Chapter 10 International Verification

When South Africa decided to abandon its nuclear weapons program, the nuclear nonproliferation regime offered South Africa few precedents for joining the Nuclear Nonproliferation Treaty (NPT) while convincing the international community that it did not have nuclear weapons. Professor Mouton's audit could provide important corroborating evidence, but it was insufficient to replace the need for international oversight.

South Africa's approach was to create a managed transparency policy of its past nuclear activities within the context of the International Atomic Energy Agency's (IAEA's) verification effort under the NPT. IAEA verification had become more stringent following the 1991 Persian Gulf War, after the weaknesses of international safeguards were revealed. As a result, the IAEA requested more information and inspected more sites than South Africa may have expected. Although South Africa was never completely transparent about its past programs, it eventually revealed a remarkable level of information about them. The government's extensive cooperation with the IAEA increased confidence in the truthfulness of its declarations.

The inspection process can be divided into two overlapping periods. The first followed South Africa's submission to the IAEA on October 30, 1991 of a report on its initial inventory of nuclear materials as of the end of September. This declaration is required of all nonnuclear weapon states acceding to the NPT. The submission of this report triggered the IAEA's investigation of South Africa's declaration of the amount and location of all its fissile material. The inspection effort was hindered during this phase by South Africa's decision to mislead the inspectors about its past nuclear weapons program.

The second phase of the inspections followed de Klerk's March 1993 announcement about the nuclear weapons program. In a unique verification exercise under the NPT, IAEA inspectors, augmented by nuclear weapons experts, were tasked to assess the status of the former nuclear weapons program, determine that all weapons had been dismantled, and verify that the highly enriched uranium from this program had been fully accounted for. South Africa gave the Agency's inspectors full access to facilities involved in the past nuclear weapons program along with many of the historical production records of those facilities.

"Do-it-yourself option"

Verification was complicated by the nature of the South African dismantlement process, which Waldo Stumpf, the then head of the Atomic Energy Corporation, described, as a "do-it-yourself" option followed by accession to the NPT.[1] Although this option allowed South Africa to join the treaty as a non-nuclear weapon state, it immediately raised questions about whether all the nuclear weapons had been dismantled, whether sensitive nuclear weapons design information was hidden away, or whether some highly enriched uranium had been hidden and not declared upon joining the NPT.

[1] Waldo Stumpf, "The Accession of a 'Threshold State' to the NPT: The South African Experience," Excerpt from presentation given at the Conference on Nuclear Non-Proliferation: The Challenge of a New Era, organized by the Carnegie Endowment for International Peace, November 17-18, 1993, Washington, D.C.

Such concerns resurfaced well into the 1990s. For example, Wally Grant, a chief inventor of South Africa's uranium enrichment process and an important member of the right-wing Afrikaaner Peoples' Front (Volksfront), claimed to have documented the entire history of the nuclear weapons program, which he was reportedly preserving for future generations.[2] In early 1995, a British TV documentary produced for the Channel 4 Dispatches, quoted various unnamed sources who claimed (with no substantiation provided) that a South African right-wing group had secretly obtained a stock of nuclear weapons that had not been declared to the IAEA by the South African government. South African officials were quick to dismiss that individuals such as Wally Grant or right-wing groups had obtained nuclear weapons or weapons-grade uranium. Armscor officials called the British documentary "a load of nonsense," and ANC Defense Minister Joe Modize said the program had "caused mirth, but no concern."[3] Nevertheless, the possibility that some HEU was missing can never be completely dismissed. Even the IAEA conclusions do not eliminate such a possibility.

However, Stumpf argues that South Africa's dismantlement choice was the only one available to de Klerk. Because the NPT has only two categories of members -- the five acknowledged nuclear-weapon states and non-nuclear weapon states--in effect, it does not allow a state like South Africa, which had not detonated a nuclear explosive by the required date, to dismantle its weapons within the NPT and its associated INFCIRC/153 safeguards agreement.[4] The possession of nuclear weapons by a non-nuclear weapon state would be a violation of the treaty immediately upon accession. Reclassifying the weapons as "peaceful nuclear explosives" also would not be acceptable under the NPT.

The de Klerk government viewed options that would have allowed the IAEA to verify the dismantlement process directly as too burdensome and political. According to Stumpf, these options probably would have also raised international legal problems. The principal alternative involved implementing INFCIRC/66 safeguards agreements on all South Africa's nuclear activities, including the nuclear weapons, before its accession to the NPT. According to Stumpf, however, this path would have also required lengthy negotiations on each facility, and in the end, it might have encountered serious legal obstacles. (For example, redefining the weapons as PNEs would likely have conflicted with more recent interpretations of INFCIRC/66). In addition, South Africa was unsure prior to ratifying the NPT if the IAEA's ruling body, the Board of Governors, would allow IAEA inspectors to become involved directly in a safeguards effort that allowed or required access to sensitive nuclear weapons information.

In choosing the "do-it-yourself" options, the South African government realized that it would need to be fully transparent to the IAEA about its past nuclear materials production activities. Stumpf relates an incident with the IAEA's Director General Hans Blix in February 1991 in Vienna, when it was clear that South Africa would soon be joining the NPT.[5] Blix asked Stump how the IAEA would convince the world that South Africa had acceded to the NPT openly,

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[2] Mitchell Reiss, *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities* (Washington, D.C.: The Wilson Center, 1995), p. 19.

