Chapter 1 Laying the Foundation

South Africa's nuclear development dates back to World War II when the US Manhattan Project was looking worldwide for uranium to make nuclear weapons. In 1944 Great Britain requested South Africa's Prime Minister Jan Smuts to investigate reported deposits of uranium in South Africa and South West Africa (now called Namibia).[1] Following an extensive investigation, Smuts announced that uranium had been discovered in many of South Africa's gold mines.[2]

After several years of exploration and development, South Africa started its first full-scale uranium extraction plant in 1952, built with extensive US and British aid. By 1955 sixteen uranium extraction plants were in operation.[3] Until the mid-1960s, South African uranium was sold to the Combined Development Agency, the purchasing organization created by Britain and the United States to obtain adequate uranium supplies for their nuclear weapons programs.

Initially, the development of uranium production was controlled directly by the South African Prime Minister's office. However, in 1948 the country's Atomic Energy Board (AEB) was established by an Act of Parliament to control all nuclear matters, particularly the production and sale of uranium on behalf of the government.

The First United Nations Conference on the Peaceful Uses of Atomic Energy, held in Geneva in 1955, stimulated the AEB's interest in creating an indigenous South African nuclear research and development program. Upon its return, the South African mission to the UN conference recommended that South Africa send scientists abroad for training to enable them to build an experimental reactor. It also recommended the construction of a nuclear power reactor at Cape Town.

In November 1956, the AEB established the Research Advisory Committee. One of its first acts was to appoint A. J. A. "Ampie" Roux, then a senior official at the Council for Scientific and Industrial Research (CSIR), to draft a nuclear research and development program. The committee also hired the AEB's first two research engineers. They were charged with surveying the processes for producing heavy water as a moderator in nuclear reactors.

One month later, the government created a national Commission of Enquiry into the Application of Nuclear Power in South Africa, under terms of reference drafted by the AEB. The commission appointed Roux to draft a plan for a South African nuclear research and development program.

While Roux was producing his report, the two AEB engineers started to investigate heavy water in the first applied research undertaken by full-time AEB staff. The AEB had come to believe that it

[1] A. R. Newby Fraser, *Chain Reaction: Twenty Years of Nuclear Research and Development in South Africa* (Pretoria: Atomic Energy Board, 1979). Although this book was written with the express purpose of hiding the existence of a nuclear explosive program and suffers from the biases implicit in a near-official history of the program, it still contains much useful and otherwise unavailable information about the early history of the South African nuclear program.
[2] Johann Viljoen and Deon Smith, *The Birth, Life, and Death of South Africa's Nuclear Weapons Program*, Manuscript commissioned by the Institute for Science and International Security, 1999, unpublished.
[3] Daniel M. Kemp, Pieter J. Bredell, A. Albert Ponelis, and Einar Ronander, "Uranium Enrichment Technologies in South Africa," International Symposium on Isotope Separation and Chemical Exchange Uranium Enrichment, Tokyo Institute of Technology, October 29-November 1, 1990, Tokyo, Japan.

could economically produce heavy water. After six months of study in South Africa, the two AEB engineers spent 18 months working intensively with the Heavy Water Group at the Harwell Atomic Energy Research Establishment in Britain. They also visited heavy water plants in Germany.

National Plan

Roux spent about a year and a half developing his draft plan for a South African nuclear research and development program. After visiting ten countries, interviewing hundreds of experts, and seeking the views of South African governmental, mining, and industrial authorities, he presented his plan to the AEB in June 1958.

Roux's ambitious plan recommended a dramatic shift in South African industry from a "repair and maintenance" industry to a highly sophisticated industry capable of manufacturing nuclear reactors.[4] The plan's objectives included enabling South Africa to derive additional benefit from its position as a major uranium producer and permitting it to make significant contributions to nuclear energy. Roux was also reportedly aware of the need for a program that could keep South Africa's best scientists and engineers from immigrating to other countries.

Roux's plan recommended the pursuit of four major avenues:

- Development of the production and refining of nuclear materials, including heavy water and thorium, but especially uranium. The materials effort was to include the improvement of uranium mining and extraction methods and for the study of further steps in uranium processing with the goal of improving the uranium's worth;
- Investigation into the application of nuclear energy for electricity production, including the development of a power reactor concept appropriate to South Africa;
- Research into the uses of isotopes and radiation in medicine, agriculture, commerce, industry, and research;
- On-going research fundamental to a nuclear energy program.

