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Reformed Rogue States - South Africa: London Security Policy Study

Dr Glen M. Segell, FRGS

GLEN SEGELL

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Unit 108,
14 Tottenham Court Road
London, W1T 1JY
United Kingdom
Tel: +44 (0) 795 630 4012
Fax: +44 (0) 870 130 4748
E-mail: glen@segell.net

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Abstract

The objective of the Non-Proliferation Treaty (signed in 1968) is to prevent the spread of nuclear weapons and weapons technology, to promote co-operation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament. The effectiveness and extension of the Treaty is brought into debate through its Treaty provisions and through the activities of states. South Africa being the arch rogue in flouting the effectiveness of the Treaty having developed a sophisticated nuclear weapon infra-structure 1969-1991. South Africa dismantled this infra-structure, acceded to the NPT and then become an ardent supporter in the Reviews of 1995, 2000 and 2005.

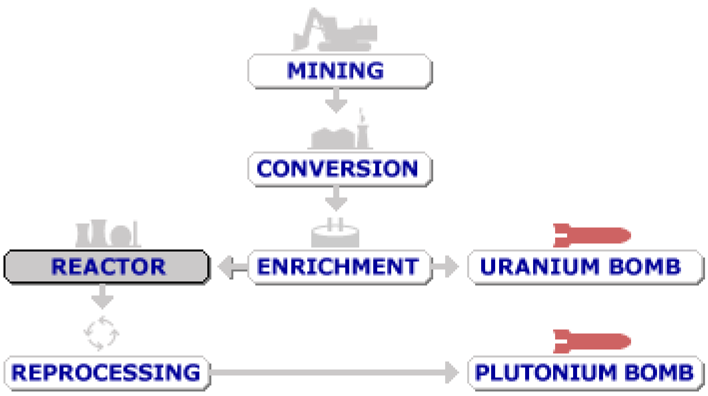
Contents:

Introduction

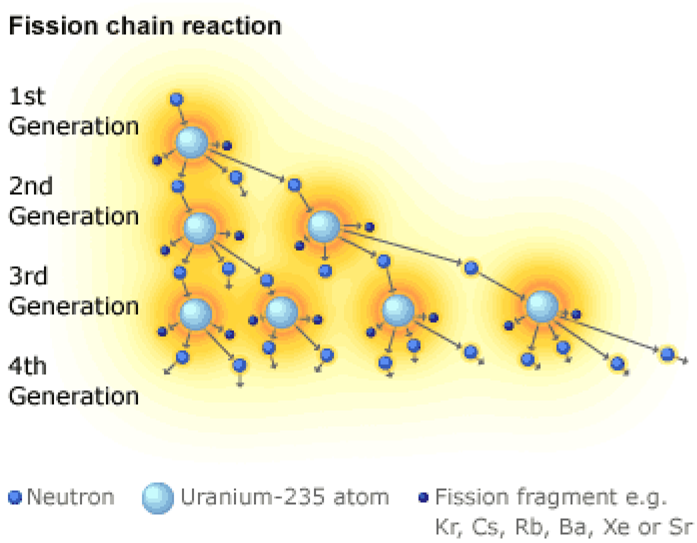
(IAEA Logo)

The Non-Proliferation Treaty (NPT) is a landmark international treaty whose objective is to prevent the spread of nuclear weapons and weapons technology, to promote co-operation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament. The NPT represents the only binding commitment in a multilateral treaty to the goal of disarmament by the nuclear-weapon states. Opened for signature in 1968, the Treaty entered into force in 1970. Since its entry into force, the NPT has been the cornerstone of the global nuclear non-proliferation regime. Adherence to the Treaty by 188 States, including the five nuclear-weapon states, renders the Treaty the most widely adhered to multilateral disarmament agreement. There are review of the NPT in accordance with Article VIII, Paragraph 3, that envisages a review of the operation of the Treaty every five years. This has included the 1995 NPT Review and Extension Conference, the 2000 NPT Review Conference and the 2005 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) that met from 2 to 27 May 2005. The 2005 NPT Review Conference was seen to have ended in failure on 27 May 2005 due to arguments between Iran, Egypt and the United States. The 2005 conference was unable to make formal progress on efforts to hinder states from withdrawing from the treaty, control nuclear material and technology, and bolster disarmament. Nevertheless there was consensus that the Treaty had not been undermined and agreement was made for another review conference in 2010. It was not the most dramatic of failures in the history of the NPT.

The most dramatic failure that undermined the essential concept of the NPT was South Africa, who was not a signatory to the Treaty when it was agreed upon in 1968 and indeed is now accepted to have commenced a nuclear weapons program in 1969. This program continued until 1991 with a sophisticated infrastructure of uranium mining, conversion and enrichment, reactors and critical assemblies, fuel fabrication, waste disposal and weapons dedicated facilities, as well as planning for seven nuclear devices with airborne and artillery delivery systems. Assisting in the nuclear program, with or without their knowledge that it was also a weapons project, were two signatories to the NPT – France and the United States as well as Israel who is not a signatory to the NPT. In doing so South Africa was a state rogue to the values and norms of non-proliferation codified in the NPT while France and the United States were violating their signatory to the NPT and Israel was flouting its concepts. However, on 10 July 1991 South Africa acceded to NPT as a non-nuclear weapon state and by 1993 had dismantled its entire nuclear weapons program. In doing so South Africa had become a reformed rogue state. South Africa is the first and to date only country to build nuclear weapons and then entirely dismantle its nuclear weapons program. It is the purpose of this paper to detail the South African nuclear infra-structure. In doing so it follows the spirit of the Review Conferences in questioning the effectiveness of the NTP.



Mining



Uranium is the basic raw material of both civilian and military nuclear programmes. It is extracted from either open-cast pits or by underground mining. Although uranium occurs naturally all over the world, only a small fraction is found in concentrated ores. When certain atoms of uranium are split in a chain reaction, energy is released. This process is called nuclear fission. In a nuclear power station this fission occurs slowly, while in a nuclear weapon, very rapidly. In both instances, fission must be very carefully controlled. Nuclear fission works best if isotopes - atoms with the same atomic number, but different numbers of neutrons - of uranium 235 (or plutonium 239) are used. Uranium-235 is known as a "fissile isotope" because of its propensity to split in a chain reaction, releasing energy in the form of heat. When a u-235 atom splits, it emits two or three neutrons. When other u-235 atoms are present, these neutrons collide with them causing the other atoms to split, producing more neutrons. A nuclear reaction will only take place if there are enough u-235 atoms present to allow this process to continue as a self-sustaining chain reaction. This requirement is known as "critical mass". However, every 1,000 atoms of naturally-occurring uranium contain only seven atoms of u-235, with the remaining 993 being denser u-238.

