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South Africa's nuclear weapons programme

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English summary

In the 1970s and 1980s, South Africa had a secret nuclear weapons programme and built up a small arsenal of six simple, gun-type nuclear bombs. The bombs were deliverable by airplane, but were probably only intended as a deterrent. The programme was cancelled in 1989 while the seventh bomb was still under construction, and by 1993 all the weapons and weapons production plants were dismantled. With this, South Africa became the only country known to have developed and produced nuclear weapons and then completely disarmed.

South Africa's nuclear weapons programme is especially interesting because the programme was kept secret both internally and externally, and because the weapons were technically simple. The weapons programme can therefore be seen as an example of what a state can manage secretly and with relatively few resources. South Africa's situation still differs from most other states because the country from the 1950s onward was one of the world's largest producers of uranium and therefore had no need of importing nuclear raw materials for the programme.

This report discusses the technical aspects of the development of South Africa's nuclear weapons programme. It also describes the political circumstances that lead to the construction of the programme and the subsequent disarmament.

Sammendrag

Sør-Afrika hadde på 1970- og 1980-tallet et hemmelig kjernevåpenprogram og bygde opp et lite arsenal på seks enkle prosjektilbaserte atombomber, såkalte kanonløpsvåpen. Bombene kunne leveres med bombefly, men var etter all sannsynlighet kun ment som et avskrekningsforsvar. Programmet ble avsluttet i 1989 mens den syvende bomben fremdeles var under bygging, og innen 1993 var alle våpnene og våpenproduksjonsanleggene ødelagt. Med dette ble Sør Afrika det eneste kjente tilfelle der en stat har anskaffet kjernevåpen og deretter rustet ned totalt.

Sør Afrikas kjernevåpenprogram er spesielt interessant fordi våpenprogrammet ble holdt hemmelig både utad og innenlands, og fordi våpnene var teknologisk sett enkle. Våpenprogrammet kan derfor sees på som et eksempel på hva en stat kan få til i det skjulte med relativt små ressurser. Sør Afrikas situasjon skiller seg likevel ut fra de fleste andre stater ved at landet fra 1950-tallet og fremover var en betydelig produsent av uran og dermed ikke hadde behov for å importere kjernefysisk råmateriale til våpenprogrammet.

Denne rapporten diskuterer den tekniske siden ved utviklingen av kjernevåpenprogrammet og beskriver også de politiske forholdene som bidro både til oppbygningen av programmet og deretter nedrustningen.

Contents

List of abbreviations

AEB = The Atomic Energy Board

AEC = The Atomic Energy Corporation

ANC = African National Congress

Armscor = The National Armament Corporation

ESKOM = The South African Energy Supply Commission

HEU = Highly Enriched Uranium

IAEA = The International Atomic Energy Agency

LEU = Low Enriched Uranium

NTP = Treaty on the Non-proliferation of Nuclear Weapons

PAC = Pan-Africanist Congress

SWA = Separative Work Unit

UCOR = The Uranium Enrichment Corporation

UF_6 = Uranium hexafluoride

1 Introduction

On 21 March 1993, South Africa's President Frederik Willem de Klerk publicly acknowledged that South Africa had developed nuclear weapons. In a speech to the Parliament, simultaneously broadcasted by a national radio station, he admitted that there had been a nuclear weapons programme, but stressed that the programme had been strictly limited and intended as nothing more than a deterrent.

In 1989, when the programme was terminated, the country possessed six working weapons based on enriched uranium, in addition to a seventh device still under production. According to de Klerk, there had been no plans to build more than seven weapons and no definite plans for more advanced weapons. [1;2]

South Africa is so far the only country in the world known to have developed and then completely dismantled a nuclear arsenal. The programme was kept secret for the whole period it was conducted, and involved relatively few workers and scientists, and little or no foreign assistance. This makes South Africa an interesting case to study as an example of a small, independent nuclear player.

2 History

2.1 The beginning

South Africa has some of the largest uranium deposits in the world, and when the value of these mineral deposits first became clear in the 1940s, South Africa was far from the international outcast it later became. With a flourishing economy and a high level of technology, the country quickly became a leading state in international nuclear organisations after World War II and worked closely with the western powers, especially the United Kingdom and the United States. [3]

In 1945, the South African Chamber of Mines carried out a study to assess the amount of uranium in South Africa's gold mines, and concluded that uranium co-existed with gold in nearly all the mines. One of the first acts of the National Party government when it was elected in 1948 was to pass *The Atomic Energy Act*, which established *The Atomic Energy Board* (AEB) as the organisation responsible for nearly all activities involving nuclear technology in South Africa. The board was to oversee all nuclear activities and explore the possibilities for export and national exploitation of uranium. The AEB's mission was later expanded to include research and development work.

The company *Calcined Products (Pty) Ltd (Calprods)* was formed in 1951 with the objective of processing uranium from by-products of the gold mining industry. The first uranium plant opened in 1952, and in 1955 there were sixteen mines in operation. Young South Africans were encouraged to study nuclear physics and engineering abroad, and many of these students later returned from their studies in the United States, the United Kingdom, Germany or France to work in the South African nuclear programme. The United Kingdom also supplied technical assistance for the uranium mining.

In 1946, the United States, the United Kingdom and Canada had formed "The Joint Development Agency" to try to control and safeguard all uranium trade in the world, and until 1963, when South Africa broke ranks and concluded a multi-year contract to sell uranium to France on the same conditions as to the other nuclear states, almost all South African exports went through this group. South Africa had also delivered a small amount of uranium oxide to Israel in 1962 and 1963, but that transaction had been declared to the IAEA, and the uranium was supplied under the commitment that it would be used solely for peaceful purposes. The sale to France was made on the same terms as the sales to the other nuclear weapons states, that is, unsafeguarded. The decision annoyed the United States and the other western powers involved in the agency, but South Africa did not break any formal international agreements[1].

The uranium company Calprods was replaced by a new private company, *The Nuclear Fuels Corporation of South Africa (Pty) Ltd* (NUFCOR) in 1967. [4;5]

2.2 International cooperation

When the *International Atomic Energy Agency* (IAEA) was founded in 1957, South Africa was an active and important participant, and was given a permanent seat on the membership board as the most advanced state in Africa in nuclear matters.

South Africa and the United States developed an additional bilateral agreement on nuclear cooperation under the "Atoms for Peace" programme. This agreement allowed South Africa to purchase an American research reactor. The United States also supplied the reactor with highly enriched uranium (HEU)[2] fuel and trained South African personnel. This reactor was built on a site called Pelindaba outside Pretoria (see Figure 2.1 and Figure 3.1) and given the name *Safari I*. The site also housed the headquarters for the AEB. Safari I began operating under IAEA safeguards in 1965.

Another reactor, *Safari II* (sometimes also called *Pelinduna* or *Pelinduna-zero*) was commissioned in 1967. This was an LEU-fuelled, heavy water moderated reactor that was developed in South Africa. Fuel and heavy water were supplied by the United States. Safari II was decommissioned in 1969, mostly for economic reasons. All the spent fuel was transported to

[1] France performed its first nuclear test explosion on 13 February 1960
[2] Natural uranium consists mainly of the isotope uranium-238 with small amounts of uranium-235. As only the uranium-235 isotope can undergo a nuclear chain reaction, uranium for nuclear devices must be *enriched* to higher levels of this isotope. Highly enriched uranium means uranium with more than 20 % uranium-235. Uranium enriched to lower levels is called low-enriched uranium (LEU).

the United Kingdom for reprocessing before it was sent back to the United States. (See also section 3.3).

