

SOUTH AFRICA'S NUCLEAR WEAPON PROGRAM: LESSONS FOR U.S. NONPROLIFERATION POLICY

by Frank V. Pabian

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President de Klerk's surprising announcement on March 24, 1993, that South Africa had dismantled six indigenously produced, gun-assembled nuclear weapons beginning in early 1990 was a welcome sign of transparency in what had formerly been an extremely covert, albeit highly-suspected, nuclear program. The announcement, while both significant and unprecedented, was somewhat anticlimactic in that South Africa had already acceded to the nuclear Non-Proliferation Treaty (NPT) on July 10, 1991, and had completed signature and the entry into force of its International Atomic Energy Agency (IAEA) safeguards agreement on September 16, 1991. Nonetheless, the additional transparency resulting from the announcement provided a greater basis for confidence in South Africa's newly-found nonproliferation commitment. Previously, members of the African National Congress (ANC) and oth-

ers had argued that South Africa's NPT accession alone (particularly in view of the Iraqi and North Korean cases) was insufficient.¹

In his belated announcement, President de Klerk admitted that South Africa's nuclear weapon era spanned the period from November 1979 (when the first prototype nuclear explosive device was completed) to February 1990 (when he gave the order to begin dismantlement of all of South Africa's nuclear explosive devices). De Klerk emphasized that all six of the devices (and an incomplete seventh) were dismantled just prior to South Africa's accession to the NPT. Figure 1 (see page 11) provides a time line of key activities of South Africa's nuclear weapon program, along with the external factors that had a direct bearing on the program.

Unlike post-Gulf War revelations about Iraq's nuclear weapon program, the scope, size, and sophistication of South Africa's nuclear

weapon program cannot be viewed as having been a major shock to the U.S. nonproliferation intelligence and policy communities. Among the more telling indicators had been that South Africa remained entirely outside the NPT umbrella during its nuclear weapon acquisition process. Further, its indigenous capability to produce and stockpile highly-enriched uranium (HEU) had been public knowledge since the late 1970s.² The 1977 exposure of South African preparations for an underground nuclear test in the Kalahari Desert removed most, if not all, doubts about South Africa's intentions and capabilities.³ It was less a question of *would* they, or *could* they, than to what extent *did* they.

Because South Africa is the only nuclear weapon state to have forsworn nuclear weapons after having actually crossed the threshold, it is useful to review the factors that led to the inception, maintenance, and eventual renunciation of its

nuclear program and, more importantly, to review U.S. policies that encouraged or discouraged this program.

To this end, this article reviews the evolution of U.S.-South African relations through successive U.S. administrations; assesses the effectiveness of U.S. efforts to use nuclear export controls as a nonproliferation tool in South Africa; and concludes with the lessons and implications for U.S. nonproliferation policy.

THE EVOLUTION OF U.S.-SOUTH AFRICAN NUCLEAR RELATIONS

U.S. nuclear cooperation with South Africa began in the closing days of World War II with the search for uranium for the then-secret "Manhattan Project." As a result of the favorable findings of significant low-grade uranium ores in association with Witwatersrand district gold deposits, the United States and South Africa jointly developed uranium extraction processes for those ores. In 1950, to secure guaranteed supplies of natural uranium for their expanding nuclear weapon programs, the United States and United Kingdom signed a purchasing agreement with South Africa that provided the impetus for South Africa's development into one of the world's major uranium producers.⁴ In 1957, a U.S. agreement for nuclear cooperation with South Africa was negotiated under the Atomic Energy Act of 1954; this agreement was amended three times. Under this agreement, as amended, the United States provided the nuclear research reactor SAFARI-1,⁵ trained South African scientists, and supplied enriched uranium as fuel for the SAFARI-1 reactor up until 1976. The

reactor and its fuel have remained under a trilateral safeguards transfer agreement (INFCIRC/70) between South Africa, the United States, and the IAEA since its commissioning in 1965. In late 1976, the founder of the South African nuclear program, Dr. A. J. Roux, declared:

We can ascribe our degree of advancement today in large measure to the training and assistance so willingly provided by the United States of America during the early years of our programme.⁶

Over the past 25 years, the cornerstone of U.S. nuclear nonproliferation policy has been an unequivocal support for the NPT. The NPT, with its associated IAEA full-scope safeguards, and the United States' own Nuclear Non-Proliferation Act (NNPA) remain today the central legal instruments for advancing U.S. nonproliferation interests.⁷ The desire to obtain South Africa's accession to the NPT soon became a major priority.⁸

It has been argued that as a result of South Africa's perception of the importance of the NPT to the United States during the early and mid-1970s, "the South Africans steadily raised the 'price' to the United States for adherence, to a level unacceptable to overall US policies."⁹ Furthermore, during the Carter administration (with its push for revitalization of the NPT regime), it appeared to the United States that, "the only advantage for South Africa in threatening a nuclear weapon program would be as a bargaining chip to elicit US help."¹⁰ True or not, it is useful to consider the perception of the role of such a bargaining chip in the bilateral relations between the United States and other potential proliferant nations, whether or not

such nations are NPT parties (e.g., North Korea, Brazil, and Argentina). One other result of South Africa's refusal to sign the NPT was that direct U.S. involvement in South Africa's nuclear program—and any commensurate leverage it might have brought with it—was largely nonexistent after 1976.

The South Africans now claim that they first became interested in nuclear explosives as a result of efforts by the United States to promote the peaceful uses of nuclear explosives via the U.S. Plowshare Program. Once sufficient quantities of enriched uranium appeared certain, and following "a very modest investigation" of Plowshare-type applications (limited only to literature studies), the South African Minister of Mines authorized a peaceful applications program in 1971. In early 1974, a report was prepared that concluded that the development of a nuclear explosive device for peaceful uses was feasible. South African Prime Minister John Vorster approved the program, and funds for the development of the Kalahari Nuclear Test Site were allocated. The South Africans admit that this "peaceful" program was, nonetheless, treated as top secret, particularly so following the adverse world reaction to the Indian "peaceful" test in May 1974.¹¹

Isolation Instituted: The Ford Administration (1974-77)

As the 1970s progressed, there was a marked deterioration in the security situation in the southern African region (and with it increased Afrikaner angst), which the South Africans claim forced them to redirect their clandestine "peaceful" nuclear program to the development

of weapons. The increasing instability looming on its borders was largely brought about by: 1) Portugal's withdrawal from its African colonies (Mozambique and Angola) and the uncertainties about the true intentions of the Warsaw Pact countries that moved in to fill the power vacuum; 2) the end to white rule in Zimbabwe (formerly Rhodesia); and 3) black African nationalist pressure on Namibia (then-South African-controlled South West Africa). Actions by the Soviet Union were particularly worrisome because of that country's hegemonistic policies in southern Africa, and its willingness to use surrogates (i.e., Cubans in Angola).

By 1976, a number of other political/military factors did not bode well for South Africa's security future. Prior to that time, South Africa had viewed itself as a partner with the West in "the bulwark against Communism" in Africa. In 1975, South Africa, with U.S. covert support, intervened militarily against the Soviet-backed *Movimento Popular de Libertacao de Angola* (MPLA) in the Angolan civil war. However, once this clandestine alliance was discovered and made public, the United States (due in part to the Congressionally-mandated Clark Amendment preventing military assistance to any party in Angola) dissociated itself from the whole operation.¹² It was also in 1975 that the United Kingdom terminated the 1955 Simon's Town Agreement for bilateral South Atlantic naval defense.¹³

These perceived betrayals by both the United States and the United Kingdom, at least when viewed from the perspective of then-Defense Minister P. W. Botha, helped solidify the so-called "Jaagermental-

ity" and the resulting "total strategy" to defend against the feared "total onslaught" that he spoke about after he became Prime Minister in September 1978.¹⁴ This increasing isolation by the West, coupled with the tightening restrictions on the supply of conventional arms by the international community (the U.N. Security Council enacted a mandatory arms embargo in November 1977 following the Kalahari episode, described below), convinced the South African government that it would have "no alternative but to develop a nuclear deterrent."¹⁵

Commensurate with the additional international political and economic isolation growing from its control of Namibia and its domestic racial policies, South Africa faced what the current head of the South African AEC, Dr. Waldo Stumpf, refers to as "nuclear isolation." It is South Africa's position that, during the 1970s:

some of the nuclear weapons states (and in particular the United States) increasingly started to apply unilateral restrictions on nuclear trade or exchange of information and technology with South Africa. This was part of a newly adopted policy to deny access to 'sensitive technology and materials to politically unacceptable states', a category into which the United States increasingly classified South Africa at the time.¹⁶

The examples Stumpf cite include the 1975 U.S. abrogation of the fuel supply contract in which the United States had promised to supply 93 percent enriched uranium fuel for the SAFARI-1 research reactor. According to Stumpf, the United States added "insult to injury" by not returning South Africa's prepayment for a canceled fuel consignment until

1981 (during the Reagan administration).

It should also be noted that in 1977, Dr. Neil Barnard, a political scientist and protege of P. W. Botha (and subsequent member of his State Security Council as the head of the National Intelligence Service), authored a paper entitled, "The Deterrent Strategy of Nuclear Weapons."¹⁷ In this paper, he concluded by saying that:

Although nuclear strategy is no fool-proof formula for survival, it offers a helpful method to stabilize international relations in an uncertain world. Partly as result thereof, South Africa must increasingly direct its strategic attention to this field.¹⁸

He added that "The acquisition of nuclear weapons will not necessarily isolate South Africa any further," and that "without a strong power base all modern diplomacy is doomed to failure."¹⁹

Isolation Intensifies: The Carter Administration (1977-1981)

From 1976 onwards, U.S.-South African relations worsened, particularly after the 1976 Soweto riot. As one observer noted, "The decolonization and its aftermath brought the United States and South Africa into protracted, often conflictual, contact on a wide range of problems related to the issues of Namibian independence and apartheid."²⁰ Nuclear proliferation would certainly have to be added to that list.