[3] See for example, "Right-Wing Nuke Arms Claim Denied," *The Citizen*, February 16, 1995, p. 3.

[4] Information Circular/153 is an agreement detailing the rules and procedures by which IAEA safeguards are carried out in non-nuclear weapon states which have signed the NPT.

[5] Stumpf, Transcript of speech at South African Embassy, op. cit.

without a nuclear weapons program. Stumpf replied that South Africa would make available additional records of its enrichment plants. Later, upon implementation of the safeguards agreement, South Africa issued a standing invitation to the IAEA to "visit anywhere, anytime, any place -- within reason."[6]

This policy of transparency and openness, according to Stumpf, was chosen as a fundamental part of South Africa's entire "rollback" strategy.[7] The South African government decided that a policy of cooperation and transparency would avoid the type of confrontational inspections that were occurring in 1991 in Iraq and about to commence in North Korea. If such confrontations occurred, according to Stumpf, South Africa's effort to gain international credibility would have been jeopardized.

This policy was also seen as necessary because at the time, the NPT and its associated INFCIRC/153 safeguards agreement contained no agreed-upon procedures to promote transparency of activities or data beyond the nuclear materials and facilities declared in the initial report. Although the initial South African declaration was a comprehensive document which included quantitative data on all types of nuclear material on a facility-by-facility basis, it was limited to nuclear materials subject to safeguards at the time the agreement entered into force, or September 30, 1991.[8] According to Stumpf, based on commonly accepted safeguards interpretations, South Africa was under no obligation to reveal: (1) projects or programs that predated the time of entry-into-force; (2) dual-purpose facilities that already had been converted to non-nuclear work; and (3) historical flows of nuclear materials.

The IAEA's inspection effort

When the NPT took effect in South Africa in the summer of 1991, the IAEA was undergoing a fundamental reformation as a consequence of the dramatic revelations of Iraq's secret nuclear weapons program and the failure of the IAEA to detect those secret activities. The IAEA was under intense international pressure to be more aggressive in its verification effort in South Africa and to rely on member states for additional information about South Africa's past nuclear activities.

In a dramatic move, the IAEA General Conference voted on September 20, 1991 to request the Director General to verify the completeness of the inventory of South Africa's nuclear installations and materials and to report back to the Conference. Instead of verifying only the correctness of South Africa's declaration, as it had done in past cases, the IAEA was instructed to also determine that South Africa's declaration was complete. Determining completeness is a more difficult step to accomplish, and it is far more important than just determining the correctness of a declaration when deciding if a country has met its NPT obligations.. In practical terms, the inspectors were charged to determine if South Africa had declared all its nuclear material or had hidden some of it. The most important nuclear material when the IAEA's first inspections started in November 1991 was the HEU. Because it is not possible logically to prove

[6] Stumpf, "The Accession of a 'Threshold State' to the NPT," op. cit., p. 8.
[7] Stumpf, "The Accession of a 'Threshold State' to the NPT," op. cit.
[8] IAEA, *The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, INFCIRC/153 (corrected), June 1972, paragraph 62.

that South Africa was not hiding any nuclear material, i.e. one cannot prove a negative, the IAEA had to create methods to develop confidence that South Africa had declared all its HEU. To accomplish these goals, the IAEA's Director General appointed a special technical team of senior safeguards officials, several of whom had gained valuable experience in Iraq after the Gulf War.

Although the IAEA realized that South Africa was hiding its former nuclear program, it was rather tentative in pressing South Africa to reveal it. When the IAEA received South Africa's initial declaration, it saw immediately that much of the HEU was reported in the form of metal ingots, a form which immediately raised suspicions that this material had been removed from nuclear weapons. Yet the IAEA formally said nothing about its suspicions to the public nor directly challenged South Africa's deception in its safeguards reports to its members. Such a direct approach was complicated by INFCIRC/153 safeguards agreements at the time, which were widely interpreted as requiring the IAEA to keep secret virtually all the information in the initial declaration and most other information provided by the state. In addition, South Africa conditioned its transparency policy on the IAEA maintaining a high level of confidentiality about the information the government was providing to the inspectors. As a result, the IAEA believed it had neither a mandate to reveal its suspicions about past use of this material, i.e. to "blow the whistle" on South Africa, nor the motivation to undermine South Africa's commitment to transparency, albeit involving obvious untruths about its nuclear programs.

That the IAEA knew that South Africa was likely lying is also revealed by the information supplied to the IAEA by member states. In August 1992, the IAEA received information, possibly from the United States, about South Africa's nuclear weapons program. According to a declassified 1993 document, the IAEA had "received US briefings on most aspects of the weapon program."[9] The information was detailed and accurate, although like much intelligence information, it also contained inaccuracies (for comparison, see earlier chapters). The IAEA received the following information, according to a "Note to File":

- In 1974 South Africa constructed a criticality facility outside the Valindaba perimeter, which was mothballed in 1978. This reference is to building 5000.
- In 1973 the Kalahari test site was surveyed and two large-diameter shafts were prepared. The site was abandoned in 1978.
- In 1978 responsibility of the nuclear weapons program was transferred to Armscor under the Department of Defense. Armscor's subsidiary Kentron was responsible for producing advanced weapons and missiles, including nuclear weapons. The Jericho missile program was established in the same year.
- The Naschem Boscop Plant in Potchefshoom had a flash x ray, high speed camera, and a high explosive bunker.
- Armscor had a flash x ray bunker, evidently a reference to the high explosive bunker at Advena Central Laboratories.

