Chapter 7 Advena Central Laboratories

The 1987 decision to improve the quality and possibly the quantity of nuclear weapons opened the next phase of South Africa's nuclear weapons program. In a difficult economic time, monies were found to renovate and expand South Africa's capability to make nuclear weapons. The new complex was more spacious and capable, and a far nicer work environment than the Circle facility. The Circle building, located about five minutes from the new complex by car, became known as the "old building." As the inhabitants of Circle did not like this name for the old building, they decided to call it the "Castle," since its physical appearance to a certain extent resembled a castle.

The new facility cost about 36 million rand (about $15 million in 2016 dollars). Its codename was Advena Central Laboratories. The name's genesis is unknown, but Advena in Latin means the foreigner or stranger. Figure 1 shows two of the site's main buildings. Figure 2 is a commercial satellite image of the site taken after the nuclear weapons program ended.

The occupation of the new Advena facilities started during 1988, and the process of commissioning was still underway when the nuclear weapons program was terminated in the fall of 1989. Once Advena was completed, the Circle building would have been used for the maintenance of the existing gun-type nuclear weapons. Advena would have concentrated on new types of weapons. After the program was cancelled, Armscor commercialized the facility, as will be discussed later.

Figure 1 Advena Central Laboratories. The integration building is in the foreground and the main building is behind. The wide wing of the main building on the left of the main building holds the clean room. A double fence is visible on right of the photo. Photo Credit: Armscor

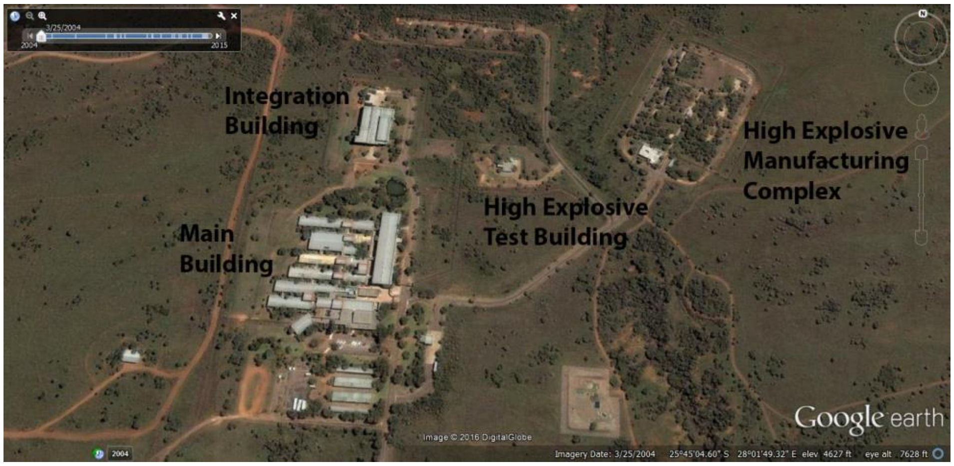

Figure 2 Google Earth commercial satellite image of Advena Central Laboratories taken in 2004.

Why Advena?

The decision to build new facilities was motivated first by the decision to build the next generation of nuclear weapons. The government had mandated the development of implosion-type warheads, the continuation of theoretical work on all types of nuclear explosives including boosted and thermonuclear designs, and most importantly, the integration of a nuclear warhead onto a ballistic missile. The new site was designed by Armscor to be able to carry out these missions.

The development of a nuclear-tipped ballistic missile had emerged in the late 1980s as a feasible South African priority--one that was expected to drive Advena's first decade of operation. For ballistic missile warheads, Armscor planned to upgrade the 500-series gun-type nuclear weapons. Armscor said it planned to "replace the seven cannon-type devices with seven up graded devices, when they reached the end of their estimated life by the year 2000."[1] To that end, Advena planned to conduct nuclear-weapons development work on advanced gun-type and implosion-type devices able to fit on a ballistic missile. The site was designed with sophisticated capabilities in high explosives, ultra high-speed diagnostics, theoretical calculations, metallurgy, high-speed electronics, and environmental and reliability testing.

Although Advena had many capabilities for advanced nuclear weapons work, its rate of weapons production would have been modest. Each year, it could have produced no more than about two to three weapons.

Advena Central Laboratories was built so that it could both develop and produce implosion-type devices. A key part of that effort was mastering high explosives. The new facilities could test

[1] Armscor, Written responses to queries by one of authors, Spring 1993.

larger amounts of high explosives than Circle, and these new capabilities allowed for an expansion of its development and evaluation of implosion technologies.

Moreover, Advena was also embedded with other capabilities to support the missile program. It was diversifying into conventional military pyrotechnics and missile control components, such as "jet vanes."

Despite the commitment to boosted and thermonuclear weapons development, Advena did not have a capability to handle tritium. Although South Africa had acquired tritium from Israel in the 1970s, and the AEC made lithium 6, Advena's lack of tritium capability suggests that boosted and thermonuclear weapons were not an Armscor priority beyond theoretical studies, as will be discussed below.