NNPA and the Koeberg Fuel Dispute

One of the reasons for change in the conduct of U.S.-South African policies during the Carter administration was that "Carter and many

of his closest advisors saw African nationalism, not Communist aggression, as the driving historical force in southern Africa, a force deemed largely consonant with American interests.¹²¹ U.S.-South African relations were strained by the Carter administration's support for a majority-rule government in South Africa. Following the unprecedented August 1977 U.S.-Soviet cooperation to bring pressure on South Africa to halt detected preparations for an underground nuclear test in the Kalahari Desert, U.S.-South African relations deteriorated further.

Nonetheless, even under President Carter, a strong advocate for nuclear nonproliferation, U.S. policy opposed a complete ban on nuclear cooperation with South Africa. In October 1977, U.S. Ambassador to the United Nations Andrew Young (an important player in the formulation of Carter's Africa policy and an outspoken critic of the South African government's apartheid policies) approved of the subsequent mandatory U.N. arms embargo against South Africa. But he conceded that to completely end the nuclear relationship would preclude any possibility of influencing South Africa toward NPT adherence, saying, "it is almost because you can't trust them that you have to stay close to them."²²

That policy was subsumed in March 1978, however, by the action of the U.S. Congress when it enacted the NNPA. The act, in essence, precluded the transfer of nuclear technology to countries lacking full-scope IAEA safeguards. The NNPA was also retroactively applied to all previous agreements and contracts, and led directly to the U.S. refusal to issue permits for the export to France of uranium of South

African origin (uranium already enriched by the U.S. Department of Energy (DOE) for the Koeberg nuclear power station under a 1974 U.S.-South African contract) or its re-export from France to South Africa as fabricated fuel. This U.S. action effectively canceled the 1974 agreement and left South Africa with no other reliable source of supply for power reactor fuel. This was particularly costly to South Africa as it was forced to construct an entirely indigenous power reactor enrichment (Z plant) and fuel fabrication supply line (BEVA plant) that would otherwise have been unnecessary.²³

From the South African perspective, the United States aggravated the situation as it had in the earlier case involving SAFARI-1 fuel—by demanding payment for enrichment services already performed, but for which South Africa could not receive any benefit. The impasse was partially resolved in 1981, when the Reagan administration agreed to allow France to manufacture fuel for Koeberg under the condition that enriched uranium be obtained from a non-U.S. source (via American and European brokers) through Switzerland and Belgium. One fuel source was that produced in France for the Kaiseraugst power plant near Basle that had been canceled due to environmentalist opposition. Another source may have been the Belgian Group Synatom. Subsequent core loads were reported to have been fabricated with low-enriched uranium of Chinese origin.²⁴ One report adds that, "Despite advance knowledge, the Reagan administration turned a blind eye" to those purchases.²⁵ In reality, there may have been little the United States could have done to stop the sales,

and, in any case, stopping the sales would have had virtually no impact on South Africa's weapon program. In 1984, South Africa was finally allowed to sell both its enriched and unenriched uranium held in the United States to another NPT country (subject to U.S. approval). However, because of severely depressed market conditions at the time, the South Africans were forced to suffer a "substantial financial loss" (the official claim is 57 million rand—about \$30 million²⁶).

The South Africans state that they viewed this U.S. pressure "very negatively," particularly when both the SAFARI-1 and Koeberg reactors were subject to IAEA INFCIRC/66 safeguards. The resulting "severely-strained" nuclear relations between the United States and South Africa reportedly continued until as recently as early 1994, "although to a lesser degree."²⁷ The South Africans and others argued that such episodes would cast doubt on the credibility of the United States as a reliable supplier in the nuclear field from the point of view of other nations.

IAEA Censure and Further Isolation

In September 1979, a U.S. Vela satellite reportedly detected what was suspected to have been a low-yield nuclear explosive test off the coast of South Africa.²⁸ The South African government asserts that it never tested a nuclear weapon, and the U.S. government has never confirmed that any such test actually took place. However, the timing of the event, only two years after the discovery of test preparations in the Kalahari Desert (August 1977), further strained U.S.-South African nuclear and political relations dur-

ing the Carter administration. Additionally, it was during this same period that South Africa was subjected to a number of international pressures in the nuclear arena that served only to pour salt in the wound (invoking what can be termed the "humiliation factor" in promoting the proliferation of nuclear weapons). Parallels can be drawn to at least one other case—Iraq—whereby the Iraqi nuclear weapon program received new impetus following the humiliation of the Israeli bombing of the Osirak reactor in 1981.

In 1977, South Africa was removed from its seat on the IAEA Board of Governors and replaced by Egypt. As the most advanced nuclear program in Africa, the South Africans felt that under Article VI of the IAEA Statute, the seat was rightfully theirs.

Then, in 1979, South Africa was denied participation in the IAEA General Conference through the rejection of its delegate's credentials by a resolution that also urged South Africa to join the NPT and place all its nuclear facilities under IAEA safeguards. The irony of the situation was not lost on the South Africans (as Stumpf again points out) because the IAEA conference that year was held in New Delhi, the capital of India, a country that had conducted a nuclear test in 1974 without any similar punitive action having been taken against it by the IAEA.²⁹ But, it should be noted, the United States voted against the expulsion of South Africa stating that—in the absence of NPT membership—South Africa's membership in the IAEA remained the only means of providing at least some external influence through inspections and safeguards at some facilities.³⁰

Stumpf has stated that it was clear

to South Africa that the actions of the United States and international community were so politically biased that there would be no tangible benefit from South Africa's accession to the NPT without prior "fundamental internal political reform" in South Africa.³¹

Along these lines it is useful to review points raised by the South African Foreign Ministry in a "secret" memorandum to the U.S. government, dated May 14, 1981, which was "leaked" to TransAfrica, an U.S.-based African-American lobby group.³² In that memorandum, South Africa, in referring to the unilateral U.S. actions mentioned above (concerning the 1974 extension of the 1957 U.S.-South African bilateral "Cooperation on the Peaceful Uses of Atomic Energy"), emphasized that South Africa had continued to honor diligently the agreements and safeguards arrangements on the SAFARI-1 reactor and on the fuel that had been provided by the United States. However, in June 1978, during discussions between the United States and South Africa:

it became abundantly clear that the United States would not supply the fuel in question unless South Africa acceded to the NPT and subjected all its nuclear facilities and activities to international safeguards. More restrictive conditions were thus imposed unilaterally by the United States after conclusion of the contract.³³

In that same memorandum South Africa outlined its position as follows:

1) South Africa is not in principle opposed to the NPT, provided that its basic requirements can be met; 2) South Africa will continue to conduct and

administer its affairs in a manner which is in line with the spirit, principles, and goals of the NPT; and 3) South Africa's nuclear programmes are geared to the peaceful application of nuclear energy and at no time has she tested a nuclear device.³⁴

Finally, South Africa explained the basis for its refusal to sign the NPT at that time by stating:

It must be realized that South Africa is threatened by the Soviet Union and its associates and by certain African countries with Soviet support and encouragement. South Africa has no hope of any assistance from the United Nations in case of attack. On the contrary, it is continually being threatened with action under Chapter VII of the Charter of the United Nations. While this state of affairs continues, South Africa cannot in the interest of its own security sign the NPT and thus set the minds of its would-be attackers at rest, allowing them to proceed freely with their plans against us.³⁵

A Reorganized Nuclear Weapon Effort

Largely as a result of this state of affairs in 1978 during the Carter administration, South Africa made two decisions. First, it decided to establish a completely autonomous one-through nuclear fuel cycle (i.e., no reprocessing) to meet all the requirements of its research and power reactors and thereby free itself from dependence on unreliable outside supplier states. Second, it decided to proceed with a major transformation and expansion of the nuclear weapon program. Responsibility for the weapon program shifted from the Atomic Energy Corporation (AEC) to the Armaments Corporation

(ARMSCOR), and more specifically to the ARMSCOR aerospace subsidiary Kentron (in a compartmented program initially known as "Circle," which after 1988 became a new ARMSCOR subsidiary Advena).³⁶

A new facility for the Circle project, located approximately 15 kilometers east of the AEC's Pelindaba/Valindaba nuclear complex, was commissioned in 1981.³⁷ At that time, a program was set up to include:

- 1) the production of a number of gun-assembled nuclear weapons with their associated air-drop delivery systems;
- 2) studies of implosion and thermonuclear technology and the accompanying longer-range ballistic missile delivery systems; and
- 3) research and development for the production of plutonium, lithium-6, and tritium (at the Gouriqua site on the Cape coast).³⁸

Isolation Tempered with Pragmatism: The Reagan and Bush Administrations (1981-1993)

Constructive Engagement Policy

The Reagan administration established the policy of "constructive engagement," whereby the United States would temper its condemnatory rhetoric regarding South Africa's human rights violations in an effort to form a less antagonistic relationship with South Africa. The objective of the policy was to increase the diplomatic dialogue between the United States and South Africa's Afrikaner elite, to reduce the isolation of this elite, and to persuade it to move toward political reform. This strategy was judged

(by its architect, then-U.S. Assistant Secretary of State for African Affairs Chester Crocker) to be the most effective way to protect U.S. economic and strategic interests in southern Africa through promotion of regional political stabilization.