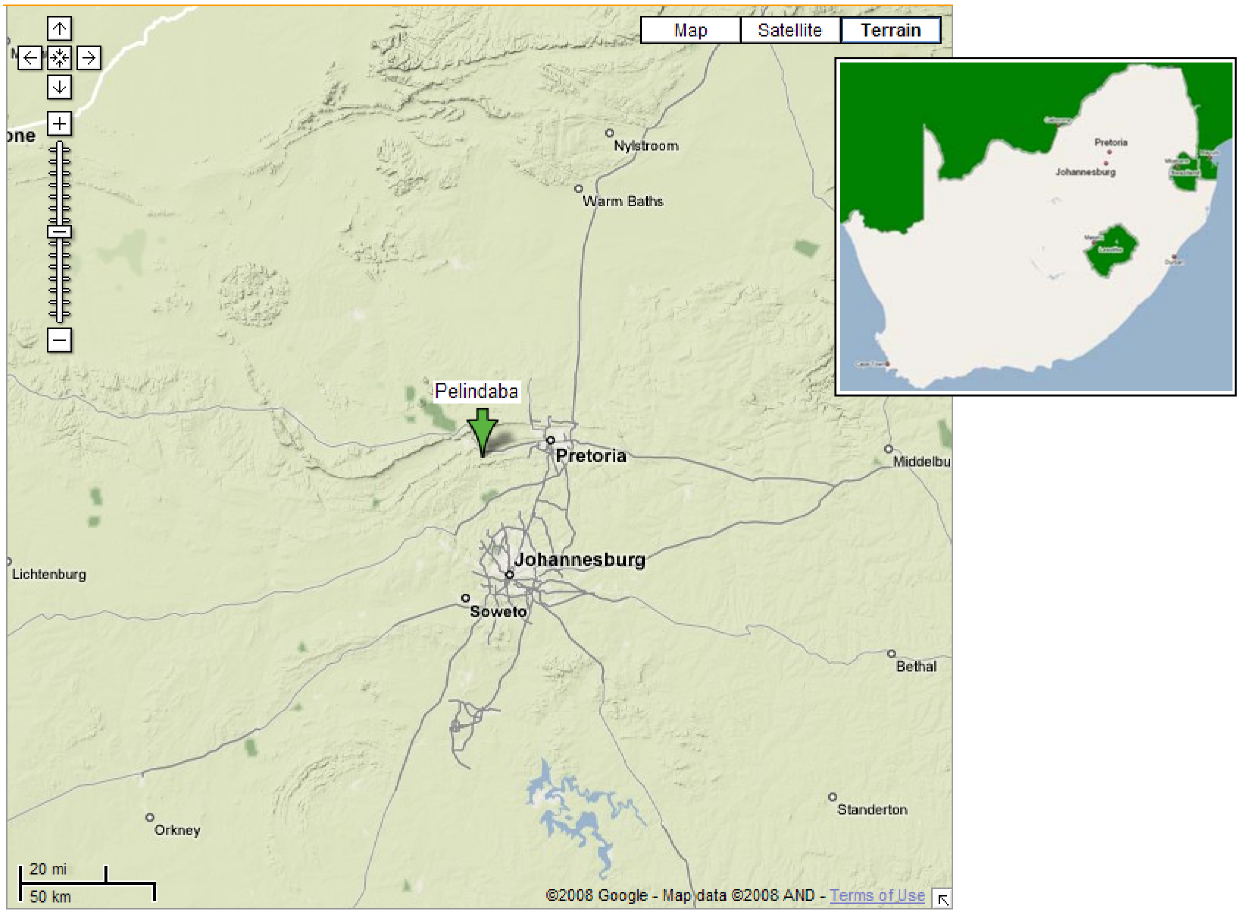

Figure 2.1 Pelindaba, 15 km west of Pretoria, where the Safari I reactor is located and much of the nuclear research and development work took place.

The United States continued to supply HEU for the Safari I reactor until 1975 when it suspended the agreement as part of the increasing international set of sanctions against South Africa. [3;6]

2.3 Uranium enrichment

In the 1960s, the South African government started to look into uranium enrichment. There existed several legitimate, non-weapons related reasons for doing this. The country wanted to improve its nuclear capacity, and domestic uranium enrichment could increase the value of the uranium export. A small, experimental project for laboratory scale uranium enrichment was initialised, but kept strictly secret for the time being. The engineers considered several enrichment techniques, using both laser and gas centrifuge technology, and by 1967 they had managed to develop a functioning gas separation technique. In 1970, Prime Minister John Vorster made the enrichment programme public, and the government established the *Uranium Enrichment*

Corporation (UCOR) to build a pilot enrichment plant. The plant was to be built at Valindaba,[3] a few kilometres from the Safari I research reactor. [6]

The pilot enrichment plant in Valindaba, referred to as the *Y-Plant* (see Section 3.2), was commissioned in 1974, but did not successfully produce highly enriched uranium until 1978. This plant was not opened for IAEA inspections, nominally to protect business interests and industrial secrets.

2.4 Apartheid and South Africa's position in the world

Before 1948, South Africa was considered a self-governing dominion of the British Empire, and the United Kingdom provided security guaranties in both world wars. When the Afrikaner dominated National Party gained power in the 1948 election, the government loosened its ties with the United Kingdom, but continued a close relationship with other western powers, mainly the United States.

Over the following years, the National Party implemented the *apartheid*[4] laws, which were meant to create a system that would keep the various racial groups of South Africa separate. Blacks and coloureds had never enjoyed full political rights in South Africa, but the new laws limited their rights further. In the Cape Province, the large mixed race coloured population had had the right to vote in general elections, and they lost this when the Parliament passed the "Separate Registration of Voters Act" in 1951.[5] New laws regulating all aspects of social, educational and economic life were implemented to protect the apartheid system, and the increasing restrictions led to a growing number of strikes and protests throughout the 1950s.

A turning point in the world's perception of South Africa was the *Sharpesville massacre* on 21 March 1960. The widely unpopular pass laws predating the apartheid system, which required all adult South Africans at all times to carry a pass book that stated their race, had met increasing opposition. In 1960 the *Pan-Africanist Congress* (PAC), an African rights organisation that had sprung out from the larger political movement the *African National Congress* (ANC), arranged a civil disobedience campaign in which blacks went to police stations all over the country to turn themselves in for not carrying a pass book. In the Sharpesville Township at least 5000 people showed up at the police station, and when they refused to go away, the police started firing into the crowd. 69 people were killed and more than a hundred wounded. In the aftermath, the government outlawed both the PAC and the ANC.

Strong international condemnation followed the massacre, especially from the newly independent, neighbouring African states. The discord eventually led South Africa to withdraw from the British Commonwealth on 31 May 1961. The United Kingdom imposed restrictions on

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[3] In some sources, this site is also referred to as *East Pelindaba* or just *Pelindaba.*
[4] "Apartheid" literary means "separateness"
[5] The act was disputed in court, and was not settled until 1955.

arms sales to South Africa in 1962, and the United States followed a year later. The United Nations Security Council passed a voluntary arms embargo the same year. [3;7]

The *Treaty on the Non-proliferation of Nuclear Weapons* (NPT) was signed in 1968 and entered into force in 1970. The treaty was a compromise in so far as it acknowledged the right of the five states that at the time already had preformed a nuclear test explosion[6] to develop and keep nuclear weapons, but renounced all other states the right to have such weapons. South Africa refused to sign the treaty, stating that the principle was unfair.

2.5 Changes in Southern Africa

After World War One, the League of Nations gave South Africa the mandate to control the former German colony of German South Africa (the present *Namibia*), giving it the name *South West Africa*. Over the years, South Africa treated the colony steadily less as an independent state and more as a province, and also imposed apartheid laws there. In 1966, the United Nations deprived South Africa of the mandate to rule South West Africa, and declared that it should be given independence under the name Namibia from 1968. South Africa opposed this, and a very long war for an independent Namibia began. Namibia did not gain full independence until 1989.

In 1974, a regime change in Portugal lead to the independence for the Portuguese colonies in the region around South Africa. In Mozambique, a pro-Soviet regime heavily opposed to South Africa's white minority rule assumed power, and in Angola a bloody civil war ensued, in which South Africa supported one side, and the other side was supported by Cuba.

[6] China, France, the Soviet Union (now Russia), the United Kingdom, and the United States

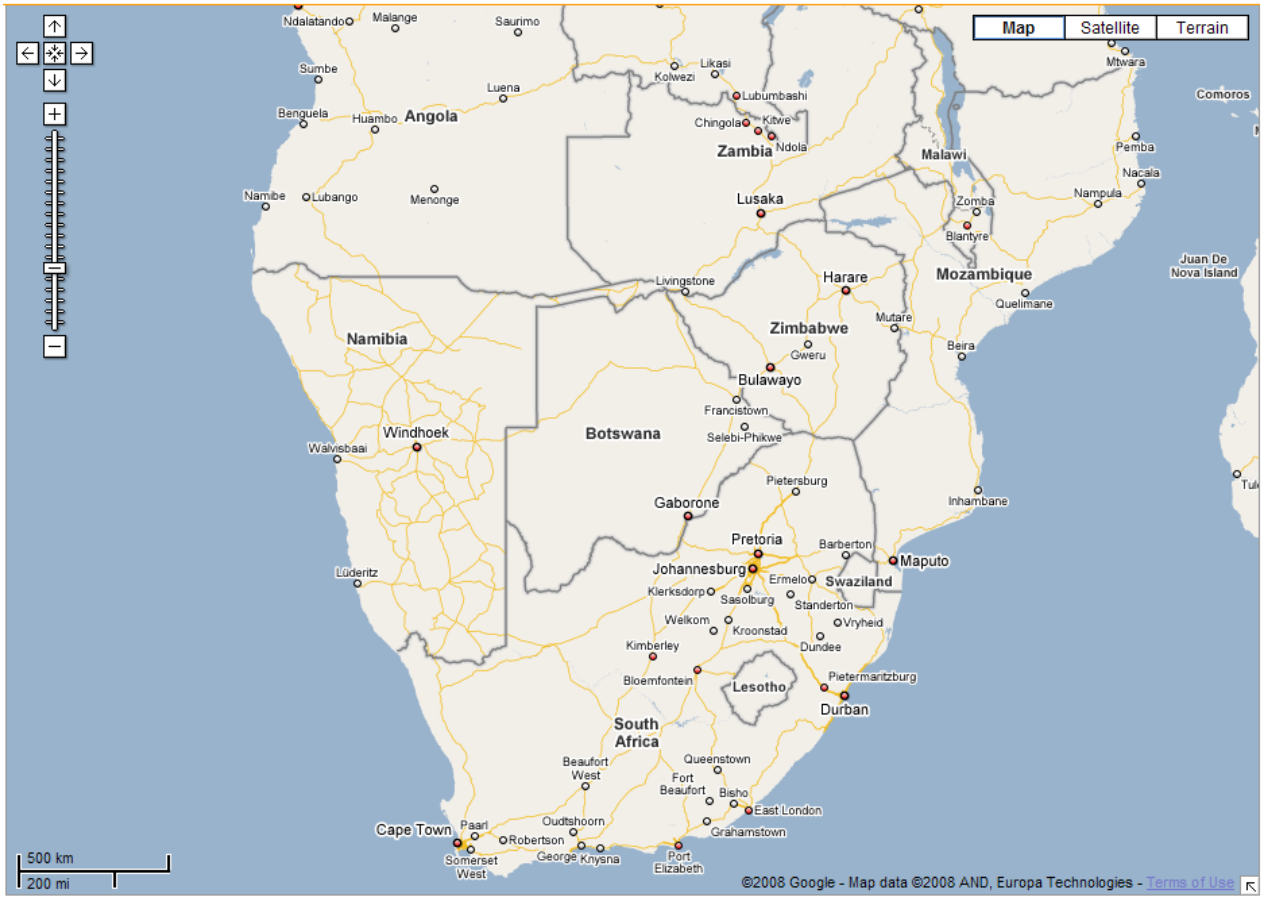

Figure 2.2 Southern Africa today.

