# CHAPTER 8

# DISMANTLING THE SOUTH AFRICAN NUCLEAR WEAPONS PROGRAM: LESSONS LEARNED AND QUESTIONS UNRESOLVED

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## INTRODUCTION

Reducing and ultimately eliminating nuclear weapons has been made a centerpiece of the Barack Obama administration. However, doing so requires sustained diplomatic engagement with other nuclear weapons states and, more importantly, effective verification and confidence-building measures to ensure the drawdown is transparent, verifiable, and irreversible. But, it would also be important to ensure that non-nuclear weapons states do not harbor a "bomb in the basement." Specifically, how might one verify that states that have previously developed a nuclear weapons program or produced weapons-usable material have properly declared them and given them up? History has shown that, while critical to nonproliferation efforts, the International Atomic Energy Agency (IAEA) is no match for a country intent on building a nuclear deterrent, even in the face of international enmity. It would therefore be instructive to look to previous examples in which a country accumulated significant nuclear "know-how," a deterrent, or weapons-usable material to identify any precedents and what they might suggest.

In the annals of history, there is only one country that has developed a nuclear weapons program,

a limited nuclear deterrent, and then dismantled that program and declared it for international inspection: South Africa. Between the 1960s and 1989, South Africa developed a limited nuclear deterrent and then opted to dismantle that deterrent, decommission its nuclear weapons complex, down-blend its nuclear weapons fissile material, come clean to the international community, and accede to the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state. For many, this was seen by the international community as an extraordinary turn of events, and South Africa has been lauded for these efforts. However, a deeper examination of the South African case raises a number of outstanding questions that beg the question of just how irreversible and transparent the South African disarmament was and how this might complicate current "getting to zero" efforts.

For example, before then-South African President F. W. de Klerk disclosed the nature of his country's nuclear deterrent, the program had been fully dismantled and upwards of 12,000 documents associated with the program destroyed. While some have noted that this was done to ensure that the incoming African National Congress (ANC) government was unable to access nuclear weapons know-how, the document destruction leaves a significant gap in what the world knows about the South African nuclear program 20 years hence. In addition, when IAEA inspectors examined the remains of the South African weapons program and attempted to verify how much weapons-usable highly enriched uranium (HEU) was produced, they were stymied by the significant material imbalances.

While inspectors claim they were able to reconcile those imbalances to within an acceptable level of

confidence, the question remains as to how acceptable that level of confidence is and whether there are unexplained imbalances that remain. These unresolved questions and our limited ability to answer them 20 years later suggests that actions should be taken to clarify the record regarding the South African program and to provide critical lessons as the United States pursues global nuclear weapons disarmament.

## DETERMINING HISTORICAL PRODUCTION: WHY?

While the move was considered a beacon of transparency, it is curious that de Klerk ordered the wholesale destruction of all documentation relevant to the nuclear weapons program **before** the IAEA had a chance to verify anything. He clearly knew that, to have credibility, the IAEA would have to be called in to verify the dismantlement and that this would require documentation. If the country really wanted to be transparent, then all relevant records for the enrichment facility would have had to be retained so that the IAEA could determine exactly how much HEU was produced. In fact, there was an IAEA safeguards team in South Africa when de Klerk made his big announcement.

According to the inspection team that led the verification process, there were a lot of unknowns, including being faced with a fuel cycle of indigenous origin, more than 20 years of enrichment activity, and unaccounted-for tails material that the South African government did not bother to measure. Even Waldo Stumpf, who actually ran the Atomic Energy Corporation of South Africa (AEC), has stated that:

> . . . the verification of the HEU output of the pilot enrichment plant against the natural uranium inputs, depleted uranium outputs and in-process losses posed a particularly difficult problem as far more U-235 is present in the more than 270 depleted UF6 cylinders than HEU.[1]

Why would Stumpf, who presumably was privy to all the relevant details of the fuel cycle as head of the AEC, declare that the verification process was challenging? Did the South Africans keep poor records? Did Stumpf believe that full dismantlement of the nuclear weapons facilities before the IAEA could get to them was a bad idea but was unable to say so publically?