The policy also involved the concept of "linkage" between the inter-related Angolan, Namibian, and South African conflicts.³⁹ As a result, it furthered the Reagan administration's primary policy of countering the growing Soviet influence in the region. That influence was viewed as part of the Soviets' strategy both to deny the West access to strategic minerals (such as chromium, manganese, vanadium, and platinum-group metals) and to control shipping lanes of supertankers transporting oil from the Persian Gulf region to the West.⁴⁰

It should also be noted that, by the time of the Reagan administration, the reality of South Africa as a *de facto* nuclear weapon state had set in. In response to several proposals in the U.S. Congress to outlaw all U.S. nuclear cooperation with South Africa, the Reagan administration countered that isolating South Africa in the nuclear arena would not work any more than it had in the arms or oil arenas, where exclusionary policies simply spurred South Africa to develop its own capabilities (albeit at much greater economic and social costs). In early 1983, a U.S. State Department desk officer for South Africa was quoted on this issue as saying, "It's too late for that—denial has not worked and it won't work." He added that there was more of a concern about the potential threat of South Africa operating as a renegade nuclear supplier (or so-called "maverick bull in the nuclear herd") outside of the NPT

regime.⁴¹

As was mentioned earlier, one area where the Reagan administration was willing to be more accommodating than its predecessor towards South Africa was in helping to resolve the impasse regarding the supply of fuel for the Koeberg nuclear power reactors. The resolution of that dispute recently became an issue in South African domestic politics.

In a late-1994 book authored by a South African journalist, it was claimed that the United States struck a secret deal in 1981 to keep South Africa supplied with low-enriched uranium to fuel its nuclear power program in violation of the NNPA in exchange for: 1) allowing U.S. safeguards inspectors access to South Africa's Valindaba semi-commercial plant; and 2) opening negotiations that would lead to the independence of Namibia.⁴² That book's publication led to denunciations in the Afrikaner press of Minister of Mineral and Energy Affairs Roelof F. (Pik) Botha (previously foreign minister) as a traitor to South Africa for having succumbed to U.S. pressure in "revealing details about South Africa's atomic secrets."⁴³

That claim is a gross exaggeration of the facts. The details surrounding the resolution of the Koeberg fuel dispute cannot be called secret, as it was reported in March 1982, that: "In an unprecedented move, four top U.S. State Department nuclear safety specialists visited Valindaba to discuss applying safeguards to the enrichment facility." It was also stated at the time that U.S. officials had admitted that "the Reagan administration is exploring a nuclear trade-off with Pretoria" (in connection with any settlement of the Koeberg fuel dis-

pte).⁴⁴ The safeguards discussions were evidently limited to the production of low-enriched uranium at the semi-commercial plant, as there is no evidence that any of the proprietary details of the South African enrichment process—or of the then-operational Valindaba⁴⁵ pilot plant (used to produce highly-enriched uranium for the covert assembly of nuclear weapons)—were ever discussed. One concession the South Africans did make that furthered U.S. nonproliferation policy was their agreement to act as a responsible nuclear supplier “in accordance with generally accepted international supply guidelines.”⁴⁶

Pik Botha has publicly responded to the charges of malfeasance by restating the historical facts as described above. He said he was convinced that at no time was any U.S. law violated. Moreover, as far as he was aware, the United States did not set any conditions or insist on any “explicit agreement” regarding the Namibian issue. Interestingly, he conceded that he had promised President Reagan that South Africa “would not explode a nuclear device without informing the United States beforehand.”⁴⁷

Nuclear Export Controls Maintained

Despite that breakthrough, the Reagan and Bush administrations’ policies toward South Africa contained a number of elements in common with those of previous administrations:

- 1) support for the 1977 U.N. Security Council arms embargo against South Africa (Resolution 418, which included a paragraph specifying “that all states shall refrain from any cooperation with

South Africa in the manufacture and development of nuclear weapons”);

- 2) continuation of the ban, first imposed by the Johnson administration in 1967, on U.S. naval ship visits to South African ports;

- 3) refusal to recognize the independence of the so-called “Black Homelands”;

- 4) support for the Sullivan Principles (adopted in 1977 on a voluntary basis by U.S. corporations doing business in South Africa) regarding the equitable treatment of black employees in South Africa employed by U.S. firms; and
- 5) refusal to ship enriched uranium to South Africa unless it accepted full-scope safeguards for all its nuclear facilities.⁴⁸

The Reagan administration did relax some export restrictions established in 1978 by the Carter administration on some civilian goods and on certain sales to the South African military and police. However, in September 1982, the administration also defined subsidiaries of ARMSCOR as being “military entities” and therefore subject to dual-use export restrictions.⁴⁹ Controversy also developed over applications for licenses to export helium-3 and a hot isostatic press (HIP) to South Africa.⁵⁰

One example of the Reagan administration’s willingness to allow some U.S. nuclear-related assistance is the permission granted Westinghouse Corporation to provide technical equipment and maintenance to the safeguarded, civilian Koeberg nuclear power station in late 1983. Shortly after, however, on September 9, 1985, the U.S. House of Representatives adopted the Comprehensive Anti-Apartheid Act banning nuclear cooperation of

any kind with South Africa until it signed the NPT. This act, passed by Congress in 1986 and effective on January 1, 1987, also prohibited the import into the United States of uranium-oxide produced or manufactured in South Africa.⁵¹ President Reagan issued an anti-apartheid Executive Order placing new restrictions on nuclear trade with South Africa, apart from assistance that could be deemed necessary to protect public health and safety. Concurrently, U.S. Secretary of Energy John Herrington (with State Department urging) refused to authorize retroactively 22 Americans for work at the Koeberg power station.⁵²

“Cover Your Bets”: South Africa’s Nuclear Weapon Strategy During the 1980s

Officials of the former South African government admit that they had developed a three-stage strategy for the employment of nuclear weapons by South Africa.⁵³ That strategy provided what the South African government has termed “an insurance policy” for “a worst case scenario of South African territory, including Namibia, being threatened by external invasion, supported by Warsaw pact countries”⁵⁴ as a means to force the West to intervene.⁵⁵

This so-called “catalytic deterrent” strategy,⁵⁶ that of using the existence of a nation’s nuclear arsenal (including the use, or threat of use, of a nuclear explosive test as a goad to force other nations to intervene, has also been described as “nuclear poker with extraordinarily high stakes.”⁵⁷

In a briefing for foreign press reporters, ARMSCOR managing director Tielman de Waal said that the first stage of the strategy was that of

deliberate ambiguity, neither confirming nor denying that South Africa had produced nuclear weapons. De Waal said South Africa never "intentionally" moved beyond that stage (a report on the briefing implied that it was his belief that "most Western governments were aware of South Africa's arsenal").⁵⁸

In the event that an otherwise insurmountable military threat arose against South Africa in the region, South Africa could implement the second stage by discretely revealing its nuclear weapon status to the United States and/or other Western governments to prompt them to intervene. If such notification failed to illicit the necessary response, South Africa was willing to go to the third stage of publicly revealing its capability through a nuclear demonstration test.

In view of South Africa's admitted plans to implement such a strategy in 1988,⁵⁹ it is particularly useful to review the situation that existed in southern Africa at that time to gain insight on how other nations might employ such a strategy when confronted by what they might perceive to be similarly desperate circumstances.

South Africa's Threat Perception

From late 1987 to mid-1988, the Angolan war had taken an ominous turn against the South Africans. Soon after the October 1987 defeat of the Soviet-supported offensive from Cuito Cuanavale by South African forces, Cuba raised the stakes by sending an additional 15,000 troops to Angola. In March 1988, the Cubans and Angolan forces began a series of advances in southwestern Angola near the Namibian border. According to Chester

Crocker, by late May 1988, a new southern front running 250 miles was "manned by 12,000 of Cuba's best units," and they had "some two hundred tanks and ample artillery, and their force bristled with air defense radars and five different types of surface-to-air missile systems." To make matters worse, Fidel Castro publicly warned the South African leadership that they ran the risk of "serious defeat." Again quoting Crocker, "Cuban officials publicly warned that challenging Cuba's southern front would mean that 'many white South Africans will die in battle.'⁶⁰ These actions were evidently part of a Cuban strategy whereby they would increasingly pressure the South Africans militarily (without necessarily engaging its forces) in order to drive the South Africans to the negotiating table. Despite the fact that the South Africans responded by putting heavier units in place in northern Namibia, and in early June, by activating its 140,000-man reserve force, no serious military confrontations took place.

The resulting military stalemate helped pave the way for the negotiated August 5, 1988, cease-fire (in what became known as the "Geneva Protocol") that led to the withdrawal of all South African troops from Angola by September 1, 1988. The period from August 5, 1988, through November 15, 1988—when an agreement was reached in Geneva to redeploy all Angolan/Cuban troops to northern Angola and the staged and total withdrawal of Cuban troops from Angola began—was officially described in the Geneva Protocol as "a period of particular sensitivity, for which specific guidelines for military activities are presently lacking."⁶¹ The South Africans

were most concerned about their vulnerability to a surprise cross-border attack in Namibia by the five Cuban tank brigades that continued to occupy positions within 200 kilometers north of that border.