The white government in the neighbouring former British colony of Rhodesia, finally lost its power after a long civil war in 1980, and was replaced by a black government who gave the country the name Zimbabwe. This meant that South Africa was no longer surrounded by like-minded white-ruled neighbours in the region (see Figure 2.2).

2.6 International isolation

In 1974, the UN General Assembly voted to suspend South Africa. The decision was not supported by the Security Council, but although South Africa kept its seat, the representatives no longer attended the meetings. The United Nations Security Council mandated the voluntary arms embargo from 1963 in 1977.

The United States suspended the shipments of fuel for the Safari I-reactor in 1976, even though some future shipments had already been paid for. The payment was not returned until 1981. In 1978, the United States Congress approved the *Nuclear Non-Proliferation Act* (NNPA), which outlawed all export of nuclear technology to countries not party to the NPT. This apparently complicated South Africa's efforts to import fuel for their new nuclear power plant Koeberg (see Figure 3.1), but did not affect its weapons programme [8].

South Africa had held a permanent seat on the board of the IAEA as the African nation ”most advanced” in the nuclear field from 1957 until 1977, when it was replaced by Egypt.[7] In 1979, South Africa was banned from the IAEA General Conference in India by a resolution that urged Pretoria to sign the NPT and open its nuclear facilities to international inspections [4]. This was a hard blow, and it was considered particularly unfair as India itself had not signed the NPT. In the following years, negotiations between South Africa and the IAEA regarding the treaty continued, but according to former chairman of South Africa’s Atomic Energy Corporation (AEC), Waldo Stumpf [8], they where not taken seriously by the South African side because they assumed that signing would not really give them more international acceptance without considerable political reforms to the apartheid system. Both in 1984 and in 1987, the AEC issued statements that South Africa would “observe the spirit and the letter” of the NPT, but it would not yield on the point of IAEA inspections in the Y-Plant.

3 The programme

3.1 “Peaceful nuclear explosions”

In 1971, the Mining Department under its Minister of Mines, Carel de Wet, gave the AEB permission to start research and development work on so-called “peaceful nuclear explosions” for use in mining. Because of a lack of facilities in Pelindaba where the other main nuclear facilities were placed, some of the research was moved to a laboratory in the *National Armament Corporation*’s (Armscor’s) Somchem facility in the Cape Province. At first, only three engineers were assigned to this work, which mainly consisted of theoretical studies. [9]

In the early phases, the difference between the research needed to establish a nuclear weapons programme and nuclear research for peaceful purposes is small. However, South African officials and scientists involved claim consistently that the South African programme was not considered a military project in the beginning.

It is not clear when the South African programme shifted from being a civilian, mostly peaceful research programme to weapons development and production, and exactly why this happened. An American intelligence report from 1983 indicates that the weapons programme was launched in 1973. According to de Klerk, Prime Minister John Vorster made the decision to develop a limited nuclear capacity in 1974, as a response to the situation in Angola [2;6]. The weapons were meant as a deterrent against possible enemies, such as the mostly Soviet allied neighbours in the area, and also possibly as a means to “blackmail” the West to come to its assistance in a threatening situation (see section 3.7). Other sources claim that the programme was not explicitly military in nature until 1978, when the responsibility for the programme was moved from the AEB to Armscor. [6;8]

[7] The seat was regained by South Africa in 1995 after the end of the apartheid regime.

Vorster also approved an area in the Kalahari dessert, *Vastrap Testing Range* (see Figure 3.1), for development of an underground test site for nuclear explosions. Two shafts, 200 – 400 m deep were completed by 1977. Originally, three shafts were planned, but one had to be abandoned due to flooding caused by unsuitable geological conditions.

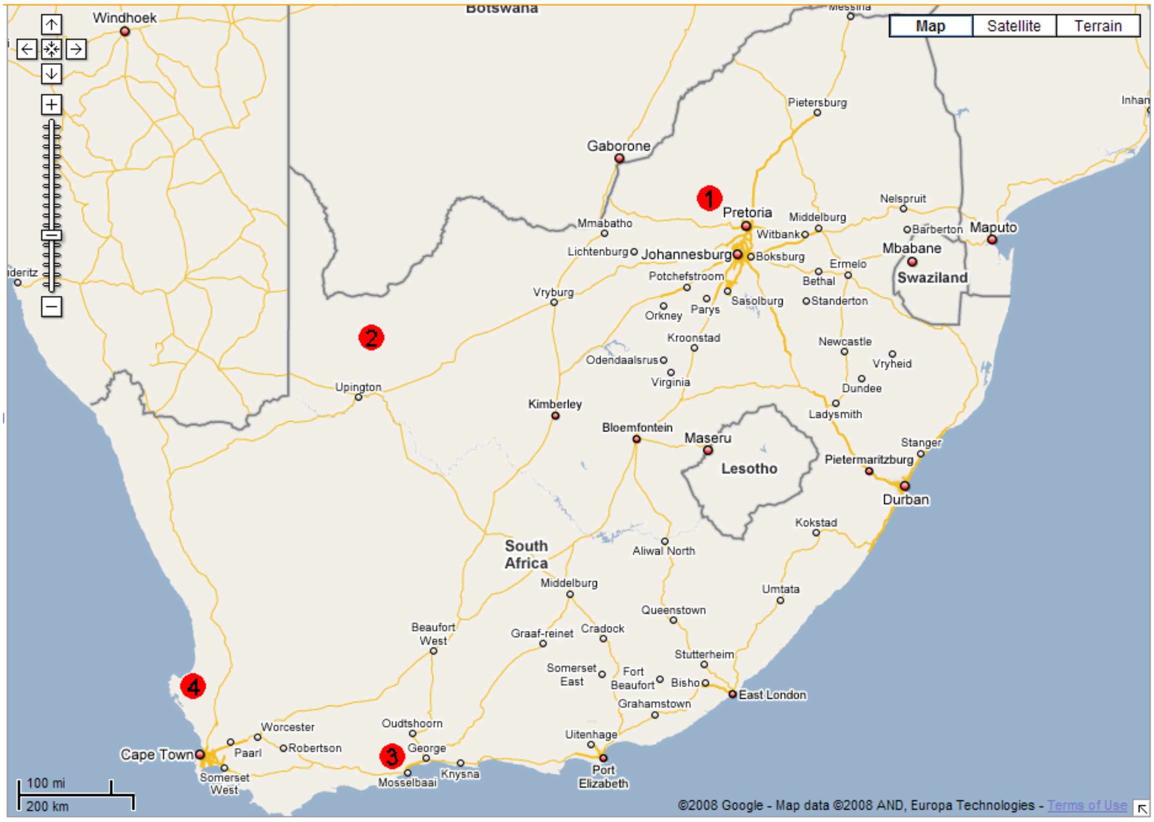

Figure 3.1 South Africa today. 1: Pelindaba, 2: Vastrap Testing Range, 3: Mossel Bay, 4: Koeberg

In 1976, scientists at Somchem constructed and tested a full-scale model for a gun-type HEU-based explosive device with a core of natural uranium. The test proved that the mechanical and pyrotechnical designs would work. The Y-Plant had still not managed to produce enough weapons grade uranium (i.e. 80-90 % U-235) for a proper nuclear charge.

3.2 The enrichment process

As mentioned in section 2.3, South African scientists had started to work on an indigenous uranium separation technique in the 1960s. In 1969, they had successfully managed to separate uranium on a laboratory scale applying an aerodynamic technique using uranium hexafluoride (UF_6) gas. This process uses the same principles as the so-called *Becker nozzle process* developed in Western Germany, and it has been suggested [3;6] that South Africa could have received some external assistance in the development of this process. However, much of the necessary information existed in published sources and a lot of engineering work had to be done in South Africa to make the process work [6].