[9] Declassified State Department document, "South Africa: Nuclear Case Closed," December 19, 1993. http://nsarchive.gwu.edu/NSAEBB/NSAEBB181/sa34.pdf

The Note to File also contained information about the organizational structure of the nuclear weapons program, including identifying the location of the Circle facility. Figure 1 duplicates this schematic.

Organizational Structure of the South African Nuclear Weapons Program, as provided to the IAEA by member states in August 1992

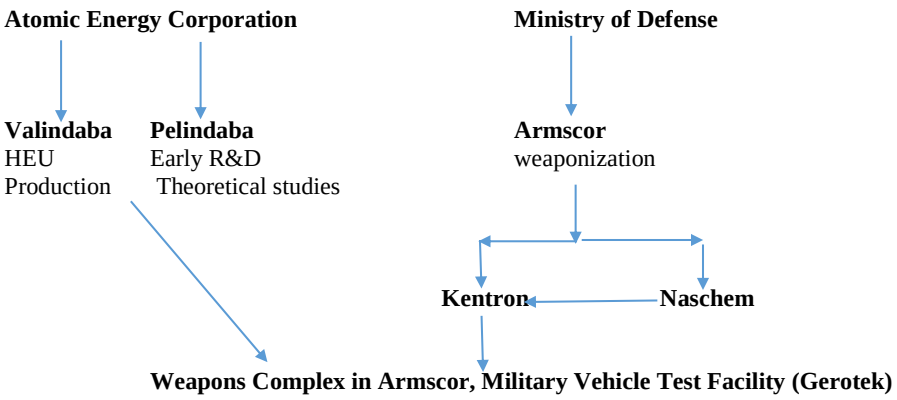

Figure 1 From the IAEA "Note to File," recording information provided by a member state to the IAEA.

The information shows that by the late summer of 1992, the IAEA understood important details about key parts of South Africa's nuclear weapons program. Using this information, it asked to visit two sites.

The IAEA started by asking to visit Building 5000.[10] Two inspectors visited the site on August 20, 1992 and took pictures and environmental samples. South African officials told the inspectors that Building 5000 was a former general purpose critical facility for the AEC's Reactor Development Group that had been decommissioned many years earlier. Although the South Africans facilitated access to Building 5000, they deliberately obscured this site's original purpose or specific role in the nuclear weapons program.

[10] IAEA, *Report on the Completeness of the Inventory of South Africa's Nuclear Installations and Material*, GC(XXXVI/1015), attachment, September 4, 1992, http://www.iaea.org/About/Policy/GC/GC36/GC36Documents/English/gc36-1015_en.pdf

Figure 3 Building 5000 as it looked in early 1994, long after being emptied of the pulse reactor used in the nuclear weapons program. Visible in the top image, right, are barrels and redundant equipment that appear similar to those described by the IAEA inspectors in their 1992 visit to the building. Bottom image: An aged emergency phone in Building 5000 that likely dates to the 1970s when the building housed the pulse reactor. The phone may have been for communicating with the reactor's control room in Building 5100 (see chapter 2).

The IAEA also requested to visit the Kalahari nuclear test site, which it visited in September 1992. It asked in particular to visit what is called the "shade."[11] To hide renovation activities at the first test shaft from overhead surveillance, Armscor had several years earlier constructed a galvanized corrugated iron hangar on a concrete foundation over one of the test shafts. South Africa referred to this building as the "shade." The South Africans told the inspectors that the

[11] *Report on the Completeness of the Inventory of South Africa's Nuclear Installations and Material*, op. cit.

Vastrap area was owned by the South African Defense Force and was used as a military target range. They said the shade was used by the air force for storage and as a workshop, providing no indication that the shade covered a nuclear test shaft.[12] The IAEA uncovered no evidence that the building had been used or was then being used for the testing of nuclear explosive devices, although it did not ask to excavate the shade's floor. Its environmental sampling did reveal the presence of natural uranium, but this was not seen as indicative of deceptive behavior.

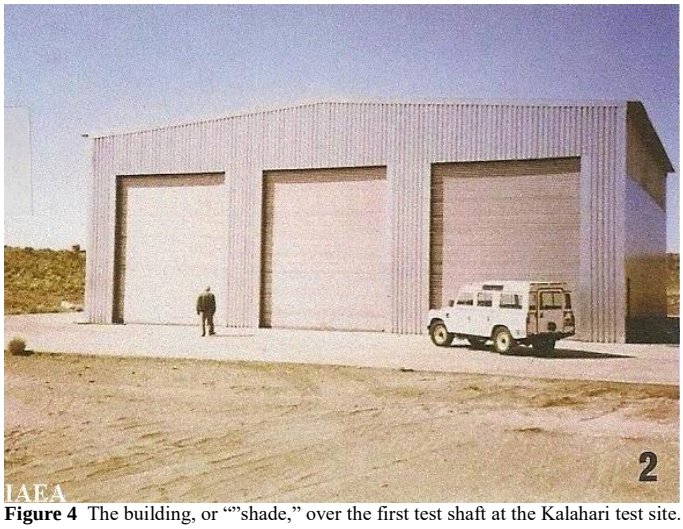

Figure 4 The building, or ""shade," over the first test shaft at the Kalahari test site. Photo source: IAEA.