In addition, the new complex could house a larger staff. The nuclear weapons program had outgrown the Circle building. The labor force had increased from 100 to 300, and more space was needed. Workers expressed frustration with the small spaces in the Circle building. They expressed relief that the new buildings were better lighted than Circle, which had no windows and felt claustrophobic. Although cognizant of the risk of observation from satellites or other methods, the designers of the main building created a design with many windows and views of gardens.

Figure 3 Landscaped areas between two of the wings of the main building.

In addition, the Circle building was designed so that only project participants could enter the building. The new site, however, allowed visitors without divulging the true purpose of the program.

The site also had a more modern feel. Inside the entrance was a mural (see figure 4) containing many South African symbols with the phrase “Explore future technology today” written in Afrikaans on the top and English on the bottom. The symbols are far more relevant to aerospace engineers than nuclear engineers, which may reflect that the former dominated this nuclear weapons program and were increasingly comfortable in that role.

Figure 4 Mural near the entrance to the main Advena building. Artist unknown.

Integration Building

The most notable new building at Advena was the integration and test facility (see figures 1 and 5). Finished in June 1989, it was designed for advanced weapons assembly and integration with delivery systems, in particular ballistic missiles. Its significance to those at the site is revealed in its nickname. This building was known as “Ararat,” a Biblical reference to the sacred land or mountain where Noah’s ark rested after the Great Flood subsided.

Figure 5 The integration building as viewed from the main building.

It had a long central bay with a large door at each end and rooms on either side of the bay. Its design allowed for a ballistic missile on a TEL to be driven into the building. Rooms on the side of the central bay were to produce reentry vehicles, balance warheads, cast and machine HEU, and store HEU, warheads, and reentry vehicles. Figure 6 shows the large central bay and a side room as it appeared in 2002, after the program ended. One of the large doors is visible in the background.

Figure 6 On left, the large central bay where a ballistic missile could enter and be loaded with a nuclear warhead. On right, one of several adjacent rooms for warhead manufacturing. The high security storage vaults were on the right side of the bay and near the far outer door. The CNC machines in the photos are not associated with the nuclear weapons program.

The high security storage vaults were located near one end of the central bay at the end of a series of production rooms. The new storage vaults contained space suitable for one small reentry body, according to Armscor.

Figure 7 Top images show the outer high security vault doors, with a view of inner vaults. The lower images show three of the four inner vaults, with two significantly longer than the other two. Each vault appears to require two codes or keys to enter.

A critical part of developing a nuclear-tipped ballistic missile is the re-entry vehicle, which holds the warhead. It must be able to withstand re-entry to the earth's atmosphere and is challenging to build. This task became more challenging because Armscor decided that the reentry vehicle would need to reenter the atmosphere at a high speed in order to thwart possible countermeasures against the warhead. The integration building was being outfitted with the necessary equipment, including balancing and mass property machines.

Work was progressing on learning how to balance warheads. The task was further complicated because Armscor decided to avoid buying sophisticated balancing equipment abroad out of fear that seeking such goods would tip off foreign intelligence agencies that South Africa was trying to mate nuclear warheads to a ballistic missile. The domestic production of adequate equipment proved difficult. Moreover, Advena had little knowledge about what would constitute adequate balancing of a warhead or a reentry vehicle. It thus expected to spend a considerable amount of time developing both the necessary theoretical and practical expertise.

Seeking foreign help was not completely avoided, however. Personnel in the nuclear weapons program developed questions about the re-entry vehicle that South Africa' space launch experts could not answer. One of the South African nuclear weapons personnel went to Israel and got the answer from unwitting Israeli experts by couching the questions in a satellite discussion. Based on an agreement at the head of government level, South Africa and Israel had agreed not to discuss nuclear weapons, only space launch-related issues. Whether this particular visit was sanctioned by Armscor is unknown.

Main Building

The main building had offices, labs, and a variety of support facilities, including a library, cafeteria, and an auditorium. Completed in February 1989, the main building had about 100 offices or rooms. The main building was known as Uitsig, or good view, in Afrikaans.

The building had a range of laboratory and small-scale industrial capabilities. Unlike the Circle building, it had a "clean room" for more advanced manufacturing, including more sophisticated electronics manufacturing. Figure 8 shows the clean room a few years after the program ended. This facility is the long, wide wing of the main building visible in figures 1 and 2.

Figure 8 Clean room in main building in early 1990s. Photo source: Armscor

Figure 9 Entrance to the electro-mechanical area in the main building, with a high security vault inside the room in left image.

The main building, like Circle, contained a range of equipment related to making nuclear weapons components. For example, in one room in the early 1990s (see figure 10) there was an Italian-supplied precision coordinate measurement machine used to ensure that manufactured items met specifications. This same type of machine, the DEA Iota 2204, can be seen in operation an online video.[2] International Atomic Energy Agency inspectors reported finding

[2] DEA IOTA 2203, YouTube, February 24, 2014, https://www.youtube.com/watch?v=P3UyXfBumAk

nuclear weapons component gauges near this machine when they inspected Advena in 1993. These are essentially exact models of a nuclear weapons component, and they asked South Africa to destroy them. Earlier, this DEA machine may have been in one of the bunkers in the high explosive manufacturing area (see below), according to a former member of the nuclear weapons program who saw a coordinate measuring machine there.