In the South African gas nozzle technique, a mixture of UF_6 and hydrogen gas is spun with a vortex mechanism inside a stationary tube. This separates the uranium isotopes U-235 and U-238 according to their weight. The radius of curvature was reduced as the gas spiralled through the tubes to exit holes at the end, where the heaviest fraction, containing more uranium-238 exited to the side, while the lighter fraction containing more uranium-235 continued straight ahead.[8] The gas had to transit through several vortex tubes in a cascade in order to reach a level of 80 - 90 % uranium-235, high enough for weapons production.

The technique was improved in the early 1970s, and in 1974 the pilot enrichment plant, the Y-Plant, was commissioned. The plant consisted of five subsequent “enrichment blocks” placed in three different buildings, and the UF_6 – hydrogen mixture went through pipes between the buildings as the enrichment level increased. According to South African officials, the plant needed a long time to reach an optimal enrichment capability, and the first amount of HEU was not extracted until January 1978. This HEU had a uranium-235 content of about 80 %. [8]

There were also other problems with the plant. In 1979, impurities in the UF_6 caused a major problem. A chemical reaction between the UF_6 gas and the hydrogen gas lead to a deposit of solid uranium inside the cascade tubes, and the whole plant had to be shut down for renovation. It did not start operating again until April 1981 and did not produce HEU until July the same year. [6;10]

After this, the plant ran mostly successfully until it was shut down in 1990. It produced HEU in the whole period except for 11 months in 1986 when it was reconfigured to make LEU for production of test fuel for the reactors in the newly commissioned Koeberg nuclear power plant. The operators of the plant were not able to completely solve the uranium build-up problem that caused the incident in 1979, but they managed to control it by carefully monitoring the amount of uranium on teflon filters inside the cascade and remove the filters before they became overloaded. The uranium on the filters was later recovered, processed back into UF_6 and used to produce fuel with a lower enrichment level (3- 45 %) for Safari I and the Koeberg reactors. Not all the uranium on the filters was reclaimed, and the loss caused by this effect and some smaller gas leaks complicated the IAEA’s later verification work.

The Y-Plant had a design capacity of 10-15 000 SWU[9] a year, and improvements made in the mid 1980s were meant to increase the capacity to around 20 000 SWU a year. If it had been operating at this level without problems, it could have produced about 60- 90 kg of HEU a year, enough for one or two simple gun-type weapons [10;11]. However, the plant never worked smoothly, and the actual output was probably lower. The exact amount of HEU produced by the Y-Plant over its lifetime has been declared to the IAEA, but the information has not been publicly released.

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[8] More common uranium enrichment techniques use spinning centrifuges or diffusion through membranes to separate the uranium isotopes.
[9] Separative Work Unit (SWU) is a complex unit used to measure the quantity of enriched uranium that can be produced by a plant.

3.3 Nuclear reactors

In the period between 1960 and 1995, South Africa had a total of four nuclear reactors.
The first reactor built was the Safari I in Pelindaba. Safari I is a research reactor commissioned in 1965, and it is still in use today. In the early period between 1965 and 1976, when the fuel for the reactor was supplied by the United States, all used fuel from the reactor was shipped to the United Kingdom for reprocessing and storage. In the beginning, the reactor had a capacity of 6.6 MW_t[10] , and it was upgraded to 20 MW_t in 1969. In 1977 the power level of Safari I was reduced back from 20 MW_t to 5 MW_t to conserve fuel, and the reactor, which originally had used weapons grade HEU, was converted to use 45 % enriched fuel.[11]

After the dismantlement of the weapons programme, the Safari I reactor was again reconfigured to run on weapons grade uranium, and it was used to burn some of the HEU from the weapons programme [10;12]. Today, Safari I runs on 20 % LEU and is mainly used for research and to produce isotopes for medical use.

The second reactor, Safari II, which only operated for two years between 1967 and 1969, was an indigenously constructed, heavy water moderated and sodium cooled reactor, designed to use 2 % enriched uranium fuel. Both the fuel and the heavy water were supplied by the United States. The reactor was decommissioned because it was expensive and drained resources from the uranium enrichment programme.

South Africa also has a commercial power plant, the Koeberg, with two pressurized water reactors with a combined capacity of 1840 MW_e, using LEU-fuel. The construction of these reactors was started in 1976 by the French consortium Framatome-Framateg, but they were not commissioned until April 1984 and July 1985, respectively.

In the early 1980s, the AEC had additional plans to build a 150 MW_t pressurised water research and development reactor at Gouriqua near Mossel Bay in the Cape Province (see Figure 3.1), but the funding for the project was terminated in 1985. If the reactor had been built, it could have been used to produce plutonium and tritium. [6]

3.4 The Kalahari incident

A full-scale test of a nuclear device was planned at the Vastrap Testing Range in August 1977 (see Figure 3.1). According to South African officials, this was meant to be a “cold” test, with a core made of natural uranium, and not a real nuclear explosion.[12] A test with a HEU core was planned for the following year.

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[10] MW_t (thermal mega watts) is the measure of the thermal energy produced, while MW_e (electric mega watts) is the measure of the energy in the electric output. For a nuclear power plant, the thermal energy is always much larger than the electric energy output.
[11] In the 1980s, this fuel was produced in South Africa from HEU made by the Y-plant.
[12] It is also unlikely that the Y-plant should have been able to produce enough HEU for a real detonation this early.

The purpose of the Kalahari test site was strictly secret, but the considerable preparation work on the testing range was fully visible from satellites. It would have been possible to bury or hide the equipment completely, but this would have been expensive, and the South African government probably considered the likelihood of discovery small. Also, India, another state that had not signed the NPT, had performed a test of a “Peaceful Nuclear Explosive” in 1974 and had received very little international condemnation. This may have lead South African officials to underestimate the world’s reactions to a similar test.

In the summer of 1977, the construction work at the Vastrap Testing Range was detected by a Soviet intelligence satellite. The Soviet Union drew the conclusion that South Africa was preparing for a nuclear test and alerted President Jimmy Carter of the United States. Several western nations, including France which were co-operating with South Africa on the construction of the Koeberg nuclear power plant, initiated a formidable pressure against South Africa. The country succumbed and the test was cancelled. The site was quickly abandoned and the test shafts were sealed. [3;6]

3.5 “Melba”

From 1978, the Y-Plant was able to produce HEU, and the first real bomb was assembled in 1979. It was given the codename “Melba”, and was a so-called gun-type device with a core of about 55 kg HEU (see also Section 3.8). When the device was first constructed, this HEU consisted of 80 % uranium-235, but later, as the Y-plant produced more and better HEU, the original core was exchanged for one consisting of 90 % uranium-235. The bomb itself was not tested, but the AEB did conduct a criticality test moving two pieces of HEU close enough together to almost achieve a chain reaction, similar to the “tickling the dragon’s tail” experiment in Los Alamos in 1945. [6]

“Melba” was not designed as a deliverable weapon; it was only intended to be used in an underground test to demonstrate South Africa’s nuclear capabilities. The device was kept until the nuclear weapons programme was abandoned in 1989.

3.6 The Vela incident

On 22 September 1979, the American satellite *Vela 6911* detected a double flash of light characteristic of a nuclear explosion. The flash originated from an area in the Indian Ocean about 1000 km from mainland South Africa, near South African controlled Prince Edward Island (see Figure 3.2).

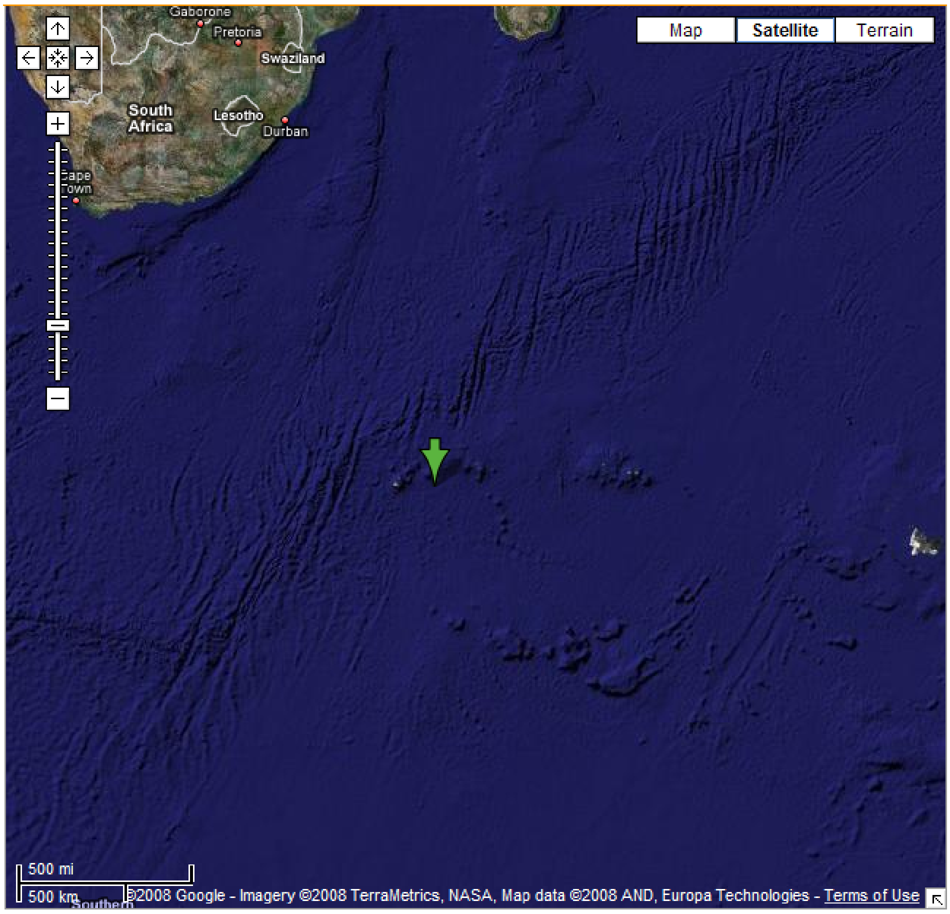

Figure 3.2 The location of the Vela signal, close to South Africa controlled Prince Edward Island.

