Case Studies:
Civil Nuclear Programs and Weapons Proliferation

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This paper concerns countries which have pursued nuclear weapons under cover of a civil nuclear program. The case studies, arranged alphabetically, cover these 21 countries: Algeria, Argentina, Australia, Brazil, Burma, Canada, Egypt, India, Iran, Iraq, Israel, Libya, North Korea, Pakistan, Romania, South Africa, South Korea, Sweden, Syria, Taiwan, and Yugoslavia.

The criterion for the inclusion in the above list is concrete activity in pursuit of nuclear weapons, linked to a civil nuclear research or power program, e.g. weapons-related experiments or fissile material production.

If the threshold was lowered to include countries which had an interest in developing nuclear weapons, and a civil nuclear program, but without any clear links between the two, the list could include other countries such as Indonesia and Italy.

Nor does this paper cover nuclear threshold or breakout states such as Japan and Germany which could build nuclear weapons in a short space of time if they decided to do so based on their advanced nuclear programs and broader technological infrastucture.

Some countries that are included in the list of 21 countries and are discussed in this paper ... but arguably shouldn't be:
* Burma may or may not qualify for inclusion using the above criterion – concrete activity in pursuit of nuclear weapons, linked to a civil nuclear research or power program. The Burmese regime may or may not be pursuing weapons and its pursuit of research reactor technology and other dual-use technology may or may not be relevant to its suspected interest in nuclear weapons.
* Canada is included in the list because of its use of research reactors to produce plutonium for US and British nuclear weapons, but to the best of my knowledge there was no interest in developing a domestic nuclear weapons capability in Canada.

Some countries that are not included in the list of 21 countries and are not discussed in this paper ... but arguably should be:
* The declared nuclear weapons states – the US, Russia, China, France and the UK – are not discussed in this paper although there are varying degrees of overlap between civil and military programs in these countries, e.g. routine transfer of personnel, e.g. the use of a power reactor to produce tritium for weapons in the USA, and presumably there are more than a few links in Russia and China where the civil and military nuclear sectors remain fairly closely connected.

* Of the five declared weapons states, France was the only one where a civil nuclear program played any significant role in the initial development of nuclear weapons. Matthew Bunn writes: "France's initially civilian nuclear program provided the base of expertise (and some key advocates) for its later dedicated military program (which had substantial interconnections with the civilian program, with both under the Commissariat de L'Energie Atomique, and material for the weapons program sometimes produced in power reactors)." (Matthew Bunn, 2001, "Civilian Nuclear Energy and Nuclear Weapons Programs: The Record", <http://ocw.mit.edu/NR/rdonlyres/Nuclear-Engineering/22-812JSpring2004/DA39D9C3-72E5-426E-840C-712594207E23/0/prolif_history.pdf>.)
* Norway is occasionally mentioned as a country that pursued nuclear weapons. However, ISIS states: "The Norwegian Defense Research Establishment considered atomic weapons as one of several justifications for recommending R&D activities to develop a nuclear reactor in Norway in the late 1940s. However, there is little indication that Norway actually pursued a nuclear weapons program" (ISIS: <http://isis-online.org/country-pages/norway>. See also Astrid Forland, "Norway's Nuclear Odyssey: From Optimistic Proponent to Nonproliferator", The Nonproliferation Review, Vol 4(2), Winter 1997.)
* Switzerland developed plans to build nuclear weapons in the 1950s and 60s but the plans were never seriously pursued. See <http://nuclearweaponarchive.org/Nwfaq/Nfaq7-4.html>
* Poland has pursued nuclear research programs since the 1960s, sometimes under military control according to this source: http://www.spiritus-temporis.com/list-of-countries-with-nuclear-weapons/states-formerly-possessing-nuclear-programs.html

More information on nuclear civil/military connections including country case studies:
https://nuclear.foe.org.au/power/weapons

Main source:
Unless otherwise indicated, the case studies below are taken from: Jim Green, 2002, "Research Reactors and Nuclear Weapons", https://nuclear.foe.org.au/research-reactors-nuclear-weapons/

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ALGERIA

In early 1991, US intelligence agencies discovered that Algeria was secretly building a large research reactor, known as Es Salam, about 150 kilometres south of Algiers. This raised suspicions since the reactor appeared to be unusually large in relation to Algeria's rudimentary nuclear research program, and it was not subject to IAEA safeguards. The Algerian regime said the reactor was being supplied by China and it had a power rating of 10-15 MW(th). A reactor of that size, using LEU fuel, might produce a few kilograms of weapon grade plutonium annually. In addition, roughly 1.5 kilograms of plutonium could be produced annually by irradiating natural uranium targets in the reactor. The reactor first went critical in February 1992 and was commissioned in December 1993. In January 1992, Algeria agreed to place the Es Salam reactor under IAEA safeguards, and inspections began the same month. The Algerian regime nominated several peaceful purposes for the reactor including medical research.

A second construction phase was completed by mid 1996, with the completion of a Chinese-supplied hot cell facility and an underground tunnel connecting the reactor to the hot cells. Underground waste storage tanks, and a building containing six liquid storage tanks, were also built in the mid 1990s. A large building near the reactor appears to be unused, has no announced function, and was possibly built to house a small reprocessing plant.

In May 1997, work began on a third construction phase including a radiopharmaceutical production facility and other auxiliary facilities. It was stated that the radiopharmaceutical production facility would allow production of cobalt-60 even though cobalt-60 can be purchased cheaply from many suppliers. The hot cells, or the radiopharmaceutical production facility, might be used to extract plutonium from irradiated fuel or targets.