The goal of this plan was to set up a comprehensive nuclear energy program that would allow South Africa to "become as independent of foreign influence concerning its needs in this area, as possible."[5] A major aspect of the plan was to provide financial and other assistance for the training of researchers in nuclear energy, both in South Africa and abroad.

In September 1959, the then Minister of Mines Jan de Klerk announced that the Cabinet had approved the proposed nuclear research and development program and its relative independence. Interestingly, Jan was the father of F.W. de Klerk, who would become President in 1989 and end the nuclear weapons program and accelerate the process that led to major downsizing of South Africa's nuclear energy programs.

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[4] *Chain Reaction*, op. cit., p. 40.

[5] *Draft Speech of Prime Minister P.W. Botha for the Opening of Kentron Circle,* File No. 13/2/8/C, May 4, 1981, in Afrikaans, Original in Nic von Wielligh and Lydia von Wielligh-Steyn, *Die Bom* (Pretoria: Litera Publikasies, 2014), Appendix, translated by Schreiber Translations, Inc. for Institute for Science and International Security, July 7, 2015. See also their English version, *The Bomb* (Pretoria, Litera Publications, 2015).

Roux should be considered the father of nuclear development in South Africa. Shortly before his draft nuclear plan was approved, he became the Research Director of the AEB. Later his title was changed to Director General. In 1967, he was appointed Chairman (later renamed President) of the AEB, a position until then reserved for the Minister of Mines.

Pelindaba

The AEB needed a more suitable site to carry out its program than its office suite in Pretoria. A new site would need to be relatively isolated to permit the safe operation of reactors, but also close to major population centers, universities, and industries. The site would also need a major source of water, adequate electricity supply, and good access to roads.

The AEB picked a site south of the Hartbessspoort Irrigation Dam and on the east side of the Crocodile River, located about 30 kilometers west of Pretoria. The site was acquired in the early 1960s and construction of the National Nuclear Research Center started shortly thereafter. The first buildings, including the administration building, the chemistry building, and the Van de Graaff building, were occupied starting in late 1963.[6]

A prospective name for the site was selected in a similar way as other major nuclear centers in the world, namely by referring to the town or village serving the establishment.[7] Although no settlement was located near the site, the scientists learned of former plans to create the township of Pelindaba right down the road.

Before picking Pelindaba as a name, however, the scientists decided to research its meaning. They learned that Pelindaba was the conjunction of two indigenous African words, "Pelile" meaning "finished" and "Indaba" meaning "a council." Put together, they imply the end of discussion. "That's it," Roux reacted, "We have talked enough; now we get on with the job."[8]

The job was formidable. To implement its nuclear research and development program, the AEB needed to recruit and train a staff, obtain significant amounts of nuclear and nuclear-related information, construct research and support facilities at Pelindaba, and procure and install a wide range of equipment, including research reactors and other complex facilities. Toward these objectives, South Africa depended extensively on its civil nuclear cooperation agreements with the United States and Britain.

Perhaps the most pressing need of the new program was qualified scientists. Starting immediately after the program received government approval, the AEB recruited South African scientists with proven ability and sent them for overseas training in nuclear science and technology in the United States and Europe. In the late 1950s and early 1960s, eleven South Africans, including those who became the initial Research Division Heads at the AEB, participated in the US Argonne International School of Nuclear Science and Engineering and its successor organization.[9] A seven-

[6] *Chain Reaction*, op. cit., p. 52.
[7] *Chain Reaction*, op. cit., p. 49.
[8] *Chain Reaction*, op. cit., p. 50.
[9] Department of Political and Security Council Affairs, UN Center for Disarmament, Report of the Secretary-General, *South Africa's Plan and Capability in the Nuclear Field* (New York: United Nations, 1981), p. 15; and *Chain Reaction*, op. cit., p. 62.

man team was sent concurrently for training at Oak Ridge National Laboratory. Upon their return, the Division Heads developed the organization of their divisions and the recruitment of scientific personnel, including sending their new employees for training overseas.