The Vela satellites were designed in the early 1960s to monitor nuclear explosions and had been successful at this. However, in 1979 Vela 6911 was old; it had originally been scheduled for replacement years earlier. The electromagnetic pulse sensor was no longer working and could therefore not verify that the signal came from a nuclear explosion. No other sources found conclusive seismic or radiologic evidence of a nuclear explosion in the area. After some initial discussion, the Carter administration put down a panel of independent experts to examine the data under the chairmanship of MIT professor Jack Ruina. In the summer of 1980, the Ruina panel concluded that even though a nuclear explosion could not be ruled out, the Vela 6911 signal probably originated from something else. It could have been caused by a combination of natural phenomena or from a malfunction in the satellite. Several sources claim that many scientists, including a number of those at the Los Alamos National Laboratories who had been involved in the development of the satellite's optical sensors, were not satisfied with this conclusion. [3;12-15]

There has been a lot of speculation around what really happened that day in 1979. Most suggestions lean in the direction of a nuclear test conducted by either South Africa or Israel or by the two countries in cooperation. From the publicly available information about South Africa's nuclear programme, it seems unlikely, but not entirely impossible, that it could have conducted a test in 1979. Israel has never conducted a public test explosion. The South African naval base Simonstown near Cape Town was declared “off limits” from 17 to 23 September 1979 due to a naval exercise, but there are no firm evidence that this was not an ordinary exercise[13] [12]. Israel and South Africa had a close relationship in this period, and South Africa openly supplied Israel with uranium in the 1960s [4].

South Africa’s Prime Minister John Vorster made an official visit to Israel in 1976, and several Israeli officials visited South Africa in the early 1970s. Several analysts claim that in addition to the official talks, the countries also conducted secret military and nuclear deals [9;13]. The South African Newspaper Johannesburg City Press reported in 1993 that South Africa purchased 30 g of tritium from Israel in exchange for 50 metric tonnes of natural uranium in the form of yellowcake,[14] beginning in 1977. Tritium is a highly radioactive material that among other things can be used in the neutron initiator in nuclear bombs. South African officials have admitted to buying tritium, but have refused to name the source. [17;18]

Israel was technologically advanced, but lacked raw materials and areas where they could conduct nuclear tests. A joint test could therefore have been in the interest of both countries.

On the other hand, no South African officials have ever acknowledged technical co-operation with Israel (or any other foreign country) on the nuclear weapons programme. In his 1993 speech de Klerk strongly emphasised that South Africa had developed the weapons alone, without any foreign help in the form of technology or nuclear materials. Also, even though South Africa had not signed the NPT, it had signed the *Partial Test-Ban Treaty* from 1963 that bans all nuclear test explosions in the atmosphere, in outer space or under water. A nuclear explosion out on the open sea is clearly forbidden by this treaty, and it seems unreasonable that the country would run the risk of being caught breaking this treaty as long as they had underground test facilities in the Kalahari where they could perform a test without breaking any international agreements.

Waldo Stumpf, who was head of the AEC at the time of the nuclear dismantlement, has denied any knowledge of a test in the Indian Ocean and also emphasized that South African measuring stations did not detect any radioactive fallout after the incident [8]. Samples taken from sheep thyroids in Western Australia showed slightly elevated levels of radioactive iodine-131 after the incident, but the levels were not high enough to allow a definite conclusion [16]. The weather conditions in the area at the time of the incident would also have made it difficult to detect any possible nuclear fall-out [12].

In 1997, the question was re-opened after the Israeli newspaper *Ha’aretz* had quoted the deputy foreign minister of South Africa, Aziz Pahad, claiming that the Vela satellite signal was indeed

[13] In 1979, the commander of the Simonstown naval base was Commodore Dieter Gerhardt who was later revealed to be a Soviet spy. He claimed in an interview with the Johannesburg City Press in 1994 that he was convinced that a joint South African-Israeli test had taken place, even if he himself had not been involved. [12;16]

[14] Yellowcake is a mixture of different uranium oxides, produced by milling and chemical processing of uranium ore.

from a nuclear explosion and implying that a joint South African and Israeli nuclear test had taken place. However, Pahad's office quickly issued a correction, in which it stated that Pahad had been misquoted, and that he had only mentioned in the interview that there were *strong rumours* about such a test. As a lot of the documentation about the South African nuclear programme was destroyed on de Klerk's orders after the programme was dismantled, it may be difficult even for the present government to uncover all the details of what went on during the early years of the nuclear weapons programme. [16]

3.7 The deterrent strategy

Prime Minister John Vorster had some of his senior officials outline a strategy for the nuclear programme after the 1977 cancellation of the test explosion. Vorster resigned in September 1978, and was replaced by the Minister of Defence, Pieter Willem Botha.[15] P.W. Botha was already heavily involved in the nuclear weapons programme, and one of the first things he did as Prime minister was to appoint an "action committee" with representatives of the AEB, the armament corporation *Armscor* and the defence forces to recommend a future nuclear strategy. The committee delivered its first report in July 1979, in which it proposed to manufacture seven nuclear devices and to shift the responsibility for the programme from the AEB to Armscor [9].

P. W. Botha was the architect behind the South African nuclear deterrence strategy. This strategy was developed in the late 1970s and consisted of three gradually escalating phases. In the first phase, the "strategic uncertainty" phase, the country would neither confirm nor deny its possession of nuclear weapons. If the country faced a direct, military threat against its territory, it would go to phase two and inform some western powers, presumably the United States, about its capabilities. The hope was that this would lead the western powers to intervene on South Africa's behalf to avoid possible use of nuclear weapons in the region. As a last resort, South Africa could go to the third phase and publicly announce its nuclear weapons capability, possibly in combination with an underground test explosion.

All South African officials involved in the programme claim that there were never any plans for military use of the weapons. However, they were convinced that the weapons had to be fully functional and deliverable for the deterrence strategy to work. The South African military had drawn up a strategic list of targets for conventional weapons, and this list could have been used also for the nuclear bombs if the deterrence had failed. [8;9]

3.8 From science to weapons

After the construction of "Melba" in 1979, the government transferred the research on nuclear weapons from AEB to Armscor. From this point on, there can be no doubt that the goal of the programme was to construct real, deliverable bombs. Over the years, Armscor constructed several simple gun-type devices and studied and produced conventional high explosives to improve the

[15] P.W. Botha was appointed Minister of Defence in 1966 and stayed in this position for two more years after he became Prime Minister in 1978. He continued as Prime Minister and later President until 1989. (A change in the constitution abolished the position of Prime Minister in 1984.)

ignition mechanism and the safety. Armscor also studied additional nuclear technology, implosion, thermonuclear technology and "boosting" and researched the production and recovery of plutonium and tritium.

In 1982, AEB and UCOR was merged to form the new Atomic Energy Corporation, AEC, responsible for all nuclear matters.

Armscor controlled a site approximately 15 km from Pelindaba, called Gerotek. This was a large area used to develop and test military vehicles, and a new top-secret facility for the development of nuclear weapons, called the *Kenron Circle Facility*, was constructed here. The Circle building had a total of about 8000 m^2 of floor space; about half of this was laboratories and engineering workshops, the rest offices and conference rooms. The entire complex was commissioned in 1981. In the early 1980s, about a hundred people were involved in the nuclear weapons programme; by 1989 the number had grown to about 300.

The Armscor programme focused on efficiency and deliverability. The first prototype was finished in 1982, and it took another five years until the second bomb was made and a complete delivery system was in place. In 1989, Armscor had four bombs, all of them with a design similar to the American bomb "Little Boy" which was dropped over Hiroshima in 1945 (see Figure 3.3). Each bomb contained about 55 kg HEU and had an estimated explosive power of about 10 to 20 kilotons of TNT. Because the devices were never tested, no accurate data regarding the yield exist, and some estimates are lower, down to about five kilotons. Most of the HEU, about 40 kg was forged into a hollow shape, and the remaining 15 kg could be shot into it through a gun barrel. Each bomb was 180 cm long and 65 cm in diameter, had a total mass of one ton and could be delivered by a modified Buccaneer airplane.[16] Unlike most modern nuclear weapons, the bombs contained no neutron initiator to trigger the nuclear chain reaction; they relied on naturally occurring stray neutrons from cosmic radiation or spontaneous fissions in the bomb material [6;20].