A one MW(th) reactor was supplied to Algeria by Argentina in the 1980s, located about 20 kilometres east of Algiers. The reactor itself was of little significance in terms of weapons proliferation (partly because of its limited capacity, partly because the reactor was subject to a site-specific safeguards agreement with the IAEA) but it was a stepping stone for more dangerous facilities. All the more so because, as the Argentinian nuclear agency Invap notes on its website <www.invap.com.ar>, the project involved "genuine transfer of technology", with over 50 Algerian professionals and technicians, and a number of Algerian firms, involved in the project.

Further discussions were held with a view to Argentina supplying Algeria with another reactor and hot cells, but these discussions did not progress. Argentina did however supply a fuel-fabrication plant, located in Draria, which could potentially be used to produce targets for plutonium production although it is subject to IAEA safeguards.

In 1995, Algeria formally acceded to the NPT. IAEA inspections discovered that about three kilograms of enriched uranium, several litres of heavy water, and several pellets of natural uranium supplied by China had not been declared to the IAEA. The IAEA does not have the authority to inspect all facilities at the nuclear site south of Algiers, and some questions remain unresolved. Many of these questions could be resolved if Algeria agrees to additional inspections under the IAEA's Additional Model Protocol. Considerable quantities of plutonium could be produced without breaching NPT commitments.

Despite the information available about Algeria's nuclear program, it remains unclear whether a nuclear weapons program was underway in the 1980s and 1990s, or whether there are currently plans to produce and separate plutonium for nuclear weapons.

Sources and more information:

David Albright, 1993, "A Proliferation Primer", Bulletin of the Atomic Scientists, June, <www.thebulletin.org/issues/1993/j93/j93Albright.html>.

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Rodney W. Jones, Mark G. McDonough with Toby F. Dalton and Gregory D. Koblentz, 1998, Tracking Nuclear Proliferation, 1998, Washington, DC: Carnegie Endowment for International Peace.

Daniel Poneman, 1985, "Argentina", in Jed. C. Snyder and Samuel F. Wells Jr. (eds.), Limiting Nuclear Proliferation, Cambridge, Mass.: Ballinger, pp.89-116.

Leonard S. Spector with Jacqueline R. Smith, 1991, Nuclear Ambitions, Boulder, Co: Westview Press, pp.223-241.

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ARGENTINA

A civil/military nuclear program was pursued by Argentina from the 1950s. After a military junta seized power in 1976, and motivated in part by Brazil's 1975 deal with West Germany to obtain extensive nuclear fuel cycle facilities, Argentina's nuclear program expanded and the military objective became more pronounced. Argentina rejected IAEA inspections of most of its nuclear facilities, and at the time refused to sign the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (the Treaty of Tlatelolco) or the NPT.

The first Argentine research reactor was manufactured and assembled in Argentina using US plans. Several more research reactors were constructed, some with little or no foreign assistance. By the late 1960s, Argentina had developed the infrastructure to support a nuclear power plant, and in 1968 it purchased a 320 MW(e) power reactor from the West German firm Siemens.

One military option considered from the late 1960s to the early 1980s included a plan to build a 70 MW(th) research reactor which could produce unsafeguarded plutonium. Another option was diversion of plutonium from safeguarded power reactors.

In the late 1960s, Argentina, possibly with assistance from an Italian firm, built a laboratory scale reprocessing facility at Ezeiza. This facility was closed in 1973 after intermittent operation and the extraction of less than one kilogram of plutonium. In 1978, the Argentine nuclear agency CNEA began construction of a second reprocessing facility at Ezeiza that had a design capacity of 10-20 kilograms of plutonium per year. The stated intention was to reprocess spent fuel from power reactors and to use plutonium in the same reactors or in breeder reactors which were (ostensibly) under consideration. Due to economic constraints, and political pressure from the US, construction on the second Ezeiza reprocessing plant was halted in 1990.

Argentina announced in 1983 that a gaseous diffusion uranium enrichment plant had been under construction since 1978 – although Argentina's nuclear power reactors did not require enriched uranium fuel – and that the plant had already produced a small amount of enriched uranium. Argentina claimed that the enrichment plant was built to service research reactors. An official involved in building the plant said that Argentina had thrown off Western intelligence agencies by encouraging them to look for a nonexistent plutonium production reactor. The enrichment plant is capable of producing up to 500 kilograms per year of 20% enriched uranium or about 10 kilograms per year of 80% enriched uranium. However it is believed that the plant produced only small amounts of LEU and no weapon grade uranium. Before building the enrichment plant, Argentina had been supplied with enriched uranium by China and the Soviet Union.

Argentina has supplied nuclear equipment to several countries suspected of pursuing covert nuclear weapons programs. A report from the Carnegie Endowment for International Peace stated (Jones et al., 1998): "The restoration of democratic governance in 1983 did little to change the liberal export policy of the Argentine military, especially as it pertained to North Africa. In 1985, Argentina and Algeria concluded an agreement under which Argentina exported a one MW(th) research reactor that went critical in 1989 – Algeria was not a NPT member and had no safeguards agreement at the time. Under a second agreement, discussed in 1990 but never concluded, Argentina would have sent an isotopic production reactor and hot cell facility to Algeria."

Extensive nuclear cooperation between Argentina and Libya is believed to have taken place. Argentina was also closely involved in the development of Iran's nuclear industry in the 1980s and 1990s. Other recipients of nuclear exports from Argentina include Brazil, Egypt, India, Peru and Romania. In the early to mid 1990s, as military influence over the nuclear industry waned, export controls were tightened.

From the late 1980s, Argentina and Brazil allowed joint inspections of each other's nuclear facilities, and this agreement was formalised in 1991. In the mid 1990s, Argentina and Brazil joined the Treaty of Tlatelolco, the Nuclear Suppliers Group, and the NPT.