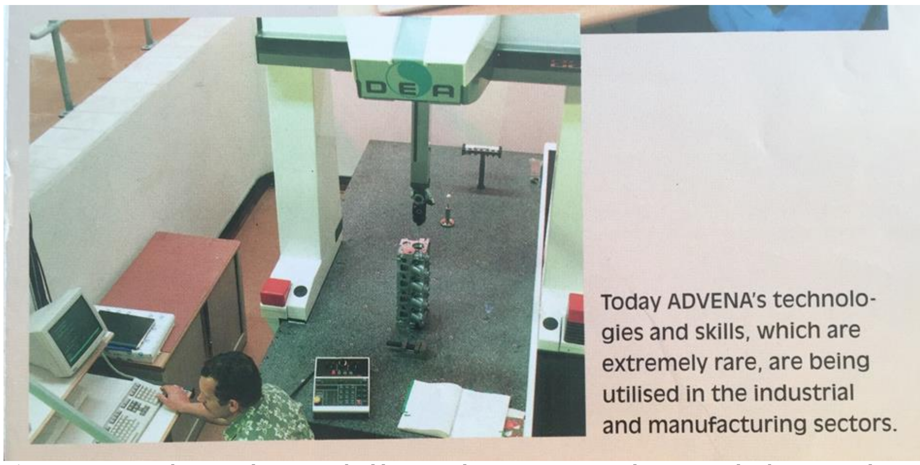

Figure 10 DEA machine in Advena main building in early 1990s. Source: Advena Central Laboratories advertising brochure from the early 1990s.

Armscor decided to create its own nuclear weapons theoretical group at Advena. Some of its members moved to Advena from the AEC's program still housed in building 5100 below the main site at Pelindaba. By the late 1980s, four or five people remained in the AEC theoretical group and were involved in nuclear weapon simulations and investigations of basis processes in a nuclear explosion, including neutronics and nuclear physics. However, they were not involved in designing nuclear devices. After the opening of Advena and the creation of an in-house theoretical group in 1989, the AEC ended its theoretical work on nuclear weapons, in essence ending the last vestiges of the Reactor Development Division. Figure 11 shows some of their offices at Advena, as they appeared during a visit in 2002. Those who moved from the AEC to Advena believed they had moved nearer to the center of the weapons program.

Figure 11 Wing that housed the nuclear weapons theoretical group. The partitions had been removed and the room converted to another purpose. A large vault was at the other end of this wing (not shown).

Armscor and the AEC acquired various computer codes abroad and then applied them to the weapons program. These included codes for calculating two dimensional shaped charges. However, the weapons program in general was satisfied with one dimensional integrated neutron and hydrodynamic codes. The weapons-specific computer codes, which had been created over many years, were at the AEC until May 1988, when they were transferred to Advena with the closure of the Reactor Development Division.

High Explosive Test Facility

The high explosive test facility, which was completed in July 1991, was a small building licensed to withstand the blast of up to 10 kilograms of TNT while measuring blast phenomena. It was intended to develop the shaped charges of an implosion-type nuclear device. It was known as Toiings, or tatters, in Afrikaans.

Figure 12 The high explosive test facility, with integration building in background.

The core of the building is a test chamber with thick concrete walls lined with wooden beams that prevented shrapnel from chipping the concrete walls. Figure 13 shows the inside of the blast chamber, where shaped charges were tested, and the three-tonne blast door. Portals are visible through which flash x-ray machines and fast cameras record the blast. Figure 14 shows the room with the pedestals that held this equipment and the portals. The facility housed a 450 keV flash x-ray, possibly of U.S.-origin, and a streak camera (100-1000 ns/mm).

Figure 13 The inside of the high explosive test cell, able to conduct tests of up to 10 kilograms of high explosives. The tests would be conducted in the sand pit. Open and closed portals are visible. The cell was sealed by a three-tonne door that was closed hydraulically.

Figure 14 The inside of the high explosive test facility showing where the flash x-ray and streak camera had been positioned on pedestals behind the portals. The photo was taken in 2002 after the facility had been repurposed to a classroom on nature conservation for ex-military personnel.

In contrast, the indoor high explosive test cells in the Circle building could handle only 2.5 kilograms of high explosives. Figure 15 shows the blast door to Circle's ballistic testing area, which had eight small cells, each of which had a blast cover on top of it. Circle's facilities appear significantly smaller than the test chamber at the Advena site.

Figure 15 In left image, the heavy, electrically controlled sliding blast door to the test cell area (closed). On right image, orange blast covers cover the high explosive test cells in the western end of the Circle building. Each cell was considerably smaller than the blast chamber at Advena.