The Note to File shows that the IAEA was informed about a nuclear weapons complex at Gerotek, namely the Circle facility. Whether it was given the precise location is unknown. However, the IAEA did not ask to visit this site until after President de Klerk's March 1993 announcement. The reason for not doing so is unknown.

These visits would have added to the IAEA's disbelief in South Africa's willingness to fully disclose its past nuclear activities. In a study of South Africa's deception practices, Frank Pabian, one of the foremost experts on South Africa's nuclear weapons program, identified both building 500 and the test site cases as clear-cut efforts of "dissimulation and obfuscation in keeping with the original NPT accession plan" of South Africa.[13] Nonetheless, the accumulating information necessarily raised questions about whether South Africa was also hiding highly enriched uranium.

[12] On the floor on one side of the shade, the inspectors saw a large concrete ramp which appeared to have been cast in situ. This structure may have allowed a test device or other equipment to be wheeled over the test shaft. See "Rendering Useless South Africa's Nuclear Test Shafts in the Kalahari Desert," by David Albright, Paul Brannan, Zachary Laporte, Katherine Tajer, and Christina Walrond (Washington, D.C.: Institute for Science and International Security, November 29, 2011), http://isis-online.org/uploads/isis-reports/documents/Vastrap_30November2011.pdf

[13] Frank V. Pabian, "The South African Denuclearization Exemplar," *Nonproliferation Review, 2015,* Vol. 22, No. 1, pp. 27-52. http://dx.doi.org/10.1080/10736700.2015.1071969

HEU Verification

Because of the difficulty of ensuring that the declaration was complete, in the fall of 1991 the IAEA informed South Africa that success would require closer cooperation. The inspectors intended to create a "balance" in terms of uranium and uranium 235, involving all of South Africa's production, imports, and exports of enriched and depleted uranium. This result would then be verified by comparing it to the accounting and operating records of the Y and Z Plants.

This approach required a greater level of cooperation than Stumpf had earlier volunteered to the IAEA. Nonetheless, consistent with its overall policy to be transparent about nuclear materials, South Africa agreed to supply additional access to records of the Y and Z Plants but without providing the source of imported uranium.

The priority was the HEU because it had been used in nuclear weapons. South Africa had also produced a large quantity of low enriched uranium (LEU) in the Y and Z Plants, but creating the balance of this material was a lower, albeit no less difficult, priority. Creating an accurate balance of the HEU was complicated because it had been produced for over fifteen years in the Y Plant, which was part of a nuclear weapons program that only slowly met civilian standards of nuclear material accountancy.

The underlying idea of the balance approach was to conduct a consistency check on the isotopic balance of the HEU inventory. It compared the amount of uranium-235 in natural uranium entering the Y Plant to the amount of uranium-235 leaving the plant in enriched uranium product and depleted uranium waste. To illustrate this process, consider 1,000 kilograms of natural uranium entering or being "fed" into the plant. It contains about 7.11 kilograms of uranium-235. If the plant produces uranium enriched to 90 percent uranium-235, and the waste contains uranium with 0.4 percent uranium-235 (tails assay of 0.4 percent), then it would produce about 3.47 kilograms 90 percent material and 996.53 kilograms of waste. In this theoretical example, the product contains 3.12 kilograms of uranium-235 and the waste contains 3.99 kilograms of uranium-235, matching the original amount of the natural uranium feed.

In the case of the Y Plant, however, the situation was highly complex. A balance would prove elusive. The total amount of natural uranium entering the plant--the "feed"--was about 384 tonnes, or 384,000 kilograms. The plant produced HEU of many enrichment levels. In total, South Africa produced almost 1,000 kilograms of HEU with an average enrichment of about 70 percent (see tables 1 and 2 in chapter 3).[14] Of this, about 550 kilograms of HEU were enriched over about 80 percent in the isotope uranium 235. About 480 kilograms of this HEU were assigned to the nuclear weapons program, much of which was later taken from dismantled nuclear weapons at the end of South Africa's nuclear weapons program. Earlier, a fraction of this HEU was returned to the AEC as manufacturing scrap and slated for recovery. Another 90 kilograms of weapon-grade uranium were used to blend up a stock of imported LEU to the appropriate level needed for the Koeberg nuclear power reactors. South Africa also

[14] David Albright, *Highly Enriched Uranium Inventories in South Africa Status as of end of 2014* (Washington, D.C.: Institute for Science and International Security, November 16, 2015). http://isis-online.org/uploads/isis-reports/documents/Highly_Enriched_Uranium_Inventories_in_South_Africa_November_2015.pdf
See for example, Peter Fabricius, "SA playing both sides of the nuclear coin," *The Star*, March 30, 2012.

inadvertently produced another 450 kilograms of HEU enriched to less than about 80 percent as a result of problems in the enrichment plant. Almost 250 kilograms of this HEU were deposited in filters and powders or other scraps, most of which were slated for chemical recovery. The Y Plant also produced many tonnes of low enriched uranium for the Koeberg reactors. The depleted uranium waste, or "tails," contained about 371,000 kilograms with a wide variety of tails assays between less than 0.2 percent and up to 0.6 percent, and an average of about 0.45 percent. In addition, the depleted uranium was treated as a waste.