Nassauer states: "Argentina has had a civilian nuclear program for many years. The first research reactor was supplied by the United States in the 1950s. Later several more were built and two heavy-water power reactors were supplied by Germany and Canada. Thus there is a capability to produce plutonium. During the 1970s Argentina added a nuclear weapon program and built an unsafeguarded plutonium reprocessing plant, reportedly with help from Germany and Italy. In 1983 Argentina announced it had successfully enriched uranium in a secret, unsafeguarded facility at Pilcaniyeu, ostensibly for civilian purposes. (None of the Argentinean power reactors require enriched uranium.) However, today all nuclear facilities in Argentina are under IAEA safeguards since the weapons program was abandoned in the late 1980s when a civilian government succeeded the military Junta, an agreement with Brazil was reached, and Argentina gave in to US pressure. (Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>)

Sources and more information:

David Albright, 1993, "A Proliferation Primer", Bulletin of the Atomic Scientists, June, <www.thebulletin.org/issues/1993/j93/j93Albright.html>.

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Daniel Poneman, 1985, "Argentina", in Jed. C. Snyder and Samuel F. Wells Jr. (eds.), Limiting Nuclear Proliferation, Cambridge, Mass.: Ballinger, pp.89-116.

Leonard S. Spector with Jacqueline R. Smith, 1991, Nuclear Ambitions, Boulder, Co: Westview Press, pp.223-241.

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AUSTRALIA

During the 1950s and 1960s, the Australian government made several efforts to obtain nuclear weapons from the US or the UK. Nothing eventuated from the negotiations although the UK was reasonably supportive of the idea at times.

From the mid 1960s to the early 1970s, there was greater interest in the domestic manufacture of nuclear weapons. The government never took a decision to systematically pursue a nuclear weapons program, but it repeatedly took steps to lessen the lead time for weapons production by pursuing civil nuclear projects. Consideration was also given to delivery systems – for example the 1963 contract to buy F-111s bombers from the US was partly motivated by the capacity to modify them to carry nuclear weapons.

The Australian Atomic Energy Commission's (AAEC) major research project from the mid 1950s to mid 1960s concerned the potential use of beryllium (or beryllium compounds) as a moderator in civil reactors. The AAEC's first reactor, the High Flux Australian Reactor (HIFAR), was one of the instruments used for this research. Historian Wayne Reynolds (2000, p.27) suggests that the beryllium research may also have been connected to British interest in thermonuclear weapons.

In 1962, the federal Cabinet approved an increase in the staff of the AAEC from 950 to 1050 because, in the words of the Minister of National Development William Spooner, "a body of nuclear scientists and engineer skilled in nuclear energy represents a positive asset which would be available at any time if the government decided to develop a nuclear defence potential." (Reynolds, 2000, p.194.)

Despite the glut in the uranium market overseas, the Minister for National Development announced in 1967 that uranium companies would henceforth have to keep half of their known reserves for Australian use, and he acknowledged in public that this decision was taken because of a desire to have a domestic uranium source in case it was needed for nuclear weapons.

The intention to leave open the nuclear weapons option was evident in the government's approach to the NPT from 1969-71. Prime Minister John Gorton was determined not to sign the NPT, and he had some powerful allies such as Philip Baxter, Chair of the AAEC. The Minister for National

Development admitted that a sticking point was a desire not to close off the weapons option. When the Government eventually signed (but did not ratify) the NPT in 1971, it was influenced by an assurance from the Department of External Affairs that it was possible for a signatory to develop nuclear technology to the brink of making nuclear weapons without contravening the NPT.

In the late 1960s, the AAEC set up a Plowshare Committee to investigate the potential uses of peaceful nuclear explosives in civil engineering projects. Plans to use peaceful nuclear explosives were never realised, partly because of the implications for the Partial Test Ban Treaty (to which Australia was a signatory), and the Plowshare Committee was disbanded in the early 1970s.

In 1969, Australia signed a secret nuclear cooperation agreement with France. The Sydney Morning Herald (June 18, 1969) reported that the agreement covered cooperation in the field of fast breeder power reactors (which produce more plutonium than they consume). The AAEC had begun preliminary research into building a plutonium separation plant by 1969, although this was never pursued.

A split table critical facility – built in 1972 at Lucas Heights but conceived in the late 1960s – was connected to the interest in fast breeder reactors and was possibly connected to the interest in weapons production. The facility was supplied by France. It proved to be difficult to secure supplies of enriched uranium or plutonium for experiments using the critical facility, which was widely regarded as a "white elephant" and was later dismantled.

In 1968, government officials and AAEC scientists studied and reported on the costs of a nuclear weapons program. They outlined two possible programs: a power reactor program capable of producing enough weapon grade plutonium for 30 fission weapons annually; and a uranium enrichment program capable of producing enough uranium-235 for the initiators of at least 10 thermonuclear weapons per year.

In 1969, federal Cabinet approved a plan to build a power reactor at Jervis Bay on the south coast of New South Wales. There is a wealth of evidence – some of it contained in Cabinet documents – revealing that the Jervis Bay project was motivated, in part, by a desire to bring Australia closer to a weapons capability. After Gorton was replaced as leader of the Liberal Party by William McMahon in 1971, the Jervis Bay project was reassessed and deferred. The Labor government, elected in 1972, did nothing to revive the Jervis Bay project, and Australia ratified the NPT in 1973.

Even before the cancellation of the Jervis Bay project, Baxter was making efforts to promote an Australian uranium enrichment plant, building on a small enrichment research program begun in secret at the AAEC in 1965. Baxter's interest in the plant was largely military, as revealed by his written notes calculating how much HEU – and how many HEU weapons – could potentially be produced with an expanded enrichment program. Early, experimental work would of course have to be expanded to achieve Baxter's aim, and the process modified, but these were not insurmountable obstacles. As Tony Wood (2000), former head of the AAEC's Division of Reactors and Engineering, noted: "Although the Australian research team contained only a small number of centrifuge units, it is not a secret that one particular arrangement of a large number of centrifuge units could be capable of producing enriched uranium suitable to make a bomb of the Hiroshima type."