Not all states that aim to attain nuclear weapons status could do so as easily as South Africa given that she has rich natural resources and is able to mine her own uranium ore with extensive mining experience from mining other ore such as gold and coal. In this the start of South Africa's nuclear program was not the purchase of uranium ore or indeed enriched/refined uranium but local development with international assistance. After World War II South Africa became a major supplier of uranium to other countries who were developing peaceful nuclear energy programs as well as nuclear weapons projects. Thousands of tons of uranium ore were mined with international approval. It is more than likely that South Africa's nuclear weapon project would have been detected in its early stages had she needed to procure uranium from another country. A review of the known uranium mines indicates the extent of such domestic uranium capability. At various stages there were 13 uranium mines at different locations around the country being:

Blyvooruitzicht located at Gauteng province, 75 kilometers south west of Johannesburg, near the towns of Blyvooruitzicht and Carletonville. The facility consists of underground and surface mining operations, a metallurgical plant, tailings deposition facilities, and facilities, which have the capacity to produce 500 tons of uranium per year. It was constructed in October 1949, and first produced yellow cake in 1951. Although the uranium mining and milling facility was closed in December 1984, it is currently active in gold production.

Buffelsfontein Gold Mines located at Klerksdorp, Free State mines uranium (U308) underground and surface (waste rock dump). The facility is also currently active in gold production. The facility was authorized to operate in 1957 and consists of underground and surface mining operations, a metallurgical plant, tailings deposition facilities, and infrastructural facilities (including the East Shaft, Pioneer Shaft, Orangia Shaft and Surface Dumps), which have the capacity to produce 400 tons of uranium per year.

Chemwes near Stilfontein has a primary function of Uranium (U308) production The facility has the capacity to produce 500 tons of uranium (U308) per year. It was established in the 1970s, and was closed in 1988. MINE Waste Solutions (MWS), which is a nonlisted mine cleanup company, was expected to continue its plans to rehabilitate the facility in October 2001, after securing R75 million in funding from an investment bank and the Industrial Development Corporation (IDC).

Driefontein is 60 km southwest of Johannesburg with 18,900 employees for a primary function of Uranium (U308) production The facility consists of an underground mine with seven operating shaft systems, which access the Ventersdorp Contact Reef (VCR), the Carbon Leader Reef (CLR), two primary metallurgical plants (East plant: Shafts 1,2,4; West plant: Shafts 5,6,7), and a secondary recovery plant (the West Reclaim Plant). It has the capacity to produce 500 tons of uranium (U308) per year.

East Rand near Boksburg is the second deepest mine in the world, with depths of over 3,600 meters below the surface, a milling capacity of 3.5 mpta, and 250 tons of uranium (U308) production per year. East Rand was authorized to operate in March 1978, and closed in February 1991.

Harmony in the District of Virginia, Free State has a capacity to produce 150 tons of uranium (U308) per year, was authorized to operate in 1955, and closed in January 1998.

Hartebeestfontein 150 km southwest of Johannesburg, near the town of Klerksdorp undertakes underground uranium (U308) extraction and surface (waste rock dump) mining. The facility consists of underground and surface mining operations, three metallurgical plants, tailings deposition facilities, and infrastructural facilities (East and West Section), which have the capacity to produce 350 tons of uranium per year. The facility, active in gold production, produced 646,000 pounds of U_3O_8 (248.5 tU) in 1996.

The Joint Metall Scheme (JMS) subordinate to Anglo-American Corporation of South Africa Ltd has the capacity to produce 500 tons of Uranium (U308) per year. It was established during the uranium price boom in 1977, and closed in July 1993.

The Metallurgical Scheme in the Free State has the capacity to produce 450 tons of uranium per year. The plant re-treated gold tailings material, which produced sulfuric acid, uranium, and gold. Although uranium production ceased in 1990, other operations continued until 1995.

The Phalaborwa Complex 550 km northeast of Johannesburg in the lowveld plains of Northern Transvaal, close to the Kruger National Park employs 2,400 in a complex that covers an area of 1,950 hectares. Uranium (U308) extraction as a by-product of copper mining. It also mines magnetite, vermiculite, apatite, zirconium and titanium. The facility consists of a copper smelter, refinery, and concentrator, capable of producing 150 tons of uranium (U308) per year. There are three separate mineralized zones of which the northern zone is phosphate-rich while the central (Loolekpe) zone is predominantly used for copper production (since 1964). In 2001, A new underground mine, costing $430 million, was established to continue its mining operations with a further 20-year life.

Vaal Reefs operated by Anglo American Corporation of South Africa Ltd with 16,500 workers has the capacity to produce 1500 tons of uranium per year. Vaal Reefs was the top South African producer in 1996 with 2.372 million pounds of U3O8.

West Rand Consolidated Mine has shafts with depths to 3900 meters, are some of the deepest in the world. The facility has the capacity to produce 500 tons of uranium (U308) per year. The facility was authorized to operate in October 1952 with full scale production of yellow cake and closed in August 1981.

Western Deep Level at West Rand, is the deepest mine in the world (4.2km / 2.6 miles) with the annual capacity to produce 300 tons of uranium (U308). In July 1993, the mine closed, after producing 595,000 lbs of uranium.

Conversion and Enrichment

(Yellow Cake Uranium)

Once extracted, uranium ore is taken to a mill to be crushed and ground into a fine powder. This is then purified in a chemical process and reconstituted in a solid form known as "yellow cake", due to its yellow colouring. Yellow cake consists of 60-70% uranium, and is radioactive. The basic aim of nuclear scientists is to increase the amount of u-235 atoms, a process known as enrichment. To do this, uranium must first be converted into a gas, uranium hexafluoride by heating it to about 64 degrees centigrade. Uranium hexafluoride is corrosive and reactive and must be handled very carefully. Pipes and pumps at conversion plants must be specially constructed from aluminium and nickel alloys. The gas is also kept away from oil and grease lubricants to avoid any inadvertent chemical reactions.

Although the mining of uranium ore is an important first step to any nuclear program be it for peaceful energy or as a weapons project it has no value unless the core can be converted and enriched. The uranium ore being mined is just rock. Progressively South Africa developed her conversion and enrichment facilities at four locations. Initially this was for the research facilities known as SAFARI in the Transvaal province and then for the nuclear energy reactors known as KOEBERG in the Cape province. In addition enriched uranium was also supplied directly by the United States. The four conversion and/or uranium or enrichment facilities are:

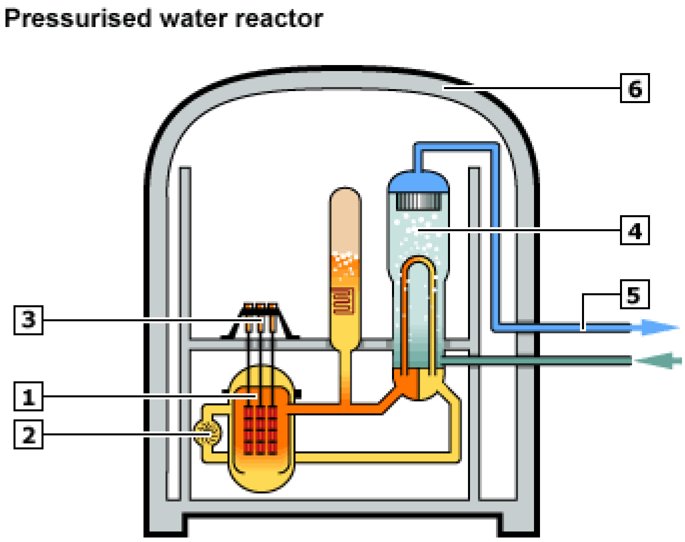
The conversion facility (HEU-UF6 production plant) located at Pelindaba undertakes U3O8 (yellow cake) to UF6 conversion. By the end of the 1960s, South Africa was producing uranium tetra fluoride (UF4), an intermediate product in hexafluoride conversion, which facilitated the production of uranium hexafluoride (UF6) on a laboratory scale in the early 1970s. In 1975 a small UF6 production plant was authorized to operate at Pelindaba, which began producing UF6 on an industrial scale the following year. The facility was closed in 1998;

Enrichment also takes place at the Molecular Laser Isotope Separation (MLIS) plant at Pelindaba East. This is a joint project of the AEC and Cogema (French nuclear firm);

The Y-plant adjacent to the Pelindaba Nuclear Research Center located approximately 35 km west of Pretoria employed a total of 250. The plant, which was originally designed to produce 10-15,000 separative work units (SWUs) annually, was later enhanced to produce 20,000 SWUs annually. The facility included an aerodynamic process enrichment plant that produced highly enriched uranium (HEU) for South Africa's nuclear weapons program. The enrichment process used the centrifugal effect of spinning uranium hexafluoride and hydrogen gases inside a tube to separate the heavier uranium-238 fraction from the lighter uranium-235 fraction. It also produced 45% enriched uranium for the SAFARI research reactor, low enriched uranium (LEU) test assemblies for the Koeberg nuclear power reactors, and LEU blending stock. The Y-plant consisted of one stripper section and five consecutive enrichment blocks located in three large building called C, D, and E. The plant, authorized to operate at the end of 1974, developed its capacity to produce weapons-grade uranium in March 1977. The initial extraction of HEU occurred in January 1978. The facility was closed in 1990 as part of the termination of South Africa's nuclear weapons program.

The Z-plant at Pelindaba was designed to produce LEU for commercial production. This facility had a capacity of 300,000 SWUs per year, with a maximum enrichment of 3.25%. The uranium hexafluoride plant, completed in 1986, had the capacity to produce 700 tons a year. Roughly two-thirds of its annual capacity was required to fuel the Koeberg reactors. From 1988 to mid-1993 those reactors consumed 95% of the total actual output. This facility was shut down on 31 March 1995.

Reactors and Critical Assemblies

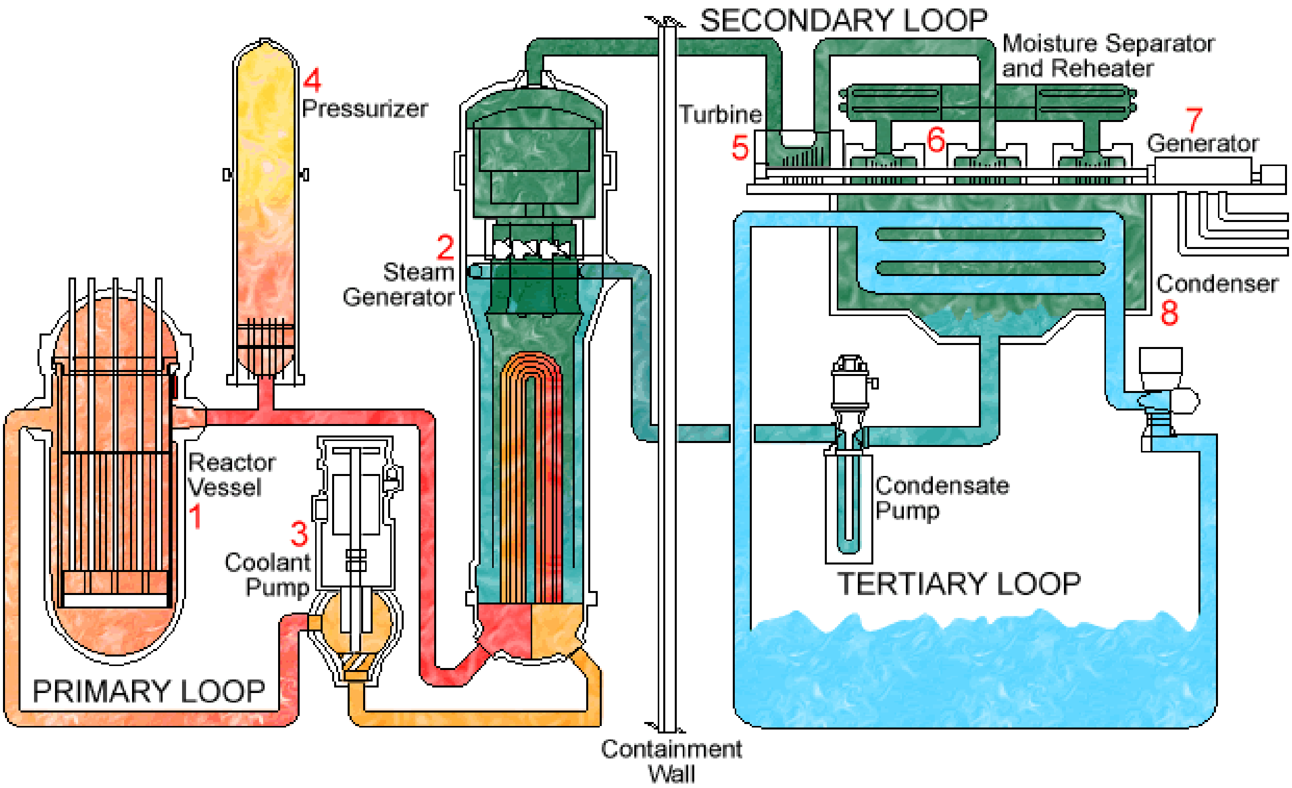


1. Reactor core
2. Coolant pump
3. Fuel rods
4. Steam generator
5. Steam pumped to turbine, which generates electricity
6. Containment building

Nuclear reactors work on the principle that nuclear fission releases heat, which can be harnessed and used to heat water into steam to drive turbines. A typical nuclear reactor uses enriched uranium in the form of fuel 'pellets', each roughly the size of a coin and about an inch long. The pellets are formed into long rods known as bundles, and housed inside a heavily insulated, pressurised chamber. In many power stations, the bundles are submerged in water to keep them cool. Other types use carbon dioxide or liquid metal to cool the reactor core. To function in a reactor - ie produce heat through a fissile reaction - the uranium core must be supercritical. This means that the uranium must be in sufficiently enriched form to allow a self-sustaining chain reaction to occur. To regulate this process, and allow the nuclear plant to function, control rods are inserted into the reactor chamber. The rods are made of a substance, typically cadmium, which absorbs neutrons inside the reactor. Fewer neutrons means fewer chain reactions are started, slowing down the fission process. There are more than 400 nuclear power stations across the globe, producing about 17% of the world's electricity. Nuclear reactors are also used to power submarines and naval vessels.