To successfully import high speed cameras for implosion-related testing, Armscor knew that it would need to deceive a foreign supplier, which would never approve an export to South Africa's nuclear weapons program.[3] At the time, South Africa could buy such cameras for a civil industry. So, in at least one case, Armscor used a mining company as a front. Armscor invested funds to create a high explosive facility at the mining company so that this facility could plausibly argue that it needed a fast camera. The camera was bought using a false end user certificate of this mining company. Once received, it was diverted to Armscor. At some point, the exporter visited the mining company to check that the camera was there. However, the exporter gave the mining company typically two weeks advance notice of their visit, reflecting the time needed to receive a visa. Two weeks was more than enough time to move the camera back to the mining company, so that it could be seen by the supplier. After the supplier left, it was moved back to Armscor.

High Explosive Processing Facility

The high explosive manufacturing facility, finished in September 1989, was composed of six bunkers, a control building, and an administrative office involved in high explosives processing,

[3] Interview with former senior member of South Africa's nuclear weapons program, 2003.

storing, testing, and manufacture. The general assembly bunker (G6) was licensed to handle up to 200 kilograms of high explosives. The facility was known among the workers as Knopppiesaagte, or valley with bulges, in Afrikaans (figures 16-20).

Figure 16 High Explosive Manufacturing Site

Figure 17 Gate into high explosive bunker area.


Figure 18 Entrance to bunker G2 from outer perimeter road.



Figure 19 Top photo, bunker G6 looking in direction of G2. Lightening arresters are visible. Bottom photo, inside bunker G6. The cars are unrelated to the former nuclear weapons program.

Figure 20 Inside the control building at center of site. Original panels from nuclear weapons program.

Just before the end of the program, Advena illicitly acquired an explosion-proof 5 axis computer-numerically controlled milling machine from Japan (Ikegai) to machine precisely high explosive lens in the manufacturing bunkers. The precise shaping was judged necessary for the small implosion device Armscor was developing for its ballistic missiles.

Advanced Nuclear Weapons

The South African nuclear weapons program remained focused on developing and then improving deliverable gun-type devices. Since its start, however, members of the program had studied and developed advanced nuclear weapons, and South Africa had a long list of them in which it expressed interest. Nevertheless, as the program evolved, implosion-type nuclear devices received the most attention followed by the use of thermonuclear materials to "boost" the explosive yield of a fission weapon. Several advanced weapons concepts were barely studied, discarded, or postponed until some distant future.

Further, questions have been raised about whether South Africa received nuclear weapons assistance from other countries. China and Israel in particular are mentioned. South African officials have maintained that South Africa did not receive nuclear weapons designs or devices from any other country.

Advena Central Laboratories

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Building	Completion date	Comments
Offices and labs	February 1989	The main building had about 100 offices and a "clean room" for more advanced manufacturing, including more sophisticated electronics manufacturing. The main building was known as Uitsig (good view in Afrikaans)
Integration and test facility	June 1989	Designed for advanced weapons assembly and integration with delivery systems. It had a long central bay with a large door at each end and rooms on either side of the bay. These rooms were to make and balance reentry vehicles, to cast and machine HEU, and store HEU, warheads, and reentry vehicle. The central bay was large enough to drive in a ballistic missile. This building was known as Ararat.
High explosive processing facility	September 1989	Composed of six bunkers and a control building for explosives processing, storing, testing, and manufacture. The general assembly bunker was licensed to handle up to 200 kilograms of high explosives. Facility known as Knopppiesaagte (or valley with bulges);
High explosive test facility	July 1991	A small building licensed to withstand the blast of up to 10 kilograms of TNT while measuring blast phenomena. Intended to develop the shaped charges of an implosion-type nuclear device. It was known as Toiings (tatters)
High explosives magazine	September 1989	
High explosives demolition facility	September 1989	Called Brandlaagte in Afrikaans.

Advanced Gun-Type Nuclear Devices

Armscor intended to develop a more advanced gun-type nuclear device. The target date for completing this device was 1996. The modified device would have used a more modern propellant and improved electronics. Armscor officials have made clear that if a missile warhead were developed, it may have carried an advanced gun-type warhead and not an implosion-type warhead. To that end, it needed to modify the series 500 warheads' safety mechanism that prevented the HEU projectile from entering the HEU core when the barrel and sleeve mechanism were not aligned. This system was asymmetrical about the warhead's central axis and thus not usable on a ballistic missile where symmetry is required for a successful flight. It was just starting to develop an acceptable new safety mechanism.

One loose end when the program ended was creating a new gun-type device for use in an underground test. The original Melba device was to be replaced by an updated device in 1991, codenamed Modulus; how much work was accomplished on this new device is unknown.[4] This device would be expected to incorporate the latest safety mechanisms of the 500 series of devices. It would also likely have been designed for more rapid deployment at the test site than was possible with Melba, requiring additional or upgraded placement and control equipment.

