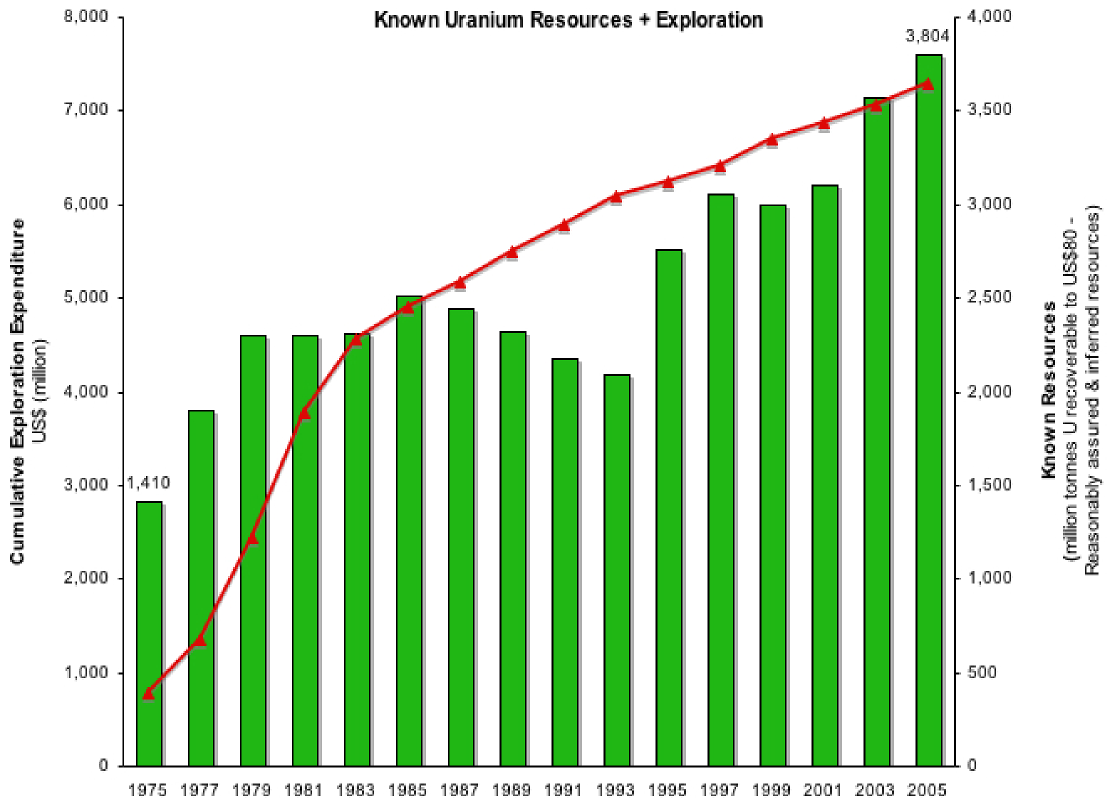
Appendix 8: Western World Uranium Production and Demand from 1954 to 2004. Source: World Nuclear Association.



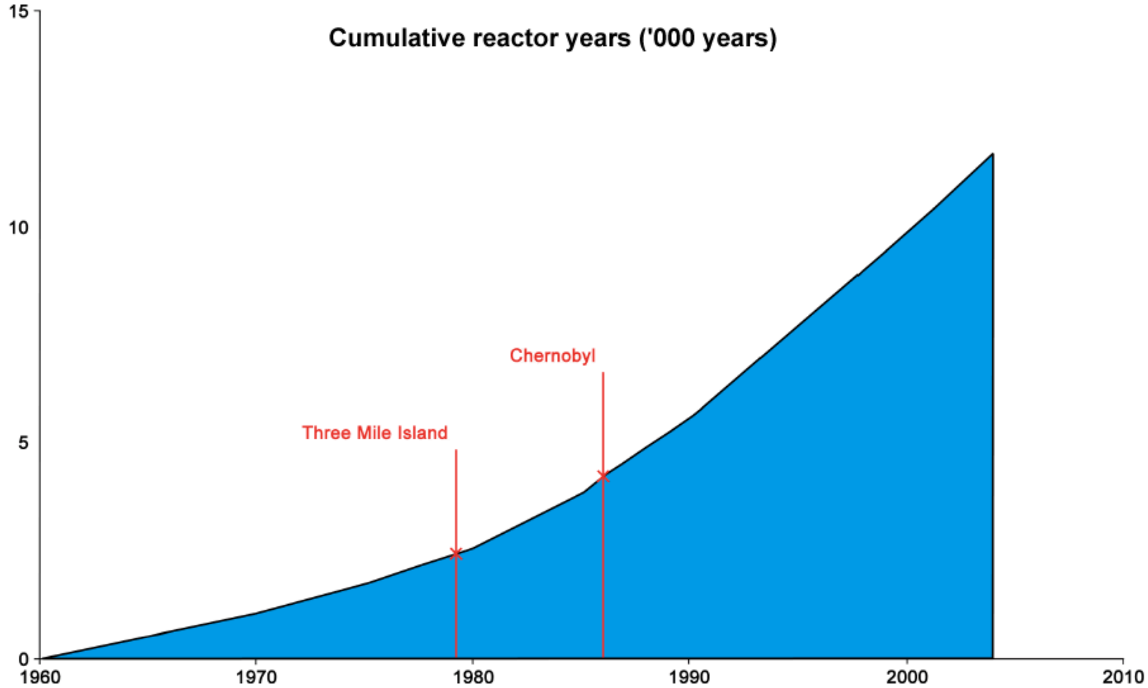
Appendix 9: Known Recoverable Sources for Uranium. Source: from OECD NEA & IAEA, Uranium 2005: Resources, Production and Demand, ("Red Book").