The depleted uranium in the chemical form of uranium hexafluoride had been placed in several hundred large cylinders and sent for storage nearby. It had not been weighed or evaluated carefully enough by the AEC during the program to meet the IAEA's safeguards accountancy standards for measuring the total uranium and its content of uranium 235. Because so much uranium-235 went into waste, the IAEA found it hard to take a balance at the Y Plant. After about a year of investigation, the IAEA concluded that the balance indicated an "apparent discrepancy," which could indicate that some HEU was either unaccounted for or had not been declared.[15] In June 1992, the apparent loss of uranium 235 was estimated as 120 kilograms, enough for more than two gun-type nuclear explosives.[16] Many were skeptical that the balance approach could work.

Nonetheless, during the next year, the IAEA further examined the records, leading to a reduction in this discrepancy. President de Klerk's March 1993 revelations also helped resolve some of the discrepancy in the HEU estimates. Despite all the hard work over two years, and the use of two different approaches, imbalances remained of about 75 and 95 kilograms of uranium 235, still more than enough for a gun-type nuclear explosive.[17] The problems remained mainly because of the uncertainty of the uranium 235 content in the depleted uranium and to a lesser extent chemical and other losses in the enrichment process, which were discussed in chapter 3.

Although the balance approach was refined in the second year of the verification effort, after the first year, in the summer of 1992, the magnitude of the imbalance had stimulated a look for another method. The conclusion was that the balance approach alone could not eliminate suspicions among some member states and the public that South Africa had hidden away some of its HEU. The most straightforward way to reduce the uncertainty would be to measure every cylinder containing the depleted uranium, in addition to all the waste drums containing small amounts of HEU generated during the various recovery operations. Characterizing the depleted uranium would be extraordinarily expensive and time consuming. Later the HEU in the drums would be thoroughly analyzed, but this effort would take years. Measuring the cylinders and drums, while straightforward, was too time consuming to meet the pressing need to verify the completeness of the HEU declaration. Moreover, that approach would have inevitably led to questions about whether South Africa had provided all the cylinders and drums for measurement.

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[15] Adolf von Baeckmann, Garry Dillon, and Demetrius Perricos, "Nuclear Verification in South Africa," *IAEA Bulletin*, 1/1995, pp. 42-48. See also IAEA, *South Africa's Nuclear Capabilities* (GC(XXXV)/RES/567), GC(XXXVI/1015), September 4, 1992.

[16] This value from an IAEA discussion about the completeness of the South African inventory also had a high degree of uncertainty attached to it.

[17] AEC Declaration, March 1994. See also Stumpf, Transcript of talk at South African embassy, op. cit. Stumpf said that the "apparent discrepancy" is "more than five times less than" 526 kilograms, which is the two sigma uncertainty in the uranium-235 content of the tails.

As a result, after the first year of investigation, the IAEA decided on a second approach that would examine the performance of the Y Plant over its entire operating history. The aim was to independently estimate the HEU output of the plant using detailed historical data. This analysis was the first of its kind for the IAEA and potentially an extremely powerful verification technique if the state cooperates sufficiently, which South Africa was willing to do.

This approach depended on knowing how the Y Plant functioned throughout its history. The IAEA therefore asked South Africa for many more documents, hoping they would still exist. AEC personnel had to search for these records, eventually locating them in metal boxes in an unheated, dusty storage shed.[18] Although South Africa had agreed to provide them, it had expected the IAEA to conduct "spot checks" of the records, rather than seek comprehensive sets of operating documents.

Nevertheless, the IAEA experts received a full set of operating records of the Y Plant, representing about 3,000 cascade-days of operating records. The records detailed daily operations at the plant in terms of the availability of each enrichment section of the plant, the rate of uranium feed entering the initial enrichment section, and the rate and assay of the enriched uranium and waste withdrawn from the plant.[19] To ensure that the records were genuine, the IAEA conducted forensic analyses on them.

The IAEA also interviewed people who had produced the records to seek clarification and additional information. The ability of the AEC to find the people involved in the operation of the Y Plant and to arrange for the IAEA to interview them would turn out to be key to the success of this approach.

Yet it was not without complications. Initial IAEA calculations of the maximum production capacity were about double the amount of enriched uranium product that South Africa declared as withdrawn from the Y Plant. The IAEA had not realized all the loss mechanisms in this one-of-a-kind facility.

The IAEA experts had to verify the unique loss mechanism that reduced significantly the expected output of the Y Plant, as discussed in chapter 3. The most important one was the loss of enriched uranium through reactions involving the process gas mixture of uranium hexafluoride and hydrogen and the Teflon filters used throughout the enrichment cascade. Early in the plant's history, this problem led to the plant "crashing" when a catalytic reaction involving larger than expected chloride impurities in the uranium feed resulted in the plating out of large amounts of uranium on the inside of the cascade, halting operation for almost two years.

South African scientists were able to prevent another catastrophe at the Y Plant by carefully monitoring the operation of the cascade and the buildup of uranium solids on filters, changing them before the buildup was too great. Controlling these chemical losses was a key reason that the plant maintained detailed records of the plant's operation. These daily records were invaluable to the IAEA.

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[18] Finding these records required the AEC to contact personnel who had already left the AEC's employment.
[19] Baeckmann, et al, "Nuclear Verification in South Africa," op. cit.