It is also notable that, prior to the 1993 disclosure, the South African government used extensive cover stories and a deception plan to ensure that the IAEA, other governments, and the public were unable to discover the real nature of its "civilian" nuclear program. Those cover stories were used even while the IAEA was on the ground at the time of the de Klerk disclosure; AEC employees were instructed to lie to inspectors about various undeclared facilities that the team observed while there. So, it is questionable the extent to which the government was able to gain any credibility with the IAEA inspectors, having previously lied to them, in the aftermath of the big reveal. Further, any calculations about production and existing stocks of HEU in the public domain were done by extrapolation and assumption. Even the U.S. intelligence agencies were unable to verify the amount of material the South African government had in its complex.

To complicate matters, the IAEA will not disclose information about inspections in any member state; the information is deemed "safeguards confidential."

This is done to protect the nuclear expertise and the security of the country as well as the credibility of the IAEA to be an objective arbiter. Given the public nature of the South African disclosure, it is unclear if member states received a classified briefing to provide the details of the South African nuclear weapons program. It may have been left to the host country to make inspection information public, if at all. But, in the more than 20 years since its nuclear program was dismantled, the South African government has yet to disclose how much weapons-grade material it produced or where it came from, whether any of that technology or expertise was gained as the result of outside assistance, and exactly what became of the HEU.

After the 1993 disclosure, speculation was rife as to how much HEU its enrichment facility has produced. At the time, the South African government did not publically reveal how much HEU it had produced or that it had on hand, saying that not doing so was in the interest of nonproliferation and because the material was being stored at a single location. However, because it has disclosed that it had six gun-type nuclear devices, as well as other relevant information, analysts had to speculate as to how much HEU was involved. One estimate, calculated based on the amount of enrichment plant feed material, enriched product, depleted uranium tails, and separative work, concluded that South Africa had 731 (plus or minus 24 kilograms) of 90 percent enriched uranium, or enough material to build 12 Hiroshima-type fission bombs.[2] At the time, the IAEA was stymied with coming up with accurate material balances because, while the South African Atomic Energy Corporation "made precise measurements of the amount of HEU and LEU, and the U-235 assays of each,"[3] they paid little attention

to the depleted uranium (DU) tails. The tails, which were stored as UF6 in more than 600 cylinders, were not weighed or assayed accurately because, according to the South African government, they were of no economic value. The unaccounted for tails created a significant amount of uncertainty in the calculated HEU inventory. It is unclear why the AEC did not adequately keep track of the DU tails material. Perhaps they knew that this would be an important part of reconciling the actual throughput and production of HEU, should the program ever come to light. Was the sloppy record keeping, coupled with the extensive document destruction, part of an elaborate ruse to insert enough uncertainty in the accounting process to make it just credible enough to satisfy the IAEA inspectors and the member states?

After nearly 20 inspection missions, the IAEA alleged that it was able to ascertain that the declared inventory was consistent with the declared production and usage data but that the calculated isotopic balance indicated "apparent discrepancies" that could be "interpreted to indicate that an amount of U-235 was unaccounted for was actually the lack of an accurate accounting of the tails. Once the DU tails were measured, a process that took several years, inspectors claimed that the discrepancy was significantly reduced and that the HEU was fully accounted for. But, how does one know for sure? The production numbers were never made public. The facility itself had already been decommissioned, and the former employees clearly had an incentive not to tell the whole story: their financial compensation after they were put out of a job.

Because of the extensive history of the South African program, the IAEA was forced to review production records going back more than 20 years. But, what is not clear is whether adequate production records had been maintained such that verification of the HEU output of the pilot enrichment plant against natural uranium inputs, depleted uranium outputs, and in-process gas losses were accurately determined.

## THE BASE CASE: WHAT IS KNOWN ABOUT SOUTH AFRICA'S PROGRAM BEFORE DISARMAMENT

A number of political factors contributed to the decision taken by the South African apartheid government to develop nuclear weapons. From a technical perspective, it did so because it could. South Africa had a large indigenous supply of natural uranium, which was readily obtainable as a by-product of gold mining and refining. It was also a major supplier of uranium to the United States and United Kingdom during the first half of the Cold War. South Africa also had substantial economic resources and had benefited from the U.S. Atoms for Peace program. This included U.S.-origin 20 megawatt thermal (MWth) South Africa Fundamental Atomic Reactor Installation-1 (SAFARI-1)[4] research and radioisotope production reactor and the requisite 93 percent HEU fuel, provided until 1976. Before the United States imposed sanctions and severed ties with South Africa, it also trained South African nuclear scientists.[5]