Implosion-Type Nuclear Devices

Although research on implosion-type devices had occurred since the beginning of the nuclear explosive program in the early 1970s, implosion research did not become a priority until the mid-1980s. One reason cited by former members of the program, is that the leaders of the program did not believe that an implosion weapon was really needed, given the focus on building gun-type nuclear devices.

By the 1980s, however, little work was being done at the AEC. Even its theoretical nuclear weapons work was not specific to an implosion design, although some of the basic physics research done in building 5100 could be applied to implosion designs.

The implosion work was taken over by Armscor. In the mid-to-late 1980s, its motivation was not strictly the development of an implosion design.[5] Armscor was interested in developing a method to use about half as much HEU per device, allowing the recycling of HEU in seven gun-type devices into 14 implosion-type devices. Another motivation was that lighter, smaller weapon systems could become available in the future, and implosion weapons could be miniaturized more easily than the gun-type devices. Another more immediate purpose, which applied to other advanced weapon designs as well, was to help maintain the interests of the scientists and engineers who were involved in the design of the gun-type devices. The goal was

[4] *Program Olympic: Collaborative Notes Following a Briefing of the Minister of Defense in Kaapstad on July 27, 1987*, dated July 30, 1987, in Afrikaans, Original in Nic von Wielligh and Lydia von Wielligh-Steyn, *Die Bom* (South Africa: Litera Publikasies, 2014), Appendix, translated by Schreiber Translations, Inc. for Institute for Science and International Security, July 7, 2015. See also English version, *The Bomb*, (Pretoria, Litera Publications, 2015).

[5] Johann Viljoen and Deon Smith, *The Birth, Life, and Death of South Africa's Nuclear Weapons Program*, Manuscript commissioned by the Institute for Science and International Security, 1999, unpublished.

to keep weapons scientists and engineers engaged by working on more challenging problems. This plan had the immediate spin-off of helping maintain the technology base for the maintenance of gun-type systems.

Armscor's implosion effort focused on developing, maintaining, and demonstrating a technical level of sophistication. Although implosion development had always been present in South Africa's nuclear explosive efforts, Advena's capabilities were far more extensive and reflected a stronger commitment to the development of a small implosion device.

Circle engineers correctly realized that a major stumbling block in developing an implosion system would be determining that a design would work satisfactorily. This problem was considerably simpler in the case of a gun-type device. The implosion program recognized that understanding compression during the detonation of the high explosives would be key to success, and decided to focus on developing good diagnostic capabilities to understand this phenomenon. The primary focus of the implosion effort during the late 1980s, according to Armscor, "was on the development of measurement systems which could be used during the 1990s." These included the development of diagnostic capabilities with flash x-rays, streak cameras, and flyer plates with pins that would allow for high explosive experiments where progress could be carefully documented.

By the end of the program, a number of implosion technologies were being developed.[6] They included:

- High explosive charge design;
- Ignition mechanisms;
- Detonic measuring techniques;
- Neutron triggering;
- Computer simulation and analyses;
- Plane wave lenses;
- Flyer plate acceleration (study on high explosive compaction);
- Casting experiments (TNT, HMS, Mixtures but not TATB);
- Isostatic pressing experiments (PBXs); and
- Machining experiments on simulants (plastics).

Safety considerations were being factored into future implosion designs. An implosion device poses a risk that an accidental detonation of high explosives will trigger a nuclear explosion. To reduce this risk, Circle engineers began producing small quantities of TATB, an "insensitive" high explosive, in 1988. Insensitive explosives ignite at higher temperatures than ordinary explosives. Firing a bullet into TATB will not cause it to detonate.

The program imposed very strict criteria on the implosion design. By the end of it, there was still no agreement on the specifications of a design, but the high explosive lens design had

[6] Information sheet provided to the IAEA by South Africa, undated but in period immediately following President de Klerk March 1993 announcement of a prior nuclear weapons program.

received most of the attention, according to a former member of the program who worked on the implosion effort.

According to Armscor leaders and members, the implosion device was to have a diameter of no more than about 50 centimeters, a size likely dictated by the RSA-3 missile re-entry vehicle. It would utilize about half the amount of HEU as the gun-type device, or 28 kilograms of weapon-grade uranium. The actual amount would have depended on the design ultimately developed, but would have likely been in the range of 20-30 kilograms of weapon-grade uranium in a solid ball. This relatively small diameter, according to another former senior Armscor member, placed a "tremendous constraint on the implosion system."

Although no full-scale prototypes had been built, nor any designs developed in detail, the program did have a cut-away scale wooden implosion model. One participant remembered that it was of the high explosive system.

Unlike South Africa's gun-type design, an implosion device would require a neutron initiator able to start the chain reaction at a precise moment. Armscor turned to the AEC to develop a miniaturized neutron generator based on accelerating deuterium into a tritium target. However, by the time the weapons program was cancelled, the AEC had built only a large laboratory model about 60 centimeters long. They were able to get pulses of neutrons but had not yet miniaturized it. The then implosion design required a neutron initiator that was no longer than about 15 centimeters, or one fourth as long as the lab model.