It was during that period of greatest insecurity that South Africa evidently took two significant actions to ensure that its nuclear deterrent capability could be used as a hedge against such a conventional military assault. First, only eight days after the signing of the Geneva Protocol, South African Foreign Minister Pik Botha suddenly announced at a press conference in Vienna (where he had been in discussions at the IAEA concerning the possibility of South African NPT accession) that South Africa had the "capability to make" a nuclear weapon "should we want to," but he refused to elaborate on that statement.⁶² Second, and more importantly, in September and October, construction began in earnest on what sources involved called a "galvanized corrugated iron shed" (or "hangar") built over one of the two test shafts at the Kalahari nuclear test site. They noted further that the shaft was reopened and inspected during "the second half of October 1988."⁶³

The South Africans now admit that they reopened the primary test shaft to effectuate plans to conduct a test in the event of a breakdown of the cease-fire in Angola in hope of prompting the Western powers to intervene, either diplomatically or militarily. This has been termed an "ace-in-the-hole" strategy.⁶⁴ However, the South Africans did not want to prematurely "tip their hand," hence the acknowledged attempts at preserving secrecy at the Kalahari site. According to ARMSCOR, the iron shed was intended to "minimize

theriskof detection⁶⁵ in that it provided some (albeit limited) ambiguity of purpose (i.e., the shed could conceivably have been used to support conventional weapons testing in the surrounding area). Immediately after President de Klerk's 1993 announcement, press reporters visited the Kalahari nuclear test site and found that it had been disguised as:

[a] South African Air Force-controlled test-range for aircraft mounted munitions....The area had been scattered with fibre-glass models of tanks and other army vehicles, presumably to make it look like a conventional 'battle school' to prying satellites.⁶⁶

At a minimum, the shed did provide cover for downhole activities that included the pumping of water out of the shaft and "easy maintenance in case of a test."⁶⁷

Considering the outcry over the 1977 discovery of the initial test preparations, a 1993 study by Professor Renfrew Christie of the University of Western Cape, South Africa, expresses particular surprise at the total public silence in the United States after the reopening of the test site.⁶⁸ He observed that the reopening "would have been enough to be construed as a threat to explode a nuclear device." Indeed, according to a report in *Nuclear Fuel*, the U.S. Central Intelligence Agency (CIA) had "put the [Kalahari] test site on a short list of routine observation targets" and "when the CIA learned of the new activity there ten years later, 'Washington went ballistic.'"⁶⁹ In the same paper, Christie asks: "Did the United States say to Botha, 'Don't you test an atomic bomb'?" ; and "Did it say to the Soviet Union, 'To prevent nuclear war, the Cubans must back off in Angola'?" ; and, "Did it say to Cuba, 'stop your ad-

vance at the Lomba River, or Cuito Cuanavale; this far and no further'?"

While some of Christie's questions concerning the U.S. reaction to the shed's construction are still pertinent, it can now be shown that his conclusion—that South Africa's use of a threat of nuclear test was successful in getting the Cubans to withdraw from Angola—was based on misinformation. Initial ARMSCOR press releases had stated that the test shafts were reopened and inspected in 1987, and also that the shed was constructed over the primary shaft in 1987.⁷⁰ Had the shed's construction been *prior* to the August 5, 1988 negotiated cease-fire, as indicated by those reports, then Christie's conclusion that such activity was likely intended as a goad to speed a peace settlement in Angola might have been valid.

However, as noted earlier, more recent information shows that the shed was in fact constructed one to two months *after* the initial negotiated cease-fire,⁷¹ and one month after the South African Defense Force withdrew from Angola (in accordance with that cease-fire). Rather than having been intended as a goad to bring about the peace settlement, the building was more likely (as the South Africans have openly claimed) an "insurance policy" to be used in the event that the peace process failed.

It should also be noted that, contrary to the initial case of South African nuclear test preparation activity in 1977 when Soviet public disclosure provoked the United States to respond publicly, the lack of public awareness of the renewal of such activity in 1988 provided the United States with a previously unavailable option for diplomatic

discretion in any response (assuming, as claimed above, the United States detected and correctly interpreted the reactivation of the test site). U.S. policymakers also would have been given one more reason to ensure that the cease-fire held. The accompanying security guarantees, providing for the withdrawal of all Cuban troops from Angola and the independence of Namibia, would also have to be assured and successfully concluded, as they subsequently were on December 22, 1988.

NPT Accession: Better Late Than Never

While maintaining its nuclear arsenal and the option to test during the Reagan administration, South Africa continued to announce a willingness "to commence negotiations with each of the nuclear weapons states" on its possible signing of the NPT. During the late 1980s, such statements usually came just before IAEA general conference sessions in which South Africa's credentials and possible expulsion were debated.⁷² South Africa's continued talks with the United States, the United Kingdom, and the Soviet Union were sufficient to "sway" the general conferences to defer suspension until South Africa finally acceded to the NPT in July 1991.⁷³

It was also during the Reagan administration that J. D. L. Moore remarked that "South Africa's policymakers well understood and shared the West's perception that dialogue had to be maintained," and that the South African strategy of "making no moves toward signature of the NPT, yet not ruling it out, was partly designed to maintain dialogue with the West."⁷⁴ However,

he also pointed out that in this dialogue the West was not able to offer the necessary "carrots or sticks" to induce South Africa's NPT accession until such time that South Africa, on its own, became convinced that it was in its best interest to do so. As a result, Moore cynically (and somewhat unfairly) concludes that Western policy had become "characterized by secrecy, nervous and distrustful watchfulness, and a feeling of being powerless to do anything decisive."⁷⁵ Regardless of how one views the influences of U.S. policies upon the South African government's decision to abandon its nuclear weapon program, however, that decision was due in large part to the removal of the external military security threat brought about by the Angolan/Namibian peace settlement and the collapse of the Soviet Union. As President F.W. de Klerk stated, "In these circumstances, a nuclear deterrent had become, not only superfluous, but in fact an obstacle to the development of South Africa's international relations."⁷⁶

Another serendipitous factor that cannot be overlooked was the September 1989 election of President F. W. de Klerk to replace P. W. Botha following the latter's stroke in January 1989. De Klerk, who had previously been among the National Party's conservatives, "saw the handwriting on the wall," and began the inexorable process towards full enfranchisement that led to the formation of a new government.⁷⁶ During the course of the subsequent dramatic domestic political reforms that President de Klerk initiated (which eliminated South Africa's remaining external political and economic security threats), a nuclear deterrent would have been a liability.

While never officially admitted, the South African government under President de Klerk had to have been concerned during the domestic political transition about the risk of "nuclear inheritance," whereby "nuclear weapons or nuclear weapons material produced by South Africa might fall in to the hands of a radical ruling faction—black or white—which might use or threaten to use them to advance extremist objectives."⁷⁸ In late 1992, there were press reports of concern about the possibility that an ANC-led government might transfer any remaining weapons-grade uranium (from the then only presumed South African nuclear weapon program) to Libya, Cuba, Iran, or the Palestine Liberation Organization to pay off old political debts.⁷⁹ David Albright and Mark Hibbs reported that one South African official admitted that South Africa acceded to the NPT and accepted IAEA safeguards because of the de Klerk government's "concern" for the future.⁸⁰

U.S. NUCLEAR CONTROLS: HOW EFFECTIVE WERE THEY?

Over the past 20 years, both the executive and legislative branches of the U.S. government instituted a number of policies to limit the spread of nuclear weapons to non-NPT party states by limiting assistance through either technical cooperation controls or trade restrictions on sensitive nuclear technology, materials, and equipment. In the case of South Africa, U.S. controls on nuclear-related trade were enhanced through additional, Congressionally-mandated, trade sanctions (though each administration generally was opposed to broad economic

sanctions) brought about as a reaction to South Africa's domestic apartheid policy. Despite U.S. efforts to restrict South Africa's access to nuclear-weapon significant goods and technology, South Africa still succeeded in producing a small, deliverable, nuclear weapons arsenal.

This was true for several reasons. The Valindaba uranium enrichment pilot plant was developed at a time when international controls were much less effective. Once more effective controls were in place, South Africa stayed with technical approaches that, largely, did not rely on controlled technology. Finally, it did manage secretly to circumvent some then-extant controls.

U.S. controls on nuclear-related exports during the 1970s and early 1980s effectively prevented South Africa from procuring many "critical" U.S.-origin technologies. However, the absence of comparable and effective international controls on other important items allowed South Africa to obtain sophisticated nuclear-related, or dual-use, equipment, including that necessary to build the Valindaba pilot plant.⁸¹

In a study of the effectiveness of U.S. technology transfer policy in South Africa, Richard Bissell points out that "the determination of West Germany and France, in particular, to pursue independent nuclear policies in the mid-1970s, effectively terminated potential leverage through US technology." He further illustrates the frustration of U.S. policy in the South African case when, after briefly attempting to halt the sale by France of the power reactors for Koeberg, then-French Prime Minister Raymond Barre replied simply that the South Africans "already had a nuclear military ca-

pability and that the reactors add nothing to it."⁸²

Bissell summed up the effectiveness of U.S. technology transfer policy to South Africa by saying that, "The issue of technology was largely dead by the advent of the Carter administration because many ties had been broken under congressional pressure . . .," and that following the simultaneous rise to power of P.W. Botha, "South Africa stubbornly pursued an aggressively independent line on all nuclear technology."⁸³

South Africa proceeded (and succeeded) with a crash program to establish an indigenous capability to produce Koeberg reactor fuel, albeit with considerable help from foreign-supplied equipment. Concurrently, it also managed to acquire a variety of other dual-use equipment, such as isostatic presses, numerically-controlled machine tools, and computers that were used to create the nuclear weapons manufacturing infrastructures.⁸⁴

Furthermore, international controls then in effect on diagnostic equipment with direct application to the development of nuclear weapon components (such as high-speed cameras, etc.), were not always effective. In fact, prior to April 1992 and the institution of INFCIRC/254 Part II, there was no international agreement on controls of dual-use technologies. To be sure, and as various observers (including Bissell) have noted, it is not clear that such high-technology, dual-use imports would have had a major impact on South Africa's relatively conservative gun-assembled nuclear weapon program.

To underscore this last point, David Albright (who visited the nuclear weapons fabrication facili-

ties in early 1994) remarked:

A major surprise about the original Advena nuclear weapons manufacturing site, the 'Circle facility,' was that the machine tools, isostatic presses, and vacuum furnaces were relatively simple and few in number. Advena had many pieces of equipment imported from Europe, but few could be found on international nuclear export control lists.⁸⁵

He claimed that technicians at Advena showed ingenuity in developing tricks to make more complicated shapes on relatively simple machines. For example, Albright notes that "a two-axis machine (designed to make two dimensional shapes) was used to create a high-specification three-dimensional shape for the gun-type device."⁸⁶ He said that this was part of a conscious effort by the South Africans to reduce the risk of exposing the program, since "*Western intelligence agencies carefully monitor controlled nuclear exports.*" Nonetheless, the South Africans admitted that this strategy sometimes slowed the program down because their equipment was not as efficient as that which was they knew existed, but which was controlled in supplier states. Regarding imported items, ARMSCOR personnel commented that, even when they did manage to circumvent some export controls to acquire a piece of equipment, they later had difficulty in getting spare parts. So, they preferred indigenous production of the necessary equipment whenever possible.