Around the time the United States, under its Ploughshare Program for peaceful nuclear explosions (PNE), and the Soviet Union decided to explore using nuclear explosions for large scale engineering proj-

ects, South Africa followed suit. Initially, the intention was to develop its own PNE research program for mining, but it was ultimately transformed into a military nuclear weapons program sometime between 1973 and 1977.[6]

However, the outside assistance it had previously received to develop its civilian nuclear program enabled South Africa to develop an indigenous uranium enrichment process, and, subsequently, to master all aspects of a complete indigenous nuclear fuel cycle. It also constructed its own reactor as part of a plan to produce plutonium, the SAFARI-2, or Pelinduna reactor at Pelindaba. The reactor used 606 kilograms (kg) of 2 percent enriched uranium and 5.4 metric tons of heavy water, both supplied by the United States. The project was abandoned in 1969 so that South Africa could devote its resources to an indigenous uranium enrichment program.[7]

What is known is that South Africa had five key facilities associated with its program: Pelindaba,[8] the AEC site that housed the SAFARI-1 research reactor (RR), a hot cell complex, a waste disposal site, and conversion and fabrication facilities (nuclear weapons were built in an isolated section of the site, the Building 5000 complex); Pelindaba East (or Valindaba[9]), which contained the AEC Y-Plant for HEU production and the Z-Plant for LEU production; Vastrap,[10] which contained two nuclear explosive test shafts built in the 1970s in the Kalahari Desert; the Circle Facilities or Advena Central Laboratories, which were ARMSCOR facilities used in the 1980s/early-1990s for design, manufacture, and storage of nuclear weapons; and Somchem, the military facility involved in the development and manufacture of explosives and propellants. There was also the site at Gouriqua, in the Cape

Province, where South Africa planned to build a reactor facility for the possible production of plutonium and tritium.

South Africa completed its first gun-type nuclear weapon in November 1979, and its subsequent weapons were built at an average rate of one every 18 months.[11] Its pilot enrichment plant at Valindaba, the Y-Plant, allegedly produced about 100 kilograms of HEU per year over the course of its run from 1978 through 1989. The enrichment process South Africa had developed used "an aerodynamic technique similar to a stationary wall centrifuge in which uranium hexafluoride and hydrogen gas spin inside a small stationary tube."[12] By 1989, South Africa had six gun-type nuclear devices, each containing 55-kg of HEU, which were stored in Kentron Circle, the Advena facility. It also had a fully functioning HEU production facility and a semi-commercial LEU production facility at Valindaba. (See Figure 8-1.)

**South Africa's former nuclear weapons programme:**
**Chronology of the main events**

- **1970** — Uranium enrichment project announced
- **1971** — Approval for R&D based on gun-assembled device relating to nuclear explosions for peaceful purposes
- **1973** — Investigation into separation of lithium isotopes
- **1974**
  — Prime Minister approves limited programme for development of nuclear weapons as deterrent
  — First stage of pilot enrichment plant commissioned
  — Approval for test site development in the Kalahari Desert
- **1975** — Work on the Kalahari test shafts commenced
- **1976** — Export from the USA of fuel for the SAFARI-1 research reactor stopped.
- **1977**
  — Kalahari test site abandoned
  — Full cascade operation of the pilot enrichment plant
- **1978** — First HEU product withdrawn from the pilot enrichment plant
- **1979**
  — First nuclear device completed by the AEC
  — Decision that ARMSCOR should take over programme from the AEC and produce all further devices

- **1980** — Construction of tritium handling laboratory completed
- **1981**
  — ARMSCOR/Circle facilities completed
  — Approval of the Gouriqua programme for commercial PWR technology development, as well as possible future tritium and plutonium production
- **1982** — Second device completed
- **1985**
  — Government decision to limit number and type of devices to seven gun-assembled devices, to further develop implosion technology and to study more advanced concepts
  — Lithium-6 Avlis programme redirected towards lithium-7 production for water chemistry control in commercial power reactors
- **1987** — Commercial programme for tritium radioluminescent light sources started
- **1987-1989** — Completion of four additional devices
- **1989-1991** — Construction of facilities at ARMSCOR/Advena central laboratories
- **1989** — Decision to terminate nuclear weapons programme (November). Gouriqua programme stopped.