(Koeberg Nuclear reactor – with Table Mountain and Cape Town in the backround)

The mining and conversion and enrichment facilities were accepted by the international community as justifiable given South Africa’s contentions that they were for the peaceful use of nuclear energy developing two research facilities (SAFAR-I and SAFARAI-2) and two energy reactors (KOEBERG-1 and KOEBERG-2). There was international assistance with little apprehension that these would lead to a nuclear weapon project given that 1) South Africa had overwhelming conventional military supremacy in the Sub-Saharan region and essentially had no need for nuclear weapons for her immediate security and defence; 2) South Africa was geographically distant from the Cold War hot-spots and hence it would not have been in South Africa's vital interests to become embroiled in them by becoming a nuclear state and hence a target and 3) South Africa did not have the inter-continental delivery systems nor defence systems to become actively involved in Cold War political and military issues as a player that could have had any influence. Hence France, the United States and Israel helped develop South Africa's nuclear reactors and critical assembles. However in aberration of their NPT obligations neither France nor the United States made adequate checks to ensure that their actions and assistance did not lead to the violation of the NPT.



(Nuclear Operating Model)

It was therefore not surprising that South Africa was able to construct and enter into use the nuclear facilities named SAFARI-1 (South African Fundamental Atomic Reactor Installation) located at Pelindaba, 30 km west of Pretoria. It is subordinate to Atomic Energy Corporation (AEC). The facility, authorized to operate in 1965 went critical on 18 March 1965 and was initially used for advanced nuclear physics research programs including commercial uranium hexafluoride, uranium enrichment, and nuclear fuel assembly production. Between 1965 and 1975, the United States supplied the reactor with about 100 kg of weapons-grade uranium fuel. SAFARI-1 is the only reactor in the world with a comprehensive on site production lifecycle. A comprehensive preventative maintenance program and an operating strategy for the continuous upgrading of plant equipment, ensure that SAFARI-1 will continue to operate well into the 21st century.

The SAFARI-1 consists of a reactor poolside, in-core irradiation positions, pneumatic facilities, and a hydraulic facility. The 20 MWt research reactor of tank-in-pool type performs various radiation applications including the neutron transmutation doping of silicon crystals and the coloration of topaz. The reactor uses fuel enriched to 45% uranium 235 from the Y plant and produces plutonium as waste material. The in-core irradiation positions have neutron fluxes of 2 x 1014 n.cm-2.s-1 at 20 MW and are primarily used for isotope production. Six positions are fitted with thimble tubes to allow sample retrieval while the reactor is on power. Five of these positions are dedicated to the irradiation of uranium target plates for the production of the fission product Molybdenum-99. The pneumatic facilities are used mainly for neutron activation analysis which involves shorter irradiations of smaller samples in lower flux regions. The hydraulic facility allows access to high flux positions while the reactor is on power. The facility also includes an isotope center that consists of hot cells with manipulators, waste handling and storage capacity, laboratories, and hydraulic-pneumatic conveying system to move radioactive material from the SAFARI-1 reactor to the isotope center.

In 1965, Israeli scientists began advising South Africa on the SAFARI-2 research reactor and operation started in 1967. The U.S. supplied 606 kilograms of 2% enriched uranium and 5.4 metric tons of heavy water to the SAFARI-2 10 MWt reactor. Because SAFARI-2 did not produce significant power or plutonium, it did not present any risks vis-à-vis weapons proliferation. The combination of problems with the reactor's design and the financial costs exceeding the costs of power stations fueled by South African coal lead to the abandonment of the criticality facility and the reactor type in 1969. The facility was dismantled in 1970 and decommissioned in the 1980s.

Experience from the research facilities led South Africa to consider thee construction and use of nuclear powered energy. The decision was taken to develop Koeberg-1 and Koeberg-2 which are located near Melkbosstrand, Cape Province, a coastal site 30km north of Cape Town. The origins of the Koeberg project dates to 1976, when a French consortium of three companies (Framatome, Alsthom, and Spie Batignolles) won the contract to build the facility, withstanding competition from a West German consortium and an American, Dutch, and Swiss consortium. The contract was awarded to the French consortium because of possible impediments that might have occurred as a result of the United States and Netherlands' opposition to apartheid. Koeberg-1, with an expected shutdown date in August 2024, is the only nuclear-fired electricity plant on the African continent. There are approximately 1,000 employees working at Koeberg, with an additional 40 employees located in the Eskom Generation and Technology Groups in the Johannesburg offices. The Koeberg-1 facility consists of the Koeberg-1 reactor, a 920 MW(e) electric pressurized water reactor, and the Pebble Bed Modular Reactor (110 MW) power unit, which is based on the high temperature gas-cooled nuclear reactor concept. The construction for Koeberg-2 began in July 1986 by the French consortium of three companies. The facility opened in 1985, went critical in July 1985, started its commercial operations in November 1985, and is expected to shutdown in November 2025. Koeberg-1 and Koeberg-2 receive low enriched uranium from the Y-plant. Koeberg-1 and Koeberg-2 supply most of the electricity of the Western Cape and about 10% of the nation's electricity consumption.

Fuel Fabrication

The final two parts of the nuclear fuel cycle were the fuel fabrication and waste disposal – two sides of the same coin. The fuel fabrication was conducted at four locations while the waste disposal was at two locations. Consideration of the construction of both the fuel fabrication and the waste disposal was an integral part of the development of both the peaceful nuclear program as well as the nuclear weapons project. Essential for the later was the security and secrecy of ensuring that any monitoring for example for health and safety purposes would not detect a weapons project. Such monitoring would naturally be part and parcel of the assistance provided by France and the United States in the construction and maintenance of the nuclear energy reactors. It could also be part of an IAEA inspection. In hindsight South Africa was successful in ensuring the integrity of its health and safety standards, in fuel fabricating to sufficient quality and indeed in the secrecy o its weapon project. The four fuel fabrication locations are:

The Hot Cell Complex at Pelindaba consists of 25 hot cells which are within 3 large high density concrete (HDC) caves and 22 smaller lead cells. The average shielding capability of the lead cells are 200-250 mm Pb equivalent and the concrete cells are 1100 mm HDC equivalent. The facility is dedicated to the post irradiation examination of locally produced Pressurized Water Reactor (RWR) fuel. Nine hot cells are dedicated to Molybdenum-99 production comprising of 2 fully independent production lines of four cells each plus a shared cell for packaging and shipment. I-131 production is performed in a dedicated production line of four hot cells with a fifth cell always on standby for backup. A further three hot cells plus one glove box is used for production of P-32 and S-35. The facility, constructed in the late 1980s, has decontaminated and reapplied the cells for isotope production purposes since the completion of the fuel investigation program.