A substantial number of nuclear scientists who set in motion Pelindaba's program were provided with highly specialized training at universities, research institutions, and industrial organizations in Britain, Canada, France, the Netherlands, Scandinavian countries, the United States, and West Germany.[10] Through 1970 about 90 South African scientists were trained at Argonne National Laboratory, Oak Ridge National Laboratory, and elsewhere in the United States.[11]

In 1977 Roux specifically acknowledged the help of the United States at a seminar in Johannesburg. He told the audience, "We can ascribe our degree of advancement today in large measure to the training and assistance so willingly provided by the USA during the early years of our nuclear program, when several of the Western world's nuclear nations cooperated in initiating our scientists and engineers into nuclear science."[12]

The program also needed extensive amounts of technical information, and South Africa's nuclear agreements for cooperation with Britain and the United States gave South Africa access to considerable amounts of it. For example, the agreement with Britain provided South Africa with information on reactors, specifications and properties of reactor materials, reactor components, reactor physics, reactor engineering, environmental and safety considerations, and the production of heavy water.[13]

Although the information obtained under these bilateral agreements is unclassified, South Africa also sought sensitive information. Early on, Roux was aware of the difficulty of obtaining sufficient information for his program. According to his draft plan presented to the AEB in 1958, "some of the most important developments in the field of nuclear power, particularly in the more highly developed countries such as the US and Britain, have so many military implications that no reference would be found to them in the unclassified literature."[14] Yet, he wrote of the key role of South African cooperation with Western countries, particularly in research areas, in obtaining information: "Any [research] contribution, however small, that can be made, will assist greatly in obtaining secret information from other countries which they would not otherwise be prepared to divulge. We have already experienced this in the little work we have done in connection with the production of heavy water."[15] Program personnel would obtain secret information about nuclear explosives, European gas centrifuges, and nuclear re-entry vehicles for ballistic missiles.

Even before the Pelindaba site was selected, the AEB ordered a research reactor from the United States. The reactor, a type called the Oak Ridge Reactor (ORR), had the power of about seven

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[10] *Chain Reaction*, op. cit., p. 8.
[11] Congressional Research Service, Library of Congress, *Nuclear Proliferation Factbook* (Washington, D.C.: US Government Printing Office, 1977), pp. 317 and 319.
[12] Jim Hoagland, "South Africa, With US Aid, Near A-Bomb," *The Washington Post*, February 16, 1977.
[13] *Chain Reaction*, op. cit., p. 8.
[14] Renfrew Christie in *South Africa's History*, at Nuclear History Program, Fourth International Conference, Sofia-Antipolis, Nice, France, June 23-27, 1993; citing A. J. A. Roux, *Proposed Atomic Energy Research and Development Programme for South Africa* (Pretoria: Council for Scientific and Industrial Research (CSIR), 1958), p. 68.
[15] *Proposed Atomic Energy Research and Development Programme*, op. cit., p. 69.

megawatts-thermal (MWth). Its power, however, could be increased with relatively minor adjustments to 20 MWth. The United States also agreed to provide weapons-grade uranium (WGU) fuel, and along with Britain agreed to receive the irradiated fuel for reprocessing. The reactor, which was named Safari-1, went critical in 1965.

At the 1977 seminar in Johannesburg, Roux also acknowledged that "much of the nuclear equipment installed at Pelindaba is of American origin, while even our nuclear philosophy, although unmistakably our own, owes much to the thinking of [American nuclear scientists]."[16]

By the mid-1960s, Pelindaba had a wide-range of facilities and equipment to satisfy the ambitions of its newly-trained nuclear research scientists. According to Wynand de Villiers, who by 1967 was head of the Director of the Reactor Development Division and later succeeded Roux as the President of the AEB, the "R&D program had been firmly established." The two most ambitious programs were an indigenous nuclear reactor and a uranium enrichment program.

Uranium Enrichment

By 1961, when the senior AEB scientists had returned from their overseas training, the future of enriching uranium locally was a frequent topic of debate.[17] A major purpose of the research and development program was to develop methods to process uranium into a form more advanced than yellow cake; enriched uranium was the ultimate goal of the AEB. The AEB believed that enriching domestically produced uranium could be lucrative financially. Another, related motivation was a South African "can-do" mentality that did not want to be denied high-tech nuclear projects. Others suspect that the leaders of South Africa also saw enrichment as a path to nuclear weapons.