- **1990**
  — Pilot enrichment plant ceased operation (February)
  — Order by State President for destruction of the six completed nuclear devices and the incomplete seventh device (26 February)
- **1991**
  — Accession to the NPT (10 July)
  — All HEU returned from ARMSCOR/Circle to the AEC (14 March to 6 September)
  — Signature and entry into force of the safeguards agreement (16 September): Initial report submitted (30 October)
  — Start of the IAEA ad hoc inspections (November)
- **1993**
  — Destruction of documentation relating to nuclear weapons programme ordered by State President on 17 March; destruction completed on 23 March
  — State President's announcement to Parliament of the existence and subsequent abandonment of the former nuclear weapons programme (24 March)
  — Preliminary visit by IAEA team members to the ARMSCOR/Circle facilities (25 March)
  — Visits of the IAEA team to access the status of the former nuclear weapons programme (22 April to 4 May, 3-11 June, and 9-13 August).

Source: Adolf von Baekmann, Garry Dillon, and Demetrius Perricos, "Nuclear Verification in South Africa," *IAEA Bulletin*, January 1995.

**Figure 8-1. IAEA Timeline of South African Nuclear Weapons Program.**

Whether or not South Africa received any outside assistance in the development of its nuclear weapons program beyond the building blocks provided through the Atoms for Peace program is subject to some question. President de Klerk claimed that the weapons were built without foreign assistance and that it never tested those weapons. Some have contended that South Africa received assistance from Israel, providing both tritium and other expertise, and there is evidence which lends credence to that contention. For example, a leaked 1988 court judgment revealed clandestine imports from Israel of tritium useful for boosting nuclear weapon yields.[13] The case involved a retired South African Air Force pilot who had transported some of the materials in question and later attempted to blackmail the government.

Interestingly, author Sasha Polakow-Suransky, a native Afrikaner, wrote in 2010 that he was provided documents by the ANC government proving that, in 1975, Israeli officials met with apartheid government officials to discuss selling nuclear weapons technologies to them, despite international sanctions prohibiting them from doing so. Meeting minutes declassified that year revealed that Israel helped South Africa "build highly advanced nuclear weapons delivery systems, long-range missiles up until 1989, when President de Klerk decided to scrap the nuclear weapons program."[14] It provided the technology upon the request of then defense minister P. W. Botha, who had asked for "nuclear-capable Jericho missiles." To this day, both South Africa and Israel refuse to acknowledge that the two countries had any relationship in which nuclear materials changed hands.

## HOW THE SOUTH AFRICAN NUCLEAR DETERRENT REMAINED A SECRET —OR DID IT?

Although there were many suspicions about the existence of a South African nuclear program, the government in Pretoria carefully cultivated a policy of ambiguity and secrecy that denied the world the smoking gun it needed to make a definitive judgment about the existence of its nuclear program or its nuclear ambitions. The government in Pretoria created sufficient ambiguity and took great pains to keep all aspects of its nuclear weapons enterprise secret: "… it is alarming how well Pretoria was able to cloak its bomb-making project for more than 15 years while more than 1,000 people worked on it."[15] South Africa's methods for concealment are instructive in trying to determine the activities in other threshold states.

In July 1970, then South African Prime Minister B. J. Vorster announced in a parliamentary speech that the government intended to develop an enrichment capability. Vorster stated that the pilot enrichment plant was to be built but that the government was not prepared to sign the NPT because it wanted to ensure secrecy and the proprietary nature of the technology and that South Africa expected to be producing 20,000 MWs of electricity domestically with nuclear power by the end of the century. Vorster added that South Africa would be enriching uranium domestically because of its abundant uranium resources and the desire to make the uranium economically attractive.[16]

The technology South Africa employed to enrich was indigenously developed by two scientists from the Council for Scientific and Industrial Research

(CSIR) in Pretoria, and based, in part, on the German Becker nozzle method.[17] The government then began development of its "Reactor Ontwikkeling" (RO) site for criticality experiments and PNE assembly at the Pelindaba site. As previously noted, the PNE program was originally created on the heels of a similar program being conducted in the United States and elsewhere for application in large-scale engineering projects. However, South Africa transitioned its PNE to develop a limited nuclear deterrent in around 1973-74. The RO building was "hidden by a ridge (an example of concealment via 'terrain masking') in the valley behind Pelindaba and was surrounded by up to three concentric security perimeters."[18]

At the time, former South African Foreign Minister Pik Botha was reported as having said that:

> It suited us that the West, and the whole outside world feared SA production of atomic weapons. We did not acknowledge their existence. In my discussions with the US over the years, my approach was what would we get in return for signing the NPT? Without ever admitting the existence of the bombs, I proceeded with the line "Let us assume the lady is pregnant. Now what can we do for such a lady?[19]

## DISARMAMENT AND DISCLOSURE— UNRESOLVED QUESTIONS

In the aftermath of the disclosure of the South African nuclear weapons program, disarmament experts and historians sought to reconstruct its precise nature, including how much material had been produced and how the program was built in extensive secrecy. However, research into the nuclear weapons history, even 20 years later, has been hampered by long-standing

secrecy laws, in addition to the destruction of records. Further, technical records that survived the apartheid-era destruction have remained secret, including those provided to the IAEA, as has the safeguards inspection report.

> A battery of secrecy laws was utilized during the program's lifetime to conceal the existence of South Africa's nuclear arsenal. But, although the need for concealment evaporated with de Klerk's decision to dismantle the programme, secrecy laws obstructing fuller public disclosure have largely persisted into the democratic era. . . . officials of two successive African National Congress-led governments have expressed strong objections to further disclosure beyond those made in 1993-1994.[20]

Although the South African constitution enshrines access to information, and the existence of the Promotion of Access to Information Act (PAIA) of 2000 and the establishment in 2002 of an interdepartmental Classification and Declassification Review Committee aimed at addressing apartheid victims' demands for access to records, are all intended to create a basis for greater openness, "many documentary requests have been rejected or delayed arbitrarily."[21]

Historians and nuclear experts have said they were frustrated by ANC members who once doubted apartheid-era officials' accounts of the past and subsequently showed "little inclination as government officials to unearth details and encourage a reexamination."[22] Moreover, as of 2003, some scientists who participated in the nuclear program still worked for the government, including Karel Fouche, general manager of the Pelindaba Nuclear Institute, who directed "a plant that used to make the HEU necessary

for weapons" and was "converted to commercial uses." Fouche said he mostly was privy to the science, not the strategy, of the weapons program. Information was highly compartmentalized, he said, adding that he doesn't believe there is much to tell."[23] But, it is the science and access to the nuclear know-how that is most critical in determining whether a latent nuclear weapons program could be rebuilt. It is also worth adding that South Africa continues to have a civilian nuclear power program as well as an extensive uranium mining infrastructure.

While some have stated that there is simply no need, given current geopolitics, to reconstruct a nuclear weapons program, history has shown that a change in circumstance, along with political will, access to information, and the ability to pursue a program under the cloak of secrecy, is all that would be required to do so.

In addition, the disclosure of nonsensitive information by current and former nuclear weapons program employees is also prohibited by secrecy laws. Nuclear Energy Act 46 of 1999 prohibits the disclosure of any information about AEC activities with respect to "restricted matter." Nuclear program personnel were also required to sign an oath pledging to comply with nondisclosure laws during and after their employment. Former AEC head Waldo Stumpf negotiated a nondisclosure agreement with the ANC government that binds him to perpetual secrecy as part of a financial settlement upon his departure.

**The U.S. Government Questions South Africa's Disclosure.**

In addition to the IAEA inspectors' suspicions prior to the 1993 disclosure, debate over the completeness of the South African government's inventory disclosures to the IAEA were actively debated within the U.S. Government. A December 19, 1993, document produced by the intelligence community stated that "South Africa went to considerable lengths not to acknowledge to either the IAEA or the public the military orientation and advanced stage of the former program. . ."[24] The intelligence bureau analysts at the U.S. Department of State took issue with the assertions by the Central Intelligence Agency (CIA) that questioned the completeness of the South African material declaration regarding the amount of HEU it had produced. State asserted that, despite the CIA's conclusions, the South Africans "reportedly kept poor operating records of enriched uranium output" so making a firm conclusion of cheating was not possible at that time.[25] In a second memo to the Nonproliferation Center, State noted that it strongly believed that:

> the collective body of information is ambiguous, and contradictions must be resolved before any firm judgments can be offered with confidence. Some information tends to support the notion of an "honest declaration"; some tends to support the "cheating" scenario; and much is open to both interpretations. There is no basis at present for assigning greater likelihood to the "cheating" scenario. More importantly, we feel it is premature to offer any general verdict at present on South Africa's conduct.[26]