Procurement Case Studies

Perhaps the best way to judge the effectiveness of nuclear export controls with respect to South Africa is to review those specific instances in

which South Africa either obtained, or sought to obtain, export-controlled commodities for its nuclear weapon program.

High-Speed Cameras and Flash Radiography Equipment

Experimental activity in support of any nuclear weapons research and development effort typically includes the recording of data from prototype experiments at non-nuclear test facilities. One method involves the collection of photographic data of high explosive or propellant tests using high-speed cameras.

In late 1989 (just after de Klerk had been elected president and about the time that he had ordered an investigation into the steps that would be necessary to dismantle South Africa's nuclear weapons), an article appeared in *Engineering Week* describing an "invaluable test and evaluation range at Boskop" operated by the ARMSCOR subsidiary NASCHEM. The range included "an advanced detonics laboratory featuring flash x-ray analysis and ultra-high-speed photography (up to 20 million frames/second) for recording detonation phenomena."⁸⁷ It appears, therefore, that by the time that South Africa finally terminated its nuclear weapon program it had acquired the imaging equipment necessary to fulfill the requirements of an implosion-type nuclear weapons research and development program.

Hot Isostatic Press

Hot isostatic presses (HIPs) provide the means of simultaneous application of heat and pressure to a body. HIPs are used for the consolidation of powders, diffusion bonding of similar and dissimilar

materials, and healing defects in castings. They are dual-use items that have many applications, including applications in the manufacture of nuclear weapon components. They are particularly useful in press-forming high explosives into spherical shapes for use in implosion-type nuclear weapons.

The United States had apparently been successful in limiting the transfer of U.S. HIP technology to South Africa through the inter-agency Subgroup on Nuclear Export Coordination (SNEC), which reviews all proposed exports of HIPs regardless of size, to countries of proliferation concern. Still, the general manager of Advena (the ARMSCOR subsidiary in charge of the Circle facility and Central Laboratories) was quoted as saying publicly in late 1992 that Advena operated an HIP (of unknown origin) and that, because of "the functional and operational specifications of their HIP and the variety of cycle options (including rapid cooling), Advena could be judged as a front-runner in this specific technology, even on the international market."⁸⁸

It is interesting to note that in South Africa, a cold isostatic press of indigenous origin was installed at the Circle facility that was used to manufacture the tungsten tamper parts for South Africa's gun-assembly nuclear weapons.⁸⁹ That South Africa was for a time hindered in acquiring HIP technology is significant in that it may have restrained South Africa from having the capability of producing implosion-type weapons earlier than 1989, when Advena Central Laboratories was completed.

Miscellaneous Items

A 1983 U.N. study, conducted by the Special Committee Against Apartheid, commented on the supply of helium-3 and described it as a material from which "tritium, an element used in thermonuclear weapons, could be derived."⁹⁰ Other items cited in that same study that were alleged to have been authorized for sale to South Africa during the Reagan administration and which were reported as "major pieces of nuclear-related equipment with dual end-uses" included: vibration test equipment ("which could be used to test the reliability of nuclear warheads"); multichannel analyzers ("capable of analyzing complex data at a test site"); and a Cyber-170-175 computer ("powerful enough to model a nuclear explosion").⁹¹

Much of the equipment used to create South Africa's first generation (gun-assembly) and second-generation (implosion) nuclear weapon manufacturing infrastructures came from European suppliers. A German-origin vacuum-induction furnace, located at Advena Central Laboratories, was used to sinter tungsten-tamper components for South African nuclear weapons.⁹² Another dual-use item, a precision-coordinate measuring machine (used in quality control of machined parts, including nuclear weapon components), was legally obtained by South Africa from Italy. This equipment was obtained solely for South Africa's nuclear weapon program, as evidenced by the fact that photographs of the equipment were provided by ARMSCOR in 1993 and in a late 1992 brochure of the Advena Central Laboratories. Advena Central Laboratories was to be South Africa's sole facility for

manufacturing implosion-type nuclear weapons and integrating them with ballistic missiles.⁹³

It has also been claimed that the South Africans "obtained an unclassified US Navy Handbook 255, entitled, *Nuclear Weapons Systems, Safety, Design, and Evaluation, Criteria For*."⁹⁴ As a result, South African nuclear weapon designers reportedly were able to use the information contained in that handbook to help them think through and resolve safety problems that might otherwise have been inherent in their own design.⁹⁵

A *Nucleonics Week* article claims that during the late 1970s, "according to Soviet intelligence," a now defunct subsidiary (known as Gamma Systems Associates) of the U.S. firm International Signal Corporation (ISC) acted as a "procurement agent in the United States to supply a wide range of dual-use equipment for South Africa's nuclear and ballistic missile programs through a network of secret shell companies."⁹⁶ The article also reports that the ISC's former head had sold equipment to South Africa since 1975 and, in 1993, was finally convicted and imprisoned for "financial fraud and illegal arms exports." Such activity provides additional evidence of South Africa's willingness (and at least partial effectiveness) to circumvent U.S. export controls. Other countries bent on acquiring nuclear weapons are likely to try similar methods in the face of similar controls.

Tightened International Export Controls

In the South African case of nuclear weapons proliferation, a key factor was that international technol-

ogy controls for curbing proliferation were initially absent. When the program began in the 1970s, neither international nor U.S. national nuclear export controls on equipment were in place. Controls on equipment did not begin until the 1974 Zangger agreements identified key nuclear equipment (IAEA INFCIRC/207). At that time, South Africa had nearly completed its pilot enrichment plant and had initiated its nuclear weapons design and development program. Subsequent export controls, particularly those involving dual-use equipment, were progressively tightened. In 1978, when all the elements South Africa required to complete its first nuclear explosive device were in place, the United States invoked the NNPA and was alone in controlling exports of dual-use equipment and material on nonproliferation grounds.⁹⁷ In April 1992, at the Nuclear Suppliers Group (NSG) plenary following the revelations on the extent of the Iraqi nuclear weapon program and the successes of its procurement networks, international consensus on the need for enhancing international export controls on a cooperative basis led to the codification of the NSG "Dual-Use Annex."⁹⁸ International agreements and domestic laws have since advanced to place many items previously acquired by the South Africans in the 1970s and 1980s under controls.

This raises the question, could South Africa have succeeded under the current control regime? Because South Africa was sufficiently industrialized, and had the requisite scientific and technological infrastructure to design and fabricate its gun-assembled nuclear weapons, South Africa would have, in all likelihood, been able to replicate most aspects

of that portion of its nuclear weapon program, even in the face of today's export control regime. However, the program's overall success probably would have been significantly hampered had today's nuclear export controls been stringently applied prior to the construction of South Africa's pilot uranium enrichment plant, thereby limiting its access to the fissile material needed to complete its weapons.

While this same conclusion could apply to a number of other countries today, South Africa's capabilities in the nuclear field (as evidenced by the revelations of the success and later termination of its former nuclear weapon program) must be viewed as significant, if not necessarily unique. It was entirely appropriate therefore, that South Africa sought, and was subsequently granted, membership in the NSG in March 1995. The inclusion of South Africa in the NSG, along with the overall improvement of export controls, heralds a new age of international collaboration in nuclear trade in which another case like South Africa's will be less likely to occur again.

Enforcement: Key to Effectiveness

For the strengthened regime to be truly effective, however, those improved controls must be coupled with stricter enforcement. Such enforcement can be brought about through the sharing of information on export denials (for both the technology that can be used for fissile materials production and any subsequent weaponization) and other data to prevent the diversion of "dual-use" items through front companies and unscrupulous merchants.

CONCLUSION: LESSONS FOR U.S. NONPROLIFERATION POLICY

Drawing nonproliferation lessons from any single country case study requires caution because so many factors are distinct to each country's circumstances. Important variables from case to case include:

- The relative strength of factors that drive or diminish a country's perceived need for nuclear weapons, and how those factors change over time.
- Whether a country is vulnerable to outside pressures to stop its nuclear program, and whether parties that have such leverage choose to apply it.
- The level and extent of indigenous resources and industrial infrastructure.
- Whether and to what extent a country chooses technical paths that require greater or lesser access to foreign technology.
- The extent to which a country already may be isolated from access to foreign technology for reasons other than nuclear weapons aspirations.

Bearing in mind, then, that each country represents only one point in a complex set of possibilities, we still can draw some lessons from U.S. nonproliferation efforts in South Africa for future cases.

1. *When a country's determination to have nuclear weapons is driven by its perception of a powerful threat to its security, nonproliferation policy measures—like export controls and trade sanctions—may do little to stop its program efforts until those security threats are diminished.*

Nonproliferation policy can be most simply viewed as having to

address a two-fold problem. That problem involves both the capabilities and motivations of the potential proliferant. Technology control regimes are potentially valuable as stop-gap measures to limit capability, but they will at most only serve as a hinderance to proliferation. They can help to "buy time" while other policies that address the broader security issues motivating proliferation can be implemented.

This was especially true for South Africa, whose nuclear weapon program by the late 1970s was not especially dependent on access to foreign technology. Furthermore, in view of the political and economic isolation it faced because of its apartheid policy, South Africa had no reason to expect that giving up its weapon program would remove its pariah status. If anything, sanctions seem to have reinforced South Africa's determination to have the bomb. Only when internal political reform had reduced its isolation from the world community was it ready to abandon the program. At the same time, however, there have been cases where the right leverage has existed to make export controls, sanctions, or other threats more effective against proliferating states. Taiwan's acquisition of nuclear weapons was prevented by U.S. intervention, backed by an implied threat that nuclear fuel supplies or even military sales would be cut off, and U.S. pressure also helped to keep South Korea's nuclear weapons interest in check.⁹⁹ Even states like Libya and Iran, over which the United States has little leverage (but which have only a very limited infrastructure) have found it very difficult to obtain necessary technology from abroad.