Because so much enriched uranium was lost in this process, the IAEA asked South Africa to conduct certain experiments that would confirm this loss mechanism. This exercise was completed satisfactorily in the summer of 1993.

Using all of this information, the IAEA experts put together an independent estimate of the daily HEU production of the Y Plant.[20] The final result was extremely close to South Africa's declared output. For example, the uncertainty in the amount of HEU produced by the Y Plant for the nuclear weapons program was six kilograms, according to South Africa's declaration. This amount is substantially less than one significant quantity, or 25 kilograms of uranium-235. After two years of intense effort, the IAEA wrote: "It is reasonable to conclude that the amounts of HEU which could have been produced by the pilot enrichment plant are consistent with the amounts declared in the initial report."[21] Despite this seemingly vague wording, the sentence allowed the ending of the completeness investigation of the HEU stock. (The lower priority investigation of the completeness of the LEU stock continued).

There will always be some uncertainty attached to quantitative assessments of HEU production. Nevertheless, the second method resulted in an HEU estimate that was so close to the declared value as to provide added confidence that the government's declaration of HEU production was both accurate and complete. In the end, successful verification required the IAEA to obtain large amounts of historical information about the Y Plant, to reconstruct in detail the daily operation of the plant, and to oversee experiments that could help explain apparent discrepancies in the initial report about HEU production.

Verifying the dismantlement of the nuclear weapons program

During his March 1993 announcement, President de Klerk promised the IAEA full access to facilities involved in the past nuclear weapons program, along with their historical records. Two IAEA inspectors, who were already in South Africa, visited several of these facilities the next day, beginning an unprecedented inspection effort that would last five months.[22] This effort focused on ensuring that there were no hidden stocks of HEU or weapons, including major weapon subcomponents.

The key to the success of this inspection effort was the IAEA's inclusion of nuclear weapon experts from the nuclear weapon states. Initial disclosures by South Africans tended to be circumspect, but the ability of the nuclear weapon experts to recognize key activities led to significantly more openness on the part of the past members of South Africa's nuclear weapons program. Using weapons experts also helped to protect sensitive information against unauthorized release to non-weapon states at the IAEA. Moreover, the most sensitive information was communicated orally and not written down. Thus, South Africa revealed the

[20] In this analysis, the loss mechanism had to be modeled because the process was so complex. For example, it was sensitive to the radiation background, meaning that effect became more pronounced in higher stages of the cascade where the uranium-235 concentration was greater.

[21] IAEA, *The Denuclearization of South Africa*, op. cit.

[22] South Africa had informed the Director General of the IAEA in advance of the contents of de Klerk's statement, so the inspectors were prepared to conduct the visits. See IAEA, "IAEA Safeguards in South Africa," PR 93/7, Vienna, March 24, 1993.

important details of its weapons program only to nuclear weapon experts or to leaders of the IAEA effort, reducing the risk that this information could pass to unauthorized personnel.

In assessing the status of South Africa's former weapons program, the IAEA focused on the program's origin and scope, and on the adequacy of measures taken to dismantle and destroy sensitive components of the devices and to recover the nuclear materials involved. Specifically, the inspectors sought:[23]

- To gain assurance that all nuclear materials used in the nuclear weapons program had been returned to peaceful uses and placed under IAEA safeguards;
- To confirm that all nonnuclear weapons-specific components of the devices had been destroyed, that all laboratory and engineering facilities involved in the program had been fully decommissioned and abandoned or converted to peaceful use (commercial nonnuclear uses or peaceful nuclear uses), and that all weapons-specific equipment had been destroyed and all other equipment converted to peaceful use;
- To obtain information regarding the dismantling program. This involved learning about the destruction of design and manufacturing information, including drawings, and the philosophy followed in the destruction of the nuclear weapons;
- To reduce the likelihood or ease of reconstituting the nuclear weapons program. Specifically, the inspectors consulted on the arrangements for, and ultimately to witness the rendering useless of the Kalahari test shafts;
- To visit facilities previously involved in or associated with the nuclear weapons program and to confirm that they were no longer being used for such purposes; and
- To consult on future strategies for maintaining assurance that the nuclear weapons capability would not be regenerated.

To achieve these objectives, the inspection teams visited many facilities, examined and audited dismantlement, destruction, and recovery records, and had extensive discussions on various phases of the program with former members of the program from both the AEC and Armscor. Where questions still remained, IAEA inspectors requested additional information.

By the start of this phase of the inspections, most of the weapons components and technical documentation had been destroyed. The inspectors, however, were able to correlate the records of the dismantlement of the HEU components of the weapons with corresponding data in AEC nuclear material accountancy records.

A similar procedure with respect to natural and depleted uranium in the devices was unsuccessful. Armscor and the AEC placed little nuclear or financial value on both materials and thus kept few records of the transfer of these materials.

Although Armscor destroyed documents as part of the dismantling process, it kept sections of each device's "build-history" log book and dismantlement record.[24] Items such as drawings and

[23] IAEA, *The Denuclearization of Africa*, op. cit., pp 3-4.

[24] The log book listed each part in a device and each change to that device. The dismantling records of the nonnuclear components of the weapons were composed of brief hand-written listings of component systems dismantled from the deliverable devices. The inspectors were told that no records had been kept documenting the

assembly instructions were removed from these records and destroyed, but information such as quantities of material and serial numbers of components were retained.