The scientists realized that building a gaseous diffusion plant would require an enormous capital investment and access to highly secret information; thus, it would be beyond South Africa's financial and scientific capabilities. Building gas centrifuges, which were then under development in Germany, the Netherlands, and Britain, was similarly beyond South Africa's reach at that time. Roux challenged his colleagues to find an enrichment method that would be substantially smaller than the giant US gaseous diffusion plants and not require the extreme demands of gas centrifuges with their problems of vibration, sealing, and high-speed bearings.[18]

Wally L. Grant, then Chief Engineer of the AEB who would later became Director General of the AEB, put forward a proposal in 1961 to evaluate the use of the vortex tube principle for the separation of uranium isotopes. The separating element is best likened to a "stationary walled centrifuge" based on the aerodynamic principle. As eventually developed, a gaseous mixture of uranium hexafluoride and the carrier gas hydrogen enters the sides of the separating element at high speed and spins inside the cylinder, causing separation of the uranium isotopes.

The South African scientists were well aware of the politically sensitive nature of uranium enrichment, which would likely have been perceived as a potential sign that South Africa was

[16] "South Africa, With US Aid," op. cit.
[17] *Chain Reaction*, op. cit., p. 95.
[18] *Chain Reaction*, op. cit., p. 95.

seeking nuclear weapons.[19] As a result, the AEB went to great lengths to keep the existence of the project secret. The project was code-named the "Gas Cooling Project" and was divided into three separate components, from which came another code-name the "XYZ project."

The project was first housed in central Pretoria in a nondescript warehouse. Experimental equipment was assembled and operated in the rear portion "away from prying eyes," and the front half comprised the workshop, which, "any casual enquirers were told, was manufacturing scientific equipment."[20] Later, the experimental work required stricter security and was transferred to the equally unobtrusive Shamrock Building in Pretoria before finally moving to Pelindaba.

The first separation of uranium occurred in November 1965, just in time for a visit by Prime Minister H. F. Verwoerd, who was a staunch supporter of the project. By 1967 the scientists had demonstrated the feasibility of the vortex-tube enrichment method in the laboratory. Although several problems remained, the AEB recommended that a pilot plant be constructed. Because of the cost involved in such an endeavor, the government undertook a lengthy, independent review of the project. In February 1969, the government approved the building of a pilot plant and additional research funds for the next five-year period. The plant, called the Y Plant, would be designed to make weapons-grade uranium, not just low enriched uranium.

Pelinduna

According to de Villiers, another key goal of the initial research and development program at Pelindaba was the indigenous construction of a power reactor. By choosing a design specifically tailored to suit South Africa's conditions, the AEB believed it could provide a central theme to the divergent research interests of the various disciplines practiced at Pelindaba and further stimulate the research groups to become familiar with nuclear science in practice. By doing so, the AEB hoped to build a center of excellence in nuclear science.[21]

In 1962 the AEB decided to pursue a natural uranium, heavy water moderated, sodium-cooled power reactor, which became known as Pelinduna (Pelindaba Deuterium Uranium Sodium (Na)). The same concept had been examined by the United States but not pursued. However, soon after Grant, the AEB's Chief Engineer, returned home from 17 months of overseas training in the United States, he proposed that the AEB pursue this reactor concept based on pressure tubes. He reasoned that this concept could significantly reduce power generating costs because the use of sodium as a coolant would transfer heat better and eliminate the need to build expensive pressure vessels, which were beyond the capability of South African industries to produce. Overall, the approach appealed to the AEB as an advanced reactor concept that South African industries could produce. Moreover, such a reactor project would encourage South African industries to improve their ability to work with nuclear-grade materials and their specialized manufacturing techniques.

The first step was to conduct a series of theoretical calculations describing the reactor system. The first calculations were done by hand, a time-consuming process with limited usefulness. Next, the

[19] *Chain Reaction*, op. cit., p. 96.
[20] *Chain Reaction*, op. cit., p. 97.
[21] *Chain Reaction*, op. cit., p. 116.

Council for Scientific and Industrial Research computer facilities were used for the calculations, until the AEB built its own computer center at Pelindaba.

To obtain the first experimental data, Grant's team built a subcritical model of the reactor system. These data improved the computer calculations, enabling good agreement between measured and calculated values and the development of more sophisticated mathematical models of the reactor system.

However, more data were needed. The next step was to build a critical facility to check operational values, such as temperature coefficients, power distribution, and control-rod values. Because of the high cost of such a facility, the AEB decided to use two percent enriched uranium fuel instead of natural uranium fuel. In this way, the reactor would need only four fuel elements instead of 19 elements, enabling a considerably smaller and cheaper facility. The critical assembly, called Pelinduna 0/4, reached criticality in November 1967. It depended on a US supply of 606 kilograms of two percent enriched uranium and 5.4 tonnes of heavy water.[22] The operation of the criticality facility marked a major milestone in the development of reactor physics in South Africa.