In the case of South Africa, it can

be argued that the U.S. foreign policy measures that eventually contributed to real nuclear restraint were those that helped establish a secure regional military environment and change South Africa's domestic political situation. On the regional security front, through "constructive engagement" the United States supervised the negotiated end to the Angolan War and the establishment of Namibian independence, while the end of the Cold War also reduced South Africa's sense of insecurity. Meanwhile, U.S. anti-apartheid measures, including economic sanctions, helped to bring about political accommodation within South Africa.

One application of this lesson would be that when (and if) a more secure regional military environment is established in the Middle East or South Asia, the opportunities for nuclear nonproliferation success will be greater in those regions as well.

2. Proliferating countries do try to circumvent export controls.

As has also been illustrated by cases like Pakistan and Iraq, proliferators go to great lengths to get around export controls. Although much of South Africa's capability to produce HEU was in place prior to the institution of effective international controls, South Africa nonetheless was reasonably adept at working around then-extant controls to acquire needed equipment for its nuclear weapons infrastructure from abroad or to manufacture it indigenously. Determined proliferants can also be expected to use unscrupulous brokers, create front companies, and falsify end-use information. The South African case has also shown that a commodity that cannot be obtained from a supplier with strong export controls

may be sought elsewhere. This reinforces the importance of current efforts to enforce existing international export controls through the identification of illicit transfer networks, share intelligence data on problem end users, harmonize controls among supplier states, and share information on export license denials.

3. Commodities on the dual-use list are not necessarily essential for a bomb.

South Africa's first-generation, gun-assembled nuclear weapon was a fairly simple device. The dual-use commodities required for its design and manufacture were correspondingly simple, typically falling below the threshold of sophistication represented by the NSG dual-use list. This is not to say that such controls do not serve an important purpose—South African nuclear weapon designers were also researching more sophisticated devices, and successful denial of NSG dual-use items would have hindered that effort. In any case, it is useful to remember that in some instances, commodities more simple and widely available than those controlled by the NSG dual-use list will be an adequate alternative for proliferating states' nuclear weapon programs.

4. The humiliation of a potential nuclear weapons aspirant by a nuclear power will generally only serve to intensify that aspirant's determination to acquire nuclear weapons by ever more covert means.

The South African nuclear weapons proliferation case shows that, following the international outrage precipitated by the Soviet Union's public revelation of the Kalahari nuclear test activity, South Africa became all the more determined to

acquire a limited nuclear weapons capability under the conservative leadership of the Afrikaner-dominated National Party by Prime Minister B. J. Vorster and his strong-willed Defense Minister and successor P. W. Botha. As a result, although the AEC's earlier research and development effort (which had been linked to the Kalahari test site) was quickly terminated, a more covert weaponization effort was then instituted under ARMSCOR auspices. This was quite similar to the situation that developed in Iraq, whereby the Iraqi nuclear weapon program was significantly stimulated (and made more covert) following the bombing of the Osirak reactor by Israel in 1981.

5. A proliferator may consider a nuclear demonstration test, or the threat of conducting one, as a diplomatic bargaining tool.

Following the Indian underground nuclear test of 1974, U.S. nonproliferation policy, in partnership with the international NPT regime, has been very effective in preventing undeclared nuclear weapon states (such as South Africa was) from using overt nuclear explosive testing, either for weapons development or to demonstrate their nuclear prowess. One possible negative side effect of the international emphasis against such testing (as seen in the South African case) is that undeclared nuclear weapon states may perceive it to be in their interests to develop a "stand-by" capability to test. The use of such a threat can provide diplomatic leverage during serious political or military crises.¹⁰⁰

FINAL THOUGHTS

For almost 20 years, U.S. nuclear nonproliferation policy towards

South Africa was interwoven into the larger tapestry of overall U.S. foreign policy. The policy tools available to achieve nonproliferation results were therefore constrained by broader U.S. global and regional policy goals. Specifically, the U.S. nonproliferation effort in South Africa was limited by the concurrent, opposing regional policies of "constructive engagement" and Congressionally mandated anti-apartheid economic sanctions, both of which were subsidiary to the overarching global U.S. foreign policy strategy for winning the Cold War. Only after success in the Cold War was achieved and with it the removal of South Africa's external security threat (the *raison d'être* of its nuclear weapon program)—was the internal political reform conducive to denuclearization finally possible.

The South Africa case demonstrates the difficulty of preventing proliferation in a state that, having once acquired the requisite fissile materials, is committed to producing nuclear weapons. At that point, export controls can at most hinder such a nation from achieving its goal. U.S. controls aimed at preventing weaponization did not prevent the development of a nuclear weapon capability by South Africa (partly because many other supplier states lacked equivalent controls). However, there is some evidence that, as controls were progressively tightened and more stringently applied by the United States and others, these controls may have had a role in keeping South Africa from achieving an implosion-design nuclear weapon before the program's termination in 1990. Also on the positive side, South Africa demonstrates that proliferation can be reversed. But, more broadly, the South

African case illustrates the unavoidable difficulties that can arise on the road to achieving U.S. nonproliferation policy goals when those goals remain subordinate to, or even in conflict with, larger policy issues.

¹ David Albright and Mark Hibbs, "South Africa: The ANC and the Atom Bomb," *The Bulletin of the Atomic Scientists* 49 (April 1993), p. 33.

² Tami Hultman and Reed Kravet, "South Africa's Nuclear Prowess," *Los Angeles Times*, August 28, 1978, p. 15.; Kenneth Adelman and Albion Knight, "Can South Africa Go Nuclear?," *Orbis* 23 (Fall 1979), p. 637; see also David Fischer, "Reversing Nuclear Proliferation: South Africa," *Security Dialogue* 24 (1993), p. 237.

³ Robert S. Jaster, "Politics and the Afrikaner Bomb," *Orbis* 27 (Winter 1984), p. 831.

⁴ A. R. Newby-Fraser, *Chain Reaction: Twenty Years of Nuclear Research and Development in South Africa* (Pretoria: The Atomic Energy Board, 1979), pp. 22-25.

⁵ Since 1967, South Africa has operated its SAFARI-1 research reactor at Pelindaba under IAEA safeguards. The neighboring Valindaba pilot enrichment plant, the source of the fissile material used in South Africa's nuclear weapons and first fully operational in 1977, was never subject to IAEA safeguards prior to its shut-down in February 1990.

⁶ *The Washington Post*, August 28, 1977, as quoted by Dr. Renfrew Christie in a speech entitled, "The Military Dimensions of Nuclear Development in South Africa," given at the Conference on Nuclear Policy for a Democratic South Africa, Cape Town, South Africa, February 11, 1994.

⁷ Jonathan B. Swartz, "Controlling Nuclear Proliferation: Legal Strategies of the United States," *Law and Policy in International Business* 20 (1988), p. 3.

⁸ According to Donald Sole, a former Chairman of the IAEA Board of Governors (1959-1960) and former South African ambassador to the United States (1977-1982), "the US, more than any other country, applied pressure on South Africa to accede to the NPT." Donald B. Sole, "South Africa and the Non-Proliferation Treaty," *American Review* 13 (Johannesburg: Rand Afrikaans University, Institute for American Studies, 1993), p. 5.

⁹ Richard E. Bissell, *South Africa and the United States: The Erosion of a Relationship* (New York: Praeger Publishers, 1982) p. 104.

¹⁰ *Ibid.*, quoting Richard Betts, "Paranoics, Pygmies, Pariahs and Nonproliferation," *Foreign Policy* 26 (Spring 1977), p. 183.

¹¹ Waldo Stumpf, *South Africa's Nuclear Weapons Programme*, (Pretoria, South Africa: Atomic

Energy Corporation of South Africa, Ltd., January 1994), p. 6.

¹² William J. Foltz, *United States Policy Toward South Africa: Is an Effective One Possible?* (Los Angeles: Center for International and Strategic Affairs, University of California, October 1983), Working Paper No. 43, p. 10.

¹³ Chester A. Crocker, "Current and Projected Military Balances in Southern Africa," in Richard E. Bissell and Chester A. Crocker, eds., *South Africa into the 1980s* (Boulder, Colo.: Westview Press, 1979), p. 77.

¹⁴ P. W. Botha was Minister of Defense from April 1966 to October 1980. He became Prime Minister on September 28, 1978, following the resignation of Dr. B. J. Vorster, by defeating two contenders, Connie Mulder and R. F. "Pik" Botha. He retained the position of Defense Minister for the next two years as well as administering the office of National Intelligence Service (NIS) Director. As a result, he had held the key reins of power that were effectively equivalent to being President of the United States as well as Secretary of Defense and Director of Central Intelligence, but without the checks and balances of a strong independent legislature or judiciary. Not only did P. W. Botha hold all three posts during the period when the decision was made to produce nuclear weapons (October 1978) and to actually assemble the first one (November 1979), but he hand-picked his successors from among his proteges, Magnus Malan for Minister of Defense and Dr. Neil Barnard for NIS chief. In 1980, P. W. Botha abolished the Senate while enlarging the House of Assembly, and under the new constitution he became president. From Shelagh Gastrow, *Who's Who in South African Politics 2* (Johannesburg: Raven Press, 1987), p. 33.

¹⁵ Stumpf, p. 7.

¹⁶ *Ibid.*, p. 8.

¹⁷ Neil Barnard, "The Deterrent Strategy of Nuclear Weapons," in the *Afrikaans Journal for Contemporary History and International Relations 2* (September 1977), pp. 74-97. Other articles of his that were published include: "Total Onslaught Against South Africa," "International Terror and Urban Terrorism," "Tricks in Modern Diplomacy." It has also been reported that he had studied nuclear strategy in the United States. From Gastrow, p. 17.