Dr. Clarence Hardy (1996, p.31), a senior scientist at the AAEC (and from 1987 its successor the Australian Nuclear Science and Technology Organisation – ANSTO) from 1971-1991, has noted that the enrichment project was given the code name "The Whistle Project" and was carried out initially in the basement of Building 21. Former AAEC scientist Keith Alder (1996, p.30) noted that the enrichment project was kept secret "because of the possible uses of such technology to produce weapons-grade enriched uranium". The project was not publicly revealed until a passing mention was made of it in the AAEC's 1967-68 Annual Report.

A feasibility study into a joint Australian/French enrichment program was nearing completion in 1972 but collaboration with the French on nuclear matters was not supported by the incoming Labor government.

Since the early 1970s, there has been little high level support for the pursuit of a domestic nuclear weapons capability. However, there have been indications of a degree of ongoing support for the view that nuclear weapons should not be ruled out of defence policy altogether and that Australia should be able to build nuclear weapons as quickly as any neighbour that looks like doing so. For example, this current of thought was evident in a leaked 1984 defence document called The Strategic Basis of Australian Defence Policy.

Bill Hayden, then the Foreign Minister, attempted to persuade Prime Minister Bob Hawke in 1984 that Australia should develop a "pre-nuclear weapons capability" which would involve an upgrade of Australia's modest nuclear infrastructure. Hayden's views found little or no support. Moreover the AAEC's uranium enrichment research, by then the major project at Lucas Heights, and pursued in the post-Baxter period with the aim of "value adding" to Australia's uranium exports, was terminated by government directive in the mid 1980s.

Several reasons can be given for the declining interest in nuclear weapons acquisition or production from the early 1970s onwards. Arguably, the development of the military alliance between the US and Australia is the key reason. Australia effectively became a nuclear weapons state "by proxy", relying on the US nuclear umbrella.

Sources and more information:

Keith Alder, 1996, Australia's Uranium Opportunities, Sydney: P.M. Alder.

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Clarence Hardy, 1996, Enriching Experiences. NSW: Glen Haven.

Jacques E. C. Hymans, 2000, "Isotopes and Identity: Australia and the Nuclear Weapons Option, 1949-1999", Nonproliferation Review, Vol.7, No.1, Spring, pp.1-23.

Jean McSorley, 1998, "The New Reactor: National Interest and Nuclear Intrigues", Submission to Senate Economics References Committee, Inquiry into Lucas Heights Nuclear Reactor. <www.geocities.com/jimgreen3/mcsorley.html>

Wayne Reynolds, 2000, Australia's bid for the atomic bomb, Melbourne University Press.

Jim Walsh, 1997, "Surprise Down Under: The Secret History of Australia's Nuclear Ambitions", The Nonproliferation Review, Fall, pp.1-20.

Tony Wood, 2000, Letter, St. George and Sutherland Shire Leader, May 2.

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BRAZIL

Quoted verbatim from: Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>

Brazil first tried to acquire centrifuge enrichment technology from Germany as early as in 1953, but was initially blocked by the United States. Washington later supplied the country with a research reactor, while Brazil continued enrichment research based on the German Becker nozzle technology. In 1975 a highly controversial agreement was concluded under which Germany would have supplied Brazil with a full closed fuel cycle, consisting of several nuclear power plants, an enrichment facility, and a reprocessing plant for civilian purposes.

While the deal was later substantially scaled back under US pressure, Brazil secretly engaged in an unsafeguarded parallel military program, with the army being responsible for the plutonium path and the navy pursuing uranium enrichment. Both used personnel trained in the civilian program and are believed to have used technology supplied for the civilian program in unsafeguarded enrichment and reprocessing facilities. Brazil's military nuclear program was ended in parallel with Argentina's. Brazil joined the NPT in the 1990s. It continues to operate nuclear power plants.

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BURMA

Comments copied verbatim from:
David Albright, Paul Brannan, Robert Kelley and Andrea Scheel Stricker, Burma: A Nuclear Wannabe; Suspicious Links to North Korea; High-Tech Procurements and Enigmatic Facilities,

January 28, 2010, <http://isis-online.org/isis-reports/detail/burma-a-nuclear-wanabee-suspicious-links-to-north-korea-high-tech-procureme>

For several years, suspicions have swirled about the nuclear intentions of Burma's secretive military dictatorship. Burma is cooperating with North Korea on possible nuclear procurements and appears to be misleading overseas suppliers in obtaining top-of-the-line equipment. Certain equipment, which could be used in a nuclear or missile program, went to isolated Burmese manufacturing compounds of unknown purpose. Although evidence does not exist to make a compelling case that Burma is building secret nuclear reactors or fuel cycle facilities, as has been reported, the information does warrant governments and companies taking extreme caution in any dealings with Burma. The military regime's suspicious links to North Korea, and apparent willingness to illegally procure high technology goods, make a priority convincing the military government to accept greater transparency.
...
There remain sound reasons to suspect that the military regime in Burma might be pursuing a long-term strategy to make nuclear weapons. Despite the public reports to the contrary, the military junta does not appear to be close to establishing a significant nuclear capability. Information suggesting the construction of major nuclear facilities appears unreliable or inconclusive. Assigning a purpose to suspicious procurements likewise remains uncertain. The procurements are multi-purpose and difficult to correlate conclusively with a secret missile or nuclear program. Although Burma and North Korea appear to be cooperating on illegal procurements, who is helping who cannot be determined with the available information. Is North Korea helping Burma acquire nuclear, conventional weapon, or missile capabilities or is Burma assisting North Korea acquire this equipment?
Nonetheless, the evidence supports that the regime wants to develop a nuclear capability of some type, but whether its ultimate purpose is peaceful or military remains a mystery. The outstanding questions about the regime's activities require that there be more scrutiny of Burma to ascertain if there is an underlying secret nuclear program. Because Burma's known nuclear program is so small, the United States and its allies have an opportunity to both engage and pressure the military regime in a manner that would make it extremely difficult for Burma to acquire a nuclear weapons capability, let alone nuclear weapons.