Inspectors used this information in combination with the hardware destroyed by mechanical cutting to reconstruct a consistent picture of the number and fate of the deliverable weapons, the demonstration device (Melba), and the pre-production experimental models. In particular, they could compare identification numbers on hardware with these records.

In general, Armscor possessed more non-nuclear components than the bare minimum necessary for the nuclear devices and experimental pre-production devices. However, the inspectors were never able to establish the exact number of each component that had been originally ordered. Nevertheless, the inspectors found no indication that South Africa had retained any sensitive non-nuclear components other than those that had been destroyed or converted to commercial non-nuclear applications or peaceful nuclear uses.

Finally, the inspectors audited the records of the transfer of HEU between the AEC and Armscor. The IAEA concluded that the HEU originally supplied to Armscor had been returned to the AEC and placed under safeguards when the safeguards agreement entered into force. The IAEA also concluded that the "findings from the team's examination of records, facilities, and remaining nonnuclear components of the dismantled/destroyed nuclear weapons and from the team's evaluation of the amount of HEU produced by the pilot enrichment plant are consistent with the declared scope of the nuclear weapons program."[25]

To confirm the completeness of the inventory of nuclear installations, the IAEA made visits to a number of facilities not originally listed by South Africa, relying on information that it had received from member states, particularly the United States. Although the NPT did not require such visits, South Africa permitted them in any case and even supplied detailed information about their activities at these sites, helping the IAEA to obtain a more complete history of the past program.

South Africa also took the IAEA to a site of which it had been unaware. It was the Witbank mineshaft where the first nuclear explosive was stored in the late 1970s and early 1980s.

At the end of these intensive inspections, the IAEA said that it did not possess "any information suggesting the existence of any undeclared facilities."[26] The annex to this chapter lists the main facilities visited by the IAEA.

Summary of information and access granted; and information not provided

South Africa had initially pledged to provide considerable information to the IAEA. However, faced with the completeness challenge, the IAEA did not consider this information sufficient and

dismantling or destruction of the components of the Melba device or any of the pre-production experimental devices (certain series 300 models).

[25] IAEA, *The Denuclearization of Africa*, op. cit., p. 11.

[26] IAEA, *The Denuclearization of Africa*, op. cit., p. 9.

requested and received the following additional information from South Africa after the safeguards agreement was implemented in the fall of 1991:[27]

- The accountancy and operating records of the Y Plant, including data on electricity consumption, which was available for the years since 1980[28];
- The accountancy and operating records of the semi-commercial enrichment Z Plant before September 1991;
- The historical flows of nuclear material, including the quantity of all imported material; and
- Historical values of material unaccounted for (MUF), as determined by the AEC for the purpose of financial control.

In the end, South Africa provided the IAEA with extensive information and access, including:[29]

- All historical nuclear material inventories and flows for a period in excess of 15 years;
- All available commissioning and operating records for both enrichment plants, spanning a period of more than 15 years for the Y Plant and a period of more than six years for the Z Plant, where only LEU production had taken place;
- Extensive details of the nuclear weapons program;
- Free access by the IAEA to numerous former facilities, now converted to commercial nonnuclear use, as well as to private industrial companies, military testing sites and conventional armaments factories;
- Free access to identified key individuals associated with the past nuclear weapons program, a number of whom had already transferred to private industry;
- Free access to Wynand Mouton, the independent auditor appointed by President de Klerk to audit the dismantling process; and
- Permission to take environmental samples from any location desired.[30]

In addition, the government updated its completeness report at least three times, incorporating more detail about the enrichment program. After President de Klerk's announcement about the program, South Africa added an overview of the nuclear weapons program to this report.

It is important to note what South Africa decided not to share with the IAEA. The government:

- Decided not to provide certain nuclear material import data. The government provided information on the quantities of imports of enriched, natural, and depleted uranium, but it decided not to provide the name of the suppliers.[31] Separate sources named China as supplying about 60 tonnes of low enriched uranium and France as providing natural uranium hexafluoride. With regards to the latter material, during a 1994 interview with a

[27] IAEA, *South Africa's Nuclear Capabilities* (GC(XXXV)/RES/567), op. cit., p. 2.
[28] Because of particular characteristics of the enrichment stages in the Y Plant, this information was hard to correlate with enriched uranium output.
[29] Stumpf, "The Accession of a 'Threshold State,' to the NPT," op. cit., p. 11.
[30] Environmental samples taken inside the Y Plant helped determine that LEU had not been used as feedstock, an action that would have significantly increased the HEU output of this facility.
[31] IAEA, *South Africa's Nuclear Capabilities* (GC(XXXV)/RES/567), op. cit., p. 1.

senior Y Plant official with one of the authors, he freely revealed that France had been the source of natural uranium. Although the official policy was not to name suppliers, informally, those names were provided.

- Decided not to reveal to the IAEA the names of the key suppliers of direct-use and dual-use equipment to its enrichment and nuclear weapons programs. Armscor officials broke with this ban and provided a list of goods it acquired for its nuclear weapons programs, although the list was not comprehensive and the names of the suppliers were sometimes omitted;[32]
- Released little information about the nuclear weapons delivery systems, particularly the Raptor glide bomb and the RSA-3 ballistic missile; and
- Did not reveal the entirety of its nuclear strategy, in particular, the threat to use nuclear weapons on the battlefield.