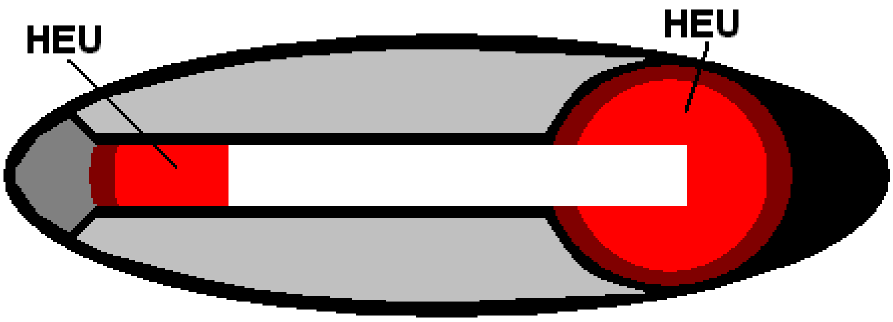

Figure 3.3 General outline of a simple, gun-type weapon. One sub-critical piece of highly enriched uranium (HEU) is shot into another sub-critical piece to form a critical mass.

[16] The South African Air Force practiced special delivery techniques for nuclear bombs using conventional bombs in a training session in the ocean outside Cape Town as early as in 1976 [19].

A more complicated bomb design, using implosion or boosting, could have reduced the need for HEU greatly. However, without any opportunity to perform a test, Armscor needed a simple and failsafe device that they could be sure would work on first attempt. Without this constraint, South Africa could have doubled its nuclear arsenal.

The nuclear bombs were stored in locked vaults, and access to each vault required two access codes and several keys. One part of the uranium core was stored separately from the rest of the bomb, and reassembly required a third code. These codes were held by the heads of the AEC, Armscor and the South African Defence Force, respectively. According to one source, the gun barrel cylinder was divided into two sections which were kept out of alignment as a final safety precaution, and the last step to rotate the cylinder parts into position and fully arm the bombs required a key and a fourth code, held only by the president [9].

In addition to making these bombs, Armscor were in the process of constructing a new device to replace the old “Melba” as a demonstration device.

3.9 Further research and limitations of the programme

Apart from the development of gun-type weapons as mentioned in Section 3.8, Armscor was also given the responsibility for further nuclear research in some areas, including separation of lithium-6 for the production of tritium that could be used in future boosted devices, studies of implosion and thermonuclear technology and production and recovery of plutonium.

Research into implosion-type devices was conducted from the beginning of the programme, but was not given high priority. A hot-cell facility in Pelindaba from 1987, which was used to examine spent fuel from the Koeberg Power Plant, applied technology similar to that used in plutonium separation, implying that South Africa had considerable knowledge in this field even though the technology was never used for weapons production. There does not seem to have been any serious investigation into thermonuclear weapons. [6]

The economical sanctions against the apartheid regime had begun working by the mid 1980s. As a result of this and internal instability, the South African economy began deteriorating. It became increasingly difficult for the government to justify its very expensive nuclear weapons programme. In 1985, the programme was taken up for reconsideration by President Botha. The review lead to further limitations on the programme, but did not change the main aim, to produce deliverable weapons. Funding for the planned pressurised water reactor at Gouriqua was stopped, halting the efforts to produce plutonium and tritium. The small research programme on separation of lithium-6, was changed to focus on production of lithium-7, an isotope with several peaceful applications. Work on improved design, implosion weapons and more advanced devices continued, but mostly on a theoretical level. [8;10]

In 1988, Armscor performed an inspection of the testing shafts at Vastrap Testing Range. The situation in Angola was becoming acute, and Cuba was threatening to send even more soldiers to the region. The South African government wanted to know how much time it would need to perform a nuclear test in accordance with the third phase of their deterrence strategy. Now, more care was taken to keep the work secret. Armscor built a large, hangar like structure over the shaft, with the cover story that they were constructing a facility for storage and repair of army vehicles. Water had seeped into the deep shafts. It was pumped up, put in containers and driven of the site to avoid attracting attention in the desert. At least one of the shafts was found to be intact and could be used for a nuclear test explosion on a few weeks notice.[17]

Some analysts claim that despite the cover, the work at the testing site might in fact have been detected by both Soviet and American satellites, and that this led both superpowers to put more effort into the negotiations that finally led to the retreat of both South African and Cuban troops from Angola. [6;9]

Despite the financial restraints, in the late 1980s, the government approved plans for a new Armscor nuclear research complex, *Advena Central Laboratories*, on the Gerotek site near the Kenron Circle facilities. The Advena complex had more modern facilities than the Circle, and it was much larger. It had sophisticated manufacturing capabilities for high explosives, metallurgy and electronics, and was intended for the development of more advanced nuclear weapons. The production work would still have been fairly limited; at most two to three weapons a year. The buildings were just completed, and the researchers had not even finished moving into them, when the new president, F.W. de Klerk, terminated the nuclear weapons programme in 1989. [6]

With the Advena laboratories, South Africa got the ability to make implosion type weapons, but in 1989 they were still apparently only considering the concepts and had not conducted any implosion tests. In the late 1980s and early 1990s, South Africa developed a medium range missile system, and it is possible that there could have been plans to equip the missiles with nuclear warheads, something that would have required more advanced and smaller nuclear weapons.

Since 1993, the Advena facilities have been used for commercial work by the state owned weapons manufacturer *Denel*,[18] but on a much smaller scale than they were planned for.

3.10 Commercial nuclear facilities

The only commercial nuclear power plant in South Africa is the Koeberg plant. The *South African Energy Supply Commission* (ESKOM) signed an agreement with the French consortium *Framatome-Framateg* in 1976, where the French company agreed to construct two reactors and supply them with fuel and services. The agreement also called for full IAEA safeguards at the plant at all times.

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[17] Both the remaining test shafts at Vastrap Testing Range were finally sealed and rendered useless by Armscor under IAEA monitoring in 1993.

[18] Denel is a former subsidiary of Armscor.

The original plan seems to have been to use South African uranium, enriched in the United States, and produce the fuel at Framtome's facilities in France, but after the United States passed the *Nuclear Non-Proliferation Act* in 1978, it refused ESKOM export permit to ship the uranium from the United States to France. The dispute lasted for several years and was not solved until 1984, when ESKOM was permitted to sell the disputed uranium to NPT countries. In 1981, South Africa succeeded to purchase LEU from the Swiss nuclear power company Kaiseraugst [21].

The Koeberg reactors did not go critical until April 1984 and July 1985, respectively. The slow progress was partially caused by the American sanctions, but also by problems with the design. Furthermore, the first reactor was the target of a bomb attack by the ANC in 1982, which caused considerable damage.

The South African government worried that an expanded international embargo would hinder the import of fuel for the power plant, and began considering the possibility of building an indigenous fuel fabrication plant.

In 1979, the AEB began constructing a larger, semi-commercial uranium enrichment plant, the Z-Plant, and a fuel fabrication plant, Beva, on a site next to the Y-Plant in Valindaba. The plan was to produce 3.25 % LEU reactor fuel for the Koeberg Power Plant. The enrichment plant had an design capacity of 300 000 SWU a year, 15-20 times the capacity of the Y-Plant and enough to supply the Koeberg with fuel and produce a substantial amount of fuel that could be sold on the world marked. The Z-Plant was commissioned in 1984, but did not begin to produce substantial amounts of LEU until 1988. In the five years between 1988 and 1993, the plant produced only an average of 150 000 SWU per year. Of the produced uranium, 95 % was used in the power plant, and the rest was sold.

Even though a slightly more efficient enrichment technique was used in the semi-commercial plant than in the Y-Plant, it was still not economically viable in competition with overseas suppliers. The Z-Plant was therefore shut down in 1995 and the fuel production plant a year later. [5]

A nuclear waste facility to handle the low and medium level waste from the power plant was constructed in Vaalputs 500 km north of Koeberg. The spent fuel was sent back to France for reprocessing.

The South Africans also investigated other forms of uranium enrichment. A laser enrichment development programme was initialised in 1983, and scientists started to work on a molecular laser isotope separation (MLIS) process. This project did not proceed very far in the 1980s, and although it continued into the 1990s after the other enrichment programmes had been dismantled, no commercial uranium enrichment takes place in South Africa today. [5;10]

4 Dismantlement

4.1 International pressure

Towards the mid-1980s, the level of international trade sanctions against South Africa steadily increased. In 1986, the United States Congress passed the *Comprehensive Anti-Apartheid Act* that forbade trade with South Africa in a wide range of areas, including nuclear materials. Some small exceptions were made in cases involving IAEA programmes or where public health and safety could be compromised, but United States citizens were refused permission to work on the Koeberg nuclear power plant. The United States, West Germany and the United Kingdom terminated all previous nuclear cooperation agreements with South Africa. France also imposed sanctions, but Framatome continued to supply nuclear fuel for the Koeberg plant, and France also still received and treated nuclear waste from the reactors.

Even though the trade sanctions stung economically, the nuclear weapons programme seems to have progressed almost unimpeded. South Africa did not rely on any foreign supplies of nuclear materials for the weapons; the basic construction of the weapons themselves meant that they could be produced without need for complicated electronics or other hard to come by components.