See also: Exploring Claims about Secret Nuclear Sites in Myanmar, January 28, 2010, <http://isis-online.org/isis-reports/detail/exploring-claims-about-secret-nuclear-sites-in-myanmar>
An analysis of several facilities described by Burmese dissidents as involved in a Burmese nuclear program.

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CANADA

Canada used research reactors to produce plutonium for US and British nuclear weapons.

Gordon Edwards from the Canadian Coalition for Nuclear Responsibility writes: "Canada's NRX reactor started up in 1946. A small plutonium extraction plant was built at Chalk River, and there the British conducted pilot plant work for their large Windscale reprocessing plant. The first British Bomb incorporated some plutonium produced in NRX. For twenty years after Hiroshima, Canada sold plutonium produced at Chalk River to the American military to help defray the cost of nuclear research. After Canada gave India a clone of the NRX, India used it to produce plutonium for its first A-Bomb test in 1974. Surprise, surprise." (Canada and the Bomb: Past and Future, <www.user.dccnet.com/welcomewoods/Nuclear_Free_Georgia_Strait/canada.htm>.)

Canada's NRU research reactor was also used to produce plutonium for US nuclear weapons. (Al Rose, NRU: Then and Now, North Renfrew Times, November 12, 1997, <http://tinyurl.com/yb8t78h>)

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EGYPT

Some excerpts from a Nuclear Threat Initiative analysis:
http://www.nti.org/e_research/profiles/Egypt/index.html

While suspected of harboring nuclear weapons ambitions at various points in history (and especially under President Gamal Abdel Nasser in the 1960s), the Egypt of 2009 is a member in good standing of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the leading proponent of establishing a weapon-of-mass-destruction-free zone in the Middle East. Many scholars and practitioners worry that Iran's nuclear activities could provoke an Egyptian policy reversal, but currently Egypt seems to perceive developing nuclear weapons as counter to its national interests.

Furthermore, despite possessing a comparatively advanced capability in nuclear technology (for the Middle East), Egypt is years away from the ability to produce nuclear weapons. Although Egypt operates two small research reactors and possesses other fuel-cycle relevant technology and expertise, none of its past efforts to acquire power reactors was successful. Historically, a combination of factors — leadership priorities, supplier-based constraints, financial difficulties, safety concerns, etc.— prevented Egypt from developing a nuclear energy program of possible weapons significance. Since 2006, reinvigorated Egyptian interest in creating a civil nuclear power infrastructure has led to a flurry of preparative activities — it remains to be seen whether recent attempts, unlike historical ones, will reach fruition. If they do, Egypt eventually could possess a hedge capability, with this capability's potential utility for a nuclear weapons program determined by whether or not Egypt develops indigenous enrichment and/or reprocessing capabilities.

...

James Walsh, who has perhaps written the most in-depth study of Egypt's nuclear program to date, concludes: "...it is fair to say that Egypt's most intensive efforts to acquire nuclear weapons (or the capability to produce them) occurred during this phase — that is, just after the disclosure of the Dimona reactor, but before the 1967 Arab-Israeli war." It is indisputable that Egypt stepped up its rhetoric on the issue of nuclear weapons following the Israeli announcement — for example, in 1961 Nasser warned that if Israel acquired such weapons, "we will secure atomic weapons at any costs."

Indeed, during this period, the Egyptian government dramatically increased its investment and research into nuclear technologies. It attempted quite persistently, for example, to acquire a sizeable power reactor—and was notably insistent that it be a natural uranium fueled heavy water-moderated reactor rather than a light water reactor.

...

More than two decades after its comprehensive safeguards agreement entered into force, the Egyptian government found itself the subject of an IAEA investigation into possible compliance violations. At issue were a number of reporting failures—while the activities themselves were permissible, they should have been reported to the Agency in a timely manner and continually monitored. The violations were discovered and investigations begun in 2004, with preliminary conclusions reported in February 2005.

More information:

* <www.globalsecurity.org/wmd/world/egypt/nuke.htm>
* WISE/NIRS Nuclear Monitor #623, March 4, 2005, "25 Years Ago", <www10.antenna.nl/wise/623/index.php>
* Wisconsin Project on Nuclear Arms Control, "Egypt's Budding Nuclear Program", The Risk Report, Volume 2 Number 5, September-October 1996, <www.wisconsinproject.org/countries/egypt/nuke.html>

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INDIA

India's nuclear research and power programs laid the foundation for its 1974 nuclear test explosion. The test explosion used plutonium produced in the 40 MW(th) research reactor known as Cirus (Canada-India-Reactor-United-States), which was supplied by Canada (construction began in 1955, first criticality was achieved in 1960). The US supplied heavy water for the reactor. The conditions imposed by Canada and the US – that the reactor and heavy water be used only for peaceful purposes – were circumvented with the assertion that the test related to India's interest in "peaceful" nuclear explosives for civil engineering projects.

The 100 MW(th) Dhruva research reactor, which became fully operational in 1988, is also believed to have been used to produce plutonium for weapons. Dhruva, like Cirus, is a heavy water moderated and natural uranium fuelled reactor. The Cirus and Dhruva reactors are estimated to be capable of producing about 25-35 kilograms of plutonium annually. India probably has enough plutonium for 60-100 nuclear weapons, most of it believed to be in separated form.