## IAEA INSPECTIONS—MORE QUESTIONS THAN ANSWERS

When President de Klerk announced that South Africa had indeed developed a limited nuclear deterrent, the IAEA had a team of inspectors on the ground. According to a report by Adolf von Baeckmann, Garry Dillon, and Demetri Perricos, this led the IAEA to "augment its safeguards team in South Africa with, among other specialists, nuclear weapons experts." The team "thoroughly examined detailed records of nuclear materials in South Africa" and was able to conclude that "there were no indications to suggest that the initial inventory was incomplete or that the South African nuclear weapons programme had not been completely terminated and dismantled."[27]

However, it was later revealed that the inspection team had difficulty in coming to these conclusions, partly because the South African program had a number of indigenous facilities that had not previously been subject to safeguards. Moreover, South Africa refused to make public the amount of HEU it had produced due to alleged concerns about proliferation. Finally, the team found that the calculated isotopic balance indicated discrepancies with respect to the HEU produced by the Y-Plant and the LEU produced by the Z-Plant. The team concluded that there could be some U-235 that was unaccounted for. Further complicating matters was the absence of accurate accountancy of the depleted uranium waste stream. They had to resort to records regarding the recovery of HEU following shutdown of the enrichment facility. Since the facilities had been dismantled before the IAEA team was able to conduct inspections, they were completely reliant upon whatever records were made available to

them as well as re-creation of plant operation. This meant they had to be authentic in order to be credible. Was the team able to authenticate those records? As many of those involved in the weapons program had also signed nondisclosure agreements in order to get their full government retirement compensation, how much did they tell the IAEA inspectors? Were they fearful that they would lose their compensation if they said too much? Even the former head of the AEC admitted that:

> Verification by the IAEA of the completeness of South Africa's declaration of inventory of nuclear material and facilities was 'no easy task' and that the inspection team would be 'forced to delve into the past…'.[28]

## MATERIAL BALANCES AND MUF

When the IAEA began its inventory inspections at the declared South African facilities in 1991 following its accession to the NPT, the inspection team found a number of decommissioned and partially or wholly dismantled facilities, including those that had produced HEU and LEU, because President de Klerk had ordered their dismantlement 2 years earlier. Much of the verification therefore rested on the documentation, records, and interviews that the South African government was able to furnish. At the time, the team concluded that the information provided by the government—the operating records of the decommissioned pilot enrichment plant—were insufficient to make any firm conclusions about the validity of the declaration. It requested additional information, including the historical values of material unaccounted for (MUF), as determined by the AEC for "financial control," the

historical flows of nuclear material, including imported material, and accountancy and operating records of the semi-commercial enrichment plant. The South African government did provide those documents, which indicated that production of enriched uranium was suspended between August 1979 and July 1981 due to technical problems. The AEC claimed that production fluctuated depending on the operational situation at the plant, withdrawal of LEU for production of Koeberg fuel elements, introduction of DU feed material, etc.[29]

However, when the team calculated the U-235 balance in the pilot enrichment plant, it found a discrepancy it attributed to the fact that the AEC lacked a "formal measurement control program" for the depleted uranium product, which accounted for a significant amount of the U-235 balance. The AEC claimed at the time that they did not measure the DU formally because the plant management placed a "low financial value" on it. The team found a similar problem when trying to reconcile the material balances at the semi-commercial enrichment plant; that is, the team once again came up with a discrepancy in the U-235 balance. Again, the team ascribed it to the material accounting system. Upon further investigation, the IAEA inspection team determined that the:

> accuracy of the physical inventory was impaired by the non-availability of suitable instruments to measure process hold-ups, the unwillingness of the plant management to interrupt production in order to drain condensers or to transfer material to measurement points, and to the lack of comprehensive measurement control programmes. The calculated values of [MUF] for each year of operation were provided to the team by the AEC, but were not taken into account in the

> evaluation of the U-235 balances in view of the uncertainties associated with their determination.[30]

As a result, the team did not do a complete mass balance of the material at the enrichment sites.