	tonnes U	percentage of world
Australia	1,143,000	24%
Kazakhstan	816,000	17%
Canada	444,000	9%
USA	342,000	7%
South Africa	341,000	7%
Namibia	282,000	6%
Brazil	279,000	6%
Niger	225,000	5%
Russian Fed.	172,000	4%
Uzbekistan	116,000	2%
Ukraine	90,000	2%
Jordan	79,000	2%
India	67,000	1%
China	60,000	1%
Other	287,000	6%
World total	4,743,000	

Appendix 10: Known Uranium Resources, including Exploration. Source: World Nuclear Association.



Appendix 11: Safety of Nuclear Power Reactors. Source: World Nuclear Association.



Appendix 12: Comparison of Accident Statistics in Primary Energy Production. Source: Ball, Roberts & Simpson, Research Report #20, Centre for Environmental & Risk Management, University of East Anglia, 1994; Hirschberg et al, Paul Scherrer Institut, 1996; in: IAEA, *Sustainable Development and Nuclear Power*, 1997; *Severe Accidents in the Energy Sector*, Paul Scherrer Institut, 2001).

(Electricity generation accounts for about 40% of total primary energy)			
Fuel	**Immediate fatalities 1970-92**	**Who?**	**Normalized to deaths per TWy* electricity**
Coal	6400	workers	342
Natural gas	1200	workers & public	85
Hydro	4000	public	883
Nuclear	31	workers	8

Appendix 13: Waste Management for Used Fuel from Nuclear Power Reactors. Source: UNSCEAR-United Nations Scientific Committee on the Effects of Atomic Radiation.

Country	Policy	Facilities and progress towards final repositories
Belgium	Reprocessing	Central waste storage at Dessel Underground laboratory established 1984 at Mol Construction of repository to begin about 2035
Canada	Direct Disposal	Nuclear Waste Management Organization set up 2002 Deep geological repository confirmed as policy, retrievable Repository site search from 2009, planned for use 2025
China	Reprocessing	Central used fuel storage in LanZhou Repository site selection completed by 2020 Underground research laboratory from 2020, disposal from 2050
Finland	Direct Disposal	Program start 1983, two used fuel storages in operation Posiva Oy set up 1995 to implement deep geological disposal Repository under construction near Olkiluoto, open in 2020
France	Reprocessing	TUnderground rock laboratories in clay and granite Parliamentary confirmation in 2006 of deep geological disposal Bure is likely repository site to be licensed 2015, operating 2025
Germany	Reprocessing but moving to direct disposal	Repository planning started 1973 Used fuel storage at Ahaus and Gorleben salt dome Geological repository may be operational at Gorleben after 2025
India	Reprocessing	Research on deep geological disposal for HLW
Japan	Reprocessing	High-level waste storage facility at Rokkasho since 1995 High-level waste storage approved for Mutsu from 2010 NUMO set up 2000, site selection for deep geological repository under way to 2025, operation from 2035
Russia	Reprocessing	Sites for final repository under investigation on Kola peninsula Various storage facilities in operation
South Korea	Direct Disposal	Waste program confirmed 1998 Central interim storage planned from 2016
Spain	Direct Disposal	ENRESA established 1984, its plan accepted 1999 Central interim storage probably at Trillo from 2010 Research on deep geological disposal, decision after 20101
Sweden	Direct Disposal	Central used fuel storage facility - CLAB - in operation since 1985 Underground research laboratory at Aspo for HLW repository Site selection for repository in two volunteered locations
Switzerland	Reprocessing	Central interim storage for HLW at Zwilag since 2001 Central low & ILW storages operating since 1993 Underground research laboratory for high-level waste repository, with deep repository to be finished by 2020
United	Reprocessing	Low-level waste repository in operation since 1959 HLW from reprocessing is vitrified and stored at Sellafield

Country	Policy	Facilities and progress towards final repositories
Kingdom		Repository location to be on basis of community agreement New NDA subsidiary to progress geological disposal
USA	Direct Disposal, but reconsidering	DoE responsible for used fuel from 1998, $28 billion waste fund Considerable research on repository at Yucca Mountain, Nevada 2002 decision that geological repository be at Yucca Mountain