Meanwhile, engineers were designing a prototype reactor and a full-scale power station. The prototype reactor was envisioned to be 30 MWth and use slightly enriched uranium fuel. A by-product of this reactor would have been plutonium. Although no significant work appears to have been done on creating a capability to separate plutonium at this time, South African nuclear engineers may have been thinking about such a capability. Later, in the late 1970s, the AEB would start to develop it.

Overall, by 1966 Pelindaba's scientists and engineers had solved many, although by no means all, of the problems in designing and building the Pelinduna power reactor. However, its most outstanding advantage, namely its high specific power, also meant that an economical reactor would need to produce about 1,000 megawatts of electricity using natural uranium fuel. This was a problem for the South African designers. In the mid-1960s, South Africa seemed unlikely to be able to integrate such a large unit into its electrical generating system until the 1980s. Although the power of an individual reactor could have been reduced considerably by using one to two percent enriched fuel, South Africa did not then possess enrichment facilities and the envisioned pilot enrichment plant would have been too small, requiring import of enriched uranium. However, the goal of the project was to develop a reactor independent of overseas fuel suppliers.[23] The cost of the project was also becoming an issue, as the AEB realized that electrical power production by a heavy water moderated reactor would be more costly than by a light water reactor.

Another significant factor was the "phenomenal success of the uranium enrichment project."[24] The two projects had reached the point almost simultaneously where each required the construction of an expensive pilot plant. In the late 1960s, South Africa was unable to afford the construction of both plants. An enrichment plant seemed more able to deliver on the goal of increasing the worth

[22] *The Export Reorganization Act-1975*, Hearings before the Committee on Government Operations, US Senate, 94th Congress, April 21, 30, and May 1, 1975, p. 102.
[23] *Chain Reaction*, op. cit., p. 124.
[24] *Chain Reaction*, op. cit., pp. 35 and 124.

of South Africa's plentiful uranium supply. As a result, the AEB cancelled the Pelinduna project in 1967.

By coincidence, the name Pelinduna had a far different nontechnical and indigenous interpretation that ended up being prescient. From "Pelile Induna," the meaning is "the chief is finished, the chief is dead."[25]

Although the Pelinduna project was terminated in 1967, the critical facility continued to operate for a few more years. Before the enriched uranium was returned to the United States in 1971, the slightly irradiated fuel was sent to Britain for reprocessing.[26]

Needless to say, many problems remained unsolved when the Pelinduna project ended, but South Africa learned a great deal about reactor physics, nuclear reactors, and the manufacture of critical facilities. That foundation would be important in the nuclear explosive program and a later reactor project whose main purpose was the production of plutonium and tritium for nuclear weapons.

Peaceful Nuclear Explosives

With the end of the Pelinduna project, South Africa decided secretly to use the expertise gained by the Reactor Development Division for the pursuit of nuclear explosives. In 1969 the AEB appointed an internal committee to investigate the economic and technical requirements for nuclear explosives for civil applications. Referred to as peaceful nuclear explosives (PNEs), these nuclear devices were being pursued by the United States and the Soviet Union for a variety of civil purposes, such as creating harbors, mines, mountain passes, and gas exploitation. The Nuclear Non-Proliferation Treaty (NPT) which entered into force in 1968 allowed for non-nuclear weapons states to use PNEs under certain, highly constrained conditions. Thus, one motivation for South Africa's own PNE program would have been to match, albeit on a smaller scale, work that was being done then by the major nuclear powers.

The decision to develop PNEs combined the knowledge and experience gained in the Pelinduna reactor project with the potential offered by enriching uranium sufficiently for use in nuclear explosives.[27] This project also had the advantage of providing a means to retain the specialists in the reactor development division. Moreover, according to Tielman de Waal, former managing director of Armscor, in the 1960s "the idea to look into the feasibility of developing nuclear explosives for peaceful applications emerged as a scientific endeavor out of a technological 'can-do' mentality."[28]

[25] *Chain Reaction*, op. cit., p. 125.
[26] *The Export Reorganization Act, 1975*, op. cit., p. 102.
[27] N. von Wielligh and N. E. Whiting, "Experience of an Ex (de facto) Nuclear Weapon State with the Application of Post-Iraq Safeguards," *International Nuclear Safeguards 1994: Vision for the Future* (Vienna: International Atomic Energy Agency, 1994).
[28] Tielman de Waal, "South Africa's Past Nuclear Program," Paper presented at a press briefing in South Africa, April 6, 1995.