India has a number of unsafeguarded power reactors. These are thought to have supplied only a small fraction of the plutonium for India's weapons program to date, with the majority produced by the Cirus and Dhruva research reactors. However, at least as much plutonium is contained in the spent fuel of unsafeguarded power reactors as has been produced by Cirus and Dhruva.

The Cirus and Dhruva reactors may also have been used for tritium production. (Tritium may also have been extracted from irradiated heavy water moderator in power reactors.)

Other research reactors – in particular the 19 MW(th) Purnima reactor – were used to conduct research crucial to the development of a weapons capability.

India's stated interest in using plutonium for power production, and the development of facilities such as a fast breeder test reactor and a mixed uranium-plutonium oxide (MOX) fuel fabrication plant, have provided further civil cover for India's military plutonium program. The ostensibly civil plutonium program has also been used to justify the development of reprocessing facilities.

India is reported to have used Cirus, Dhruva and one other reactor to produce kilogram quantities of fissile uranium-233 by irradiating thorium. Uranium-233 production will be increased significantly if India proceeds with the development of power reactors using thorium-233 fuel.

India has only a limited capacity to enrich uranium.

India has not a signatory to the NPT or the Comprehensive Test Ban Treaty.

Nassauer writes: "India produced the plutonium for its 1974 "peaceful nuclear explosion" in a Canadian-designed research reactor supplied under a 1956 agreement with no safeguards required. India's reprocessing technology is based on the US PUREX technology, declassified under the "Atoms for Peace" program and conducted in a plant designed in part by a US company. India's heavy water initially also came from the US, while additional amounts were secretly acquired from Norway and other countries. India's nuclear energy and weapons programs haven't always been integrated." (Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>)

Sources and more information:

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IRAN

Quoted verbatim from: Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>

Iran's nuclear program also goes back to the 1950s. In 1974 the Shah developed a plan to have 23,000 MW of nuclear generated electricity installed by 1995. His plan also foresaw the construction of uranium enrichment facilities (two uranium enrichment facilities were offered to Persia by Helmut Schmidt, West Germany's chancellor, in 1975) as well as a reprocessing plant. He negotiated the construction of several nuclear power plants individually with West Germany, France, and the United States.

In the end, only two German-supplied reactors were contracted. The Iranian revolution and the 1980 to 1988 Iran-Iraq War brought the Iranian nuclear program to stand-still. Nuclear research only continued through some technological assistance from China.

Finally, in 1994 Iran succeeded in engaging Russia as its new nuclear supplier. Russia was willing to finish the German-designed reactors at Busheher, provide nuclear fuel, and to possibly also help with uranium enrichment. Under pressure from the United States, Russia finally agreed to limit its support to reactor construction, training for nuclear specialists, and supplying nuclear fuel which must be returned to Russia after it is spent.

By 2002 and 2003, exiled Iranians began to claim that Iran was secretly building a substantial nuclear infrastructure not yet declared to the IAEA. When the IAEA started to verify these claims, it could confirm several. (Technically, the newly detected installations did not represent a violation of Iran's existing commitments toward the IAEA. Iran could have met its legal obligations by informing the IAEA about these installations at a later point in time.)

It also detected that Iran had not declared the import of a small quantity of nuclear materials imported about fifteen years ago. In addition, inconsistencies with respect to Iran's declarations about past nuclear activities needed to be clarified. The newly-detected components of the Iranian nuclear program included uranium conversion and enrichment facilities, for which clandestine technology imports were discovered. In addition, Iran is building a heavy-water plant and plans to build a heavy-water research reactor and a fuel rod production facility.

Since the end of 2003, Iran and the European Union 3 (France, Germany, and the United Kingdom) have been trying to negotiate a solution. The Europeans are seeking first a freeze and finally an end to all Iranian activities which could help a nuclear weapon program, i.e., all enrichment and heavy-water-related activities, as well as a binding commitment that Iran will not pursue reprocessing technologies or ever leave the NPT. Iran insists that it is legally entitled to run an open fuel cycle for civilian purposes. Indeed, none of the components of the current Iranian nuclear program is illegal under the NPT.

Thus, the negotiations can only aim at talking Iran into deliberately refraining from exercising its right as a deliberate and confidence-building measure. As the present paper is being written, these negotiations have developed into an arm-twisting exercise similar to the United States-North Korean (and later six-nations) talks.

More information and updates on Iran's nuclear program:

* ISIS <http://isis-online.org/countries/category/iran>
* NTI <www.nti.org/e_research/profiles/Iran/index.html>

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IRAQ

A civil research reactor program, plus plans to develop nuclear power, facilitated a covert weapons development program in Iraq from the early 1970s to the early 1990s which employed thousands of people spread across numerous sites.

Iraq signed the NPT in 1968 and ratified it in 1969. NPT accession was a plus for the covert weapons program because it greatly facilitated technology transfer while continued violations of legally binding NPT obligations went undetected.

Major research programs were undertaken into electromagnetic isotope separation and gas centrifuge enrichment techniques, and other enrichment methods were also investigated – chemical enrichment, gaseous diffusion, and laser isotope separation.

The enrichment projects variously relied on indigenous development of technology, deals with foreign contractors prepared to circumvent export controls, and the acquisition of freely available information and materials. If not for the 1991 Gulf War and events thereafter, Iraq may have been able to produce sufficient HEU for its first weapon in the mid 1990s.

Since so much of the enrichment work was covert, there was little or no effort or need to justify the enrichment work with reference to enriched uranium fuelled research reactors. Nevertheless, the operation of those reactors may have been used on occasions to justify requests to potential suppliers, or by suppliers to justify their actions.