South Africa's demands

In exchange for its cooperation, South Africa also had certain demands on the IAEA. According to Stumpf, the South African government insisted that three key conditions be satisfied. By meeting these demands, the IAEA significantly eased South Africa's task of establishing and maintaining transparency.[33]

First and most important, the IAEA had to assure the confidentiality of the information that it received from South Africa. Although the safeguards agreement contains a strict confidentiality clause, many of the IAEA's activities went far beyond the legal boundaries of the safeguards agreement. As a result, the IAEA and South Africa agreed to maintain confidentiality on activities in these other areas as well. Nevertheless, some information leaked out in news reports as a result of the public's intense interest in this subject. South Africa and the IAEA believed, however, that confidentiality was successfully maintained to the satisfaction of both parties.

Second, the IAEA had to avoid any political bias. Since South Africa often had been criticized at the IAEA's General Conference in the past, the IAEA was probably only able to satisfy this condition because the de Klerk government wanted to abolish apartheid and accomplish other domestic reforms. Prior good experience with the IAEA's safeguards division facilitated the establishment of confidence between the two parties.

Third, South Africa wanted the IAEA to maintain continuity with regard to the inspectors intimately involved in the verification process. Although achieving this goal was difficult for the IAEA, given its other responsibilities and the need to include nuclear weapon specialists, South Africa believed that this goal was met sufficiently.

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[32] Armscor officials were more open to providing procurement information but there were limits to what they could have provided because of the destruction of records of what amounted often to cases of illegal overseas procurements. During the 1990s, the United States and South Africa were engaged in settling a criminal case against Armscor's illegal procurements in the United States. As part of that settlement, the United States asked Armscor for the records of its department of foreign procurement, which in essence was a group of smugglers. Armscor is acknowledged by senior former South African officials as having become "quite specialized in 'sensitive procurement.'" [*Armament and Disaramament*, op. cit., p. 82]. However, according to a former senior Armscor official interviewed by one of the authors, "most documents had been destroyed long ago."

[33] This section is based on Stumpf, "The Accession of a 'Threshold State,' to the NPT," op. cit., pp. 12-15.

One has to ask whether South Africa's secrecy requests were excessive. In particular, were these extraordinary secrecy requirements aimed at stifling debate among publics and governments and thereby aiding South Africa's goal of deceiving the IAEA about the past nuclear weapons program?

Annex: Facilities Visited by the IAEA Inspectors [34]

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The facilities visited by members of the team during the assessment of the status of the former nuclear weapons program included:

(a) The buildings of the AEC establishment at Pelindaba where the initial research and development phase took place and the first demonstration nuclear device was manufactured (called Building 5000 complex), as well as the buildings where the HEU was produced (Y Plant), the uranium metal was produced (Building 2700), the laboratories involved with the tritium and lithium-6 program, and the development work on neutron generators.

(b) The Armscor/Circle establishment where the first device was ultimately stored and the other completed devices were manufactured, assembled and stored. This establishment included the high security vaults where the completed devices were stored, high explosive test cells, nuclear material casting and machining workshops, conventional workshops for the production of mechanical and electrical components, an environmental testing facility, and a high explosive magazine.

(c) The new facilities of the Advena Central Laboratories near the Circle establishment, which were intended for further nuclear weapons development work on advanced gun-assembled and implosion-type devices. The facilities included bunkers for explosives processing and testing, an "integration building" for advanced weapons assembly and integration with delivery systems, high-security storage vaults and an explosion test chamber.

(d) An explosives test facility, including a small instrumentation bunker, located on military property near Potchefstroom.

(e) A purpose-built high security vault in a military ammunition depot at Roedtan, which had been intended for the storage of nuclear devices.

(f) An ammunition depot of the South African Defense Force in an abandoned coal mine, near Witbank, about 90 kilometers east of Pretoria, which stored the first nuclear explosive device from November 15, 1979 until April 1982, when it was sent to the Circle facility for storage.

[34] IAEA, *Denuclearization of Africa*, Attachment 1, Annex 2; and other sources.

(g) The Vastrap site in the Kalahari desert, where two shafts prepared for underground testing of the devices were located.

(h) Armscor facilities at Naschem, near Boskop, and at the SOMCHEM establishment in the Cape Province. The latter was involved in the 1970s with the research and development work on the mechanical and pyrotechnic sub-systems of gun-type nuclear devices.

(i) The site at Gouriqua in the Cape Province, where construction of a reactor facility for the production of plutonium and tritium was planned. Beyond some rudimentary civil engineering preparations, the site was never developed; it was sold by the AEC to a private purchaser.

(j) The Alkantpan firing range in the Cape Province, where some development work had been undertaken on heavy metal armor penetrators, involving a small number of test firings using depleted uranium and shaped charges. Although there are common areas between this technology and implosion technology, the team found no apparent link between the Alkantpan test range and the former nuclear weapons program. The diagnostic facilities at Alkantpan were not considered particularly useful to a nuclear weapons development program.

(k) Armscor/Circle facilities at the Kentron Central Factory near Pretoria, where the nuclear weapons program had a secure office. Kentron executives were unaware of the activities of the Circle team in the building and merely provided space. This office contained the headquarters of the nuclear weapons program and conducted special activities, such as job advertising, recruitment, and interviews, and provided a commercial cover to the program. Using this office address, Circle could establish a credit rating with commercial suppliers. In addition, commercial bids and bills passed through this office.