However, in the late 1980s the South African export of uranium also started to suffer, and greater cooperation with the IAEA could be seen as a possible route to avoid the trade sanctions. In 1988, the South African delegation met with representatives from the United States, the United Kingdom and the Soviet Union to discuss a possible NPT-accession. In November, South Africa sent a letter to the IAEA, stating that it would be willing to sign on certain conditions; primarily that South Africa should be allowed to market uranium under IAEA safeguards. [21]

4.2 The end of the programme

Even though there seemed to be some progress in the negotiations between South Africa and the IAEA, it is definitely clear that South Africa made no plans to dismantle the weapons programme before de Klerk became president. Not only did President Botha order the reinvestigation of the testing facilities in the Kalahari, he also granted the Advena laboratories considerable funding for advanced nuclear research.

F. W. de Klerk was elected President in 1989, when P.W. Botha had been forced to retire after suffering a stroke. Very few people even in the South African government knew of the nuclear weapons programme, but de Klerk had been informed when he served as Minister of Mines in the late 1970s. De Klerk set up an expert committee to examine the programme and decide how fast South Africa could abandon it and accede to the NPT as a non-nuclear weapons state. The committee issued a formal recommendation to dismantle the programme and gave an outline of the necessary procedures.

On 26 February 1990 de Klerk issued written orders to stop all production of nuclear weapons. At that point, the Y-Plant had already been closed. The existing nuclear devices were to be dismantled and the uranium melted down and returned from the Armscor facilities to the AEC. The head of the AEC, Waldo Stumpf, was selected to oversee the project, and de Klerk appointed the retired nuclear physics professor and former president of the University of the Orange Free State, Dr. Wynard Mouton, as an independent auditor.

Mouton spent several months studying the weapons programme and judging the attitudes of the people involved, and in July 1990 he reported back to the president, presenting two different possible strategies for dismantlement. The fastest route would be to first destroy one part of each of the devices, and then subsequently destroy all the remaining parts. As a second option, each weapon could be destroyed separately. This would be slower, but Mouton believed it would be more acceptable to the personnel involved in the programme, because it would allow South Africa to retain a nuclear capacity until the very end, and this plan was accepted by de Klerk.

On 10 July 1991, South Africa acceded to the NPT, and the IAEA performed its first inspections in November the same year. At that point, all the equipment in the Circle facilities had been removed or destroyed, and the HEU had been transferred to the Pelindaba site. The NPT requires all members except the five acknowledged nuclear weapons states to declare all existing nuclear equipment, but they are under no obligation to declare former programmes. When the IAEA inspectors found no weapons plants in use and concluded that all the enriched uranium from the Y-Plant had been accounted for, they were satisfied with the South African co-operation.

Internally, the situation was different. The ANC realised that there had been a weapons programme and demanded that the government should declare exactly what the programme had consisted of. Finally, in a speech to the Parliament 24 March 1993, de Klerk admitted that there had been a nuclear weapons programme. The IAEA was then invited to make new inspections at the former weapons plants to verify that they were no longer in use. [6;9]

4.3 Reasons for dismantling the nuclear weapons programme

In 1989, South Africa was under a lot of pressure, externally and internally. International support for ANC was growing, and the cold war was almost over, diminishing the country's hope of being considered an ally against communism by the West. In 1988, a peace agreement between South Africa, Angola and Cuba had led to the withdrawal of the Cuban forces from Angola.

Waldo Stumpf, director of the AEC at the time of the weapons dismantlement, lists three main reasons behind the decision to dismantle the nuclear weapons programme [8]:
On 1 August 1988, a ceasefire was agreed upon for Namibia's northern border, and this was followed by the tripartite agreement between South Africa, Angola and Cuba which ensured the withdrawal of all 50 000 Cuban forces from Angola. In April 1989, the UN Security Council's Resolution 435/1078 was finally implemented and led to Namibia's independence. Finally, with the fall of the Berlin Wall in December 1989, the end of the cold war and of the strong Soviet Union influence seemed inevitable. These three events meant that South Africa no longer faced

an external military threat, and the deterrence effect of the nuclear weapons was no longer justified.

It also seems very clear that President de Klerk understood that South Africa's continued refusal to sign the NPT was an obstacle for improving the country's relations with the international community. After the fall of the Soviet Union, the idea that South Africa could pressure the United States to come to its rescue by revealing its possession of nuclear weapons must have seemed increasingly far-fetched.

The main problems that the South African government faced were now internal, not external. To increase national stability, de Klerk wanted to implement strong social reforms aimed at improving the conditions for the black and coloured majority in the country. The South African economy had been deteriorating for years, and the military budget, including funding for the nuclear programme, took up an unreasonably large share of the available funds.

Another possible reason behind the dismantlement is that white South Africans realised that the days of the apartheid system were numbered and that it was only a question of time before the country would be taken over by a black majority government. Even if this was not the main cause behind de Klerk's opposition to the nuclear weapons programme, the fear that the government could possibly end up supplying a new black-ruled state with nuclear bombs might have made it easier to gain acceptance for the decision among the people involved in the programme.

4.4 Undeclared HEU?

When the South African weapons programme was announced to the world in the early 1990s, there were considerable worries about whether the complete programme had indeed been disclosed, or if the country was still hiding something. There were also concerns that some of the nuclear weapons might fall into the hands of white separatist groups who opposed a transition to a new majority government. South Africa also had programmes involving chemical and biological weapons, nicknamed "Project Coast", which appears to have come out of government control at some point before or after the transition[19] [3].

This situation concerning the nuclear weapons programme was further complicated by the fact that South Africa had imported some unsafeguarded LEU to fuel Koeberg.[20] The amount of uranium produced by the Y-Plant over the years became central to these questions. As the Z-Plant was still operating at the time of the first inspections, the IAEA inspectors could see the process in action, something that removed most of the uncertainties involving that plant. The Z-Plant had detailed operating records for the whole operation period, and some inaccuracies in

[19] The former leader of the biological weapons programme, Wouter Basson, was arrested and trialed in 1999 on 67 charges, included several murders, drug-trafficking and fraud, but was not convicted.
[20] Because of the secrecy surrounding nuclear imports to South Africa in the 1980s, it is difficult to identify the sources of all the LEU, but several countries were involved, among them France, Belgium, Switzerland and China [6;21].

the initial declaration to the IAEA could be corrected by comparing these records to the accounting records.

The Y-Plant had been shut down when the IAEA made their first inspection of the site in 1991. It had been operating since the mid-1970s and had been upgraded and renovated several times. The plant had no accurate measurement of the depleted UF_6 waste gas from the enrichment tubes. A lot of the uranium deposited on the teflon filters was reclaimed, but the filters that were considered to contain too little U-235 to make the reclaiming worth the effort, were sent to a waste site in Valindaba together with oil and other contaminated materials. To estimate the total amount of enriched uranium produced from the natural uranium input, the IAEA needed to calculate how much U-235 had ended up in the waste site and how much had been lost in the waste gas over a period of more than ten years. [10]

The first calculations made by the IAEA contained large uncertainties about the plant's enrichment capacity, and there were some discrepancies between the inventory made by South Africa and these calculations that suggested that there could be an amount of U-235 unaccounted for. [11]

The inspectors resumed an extensive examination of the performance of the Y-Plant over the years to get a better estimate of the total production. This examination included details of handwritten log books containing information of the day-to-day performance of the plant, uranium build-up on filters etc. According to Stumpf, the IAEA even tested the paper and ink to verify that the books were authentic. On the basis of these studies, the IAEA concluded in September 1992 that the amount of materials declared by South Africa were consistent with the amount produced by the plants. [6;8;22]

4.5 Nuclear facilities in South Africa today

In 1989, South Africa had two uranium enrichment plants in operation, the Y-Plant producing HEU and the Z-Plant producing LEU for the Koeberg power plant. The Y-Plant was closed down on 1 February 1990 as part of the dismantlement of the nuclear weapons programme, but also because the gas nozzle technique used was very energy demanding and economically inefficient compared with other enrichment techniques. After the sanctions against the country were lifted, it became more economical to import enriched uranium. The Z-Plant used a more advanced cascade model and had been slightly more efficient than the Y-Plant, but was still not able to compete in the international market and closed in 1995. The Beva fuel fabrication plant in Pelindaba and the plant that converted uranium to UF_6 gas in Valindaba were shut down in 1996 and 1998, respectively. Only one mine, the Vaal River Operation, is still producing uranium.

Both the Koeberg reactors and the Safari I reactor are still in use. The Safari I is used for research and to produce isotopes for medical purposes. Until 2005, the reactor burned HEU from the nuclear weapons programme, but it has now been converted to use fuel with 20 % uranium-235. The Koeberg power plant is controlled by the government-owned electricity company ESKOM. It has a capacity of 1840 MW_e and produces about 12 % (2002) of South Africa's electricity. The fuel for these reactors is imported. [5;23]

South Africa is in need of more electrical power, and the need is growing. In 1999, still only 80 % of households in urban areas and only 46 % in rural areas were electrified [23]. The government therefore considers expanding the supply of nuclear power by building more reactors, and it is currently reviewing plans to develop and build a new kind of reactor called a pebble-bed modular reactor (PBMR). If this reactor type proves successful, the government may construct as many as 24 units with a total capacity of 4800 MW_e. There are also plans to develop a new uranium enrichment plant and eventually move the full reactor fuel cycle back to South Africa. [24]

The waste handling site in Vaalputs is still in operation. In addition to treating low and medium level waste, it also stores spent fuel from the Koeberg reactors. The spent fuel storage facility is almost full, and the government is discussing new strategies for long-time handling and storage.