The Beva Plant at Pelindaba produced LEU fuel elements for Koeberg power reactors and closed in 1995, included a front-end nuclear fuel production plant.

The MTR (Material Test Reactor) Fuel Fabrication at Pelindaba produces fuel elements for the SAFARI-1 research reactor. The spent MTR fuel elements from the SAFARI-1 research reactor are stored in a retrievable dry pipe store at the Thabana waste disposal facility.

The Zirconium Tubing Plant at Pelindaba; near Hartbeespoort Dam west of Pretoria produced cladding for fuel assemblies used in Koeberg reactors and produces zirconium tubing that sheaths fuel for thee nuclear reactors. The facility was constructed in the 1960s and closed in 1993.

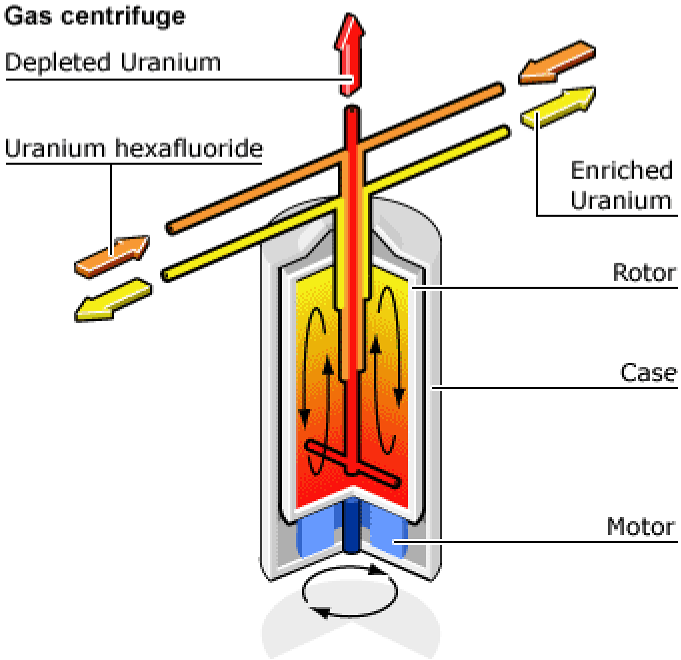
The Zirconium Tubing Plant has an additional story given that it was sold to China in 1997, and reportedly shipped to China in 1998. The agreement to sell the plant was finalized in February 1997, three months before President Nelson Mandela announced that South Africa would break diplomatic ties with Taiwan. This sale and transfer was conducted in accordance within the spirit and compliance of the NPT.

Waste Disposal

Waste Disposal takes place at two locations: the Thabana repository and the Vaalputs National Waste Repository. The Thabana repository formerly know as Radiation Hill is located at Pelindaba The facility stores spent fuel from the AEC's research activities, SAFARI-1, other radioactive waste including 2000 liters per annum of short-lived isotopes from various hospitals, together with other low-level wastes from non-nuclear industrial resources. The facility consists of eight trenches (3-8 m deep) with approximately 17 tons of uranium, steel tubular storage facility for short-lived sources, medium-active waste storage chamber for the disposal of activation products up to 30 years of half-life, CaF2 storage facility for the disposal of CaF2 sludge, and a hut for hazardous chemicals.

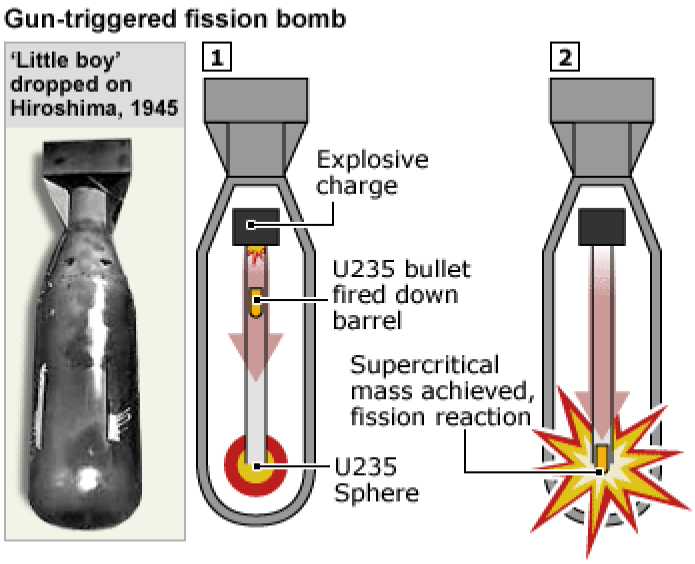
The Vaalputs National Radioactive Waste Disposal Facility is situated on the Bushmanland Plateau, in north-western Cape Province, approximately 100 km southeast of Springbok and 600 Km north of Cape Town. The facility, with a capacity of 1,470 m^3/a of low level waste (LLW)/intermediate level waste (ILW) disposal, covers an area of 10,000 ha including a disposal area of 35 ha, in an area 700 x 500 m at approximately 1000 ft above sea level. There are two pre-constructed trenches (one for ILW concrete containers and the other for drummed LLW) 100 m long x 20 m wide x 7.5 m deep. The facility disposes low and intermediate level nuclear waste from the Koeberg reactors, including clothing and other laboratory equipment, and places them in steel drums and concrete containers, of which 1500 drums and 500 concrete containers are produced annually. The facility began its operation in 1986 and was fully licensed by 1990.

Nuclear Weapons History

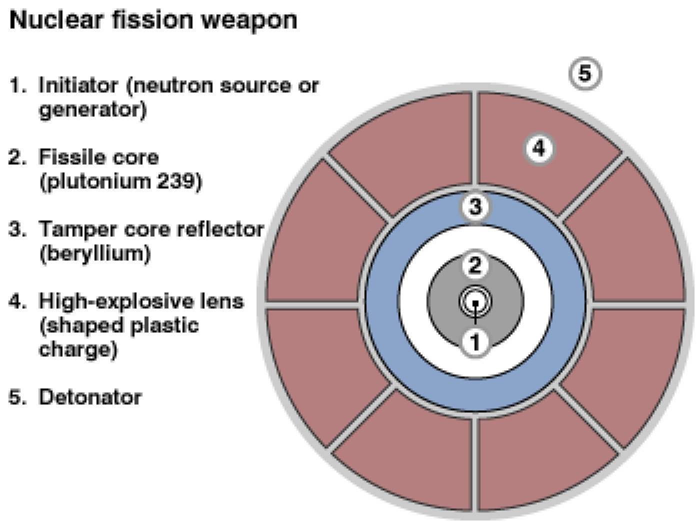


The aim of enrichment is to increase the proportion of fissile uranium-235 atoms within uranium. For uranium to work in a nuclear reactor it must be enriched to contain 2-3% uranium-235. Weapons-grade uranium must contain 90% or more u-235. A common enrichment method is a gas centrifuge, where uranium hexafluoride gas is spun in a cylindrical chamber at high speeds. This causes the slightly denser isotope u-238 to separate from the lighter u-235. The dense u-238 is drawn towards the bottom of the chamber and extracted; the lighter u-235 clusters near the centre and is collected. The enriched u-235 is then fed into another centrifuge. The process is repeated many times through a chain of centrifuges known as a cascade. The remaining uranium - essentially u-238 with all the u-235 removed - is known as depleted uranium. Depleted uranium, a heavy and slightly radioactive metal, is used as a component in armour-piercing shells and other munitions. Another method of enrichment is known as diffusion. This works on the principle that of the two isotopes present in uranium, hexafluoride gas, u-235 will diffuse more rapidly through a porous barrier than its heavier cousin, u-238. As with the centrifuge method, this process must be repeated many times.