Following the disclosure of the nuclear weapons program in 1993, the IAEA set about trying to reconcile the apparent discrepancies it discovered during pre-disclosure inspections. It received access to additional records and technical reports from the AEC, including the description of "phenomena, such as chemical losses, which were unique to the process gas mixture and the plan construction materials which influenced the output of the plant."[31] Given further "clarifications" provided by AEC officials and examination of additional historical records, the IAEA team concluded that the "magnitude of the apparent discrepancy in the U-235 balance associated with the pilot enrichment plant was reduced to such a level" that it could conclude that there was simply reasonable in-process losses.[32]

> Having regard to the uncertainties normally associated with data of this nature, it is reasonable to conclude that the uranium-235 balance of the high enriched uranium, low enriched uranium and depleted uranium produced by the pilot enrichment plant is consistent with the uranium feed.[33]

What is puzzling about this statement is that the team made this assertion despite the fact that it was unable to conduct a complete mass balance calculation because the AEC did not assay or weigh the tails and other material it deemed "waste," including some material that contained significant amounts of HEU. The team was also unable to obtain records with re-

spect to the amounts of natural and depleted uranium used in experimental or the material transferred to the nuclear weapons program "on the grounds that natural and depleted uranium had been considered ordinary metal with little nuclear significant or financial value."[34]

When IAEA Safeguards Department management raised questions about the lack of a mass balance, the South Africans were forced to assay and weigh the amount of material in the roughly 600 cylinders deemed waste. In so doing, they discovered a lot more HEU than had originally been determined by the inspection team. But, did it account for all of the HEU in the tails material? And what about the holdup material the team was unable to access?

An October 1993 report[35] estimated that the South African government had roughly 731-kg (plus or minus 24-kg) of 90 percent uranium on hand at the time of the disclosure. This was an inventory difference equivalent to the material required to make two bombs. The South African estimate of the amount of depleted uranium tails from enrichment plant operations was 370,643-kg. Taking into account the amount of material needed to start up the pilot enrichment plant and bring it to equilibrium, and the amount of fuel it produced for the SAFARI-1 research reactor and the Koeberg reactors, including how much each required given their respective designs, the report estimated that, had the pilot enrichment plant produced only HEU for weapons, it could have produced roughly 1000-kg of 90 percent uranium.

> The South African AEC estimated [sic] of the relative uncertainty (one standard deviation) in the tails assay is 15.6 percent. This, already large error in the tails

assay, produced a corresponding relative uncertainty in the calculated inventory of HEU product that is about twice as large—about 35 percent.[36]

Moreover, the gun assembly device dropped on Hiroshima—Little Boy—was built using about 50-kg of HEU enriched to 80 percent and had a yield estimated between 12 and 15 kiloton (kt). The yield range of the South African weapons was estimated to be about 10- to 18-kt. It was unknown, however, how effective the neutron reflector was in those weapons compared with the one in Little Boy. Therefore, the South African weapons could have needed as much as 60-kg of 90 percent enriched uranium per warhead. Based on what was known about production at the pilot enrichment plant, it was capable of producing enough HEU for an additional five weapons of the same design. The inventory difference, or MUF, represents another two nuclear weapons' worth, which could have been in the tails material or elsewhere.

## LESSONS LEARNED, OPEN QUESTIONS, AND WHY THEY MATTER NOW

It has been 20 years since South Africa disclosed that it had built a limited nuclear deterrent and then dismantled it. But, despite the many writings on the subject, significant gaps in public knowledge remain. How thorough was the IAEA in reconciling HEU production? Why did the de Klerk government destroy many of the "smoking guns" from the program **before** the IAEA could get to them? How successful was the IAEA team in reconciling historical fissile materials production even though the physical plant no longer existed? Much of the secrecy the South African gov-

ernment instituted in the wake of the dismantlement is still in place, despite the fact that the program has allegedly not existed for 20 years.

The South African disclosure has been held up as a beacon of transparency and of rollback of a nuclear weapons program. But, in the context of the current administration's commitment to eliminating nuclear weapons, the South African case raises at least as many questions as the IAEA has purported to have answered about the program. Questions about the amount of fissile material the South African complex actually produced, the remaining secrecy surrounding the program, the destruction of documentation and facilities prior to the disclosure and IAEA inspections of the weapons facilities, and the completeness of the IAEA's verification of the South African program all beg the question of how a country would give up a nuclear weapons program now, how it could be effectively verified, and how much confidence the public—and other governments—would have in that verification. The confidence level would have to be particularly high in order for any other country to follow suit and similarly disarm. It would also have to be high in order to convince non-nuclear weapons states that the threat has been eliminated. If the standard accorded to South Africa by the IAEA and its Member States back in 1993 were used in the context of the current "getting to zero" campaign, it is unclear that the book would be deemed to have been verifiably closed.