To develop implosion technologies, South Africa acquired a range of diagnostic and manufacturing equipment overseas. As discussed earlier, it had acquired flash x-rays and fast cameras. It also procured an isostatic press for pressing high explosives and a specialized five-axis computer controlled machine tool for precisely shaping the high explosives.

It was recognized that an implosion system would be easier to build with plutonium rather than HEU. However, without a source of plutonium, or the means to handle it safely, Armscor did little work on a plutonium-based implosion designs.

Armscor conducted at least one high explosive test of the spherical core using a surrogate material for the HEU. In 1987, the program conducted a six-point detonation test of a high explosive package with a steel ball at its center at the large Boskop high explosive test site several kilometers from Potchefshoom (southwest of Johannesburg). However, the test was unsuccessful; the steel ball was ejected and rolled down the hillside. Nonetheless, more tests were planned, using 12- and 20-point tests.

The Boskop site operated by Naschem had a high explosive detonics facility that was adequate to conduct large-scale implosion package tests. The site was comprised of a small high explosive test bunker, a flash x-ray machine of 300 KeV, and two streak cameras, one with a framing speed of half a million frames per second. Later, after the program ended, Armscor advertised this site as having a flash x-ray and an ultra-speed camera with a framing speed of up to 20 million frames per second.[7]

It is unknown whether Armscor would have ultimately built implosion devices as replacements for the gun-type devices. Armscor engineers have acknowledged that they would have faced many challenges producing an implosion weapon manufactured to the same level of demanding safety, security, and reliability specifications as the gun-type device. Nonetheless, Advena engineers appeared to be taking the right steps to build an implosion device, and they allowed for sufficient time. According to an Armscor official, a decision on building implosion weapons was still ten years away when the weapons program was canceled.

A senior Armscor official said that an implosion-weapon program would have required full-scale cold tests of the implosion system with a natural uranium core. Conducting such tests regularly, he said, “would have posed risks with regard to detection.” One solution was to build a closed facility to conduct such tests. If Armscor had decided to build a closed arena large enough to contain the detonation of large quantities of high explosives in a cold test, the arena would have cost about 12 million rand. This sum, he said, was considerable for the Advena program.

According to a former senior leader of the program, it may have been difficult to convince people that an implosion design would work without full-scale testing. If a full-scale nuclear test was needed to certify the weapon, the nuclear strategy would have had to be modified, another major challenge. This possible need for a full scale test was another factor that could have discouraged a decision to build and deploy implosion-type nuclear weapons. At the least, developing methods to provide adequate safety, security, and reliability without full-scale testing would have likely delayed the program.

Artillery Shells

For years rumors had abounded that South Africa made a warhead that could have been fired from its 155-mm artillery system, called the G-6. A major reason for this rumor was South Africa's announcement in 1982 that this system was capable of carrying a NATO nuclear warhead.[8] In fact, South Africa conducted paper studies of artillery shells armed with nuclear devices, according to its declaration to the IAEA. Nonetheless, this project did not advance beyond preliminary paper studies of nuclear-armed artillery shells, according to Armscor officials involved in the program. The studies, including at least one done in the late 1980s, included shells with a diameter of 155 millimeters. Artillery shells with a gun-type device were also worked on. Earlier, following the 1985 decision, work had stopped on an artillery shell containing an implosion system using plutonium, according to South Africa’s declaration to the IAEA.

Boosted Devices

[7] “From Bomb-filling to Advanced R&D,” *Engineering Week: ARMSCOR Annual Survey* (Johannesburg, 1989), p. 22, cited in Frank Pabian, “South Africa’s Nuclear Weapon Program: Lessons for U.S. Nonproliferation Policy,” *Nonproliferation Review*, Fall 1995. https://www.nonproliferation.org/wp-content/uploads/npr/31pabian.pdf
[8] Jaap Boekkooi, "Whose Basements Have a Bomb?" *The Star*, Johannesburg, September 29, 1982, p. 29.

South Africa was interested in the idea of "boosting" the yield of its fission weapons by using a small amount of tritium and deuterium. The idea was to increase the explosive yield from 10-20 kilotons to 60-100 kilotons. Small-scale theoretical work on the basic principles of nuclear fusion had started.[9] Both a gaseous and solid form of the fusion fuel were considered. However, the gaseous form would have required the insertion of tritium and deuterium at high pressure into a capsule or reservoir, which the program judged as beyond South Africa's capability.[10] A solid pellet of lithium, tritium, and deuterium was selected instead.

For the gun-type device, the pellet would have been placed in the HEU projectile, according to South Africa's declaration to the IAEA. Such placement would have been consistent with South Africa's command and control philosophy because the tritium in the fusion pellet decays radioactively in a relatively short period of time. Thus, the pellet would require periodic replacement.

Armscor, however, had little interest in boosted devices. In the 1980s, its weapons effort was not ready for such an advanced concept and in any case not prepared to study the practicalities of boosting. Moreover, Circle and Advena Central Laboratories did not have any facilities to handle tritium, which is very radioactive. In addition, Armscor officials said, if the purpose of the bomb program was to demonstrate capability, why would yield matter?