South Africa's interest in PNEs was not secret at first. The AEB reported in its 1969 annual report that it was researching the use of nuclear explosives for earth-moving.[29] The CIA stated, based on open literature, that during 1968 to 1969 at least one South African scientist was in the United States studying the application of PNEs.[30] This was likely Johann V. Retief, an AEB engineer in the PNE program who published in 1971 a Stanford University technical report, *Use of Nuclear Explosives for Water Resources Development in Arid Regions*.[31] In 1970 the Johannesburg *Star* reported the South African government was "keeping abreast of the latest developments in the use of nuclear explosives in civil engineering projects."[32]

However, the bulk of the AEB's work on nuclear explosives was secret, particularly its plans to develop and build them. Moreover, South Africa intended to explore developing a wide variety of types of nuclear explosives, which involved highly classified work. In its secret 1970 report, the internal AEB committee recommended the development of different types of peaceful nuclear devices:

- Gun- and implosion-type fission devices, referred to as type A. This category included also a boosted fission device called A* which involved a lithium-6, deuterium, tritium tablet at the center of the type A device;[33]
- A thermonuclear device with a fission detonator, called type B.

In March 1971, the Minister of Mines approved the first research and development work on the type A devices. Two years later, the Minister also approved theoretical work on type B devices.

Only a Peaceful Program in the 1950s and 1960s?

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[29] Barbara Rogers and Zdenek Červenka, *The Nuclear Axis* (New York: Times Books, 1978), p. 207, citing *Japan Times*, August 8, 1970.

[30] Director of Central Intelligence, *Trends in South Africa's Nuclear Security Policies and Programs: National Intelligence Estimate*, October 5, 1984, declassified version, p. 8.

[31] http://www.osti.gov/scitech/biblio/4716026-use-nuclear-explosives-water-resources-development-arid-regions See also Johann V. Retief's 1971 AEB report (in Afrikaans) *Seismic damage and the economy of the use of nuclear explosions*. Abstract:

> One of the most important restrictions on the constructive use of nuclear explosions is the damage caused to buildings and structures situated at great distances around the explosion as a result of the seismic waves generated. The effect of seismic damage on the economy of the use of nuclear explosions in general is investigated. Results of the investigation are applied to conditions in South Africa. Various phases in the mechanism of seismic damage are discussed, namely generation by the explosion, propagation by the earth's crust, amplification by the geological structure of foundations and damage to structures. Predictions are made of reaction spectra as a function of explosive force, explosive depth, placing material and distance to the observation point. The nature, extent and cost of seismic damage as a function of distance and population of urban centers and density of rural population are stimulated. Information on population distribution in South Africa are analyzed, and areas where explosions can be detonated without serious seismic damage are indicated with the aid of predictions of the cost of seismic damage. Charges with an explosive force of 10 to 100 kt can be detonated over large areas in South Africa, but bigger charges (1000 kt) are restricted to the sparsely populated areas of the Northern and Northwestern Cape.
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> See http://www.osti.gov/scitech/biblio/4395627-seismic-damage-economy-use-nuclear-explosions

[32] Quoted in *The Nuclear Axis*, op. cit., pp. 207-8, citing *The Star* (Johannesburg), January 17, 1970.

[33] The information about the lithium, deuterium, tritium tablet is from "A Brief Overview of the Development of Nuclear Explosive Devices in South Africa," by Nic von Wielligh, May 1993.

Despite repeated denials by past and current South African nuclear officials, many outside experts and African National Congress (ANC) officials rejected the proposition that South Africa's nuclear program was built only as a civil, scientific nuclear program.[34] In particular, they rejected that in the late 1960s and early 1970s the South Africa leadership intended to build only PNEs for civil applications.