¹⁸ Patrick Lawrence, "Pik's Diplomatic Thrust Causing Fission in International Nuclear Circles," *The Star* (Johannesburg), August 15, 1988, p. 13. For more on Neil Barnard's writings and influence on South African nuclear deterrent strategy see Kenneth L. Adelman and Albion W. Knight, *Impact Upon U.S. Security of a South African Nuclear Weapons Capability* (Arlington, Vir.: SRI International, Strategic Studies Center, 1980), pp. 17-20.

¹⁹ Lawrence, *Ibid.*

²⁰ Alvin Z. Rubinstein, "Preface," in Richard E. Bissell, *South Africa and the United States: the Erosion of an Influence Relationship* (New York: Praeger Publishers, 1982), p. vii.

²¹ Pauline H. Baker, "The United States and South

Africa: The Reagan Years," in *South African-United States Nuclear Relations, Appendix A*," from the series, "Update, South Africa Time Running Out" (SAIRO), (New York: Ford Foundation - Foreign Policy Association, 1989), p. xii.

²² Richard K. Betts, "A Diplomatic Bomb for South Africa?," *International Security 4* (Fall 1979), p. 113.

²³ South Africa had always justified the development of its indigenous uranium enrichment technology solely on the basis of its commercial merits. The international trend toward enriched uranium fueled light water power reactors supported the argument that South Africa could potentially obtain higher profits through the sale of a more finished, low-enriched uranium product (i.e., 3.25 percent U²³⁵) with its attendant toll charges than would be possible through the export of natural uranium alone. It can therefore be truthfully said that South Africa's uranium enrichment program "had economic and commercial roots-initially," which certainly is not the case for other proliferants such as Pakistan, for example. David Fischer, "Emerging(?) Nuclear Supplier: South Africa," paper prepared for the conference on "The Emerging Nuclear Suppliers and Nonproliferation," held in Bellagio, Italy, June 22-26, 1987, p. 1.

However, it must be remembered that the Valindaba pilot plant was designed to produce weapons grade enriched uranium (i.e., >90 percent U²³⁵) which had never been publicly admitted until after President De Klerk's announcement. Secondly, although improved process modules were incorporated into the design of the follow-on semi-commercial Z plant, the process remained extremely inefficient. The design production capacity of the plant was also only about 85 tonnes of low-enriched uranium per year, or only about 50 percent more fuel per year more than is required for the two 922-megawatt electric (MWe) power reactors at Koeberg in South Africa. South Africa had intended to sell that excess on the world market. However, while the Z plant was successfully operated after 1988, it was permanently shut down in early 1995 because it was economically nonviable when compared to foreign producers with whom South Africa can now deal.

²⁴ David Fischer, personal conversation with the author, July 28, 1995, Monterey, California. Ann MacLachlan, "Where did South Africa Find its Nuclear Fuel?," *The Energy Daily*, November 18, 1981, p. 3.; and Thomas O'Toole, "US Firms Help South Africa Get Uranium," *The Washington Post*, April 13, 1982, p. A5.

²⁵ Leonard S. Spector, *Going Nuclear: The Spread of Nuclear Weapons 1986-1987* (Cambridge, Mass.: Ballinger, 1987), p. 224.

²⁶ "Escam Lost Over R 57-M - Steyn," *Citizen* (Cape Town, South Africa), February 20, 1985, p. 1.

²⁷ Stumpf, p. 9.

²⁸ "US Monitors Signs of Atomic Explosion Near South Africa," *The New York Times*, October 26, 1979, p. 1.

²⁹ Stumpf, p. 9.

³⁰ Bissell, p. 114.

³¹ *Ibid.*, p. 13.

³² South African memorandum, as reprinted in Baker, pp. 122-125.

³³ *Ibid.*, p. 123.

³⁴ *Ibid.*, p. 124.

³⁵ *Ibid.*

³⁶ David Albright, "South Africa's Secret Nuclear Weapons," *ISIS Report* (Washington, D.C.: Institute for Science and International Security, May 1994), p. 8.

³⁷ *Ibid.*, p. 9.

³⁸ *Ibid.*, pp. 9, 12.

³⁹ Chester A. Crocker, *High Noon in Southern Africa: Making Peace in a Rough Neighborhood* (New York: W. W. Norton & Company, 1992), pp. 63-70.

⁴⁰ Scott Fisher, *Coping With Change: United States Policy Toward South Africa*, National Security Affairs Monograph Series No. 82-7 (Washington, D.C.: The National Defense University, 1982), pp. 39-48.

⁴¹ "Legislation Aimed at Cutting Off All Nuclear Commerce With South Africa," *Nuclear Week*, March 17, 1983, p. 6, and Jaster, p. 844.

⁴² Diana Streak, *Sunday Times* (Johannesburg), January 8, 1995, p. 1 (describes the book, by Stuart Murray, entitled, *Koeberg: Eskom's Nuclear Success Story* (1994)).

⁴³ *Pretoria Die Afrikaaner*, January 13-19, 1995, pp. 1, 11.

⁴⁴ Robert Manning, "South African Uranium: Secret Sources of Supply," *South* (March 1982), p. 17.

⁴⁵ Notably, "valindaba" means "no discussion" in Zulu.

⁴⁶ Michael Knapik and Rob Laufer, *Nuclear Fuel 8* (July 18, 1983), p. 1.

⁴⁷ The British Broadcasting Corporation, "South Africa: Energy Minister's Statement Says No US Law Broken in Obtaining Uranium," *Summary of World Broadcasts*, January 12, 1995.

⁴⁸ Harry R. Marshall, Jr., "US Nuclear Policy Toward South Africa," *Department of State Bulletin*, May 1983.

⁴⁹ Princeton Lyman, "US Export Policy Toward South Africa," *Department of State Bulletin*, May 1983, p. 29.

⁵⁰ Brenda M. Branaman and Geoffrey Johnson, *South Africa: Issues For US Policy*, Issue Brief No. IB80032 (Washington, D.C.: The Library of Congress, Congressional Research Service, Foreign Affairs and National Defense Division, March 18, 1980) (updated April 26, 1984), p. 8.

⁵¹ "The Regulations of Nuclear Trade: Non-Proliferation - Supply - Trade," Volume II, *National Regulations* (Paris: Nuclear Energy Agency, 1988), p. 281.

⁵² "Reagan Places New Restrictions on Nuclear Exports to South Africa," *Nuclear Week*, September 12, 1985, p. 7.

⁵³ It should be noted that the South Africans evidently had a fourth stage to their nuclear strategy that consisted of military tactical use against key airfields, ports, or large armored vehicle con-

centrations with delivery by air-drop bombs and, eventually, ballistic missiles. Though not officially acknowledged as such, this fourth stage was implicitly discussed in a post-announcement press conference on March 23, 1993, that included President F. W. de Klerk, AEC Director Waldo Stumpf, and ARMSCOR Executive General Manager Tielman de Waal. At the conference, Mr. de Waal stated that, "the devices were only intended as a deterrent. Therefore, it was never the intention to use them. However if you want to use them as a deterrent they must have a certain capability. They were designed in such a manner that they could be delivered by means of an aircraft." While it could be argued that a deliverable air-drop bomb was just an elaboration on the deterrent theme, the questions that must next be answered are: Why did the South Africans go to the added expense of constructing a second generation nuclear weapons manufacturing complex when they already had a "credible" deterrent, and why did South Africa complete the infrastructure for building 3,000-kilometer-range ballistic missiles designed for delivering nuclear weapons? (See Albright, pp. 13-16.)

⁵⁴ Stumpf, p. 20.

⁵⁵ That South African would employ a strategy of using nuclear weapons as an instrument for diplomatic maneuvering was first described by Betts (1979), p. 108. That such maneuvering might escalate from "ambiguity...to nuclear sabre-rattling" possibly involving a "test explosion...as a means of inducing the West to intervene on its behalf" in a military crisis was later enunciated by Michele A. Floumoy and Kurt M. Campbell in "South Africa's Bomb: A Military Option?," *Orbis* 31 (Summer 1988), pp. 397-398.

⁵⁶ "Inside South Africa's Atomic Lager," *Financial Times* (London), May 20, 1993, p. 1. See also Daryl Howlett and John Simpson, "Nuclearisation and Denuclearisation in South Africa," *Survival* 35 (Autumn 1993), pp. 158, 164.

⁵⁷ R. Jeffrey Smith, "South Africa's 16-Year Secret: the Nuclear Bomb," *The Washington Post*, May 12, 1993, p. 1.

⁵⁸ "SA Built Nuclear Weapons: Armscor Reveals Strategy," *The Star International Weekly* (Johannesburg), April 6-12, 1995, p. 4.

⁵⁹ *Media Statement Jointly Issued by the Atomic Energy Corporation and ARMSCOR*, March 26, 1993, p. 3.

⁶⁰ Crocker, p. 367.

⁶¹ *Ibid.*, p. 502.

⁶² "IAEA General Conference Again to Face Issue of Suspending South Africa," *Nuclear Fuel*, August 22, 1988, p. 10. It should be noted, however, that although this was not the first admission by a South African government official of such a capability, the timing was certainly significant. Previous official comments include Prime Minister Vorster's 1976 statement that while, "we are only interested in the peaceful applications of nuclear power," South Africa "can enrich uranium and we have the capability (of mounting a nuclear defense)." In 1977, Vorster's

Information and Interior Minister Connie Mulder stated, "Let me just say that if we are attacked, no rules apply at all if it comes to a question of our existence. We will use all means at our disposal, whatever they may be. It is true that we have just completed our own pilot plant that uses very advanced technology, and that we have major uranium resources." See Jim Hoagland, *The Washington Post*, February 16, 1977. Earlier hints of an interest in nuclear weapons date as far back as 1965. See Leonard S. Spector, *Nuclear Proliferation Today* (Cambridge, Mass.: Ballinger, 1984), pp. 282-283. It has also been noted that P. W. Botha told a National Party gathering (only four days after the suspected nuclear test in September 1979) that not only did South Africa have a significant conventional capability to counter any guerilla incursion, but, "if there are people who are thinking of doing something else, I suggest they think twice about it. They might find out we have military weapons they do not know about." From Robert Scott Jaster, *The Defense of White Power: South African Foreign Policy under Pressure* (New York: St. Martin's Press, 1989), pp. 165-166.