The work never moved to the point where tritium was used. In any case, the work was stopped in 1987, according to South Africa's declaration to the IAEA. However, theoretical work may have continued afterwards or could have been restarted eventually.

Whether an effort to make a boosted device would have materialized later is unknown. If it did, a new source of tritium would have been needed. Starting in 1987, the AEC started to sell the tritium that had been imported from Israel ten years earlier. Much of this tritium had already decayed radioactively since tritium has about a 12 year half-life.

The AEC decided to use its tritium handling laboratory, called the Gas Laboratory, at Pelindaba for making radio-luminescent light sources.[11] Of the initial quantity of about 19.9 grams of tritium, about 9.31 grams were withdrawn from the four cylinders through 1992 and about four grams were sold as light sources as of 1993.[12] By this date, the cylinders had been emptied and were then disposed as waste because small amounts of tritium remained on their inner walls. By 1992, over half of the tritium had been lost through radioactive decay. Some, less than a gram, was also lost through uncontrolled releases or retained on container walls and disposed. Over time, more of the unused tritium decayed or was sold.

Thermonuclear Weapons

Although thermonuclear weapons were on a list of technologies to develop, little work was accomplished. The open literature was studied and some preliminary work was done by AEC or

[9] *The Birth, Life, and Death of South Africa's Nuclear Weapons Program*, op. cit.
[10] Nic von Wielligh and Lydia von Wielligh-Steyn, *The Bomb*, op. cit., p. 175.
[11] Atomic Energy Corporation, "Tritium Programme," undated (about 1993), unpublished.
[12] "Tritium Programme," op. cit.

Armscor experts, but nothing concrete, according to a senior Armscor official. There were lectures for program personnel on the subject, but one official who attended found the presentation simplistic and more like a report on an open literature search.

Foreign Assistance on Nuclear Weapons

There have been allegations that Israel provided or offered nuclear weapons to South Africa, particularly in the 1970s. One often discussed case involves a declassified document describing a secret 1975 meeting in Pretoria between Minister of Defense P.W. Botha and Israel's Defense Minister Shimon Peres. In this meeting Botha expressed interest in receiving a limited number of units of "Chalet," provided the correct payload could be provided.[13] The Israeli Defense Minister said that the correct payload was available in three sizes. Chalet was a codename for the Jericho missile, and some have concluded that one of the "sizes" must have been nuclear. In essence, according to this interpretation, Botha was expressing interest in buying nuclear weapons from Israel and a ballistic missile to deliver them. Although the declassified document summarizing this discussion does not mention a nuclear payload, it is plausible to assume that a nuclear warhead was one option, given the coded nature of the discussion. It would also be expected in such a delicate discussion that deniability of any such possibility would be preserved.

After the document was made public, Peres and South African officials denied that the discussions involved the sale of any nuclear weapons. However, their denials do not settle the issue, given that the nature of the payload has not been revealed.

Complicating matters, following an earlier meeting in 1975 where Israeli officials offered South Africa Jericho missiles,[14] the South African military chief of staff wrote in a secret memorandum that "in considering the merits" of the offer, "certain assumptions have been made: that the warhead will be armed with nuclear warheads manufactured in the RSA [Republic of South Africa] or acquired elsewhere."[15] This memorandum added credibility to the claims that Botha was considering buying nuclear weapons later that year. However, this memorandum does not state that South Africa asked Israel for nuclear weapons or that Israel offered them. It could as well be interpreted as the defense official expressing his own views about the growing need for South Africa to make a decision about obtaining nuclear weapons and reliable, credible delivery systems. Given concerns about the growing sophistication of enemy air defense systems, he mentions the need to consider acquiring "stand-off television-guided bombs or surface-to-surface missiles," noting that at that time South Africa possessed neither and would be advised to add these "very expensive but highly efficient weapons to our armoury." In 1975 the South African defense establishment, headed by Botha as Defense Minister, was just starting a discussion about acquiring nuclear weapons. At the time, South Africa was concentrating on its peaceful nuclear explosives (PNEs) in a program run by the Atomic Energy Board that envisioned an

[13] Sasha Polakow-Suransky, *The Unspoken Alliance* (New York: Pantheon Books, 2010). See also, *Die Bomb* op. cit., which contains some of the documents in its appendix.
[14] *The Unspoken Alliance*, op. cit.
[15] "The Jericho Weapon System," from CS [Lt. General R.F. Armstrong] to C SADF, date March 31, 1975, stamped top secret. The declassified document was obtained by Peter Liberman. See Liberman, "Israel and the South African Bomb," *Nonproliferation Review*, Summer 2004.

underground test rather than deliverable nuclear weapons. Yet the official's off-hand mention of acquiring nuclear weapons elsewhere implies that he may have thought that in addition to indigenous production, Israel could also be a source for them.