## ENDNOTES—CHAPTER 8

1. Waldo Stumpf, "The Birth and Death of the South African Nuclear Programme," presentation given at the Conference "50 Years After Hiroshima," held at Castiglioncello, Italy, September 28-October 2, 1995.

2. Thomas B. Cochran, "High-Enriched Uranium Production for South African Nuclear Weapons," *Science and Global Security*, Vol. 4, No. 2, Winter 1993/94.

3. *Ibid*.

4. South African Fundamental Atomic Research Installation, Pelindaba, South Africa.

5. Frank Pabian, "The South African Denuclearization Exemplar: Insights for Nonproliferation," Stanford, CA: Stanford University, Los Alamos National Laboratory and Center for International Security and Cooperation (CISAC).

6. The exact date of that conversion is subject to dispute: Waldo Stumpf, the former head of the Atomic Energy Corporation, stated that the project took a military turn in 1977, while former South African President F. W. de Klerk said it was around 1974. A U.S. intelligence report estimated the change to have taken place in 1973.

7. "South Africa Country Profile," Nuclear Threat Initiative, available from *www.nti.org/country-profiles/south-africa/*.

8. Zulu for "No discussion."

9. Zulu for "End of discussion."

10. Afrikaans for "stand firm."

11. Sara Kutchesfahani and Marcie Lombardi, "South Africa," James E. Doyle, ed., *Nuclear Safeguards, Security, and Nonproliferation: Achieving Security with Technology and Policy*, Oxford, UK: Butterworth-Heinemann, 2008, p. 292.

12. David Albright, "South Africa's Secret Nuclear Weapons," Washington, DC: Institute for Science and International Security, May 1994, available from *isis-online.org/publications/southafrica/ir0594.html*.

13. *Ibid*.; and Verne Harris, Sello Hatang, and Peter Liberman, "Unveiling South Africa's Nuclear Past, *Journal of Southern African Studies*, Vol. 30, No. 3, September 2004.

14. "Secret documents reveal Israel and South Africa Weapons Talks," *New York Beacon*, July 3-9, 2010.

15. Editorial, "South Africa's Unexploded Bombs," *The New York Times*, March 27, 1993

16. Pabian.

17. One of the CSIR scientists, W. L. Grant, received reactor physics training in the United States.

18. *Ibid*.; and Pabian.

19. Former South African Foreign Minister RF 'Pik" Botha in an interview with Dr. Sue Onslow (LSE IDEAS Fellow) Pretoria, July 15, 2008, p. 12, available from *www.lse.ac.uk/IDEAS/programmes/africaProgramme/pdfs/bothaInterview.pdf.*

20. Harris *et al*.

21. *Ibid*.

22. Nina Lelyveld, "South Africa Provides a Cautionary Tale: The Country Disarmed Voluntarily, but Questions about Its Nuclear Program Remain. Some Say Records No Longer Exist," *Los Angeles Times*, March 13, 2003.

23. *Ibid*.

24. Classified Document, "South Africa: Nuclear case closed?" Washington, DC: United States Department of State, December 19, 1993, declassified on July 18, 2003, p. 1.

25. U.S. Department of State, "South Africa's Options to Conceal Highly Enriched Uranium," Bureau of Intelligence and Research (INR). Memo, March 3, 1992, available from *www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB181/sa29.pdf*.

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27. Adolf von Baeckmann, Garry Dillon, and Demetri Perricos, "Nuclear Verification in South Africa," IAEA Bulletin, January 1995, p. 45.

28. Stumpf.

29. "South Africa's Nuclear Capabilities," GC(XXXVI)/1015, IAEA, September 4, 1992, p. 5, available from *fissilematerials.org/library/iaea92.pdf*.

30. *Ibid*., p. 6.

31. "The Denuclearization of Africa: Report to the Director General," GC(XXXVII)/1075, IAEA, September 9, 1993, Attachment 1, p. 3, available from *www.iaea.org/About/Policy/GC/GC37/GC37Documents/English/gc37-1075_en.pdf*.

32. *Ibid*., pp. 10-11.

33. *Ibid*., p. 2.

34. *Ibid*., p. 8.

35. Cochran.

36. *Ibid*.