Officially, the key indicator of military intentions is the high level government decision to weaponize the nuclear devices, which later will be shown to date to 1977 and 1978; however, it is acknowledged that defense ministry interest in the bomb happened earlier. The political scientist Peter Liberman, based on an interview with Grant, established that "defense people" were involved in 1975.[35] A recently released official document confirms that participation was initiated by then Defense Minister P.W. Botha.[36] He said that "as far back as 1975, I, as Minister of Defense, initiated dialogues related to the possibilities of bringing about nuclear weapons" in South Africa."[37]

There is also some evidence that by the end of 1973, the leadership of the AEB was starting to refer in private to nuclear weapons. In 1973 apparently as part of a process of recruiting a South African physicist to come work at Pelindaba, Louw Alberts, then Vice President of the AEB, told him explicitly that South Africa had started a nuclear weapons program focused on developing gun-type, implosion-type, and thermonuclear weapons.[38] While working at Pelindaba from 1974-1977, including contributing to the work on the nuclear devices, he was told consistently that this effort was a nuclear weapons program. He was also told of a budding nuclear strategy that South Africa would use the nuclear option when facing insurmountable odds requiring an act of supreme heroism, referred to as Kragdardigheit, in Afrikaans.

Although a nuclear weapons motivation can be established as far back as the early to mid-1970s, what about the 1960s? Documentary evidence focusing on nuclear weapons prior to the early 1970s is currently lacking and almost all of the participants are no longer living, making confirmation difficult. However, critics of official declarations are skeptical that the South African government would have supported the nuclear program so vigorously in the late 1950s and 1960s for only a civil rationale, particularly given South Africa's growing international isolation. Instead, critics believe that another fundamental goal of the nuclear program was also acquiring the capability to make nuclear weapons. To these critics, the AEB was putting in place two paths to the bomb, one based on plutonium and the other based on weapons-grade uranium. Faced with budget constraints, the uranium enrichment pathway was selected as the way to produce nuclear explosive material.

Critics have presented as evidence statements made by South African officials during the 1960s. Below are listed several of these statements:

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[34] See for example, Christie, *South Africa's History*, op. cit.; *The Nuclear Axis*, op. cit.; or David Fig, "The Road to Koeberg: International Support for the Establishment of the South African Nuclear Industry," Africa Seminar, University of Cape Town, September 15, 1993.
[35] Peter Liberman, "The Rise and Fall of the South African Bomb," *International Security*, Vol. 26, No. 2, Fall 2001, p 52.
[36] *Draft Speech for the Opening of Kentron Circle,* op. cit.
[37] *Draft Speech for the Opening of Kentron Circle,* op. cit.
[38] Interview of South African physicist by one of authors.

- Roux said in 1960 that South Africa was capable of producing its own nuclear explosives if it was "prepared to isolate the best brains in the country and give them all the funds they needed."[39] Roux repeated his 1960 statement in 1962, but added, "It is my sincere hope that we shall never be called upon to engage in this activity."[40]

- Prime Minister Verwoerd stated during the inauguration ceremony for the Safari I reactor in 1965, that with respect to nuclear materials: "It is the duty of South Africa to consider not only the military uses of the material, but also to do all in its power to direct its uses to peaceful purposes."[41]

- Grant, speaking for the AEB in 1965, said: "On several occasions the Director-General [Roux] has indicated that South African scientists, in common with those from most developed countries, do have the technical ability to develop nuclear weapon," but he denied that any military research was being done in that area.[42]

- In 1965, Andries Visser, a member of the AEB, said: "We should have the bomb to prevent aggression from loud-mouthed Afro-Asiatic states…money is no problem. The capital for such a bomb is available."[43]

- General H. J. Martin, the Army Chief of Staff, stated in the December 22, 1968 edition of the *London Sunday Express* that South Africa was ready to make its own nuclear weapon.[44]

All of these statements are ambiguous about any underlying nuclear weapons purpose in the 1960s. However, these quotes show that the senior political and nuclear leadership of South Africa was well aware of the full potential of its nuclear program. This general awareness is confirmed by the extensive work done by Liberman.[45] He observed, "The South African leadership knew that a successful PNE program would generate a de facto nuclear weapons capability."[46] One has to conclude that the South African leaders of the nuclear program and the senior leadership also knew that a nuclear weapons capability depended on having a plutonium or enriched uranium pathway. They must have realized that the creation of such a pathway would take many years, far longer than the time needed to master the building of a relatively crude type A nuclear explosive device.