Long before the declassification of the documents discussed above, the ex-Soviet spy Dieter Gerhardt said he had learned that in 1975 Israel had offered South Africa several Jericho missiles with six "special" warheads.[16] He correctly said that the project was codenamed Project Chalet. He said that the special warheads were nuclear, based on his asking a more senior South African military official. Gerhardt's information must be taken seriously; as a senior military official who spied for over twenty years, he had "access to some of the most sensitive information" in the South African Defense Force, according to former senior defense and nuclear officials.[17] At a minimum, Gerhardt's information would imply that some senior South African military officials believed that Israel was offering nuclear weapons to Pretoria or at least considering a request from South Africa for them.

In any case, Botha decided not to proceed with buying any Chalets at that time, and the Israeli prime minister may have been unwilling to approve a sale in any case. So, the nature of the payload was never established concretely in any deal.

Avner Cohen, a well-respected Israeli nuclear historian, makes a convincing argument that Israel did not make an actual offer to sell nuclear weapons to South Africa. He writes: "To the contrary, the conversation amounted to a probe by the South Africans, which ultimately went nowhere."[18] He added that he believes that both Israel's then Prime Minister and its head of the nuclear program would have "opposed the sale of nuclear weapons, technology, or even components—not just to South Africa, but to anyone." However, what remains unclear is whether Botha made a direct or veiled request to purchase them.

The answer to what Botha intended with respect to Chalet payloads may never be known. He was an intensely secretive leader. However, what is known is that Botha himself dates 1975 as when he "initiated discussions in respect of the possibility of creating nuclear weapons" for South Africa.[19] Perhaps these negotiations with Israel focused South Africa's defense establishment on the value of nuclear weapons and its perceived need to acquire advanced delivery systems. Until then, the South African military had expressed little interest in the PNE program run by the nuclear program. As discussed earlier, all of that would change in the late 1970s, as South Africa decided to build deliverable nuclear weapons. In parallel, it decided to build the stand-off television-guided bomb and later the capability to make surface-to-surface missiles in cooperation with Israel.

This episode highlights both countries' skittishness with regard to discussing nuclear weapons. Armscor officials interviewed by one of the authors were unaware of any discussions with Israel

[16] Interview of Dieter Gerhardt, March 9, 1994.
[17] Hannes Steyn, Richardt van der Walt, and Jan van Loggerenberg, *Armament and Disarmament: South Africa's Nuclear Weapons Experience* (Pretoria: Network Publishers, 2003), p. 91.
[18] "Avner Cohen on Israel and South Africa," *ArmsControlWonk.com*, May 24, 2010 under Israel, media-criticism by Joshua Pollack.
[19] *Draft Speech of Prime Minister P.W. Botha for the Opening of Kentron Circle,* File No. 13/2/8/C, May 4, 1981, *Die Bom*, op. cit.

in the 1970s about nuclear weapons. However, they have stated often that during the 1980s, when Armscor controlled the nuclear weapons program, Armscor did not cooperate with Israel on nuclear weapons. One official added that the mere mention of cooperation on nuclear weapons was taboo.

As is well-known, there was extensive cooperation between the scientists and engineers of Armscor and Israel on rockets, which each side called space launch cooperation. However, both countries used or planned to use these rockets as ballistic missiles to carry nuclear weapons, even if in the case of South Africa the rockets would also place a satellite into orbit. Moreover, in the case of South Africa, there were Armscor experts who simultaneously worked on both the ballistic missile and nuclear weapons programs. Thus, the possibility for exchanges of sensitive nuclear weapons information cannot be excluded, despite both countries' officials stating that their countries maintained official policies banning such cooperation. However, like the case discussed earlier about a South African engineer seeking data about re-entry vehicles from Israelis, Armscor engineers or scientists may have sought other sensitive nuclear-related information. They may have operated under general instructions to pick up sensitive information whenever they could; South African nuclear officials had such orders.[20] However, other than information about re-entry vehicles discussed earlier, no evidence was found that nuclear weapon information was obtained by South Africa from Israel.

The South Africans reported good cooperation with Israel on space launch vehicles but over time that cooperation suffered from the two countries having different operational requirements for their rockets, according to a former senior Armscor official. This official also said that Israel became worried about the cooperation during the mid-to-late 1980s, as international pressure against the apartheid government intensified. Despite their deteriorating relationship, by the late 1980s South Africa with Israeli assistance had created a robust rocket program expected to launch reconnaissance satellites and deploy nuclear-tipped intermediate range ballistic missiles.

South Africa's Nuclear Future

As the 1980s closed, South Africa's nuclear weapons and ballistic missile programs were poised to make significant, albeit rather slow, advancements. Advena's main objective was to develop the necessary capability by the year 1996 to support a government decision to deploy a nuclear warhead on a ballistic missile. A multi-year development effort was viewed as acceptable because of the number of obstacles that had to be overcome. As 1989 dawned and Advena became operational, however, the political winds in Southern Africa were shifting to greater regional accommodation and peace. The planned nuclear and missile future was not to be.

[20] Albright, *Peddling Peril* (New York: Free Press, 2010), p. 105; and Interview with former leader of gas centrifuge program.