⁶³ Mitchell Reiss, *Bridled Ambition: Why Countries Constrain Their Nuclear Capabilities* (Washington, D.C.: Woodrow Wilson Press, 1995), p. 13; and personal fax to author from Johann Viljoen of the South African Council for Non-Proliferation, February 10, 1995.

⁶⁴ "South Africa 'fesses up,'" *Chicago Tribune*, editorial, March 29, 1993, p. 10. For more on this strategy, see Floumoy and Campbell, p. 401.

⁶⁵ ARMSCOR public relations fax to queries by Mark Hibbs of *Nuclear Week*, dated April 27, 1993.

⁶⁶ Mark Stansfield, "Terrain of Destruction," *Sunday Star* (Johannesburg), March 28, 1993, p. 27. During 1992 (prior to President de Klerk's announcement), the IAEA, "acting on the information received from Member States," carried out a number of inspections. They included taking environmental samples, at a location that was later declared to be an unused nuclear weapons [site] in the Kalahari desert.... The South African officials were very co-operative in facilitating access to these locations but claimed lack of detailed knowledge of their past use." See Adolf von Baeckmann, Garry Dillon, and Demetri Pericos, "Nuclear Verification in South Africa," *IAEA Bulletin*, 1/1995, p. 46.

⁶⁷ *Media Statement Jointly Issued by the Atomic Energy Corporation and ARMSCOR*, March 26, 1993, p. 3.

⁶⁸ Professor Renfrew Christie, *South Africa's Nuclear History* (manuscript in preparation) from paper delivered at Fourth International Conference, Nuclear History Program, Sofia-Antinopolis, Nice, France, June 23-27, 1993, dated June 16, 1993, p. 55. It should be noted that in 1979, Kenneth Adelman and Albion Knight suggested the need for continuous overhead monitoring because, as they put it, "If South Africa should reopen the Kalahari site, it would be better that the information be discovered first by the United States, rather than the Soviet

Union." From Adelman and Knight, p. 646.

⁶⁹ Mark Hibbs, "South Africa's Nuclear Program: the Dismantling," *Nuclear Fuel*, May 24, 1993, p. 9.

⁷⁰ *Media Statement Jointly Issued by the Atomic Energy Corporation and ARMSCOR*, March 26, 1993, p. 3, and Stumpf, p. 12. However, another report, *South Africa's nuclear deterrent programme and nonproliferation policy: additional information presented at the workshop*, circulated at the PNPN Workshop, Harare, Zimbabwe, April 2-4, 1993 (compiled by the staff of the PNPN on the basis of Stumpf's presentation at the Harare workshop), indicated on page one that the inspection activity took place in 1988 (although no month was stipulated).

⁷¹ See Reiss (1995), p. 13; also personal fax to author from Viljoen (see note 63) and subsequent conversation.

⁷² David Fischer, *Stopping the Spread of Nuclear Weapons: the Past and the Prospects* (London: Routledge, 1992), pp. 214-217.

⁷³ It should be noted that several resolutions were routinely passed denouncing South Africa for its nuclear weapons capability. In the fall of 1990, only a few months prior to South Africa's NPT accession, a U.N. committee approved (by an overwhelming majority) a resolution declaring that South Africa's nuclear capability was a threat to international peace. Only the United States, the United Kingdom, and France opposed the resolution, which was adopted in the General Assembly's main political committee. Another passed resolution demanded that South Africa submit all its nuclear facilities to IAEA inspection. Again, only the same three countries, with the addition of Israel, opposed the resolution. Finally, another resolution, condemning the build-up of the South African nuclear weapons capability, was adopted by 124 votes with only the above four countries and Liechtenstein abstaining. From *The Star* (Johannesburg, International Airmail Weekly), November 21, 1990, p. 4.

⁷⁴ J. D. L. Moore, *South Africa and Nuclear Proliferation* (New York: St. Martins Press, 1987), pp. 152-156.

⁷⁵ *Ibid.*

⁷⁶ "Text of De Klerk Address to the Parliament," from Broadcast by Johannesburg Radio South Africa Network, March 24, 1993; in FBIS-MB2403161093 (24 March 1993), p. 4.

⁷⁷ Peter Goosen, of the South African Mission to the United Nations in Geneva, personal conversation with author, July 28, 1995, Monterey, California.

⁷⁸ Spector, p. 218

⁷⁹ J. W. de Villiers, Roger Jardine, and Mitchell Reiss, "Why South Africa gave Up the Bomb," *Foreign Affairs* 72 (November/December 1993), p. 106.

⁸⁰ Albright and Hibbs, p. 33. It should also be noted that in late 1991, Dr. Waldo Stumpf, while discussing ongoing changes in South Africa's nuclear program, said, "The strategic emphasis has now completely fallen away" and that the program would have to be justified on a purely

economic basis. When "questioned about the reasons behind the change of government thinking about the objectives of its nuclear program, Stumpf said that the prospect of black-majority rule in the 'New South Africa' within a few years was a major consideration." Quoted by David B. Ottaway, *The Washington Post*, October 18, 1991, p. A23.

⁸¹ It has been alleged that the West German firm *Steinkohlen Elektrizitäts AG* (STEAG) "constructed the Valindaba Pilot Plant in the early 1970s and pulled out in 1976." The same article that was the source of this allegation claimed other German firms that had been "involved in the development of Pretoria's nuclear industry included Siemens, Messerschmidt-Boelkow-Blohm, Leybold-Heraeus, Varian-MAT and GHH-Sterkrade." *Africa Confidential* (London) 34 (April 2, 1993). At a minimum, the former head of the South African Atomic Energy Board A. J. Roux was quoted in January 1978 as saying that STEAG had, "cooperated with South Africa in the field of uranium enrichment from 1973 to September 1975, with a view to the joint construction of a commercial enrichment plant." Frank Barnaby, "Nuclear South Africa," *New Scientist*, October 19, 1978, p. 169. As a result, it has been suggested that STEAG may have provided both "technical advice and components" to South Africa. U.N. Centre for Disarmament, Department of Political and Security Council Affairs, *South Africa's Plan and Capability in the Nuclear Field*, Report of the Secretary-General, Document A/35.402, p. 17. There is also a report that two U.S. computers, approved for sale to South Africa, were installed at the Valindaba pilot plant in 1973. Tami Hultman and Reed Kraner, "South Africa's Rising Nuclear Progress," *The Los Angeles Times*, August 28, 1978, p. 1. Other imported equipment alleged to have been installed in the Valindaba pilot plant includes compressors from the French firm Hispano-Suiza and the Swiss firm Sulzer Brothers, according to Spector (1984), p. 286.

⁸² Bissell, p. 109; from Jim Hoagland, "French Leader Confirms South Africa Nuclear Capability," *The Washington Post*, February 18, 1977, p. 28.

⁸³ *Ibid.*, p. 109.

⁸⁴ The South Africans reportedly acquired intermediate range ballistic missile (IRBM) technology from Israel. See Bill Gertz, "South Africa on the Brink of Ballistic Missile Test," *The Washington Times*, June 20, 1989, p. A1. According to David Albright, the South Africans had, by 1989, completed the infrastructure at Advena Central Laboratories to "integrate" a nuclear "warhead onto a ballistic missile" at that facility. Albright noted, however, that "an unusual feature of the South African program is that if the government had deployed nuclear-tipped missiles, the warheads might have used gun-type devices, not implosion warheads as is often thought necessary." See Albright, pp. 15, 16.

⁸⁵ Albright, p. 13.

⁸⁶ *Ibid.*

⁸⁷ "From Bomb-filling to Advanced R&D," *Engi-*

neering Week: ARMSCOR Annual Survey (Johannesburg, 1989), p. 22.

⁸⁸ *Engineering News* (Johannesburg, December 4, 1992), p. 19.

⁸⁹ Mark Hibbs, "South Africa's Secret Nuclear Program: From a PNE to a Deterrent," *Nuclear Fuel*, May 10, 1993, p. 3-4; Advena Central Laboratories Brochure, p. 3; and author's conversation with David Albright, Washington, D.C., January 1994.

⁹⁰ Generating tritium from the neutron, proton reactions in a reactor is a much more difficult than simply irradiating lithium-6. According to a 1995 IAEA report, the South Africans were also planning to separate lithium-6 for the production of tritium "for possible use in boosted devices," see von Baeckmann, Dillon, and Ferricos, p. 42.

⁹¹ Jaster (1989), p. 167.

⁹² David Albright, conversation with author, Washington, D.C., January 1994.

⁹³ Albright, p. 45.

⁹⁴ *Ibid.*, p. 13.

⁹⁵ *Ibid.*

⁹⁶ Mark Hibbs, "Evidence Builds of Advanced Weapons Work by South Africa," *Nucleonics Week*, January 20, 1994, p. 5.

⁹⁷ William K. Donke, "Proliferation, Threat, and Learning: The International and Domestic Structures of Export Controls," in M. van Leeuwen, ed., *The Future of the International Nuclear Non-Proliferation Regime* (Netherlands: Kluwer Academic Publishers, 1995), pp. 205-230.

⁹⁸ See INF/CIRC/254, Part II.

⁹⁹ See Leonard S. Spector, *The Undeclared Bomb* (Cambridge, Mass.: Ballinger, 1988), pp. 70-79.

¹⁰⁰ To use Reiss's term, this negative side-effect creates a "nonproliferation paradox." See Reiss, p. 31.