So, with regard to the 1960s, we are left with a series of possibilities. Three cases can be considered which vary based on the intentions of the nuclear and political leadership:

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[39] Quoted in *Nuclear Axis*, op. cit., p. 211, op. cit. citing *Southern Africa*, March 5, 1960.
[40] Quoted in *Nuclear Axis*, op. cit., p. 211, op. cit. citing *Southern Africa*, January 5, 1962.
[41] Quoted in J. E. Spence, "The Republic of South Africa: Proliferation and the Politics of an 'Outward Movement," in Robert M. Lawrence and Joel Larus, eds. *Nuclear Proliferation Phase II* (Lawrence, Kansas: University Press of Kansas, 1974.
[42] Quoted in *Nuclear Axis*, op. cit., p. 211, citing *Cape Times*, February 19, 1965.
[43] Quoted in "The Republic of South Africa," op. cit.
[44] Cited in *Nuclear Axis*, op. cit., p. 212
[45] "The Rise and Fall," op cit., pp. 50-53.
[46] "The Rise and Fall," op cit., pp. 50-53.

1) The first case is that the program had no explicit nuclear weapons component until the mid-to-late 1970s, and the founders, including the political leadership, had no intention of building nuclear weapons. In this case, the leaders wanted a large nuclear program for reasons of prestige, energy security, and adding value to South Africa's large uranium resources. The extensive support of Prime Ministers Verwoerd and B.J. Vorster of the enrichment program during the 1960s would have been without national security motivations. Even the PNE program would have to be interpreted as one of only prestige, scientific prowess, and civil applications. The South African government has said essentially that this case is the true state of affairs.

2) The second case is that through the 1960s the political leadership wanted to develop the option to build nuclear weapons, but the scientists, perhaps including Roux, did not want to operationalize this capability or did not see nuclear weapons as necessary. The military was not interested in any case. In this scenario, the AEB would be committed to developing the wherewithal to produce weapons-grade uranium or an indigenous reactor that could make plutonium, but the scientists would intend to use these facilities and materials for civilian purposes. This case is at least plausible. Based on interviews with participants in the nuclear weapons program, many AEB scientists were against acquiring nuclear weapons. While many scientists or engineers may have tolerated working on PNEs, they would have balked at working on a program that contemplated building nuclear weapons. Moreover, the South Africa nuclear program depended critically on foreign assistance. Thus, even if South Africa intended to obtain nuclear weapons, it would benefit from keeping this ambition absolutely secret, or else risk undermining the support of Western suppliers. Even in the 1960s, Western countries were unlikely to support giving South Africa major nuclear assistance if they believed that the AEB was putting together a program to build nuclear weapons. Even a PNE program would need to be pursued in secret to avoid a backlash as more countries lost interest in PNEs and increasingly viewed them as thinly-disguised nuclear weapons. However, the political leadership would have known that once the AEB developed the capability to make nuclear explosive materials and nuclear explosives, the government could order the AEB or another agency to build nuclear weapons. Given that the AEB was a well-funded, centralized, and secretive organization, the government would have believed it could shift the purpose of the nuclear program relatively easily and quickly. From the political leadership's perspective, South Africa would have lost little if the scientific leadership viewed the program as civil only.

3) The third case is that both the political and nuclear leaders intended from the start of the program to obtain nuclear weapons in addition to a large civil nuclear program. In this case, strategic considerations of energy security and national security were at the heart of the program.

ANC officials have supported the third case and, to a lesser extent, the second one. The official declarations center on the first case, while sometimes acknowledging the possibility of the second one.

On balance, neither the first nor third case seems compelling. The first case requires a belief that the nuclear leaders were remarkably naïve during the height of the Cold War and amidst rising

international isolation. The third case suggests a level of organization and effort that would have been expected to emerge in oral statements, intelligence records, or South African historical documents.

Case two would imply a level of deception on the part of South Africa's nuclear and government leaders but it remains the most plausible scenario. It also recognizes Roux' remarkable accomplishments and vision for South Africa. As pointed out by Johann Viljoen, who joined the nuclear weapons program in the 1970s and remained until the end, the second case recognizes Roux as someone who wanted South Africa to be seen as a first world power, who could have had the idea of a nuclear weapon in the back of his mind, perhaps even viewed such weapons as an exciting possibility for the future.[47] However, he also likely did not want to make the decision to build the bomb. Granted, the AEB was going to develop a nuclear weapons capability. For Roux, the question to the national leadership would have been: do you want it? Until about 1975, the military was simply not that interested and the political leadership felt no pressure or need to decide to build nuclear weapons.

Case two also more clearly tracks the international perceptions of South Africa's efforts to achieve a nuclear weapons capability. This perception includes the growing view in the late 1960s and early 1970s that PNEs should be viewed as nuclear weapons, despite not strictly being so in the South African military sense, which prizes deliverability, reliability, and an ability to destroy a target.

[47] Interview of Viljoen with one of the authors.