5 Summary and concluding remarks

South Africa had a very limited nuclear weapons programme, with only six deliverable weapons completed and a seventh under production, all of a relatively simple type. It is unclear whether there were plans for more sophisticated weapons or a larger arsenal before the programme was cancelled, but South African officials claim that this was not the case. The nuclear weapons programme was cancelled in 1989, and the weapons were subsequently destroyed. This makes South Africa the only country in the world known to have developed and then completely dismantled a nuclear arsenal.

It is not quite clear when the decision to build nuclear weapons was taken or why it was taken, but most of the necessary infrastructure was constructed in the mid to late 1970s. During the 1970s, South Africa was facing increasing isolation internationally and also lost local allies when the former European colonies in the region became independent. The white minority government may have felt the need for a stronger defence and assumed that nuclear weapons could prevent foreign interference in the country. Threats of using such weapons could also "blackmail" the western powers to support the country against military threats in the region.

When India conducted its first "peaceful nuclear explosion" in 1974, it was condemned by the international community, but no actual sanctions were imposed against the country. South Africa may have assumed that it too would have been accepted as a *de facto* nuclear state as soon as it had actually conducted an explosion, and possibly also that this status would give it more leeway as a great power in the African region.

Based on the limited economical resources available, the need to keep the programme absolutely secret and no means of testing the devices, a very simple weapons design was a reasonable strategy. Towards the poor neighbours in the area, nuclear technology on any level must have been seen as an effective deterrence. However, the construction of the large Advena facility in the late 1980s suggests that there must have existed plans to expand the programme, even if these plans were never realised. The six bombs completed by 1989 were designed to be delivered by airplane. South Africa also had a missile programme, and smaller, more advanced nuclear warheads deliverable by missile would have been a major improvement of the country's nuclear weapons capability.

In the South African nuclear weapons programme, the enrichment process seems to have been the most difficult step. Instead of adopting a known enrichment process, South Africa developed a new method, suffering a lot of complications. From the first South African attempts to enrich uranium in the late 1960s, more than ten years passed before the country had enough HEU to produce the first bomb in 1979. As soon as more HEU was in place, more bombs were made.

South Africa received technological support from a number of countries, and several of the South Africans involved in the programme had been educated abroad. When the western countries began introducing economical sanctions and trade restrictions against nuclear technology and materials in the mid-1970s, the programme was already in progress, and even though the sanctions may have slowed the progress, they were not able to stop it. Uncertainty about the availability of nuclear fuel abroad for the power plant served as an excuse to continue the domestic uranium enrichment programme. With a large supply of naturally occurring uranium, South Africa only needed a certain technology level to produce nuclear bombs, completely independent of international support. The sanctions were not uniformly applied, so even if the larger players (the United States and the United Kingdom) stopped their supplies, South Africa was able to get the technology they needed from other countries.

The exposure of the Kalahari test site in 1977 received a lot of public attention, and at that point it must have been quite clear for all the western powers that South Africa was on the brink of developing nuclear weapons. A partly declassified CIA-report from 1984 [19] indicates quite thorough knowledge of the programme. It was well known that South Africa had an enrichment plant, the Y-plant, which was operating without any international safeguards from the mid 1970s to 1989. The capacity of the plant was not disclosed, but it seems obvious that a plant operating for such a long time would be able to produce bomb material for a substantial nuclear arsenal if it was really producing HEU. It is therefore not correct to say that South Africa managed to keep their nuclear weapons programme completely hidden.

After nearly thirty years, the origin of the double flash signal registered by the American Vela satellite in 1979 is still unclear. However, based on the facts that are now known about the status of the South African nuclear weapons programme at the time, it seems unlikely that the signal can have come from a nuclear test committed by South Africa alone.

International pressure did most likely manage to keep South Africa from conducting a test explosion after the test site was exposed in 1977, showing that the country was not immune to foreign reactions. South Africa was exposed to increasing economical and political sanctions from the rest of world from the 1960s onwards, but even though the sanctions also included nuclear materials and technology, the sanctions themselves were always first of all aimed at changing the apartheid system, not at keeping the country from developing nuclear weapons, and this influenced how effective they were.

In the end, the South African leaders determined that keeping the nuclear weapons constituted a larger problem than getting rid of them. Other states have come to the same conclusion after starting a nuclear weapons programme, but South Africa is the only one known to have come far enough to actually produce bombs before cancelling the programme. Considering the costs and resources invested in such a programme, this is quite extraordinary.

Today, all nuclear facilities in South Africa are run in accordance with IAEA openness standards, and South Africa is an active participant in the IAEA and a driving force behind the implementation of a nuclear weapons free zone in Africa. South Africa is a strong supporter of the "inalienable right" (as manifested in the NPT) of all countries to develop nuclear technology for peaceful purposes. The domestic nuclear sector has not been a focus area for the government in recent years, but this may change if the energy costs in the international markets keep rising, making nuclear power more economically beneficial. Cooperation within the IAEA framework can help the country develop new, safer and more efficient power plants. As long as the benefits of remaining in accordance with the rules of the NPT are clearly much larger than the possible benefits from acquiring nuclear weapons, there should be no reason to fear that South Africa again will start a nuclear weapons programme.

References

[1] D. Albright, "South Africa comes clean," *Bulletin of the Atomic Scientists*, May. 1993, pp. 3-5.

[2] B. Keller, "South Africa says it built 6 atom bombs," *New York Times*, 25 Mar. 1994.

[3] H. E. Purkitt and S. F. Burgess, "*South Africa's Weapons of Mass Destruction,"* Indiana University Press, 2005.

[4] D. Fischer, "*History of the International Atomic Energy Agency, - The first forty years,"* IAEA, 1997.

[5] IAEA, *"Country Nuclear Fuel Cycle Profiles,"* 2005.

[6] D. Albright, *"South Africa's Secret Nuclear Weapons,"* ISIS, 1994.

[7] N. Worden, "*The Making of Modern South Africa,"* Third edition, Blackwell Publishers Inc., 2000.

[8] W. Stumpf, "From deterrence to dismantlement," *Arms Control Today*, Dec/Jan. 1995, pp. 3-8.

[9] M. Reiss, "South Africa: 'Castles in the Air'," in *Bridles Ambition: Why Countries Constrain Their Nuclear Capabilities*, The John Hopkins University Press, 1995.

[10] D. Albright, F. Berkhout, and W. Walker, "*Plutonium and Highly Enriched Uranium 1996, - World Inventories, Capabilities and Policies,"* Oxford University Press, 1997, pp. 369-388.

[11] T. B. Cochran, *"High-Enriched Uranium Production for South African Nuclear Weapons,"* Natural Resources Defence Council Inc, Oct.1993.

[12] J. T. Richelson, "*Spying on the Bomb,"* W.W. Norton and Company Inc, 2006.

[13] S. M. Hersh, "*The Samson Option,"* Farber and Farber, 1991.

[14] "Blast from the Past: Lab scientists receive vindication," *Los Alamos Science Laboratories daily news bulletin*, 11 July 1997.

[15] W. B. Scott, "Admission of 1979 Nuclear Test Finally Validates Vela Data," *Aviation Week & Space Technology*, 21 July 1997.

[16] D. Albright, "A flash from the past," *Bulletin of the Atomic Scientists*, Nov/Dec. 1997.

[17] D. Albright, "Slow but steady," *Bulletin of the Atomic Scientists*, July/Aug. 1993.

[18] M. Hibbs, "South Africa's secret nuclear program: the dismantling," *NuclearFuel*, 24 May 1993, pp. 9-13.

[19] CIA, *"Trends in South Africa's Nuclear security Policies and Programs*", National Security Archive: **http://www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB181/sa27.pdf**, 5 Oct. 1984 (accessed 14 Mar. 08).

[20] F. Barnaby, "Issues Surrounding Crude Nuclear Explosives," in *Crude Nuclear Weapons, Proliferation and the Terrorist Threat*, International Physicians for the Prevention of Nuclear War, 1996.

[21] NTI, *"South Africa Profile, Nuclear Chronology*", The Nuclear Threat Initiative: **http://www.nti.org/e_resarch/profiles/SAfrica/Nuclear/Index.html**, Nov. 2003 (accessed 29 Jan. 08).

[22] A. von Baeckmann, G. Dillon, and D. Perrcos, "Nuclear verification in South Africa," *IAEA Bulletin*, vol. 37, 1. 1995.

[23] IAEA, *"Country Nuclear Power Profiles,"* 2003.

[24] I. Khripunov, "Africa's pursuit of nuclear power," *Bulletin of the Atomic Scientists*, Nov/Dec. 30 Nov. 2007.