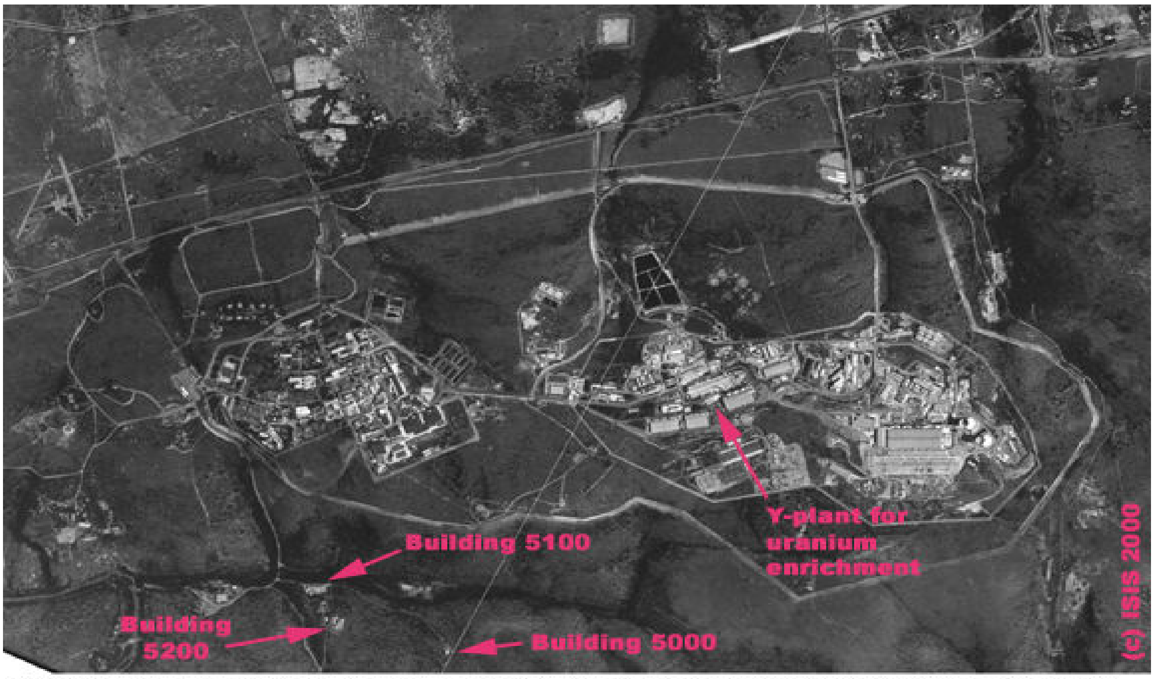
Reprocessing is the chemical operation which separates useful fuel for recycling from nuclear waste. Used fuel rods have their metallic outer casing stripped away before being dissolved in hot nitric acid. This produces uranium (96%), which is reused in reactors, highly radioactive waste (3%) and plutonium (1%). All nuclear reactors produce plutonium, but military types produce it more efficiently than others. A reprocessing plant and a reactor to produce sufficient plutonium could be housed inconspicously in an ordinary-looking building. This makes extracting plutonium by reprocessing an attractive option to any country wishing to pursue a clandestine weapons programme.



The aim of all nuclear bomb designers is to create a supercritical mass which will sustain a chain reaction and violently release vast amounts of heat. One of the simplest is a so-called 'gun' design. Here, a smaller subcritical mass is fired at a larger one, causing the combined mass to go supercritical triggering a nuclear explosion. The process occurs in less than a second. To make fuel for a uranium bomb, highly-enriched uranium hexafluoride is first converted into uranium oxide, and then uranium metal ingots. This can be done using relatively simple chemical and engineering processes. The most powerful basic fission weapon - an atom bomb - will detonate with an explosion the force of 50 kilotons. This force can be increased by a technique called boosting, which harnesses the properties of nuclear fusion. Fusion consists of the joining together of the nuclei of atoms of hydrogen isotopes to produce nuclei of helium. This process occurs when hydrogen nuclei are subjected to intense heat and pressure, both of which are produced by a nuclear bomb. Nuclear fusion has the effect of producing more neutrons and feeding the fission reaction, resulting in a bigger explosion. Such boosted devices are known as hydrogen bombs, or thermonuclear weapons.



Plutonium offers several advantages over uranium as a component in a nuclear weapon. Only about 4kg of plutonium is needed to make a bomb. Such a device would explode with the power of 20 kilotons. To produce 12kg of plutonium per year, only a relatively small reprocessing facility would be needed. A warhead consists of a sphere of plutonium surrounded by a shell of material such as beryllium, which reflects neutrons back into the fission process. This means that less plutonium is needed to achieve critical mass, and produce a self sustaining fission reaction. A terrorist group or country may find it easier to acquire plutonium from civil nuclear reactors, rather than enriched uranium, to produce a nuclear explosive. Experts believe a crude plutonium bomb could be designed and assembled by terrorists possessing no greater level of skill than needed by the AUM cult to attack the Tokyo underground with nerve gas in 1995. A nuclear explosive of this nature could explode with the power of 100 tonnes of TNT - 20 times more powerful than the largest terrorist bomb attack to date.



Significant former nuclear weapons related facilities at the Pelindaba-Valindaba Complex, near Pretoria, South Africa. December 1991 KVR-1000 image from www.terraserver.com.

It is recognised that the South African nuclear program commenced in 1969 when the South African Atomic Energy Board (AEB) formed an internal committee to research the technical and economic aspects of peaceful nuclear explosions (PNEs) for the mining industry. By 1971 the Uranium Enrichment Corporation (UCOR) was assigned responsibility for overseeing the uranium enrichment program, and construction of a pilot-scale uranium enrichment plant – the Y-plant. The South African weapons dedicated facilities have been identified as Building 5000 (Building 5100, 5200, 5300) at the Pelindaba (Transvaal) location. In the 1970s, the facility was used for conducting criticality experiments and to develop a nuclear explosive. Building 5000 contained a pulse reactor, which was used as a fast critical assembly in an experiment called "tickling the tail of the dragon" that proved the design of the gun-type device. Building 5100 contained a control room for Building 5000, offices, research and development laboratories, and machining facilities for uranium metal. Building 5200 was a critical facility to verify individually the multiplication factors of the two parts of a nuclear explosive device. Building 5300 was a laboratory for high explosives that were shaped with machines at this facility.