In 1980, Iraq announced that IAEA inspections would be temporarily suspended because of the Iran-Iraq war, and 26 pounds (about 12 kilograms) of HEU were removed from the core of the low power Tammuz II research reactor and stored in an underground canal.

In 1981, an Israeli strike on the Al Tuwaitha site destroyed the 40-70 MW(th) French-supplied Osirak reactor (a.k.a. Tammuz-1), which was shortly to begin operation. Plutonium production is likely to have been a motive for the purchase of the reactor. This was one of several attempts to bomb nuclear facilities involving Iraq:
- in 1971, when a small research reactor was awaiting shipment from France to Iraq, its core was sabotaged in a warehouse and the person supposed to certify its quality was murdered in a Paris hotel
- Iran bombed the Al Tuwaitha nuclear complex in September 1980 but inflicted little or no damage
- Iraq bombed Iran's Bushehr nuclear plant (which included two partly-built power reactors) at least six times between March 1984 and November 1987
- the US bombed two small, safeguarded nuclear reactors (the 5 MW(th) IRT-5000 Soviet-built pool-type reactor, and a French-supplied 0.5 MW(th) critical facility called Tammuz-II), and other nuclear

sites such as uranium hexafluoride conversion and centrifuge enrichment pilot facilities, in Iraq in 1991
- Iraq launched Scud missiles at the Israeli Dimona plant in 1991.

On several occasions, covert attempts to produce and separate small quantities of plutonium in IAEA safeguarded facilities took place at Tuwaitha. One exercise involved extracting plutonium from a fuel element removed from the IRT-5000 reactor. On three other occasions, fuel elements were fabricated from undeclared uranium dioxide in an Experimental Reactor Fuel Fabrication Laboratory, they were secretly irradiated in the IRT-5000 reactor and then chemically processed in an unsafeguarded Radiochemical Laboratory containing hot cells. Only tiny quantities of plutonium were separated. The plutonium separation capacity of the hot cells was probably too small to be of use in the weapons program except on an experimental basis.

In 1984, a project was established with the objective of designing and building a 40 MW(th) natural uranium fuelled, heavy water moderated and cooled reactor modelled on the Canadian NRX reactor. By that time, there was no longer any hope that France would rebuild the Tamuz-1 reactor destroyed by the Israeli air force in 1981. The reactor project appears not to have progressed beyond theoretical studies; the emphasis was on uranium enrichment. Related projects – also undeclared – concerned reprocessing and the production of plutonium metal, but only small quantities of separated plutonium and plutonium metal were produced.

Although the IRT reactor's power level was low – five MW(th) – it could have produced sufficient plutonium for one weapon over a period of several years in the fuel and/or a uranium blanket and/or targets. This risk, albeit small, was amplified by the fact that IAEA inspections of the reactor were infrequent because of the low risk status of the reactor. The IAEA (1997, p.53) states that the IRT reactor was of "very limited usefulness as a plutonium production reactor" but made a "useful" contribution to the nuclear weapons research and development program.

The IRT-5000 reactor was used to make polonium-210 for neutron initiator research, using bismuth targets. It was also used to produce small quantities of plutonium-238, which could have been used for neutron initiator research instead of short lived polonium-210.

Iraq developed a capability to produce small quantities of lithium-6, which, when subjected to neutron irradiation, yields tritium. This suggests an interest in developing "boosted" fission weapons and/or a longer term interest in hydrogen weapons.

'Dirty' radiation bombs were produced and three test bombs were exploded in Iraq in 1987. The bombs used materials (such as zirconium) irradiated in the Tammuz II and/or IRT reactors. (Atomic Energy Agency (Iraq), 1987.) The results were not promising and the project was discontinued (Broad, 2001).

After Iraq's invasion of Kuwait in 1990, a crash program was initiated with the aim of diverting approximately 36 kilograms of IAEA safeguarded unirradiated and irradiated HEU from the IRT-5000 and Tammuz II research reactors. The program called for chemical processing to extract HEU, construction of a 50-machine gas centrifuge cascade to further enrich some of the HEU, and conversion of the HEU chemical compounds to metal buttons suitable for a weapon. The crash program had not advanced to any great degree by January 1991, when the Gulf War began, but some progress had been made such as the installation of a chemical solvent plant in hot cells at Tuwaitha. The program may have continued after the Gulf War until such time as it became clear that research reactor fuel was to be removed from Iraq – the first shipment took place in November 1991.

While Iraq's nuclear research program provided much cover for the weapons program, stated interest in developing nuclear power was also significant. According to Khidhir Hamza (1998), a senior nuclear scientist involved in Iraq's weapons program: "Acquiring nuclear technology within the IAEA safeguards system was the first step in establishing the infrastructure necessary to develop nuclear weapons. In 1973, we decided to acquire a 40-megawatt research reactor, a fuel manufacturing plant, and nuclear fuel reprocessing facilities, all under cover of acquiring the expertise needed to eventually build and operate nuclear power plants and produce and recycle nuclear fuel. Our hidden agenda was to clandestinely develop the expertise and infrastructure needed to produce weapon-grade plutonium. ... Under cover of safeguarded civil nuclear programs, Iraq managed to purchase the basic components of plutonium production, with full training included, despite the risk that the technology could be replicated or misused."

Professed interest in developing fusion technology was also useful, as discussed by Hamza (1998): "Iraq took full advantage of the IAEA's recommendation in the mid 1980s to start a plasma physics program for "peaceful" fusion research. We thought that buying a plasma focus device ... would provide an excellent cover for buying and learning about fast electronics technology, which could be used to trigger atomic bombs."