These were supplemented by the Kentron Circle Facility located at Kentron Circle, 20km west of Pretoria, within another Armscor site called Gerotek. The Kentron Circle Facility consisted of the Circle building and an environmental test facility for the development and integration of gun-type devices. It had a primary function to design, assemble, produce, and store nuclear weapons. The

Kentron Circle Facility worked on developing implosion weapons with a capacity to develop test diagnostics, HE tests cells to perfect explosives placement for proper core compression, and metal machining equipment for the cores. Although most efforts were spent on producing a highly reliable gun-type device, the facility also worked on lithium-6 separation for the production of tritium for possible future use in boosted devices, studied the implosion and thermonuclear technology, and conducted research and development for the production and recovery of plutonium and tritium. The Circle Building, a two-story building with a total of 8,000 square meters of floor space, housed the facilities to develop and manufacture nuclear devices, including facilities for testing internal ballistics, igniter, propellants, and small quantities of high explosives for self-destruct mechanisms. The environmental test building was involved in the development and integration of the gun-type devices. The Advena Central Laboratories expanded nuclear delivery options to ballistic missiles. This complex also contained a cold implosion test facility, which was deemed essential for proving an implosion design.

In 1972 in addition to the facilities at Pelindaba, a small team of AEB staff began working on mechanical and pyrotechnic subsystems for a gun-type nuclear explosive device at a propulsion laboratory at Somchem, in Cape Province. The facility was subordinate to Armscor until the 1990s. It had its primary function as research and development of mechanical and pyrotechnic subsystems for gun-type nuclear weapons. In May 1974, a team at Somchem developed a scale model of a gun-type device, with a projectile constructed of non-nuclear material. Artillery testing was designated to the Vastrap test range in the Kalahari Desert; north of Upington where two test shafts were constructed in 1976. The site consisted of a shed over the two test shafts, both a meter in diameter, with one shaft 385 meters and the other, 216 meters in depth. Armscor built a shed over the shafts to conceal operations there. Since the test proved the feasibility of a nuclear explosive, the team also tested the first full-scale model of the gun-type device using a natural uranium projectile in 1976, proving the mechanical integrity of the design. In 1977, the program was transferred from Somchem to Pelindaba after Soviet surveillance satellites detected test preparation at the shaft in 1977.

Somchem had nevertheless proved its value. The AEB team at Somchem had been able to test a full-scale model of a gun-type device, using natural uranium as the projectile. Natural and depleted uranium have the same physical and chemical properties as HEU, and can be used to test the design and function of an HEU-based nuclear explosive assembly. Eventually the artillery entered mass production with the ability to deliver both conventional and non-conventional shells. The G5 was a 155mm towed howitzer and the G6 was a sell-propelled 155mm howitzer. They could also both deliver standard as well as nuclear NATO 155 mm shells. One hundred of the G5 were sold to each of the two sides in the Iran-Iraq war during the 1980's

(G6 sell-propelled 155mm howitze)

There were a number of important decision-making dates to continue the nuclear weapons program once the structure, infra-structure, research, development and testing facilities had been confirmed as viable. These were 1) 1973 scientists were instructed to develop gun-assembly, implosion, and thermonuclear weapons designs; 2) 1974 the decision to develop a limited nuclear deterrent capability is made after an AEB report to Prime Minister Johannes Vorster, concluding that it can build a nuclear explosive device - Vorster approved the development of PNEs and construction of an underground nuclear test site; 3) 1977 the government officially changes the objective of its nuclear explosive program from peaceful purposes to developing a nuclear deterrent capability and the first stages at the lower end of the cascade at the Y-plant uranium enrichment facility was commissioned where the full cascade become operational in March 1977; 4) October 1978 Prime Minister P.W. Botha decides to shift the emphasis of the nuclear program from peaceful nuclear explosives to developing airborne nuclear weapons, just one month after taking office.

The AEB then completed manufacture of South Africa's first full-scale nuclear explosive device based on a gun-type design. The device does not contain a highly enriched uranium (HEU) core, because the Y-plant has not yet produced a sufficient quantity of HEU. The AEB plans to conduct a "true" test using a HEU pit in 1978. The device with the depleted uranium pit is later "dismantled and scrapped. In 1978 the first small quantity of HEU is withdrawn from the Y-plant. The AEB constructs a "second, smaller" nuclear device leading Prime Minister Vorster to formally approve a draft document prepared by senior officials outlining South Africa's future nuclear course. As defense minister, P.W. Botha approved adoption of a three-phase nuclear deterrent strategy. In phase one, the government will neither acknowledge nor deny its nuclear capability – based on the Israel stance on nuclear deterrence declarations. If South African territory were threatened, the government would move to phase two and consider privately revealing its nuclear capability to certain international powers, such as the United States, to catalyze international intervention. This was based upon the French nuclear philosophy of dissuasion. If aid were not forthcoming, the government would move to phase three and consider demonstrating its nuclear capability in public, perhaps by conducting an underground nuclear test.

In 1979 the government decided to assign Armscor with the task of designing and building additional gun-type devices. The AEB was also to provide HEU and expertise in theoretical and neutron physics. The principal components of the Armscor nuclear weapons program included: development and production of deliverable gun-type devices; studies of implosion and thermonuclear technology; research and development on production and recovery of plutonium and tritium; and separation of lithium-6 for tritium production, for possible use in boosted nuclear weapons. An "Action Committee" created by Botha to develop plans for the production of nuclear devices recommended production of a total of seven nuclear weapons. The Y-plant was abruptly shut down "due to a massive catalytic in-process gas reaction between the UF6 [uranium hexafluoride] and the hydrogen carrier." The Y-Plant reopened to produce sufficient HEU to provide 55kg of 80-percent enriched U235 for use with the AEB's second nuclear device. The AEB assembled the device to ensure that "everything fits properly." The AEB device being a "non-deliverable demonstration device," designed for use in an underground nuclear test that would prove South Africa's nuclear weapons capability. The device was eventually transferred from temporary storage in an abandoned coal mine at Witbank to a special vault at the Kentron Circle facility. Armscor later noted that this AEB device was not a "qualified" design, indicating there was "not an adequate degree of assurance that it would detonate as intended or that it would not detonate accidentally."

In 1979 a Vela surveillance satellite of the United States detected a "brief, intense, double flash of light near the southern tip of Africa." Due to its characteristics, the American officials estimated that the flash could have resulted from the test of a nuclear device with a yield of 2-4 kilotons. South Africa emerged "as the prime suspect," but the South African government denied that it had conducted a nuclear test. There were also rumours that Israel conducted a nuclear test, either alone or in conjunction with South Africa. American President Jimmy Carter assembled a panel of non-governmental scientists to determine whether the flash registered by the Vela was the result of a nuclear explosion but could not find any conclusive evidence. It was a testing time for the NPT given that France and the United States were at the time assisting South Africa in developing its nuclear energy program with reactors at Koeberg and indeed purchasing South African uranium ore. There is no indication that either of these were curtailed or inhibited by the satellite findings or report.

Subsequently the first HEU is withdrawn from the Y-plant since its 1979 shutdown. From 1982 Armscor produced nuclear weapons arsenal at the increasing rate of one device approximately every 18 months, until it included six weapons by the late 1980s. During this period, the older gun-type devices were upgraded to airborne specifications. In 1985 after reviewing the nuclear weapons program, President P.W. Botha confirmed that the program would be limited to seven fission devices and therefore halted all work related to development of plutonium devices, ceasing efforts to produce plutonium and tritium for nuclear weapons, and limits production of lithium-6. The Atomic Vapor Laser Isotope Separation (AVLIS) program is reoriented from production of lithium-6 to production of lithium-7 for water chemistry control in power reactors. However, Advena personnel continued to work on implosion designs and theoretical research on advanced weapons. A mid-1980s organizational chart of the weapons program depicts eight divisions: Program Management and Systems Engineering, Operations Support, Engineering, Technology Development and Explosives, Personnel, Security, Health Care, and Finance.

(Buccaneer bomber aircraft)

In 1987 Armscor completed its "first qualified production model" nuclear device, which could an be delivered by a modified Buccaneer bomber aircraft. This aircraft had been procured from the United Kingdom in the 1960s as a modernisation program after British Prime Minister's Wind's of Change speech. The Buccaneer had originally been designed as a Royal Navy aircraft carrier borne aircraft that was being phased out by the Royal Air Force in preference of the F-4 Phantom. It first saw service in the South African Air Force in May 1978 at Cassinga Angola against Soviet made T34 tanks though was phased out after the South West African peace dividend in the early 1990s.

Hence by the program's termination, Armscor had manufactured four airborne deliverable nuclear devices with a viable delivery aircraft, two gun-type devices with a 155mm self-propelled howitzer as well as the HEU core and some non-nuclear components for a seventh device. This led Armscor in 1988 to construct a Kalahari test site in order to guarantee that a nuclear test could be conducted if needed, to fulfill phase three of the nuclear deterrent strategy. However, in 1989 at a meeting of his senior political aides and advisors, President F.W. de Klerk declared that in order to end South Africa's isolation from the international community, both the political system of apartheid and the nuclear weapons program must be dismantled. An "Experts Committee" formed by de Klerk and composed of senior AEC, Armscor, and South African Defense Force (SADF) officials formally recommended the dismantlement of South Africa's nuclear weapons, and outlined dismantlement procedures. De Klerk and the South African cabinet approved the plan. The Y-plant stopped producing HEU and the nuclear test site in the Kalahari Desert was completely abandoned.

Subsequently a dismantlement study commissioned by de Klerk is completed. De Klerk opts to order the dismantlement of one complete nuclear device at a time. An alternative, more rapid disarmament option would have been to destroy one-half of each device before destroying the second half. The slower option allows South Africa to maintain a nuclear deterrent until the last weapon is dismantled. Furthermore, the slower option helped acclimate the dismantlement team to the reality of de Klerk's decision to eliminate South Africa's nuclear arsenal.

On 10 July 1991 South Africa acceded to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) as a non-nuclear weapon state while the HEU from the last dismantled nuclear weapon was returned to the AEC. South Africa signed a full-scope safeguards agreement with the International Atomic Energy Agency (IAEA). On 10 October 1991 South Africa presented its initial inventory of nuclear materials and facilities to the IAEA. In 1992 The IAEA reported that the high-enrichment separation units of the Y-plant had been dismantled and removed, and that the remainder of the plant has been decommissioned.

In 1993 in a speech before the South African parliament, President F.W. de Klerk announced that South Africa had a nuclear weapons program during which time it constructed six of seven planned nuclear devices. According to de Klerk, the devices constituted a deterrent and South Africa never intended to use them offensively. South Africa's strategy was that if the situation in southern Africa were to deteriorate seriously, the government would confidentially indicate its deterrent capability to one or more of the major powers – such as the United States – in order to persuade them to intervene. De Klerk stated that all of South Africa's fissile nuclear material had been accounted for, and all hardware and design information had been destroyed. De Klerk declared that South Africa has never conducted a clandestine nuclear test. On this same date, officials destroy the last documents on policy making in the South African nuclear weapons program. Approximately 1,000 personnel participated during the life span of the weapons program, with about 400 involved at the height of the project. Officials at Armscor estimate that each gun-type nuclear device would have had a yield of 10-18 kilotons.

In 1993 in the presence of IAEA inspectors, Armscor rendered useless the nuclear test shafts at the Vastrap site in the Kalahari Desert by filling them with concrete while the government proclaimed the Act on the Control of Non-proliferation of Weapons of Mass Destruction. The legislation created the South African Council for the Non-Proliferation (NPC) of Weapons of Mass Destruction, which was charged with export control authority for all nuclear dual-use items. The Act may any involvement by South African citizens in the development of nuclear, biological, or chemical weapons, and ballistic missile systems to deliver such weapons, a criminal offence. The IAEA General Conference accepted the completeness of South Africa's inventory of materials and facilities. The General Conference also accepted South Africa's declarations on the dismantlement and destruction of equipment for its nuclear weapons, on transfer of dual-use equipment and facilities to non-nuclear or civilian nuclear uses, and on destruction of the two Vastrap test shafts under IAEA supervision. With these determinations it is accepted that South Africa had completed its nuclear disarmament had become a reformed rogue state.

Conclusion

The example of South Africa demonstrates that if a state wishes to acquire nuclear weapons and the means to deliver them then it will do so. South Africa developed its nuclear weapons program whilst facing some of the most stringent arms embargoes and economic sanctions known in the history of the United Nations due to its apartheid policies and regime. South Africa's nuclear scientific community was of the smallest and most ostracised using technology from textbooks. The South African nuclear weapons program also questioned the viability of implementing international agreements such as the NPT. Assistance to South Africa came from two states that were signatories to the NPT – France and the United States and from a third state – Israel that refused to sign the NPT. The South African nuclear delivery systems were modified outdated aircraft and locally developed artillery that any state with a basic auto mobile industry could also develop. For the main part the South African nuclear weapons program was undertaken in secret over a period of more than two decades. Essentially this demonstrates that the NPT, like other international arms control and disarmament agreements and treaties, rests on self-regulation and compliance. International verification and monitoring of the entire earth's surface is indeed impossible. In this the process and debate of reviewing the NPT is as crucial as being a signatory. The NPT review is an important process for states to undertake a introspective evaluation of their intentions and actions and to debate these with other states. The negotiations attain significance in breaking down mis-perceptions about other states intentions and in developing new schemes. For example, the Model Nuclear Inventory is a comprehensive database of all nuclear materials, both military and civilian, in the 44 States recognized as having a significant nuclear capability.

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