Prescient warnings were voiced in 1981 following Israel's attack on the Osirak reactor. On June 13, 1981, US Rep. Edward Markey (D-Mass.) called the IAEA "an international charade ... riddled with loopholes" and said it was "possible for a country which is under IAEA inspections to take all the necessary steps to build a bomb and escape detection. In fact, the IAEA gave a convenient cover to the Iraqi bomb program". (Quoted in Nucleonics Week, June 18, 1981, p.4). Sigvard Eklund, then IAEA Director General, defended the IAEA somewhat clumsily, stating that, "You can't be accused of murder because you have acquired a gun." (Nucleonics Week, June 25, 1981, p.3.)

IAEA safeguards inspector Roger Richter resigned in 1981, having written to the US State Department the year before stating: 'The most disturbing implication of the Iraqi nuclear program is that the NPT agreement has had the effect of assisting Iraq in acquiring the nuclear technology and nuclear material for its program by absolving the cooperating nations of their moral responsibility by shifting it to the IAEA. These cooperating nations have thwarted concerted international criticism of their actions by pointing to Iraq's signing of NPT, while turning away from the numerous, obvious and compelling evidence which leads to the conclusion that Iraq is embarked on a nuclear weapons program." (Quoted in MacLachlan and Ryan (1991); see also Nucleonics Week, June 25, 1981, p.3.)

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ISRAEL

The Israeli nuclear weapons program was launched in 1956, in the wake of the Suez crisis. The natural uranium fuelled IRR-2 (Dimona) research reactor, supplied by France, is central to the program. Estimates of the power of the IRR-2 reactor range from 40-150 MW(th). The reactor has been used to produce plutonium, the fissile material in most or all of Israel's estimated 100-200 nuclear weapons. Israel is not a signatory to the NPT but signed the Comprehensive Test Ban Treaty in 1996.

The IRR-2 reactor may also have been used to produce tritium.

France also supplied information on the design and manufacture of nuclear weapons, and assisted in the construction of other facilities at the Dimona site including a reprocessing plant.

Israel has made some progress in the development of laser enrichment technology, but plutonium from the Dimona reactor is still the primary source of fissile material for the weapons program.

There are no power reactors in Israel, although the pretense of a nuclear power program may have facilitated the transfer of materials and expertise from France and other countries.

Nassauer writes: "Israel's successful weapons program was based on a plutonium production reactor and a reprocessing plant ostensibly provided for peaceful purposes by France without safeguards and under substantial secrecy. Norway had provided heavy water for peaceful purposes. The uranium reportedly came from Argentina, Niger, South Africa, and others. About 200 tons was scheduled to come from a Belgian ship from which it disappeared in 1968 while the ship was at sea. Notably, Israel represents the single case known in which the supply of uranium was a major problem." (Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>)

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LIBYA

Libya pursued – then abandoned in December 2003 – a nuclear weapons program under cover of a civil program. It included the pursuit of uranium enrichment technology, training nuclear scientists, establishing a nuclear research reactor and research centre, attempts to purchase nuclear weapons from (declared and undeclared) nuclear weapons states, and purchase of nuclear technology from the A.Q. Khan network.

More information on Libya's nuclear program:
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NORTH KOREA

(Update: In October 2006, North Korea tested a nuclear weapon, believed to have used plutonium produced in its 'Experimental Power Reactor'.)

North Korea's covert weapons development program proceeded under cover of a planned nuclear power program in the 1980s following the acquisition of research reactors in the 1960s and 1970s.

The majority of North Korea's nuclear facilities are at the Yongbyon Nuclear Research Centre, including a five MW(e) (20-30 MW(th)) "experimental power reactor", a large-scale reprocessing plant for plutonium extraction (only partially completed but functional nonetheless), a number of hot cells that can be used for plutonium extraction, a high explosive testing facility, a fuel fabrication plant, a partially completed 50 MW(e) power reactor, a four MW(th) research reactor and a critical assembly. A 200 MW(e) power reactor was partially built at Taechon.

The three reactors were based on the gas graphite moderated, natural uranium fuelled Magnox design – suitable for co-generation of electricity and plutonium. North Korea appears to have pursued these reactor construction projects with only minimal foreign assistance. Similarly, the partially completed reprocessing plant was built with minimal foreign assistance.

North Korea became a party to the NPT in 1985 but did not allow IAEA inspections until 1992. North Korea admitted in 1992 that it had separated about 100 grams of plutonium in March 1990 and that the plutonium came from failed fuel elements from the five MW(e) reactor. The Yongbyon reprocessing plant (which North Korea calls a Radiochemical Laboratory) and possibly also hot cells were used to separate the plutonium.

Inspections and tests by the IAEA, coupled with North Korea's refusal to comply with some requests from the IAEA, raised suspicions that larger volumes of plutonium, possibly enough for 1-2 weapons, have been separated from spent fuel which may have been unloaded from the five MW(e) experimental power reactor in 1989.

The reactor's inventory of spent fuel was unloaded in May 1994, and that spent fuel contains between 17-33 kilograms of (unseparated) plutonium; it has been stabilised and "canned" by the US and is stored under IAEA safeguards in North Korea.

If completed, the 50 MW(e) reactor would be capable of producing much larger volumes of plutonium than the five MW(e) reactor, as would the 200 MW(e) reactor. It is believed the plan was to use the 50 MW(e) reactor primarily as a plutonium factory, and to use the 200 MW(e) reactor primarily for electricity generation and as a back-up for plutonium production.

Following a protracted international controversy, North Korea and the US signed an "Agreed Framework" in October 1994. Among other things the Agreement provided for a verified freeze of the activities at the North Korean facilities believed to have supported the weapons program, the eventual dismantling of those facilities, removal of some material including spent fuel from the five MW(e) reactor, and the construction of two power reactors of a design less suitable for producing weapon grade plutonium than the Magnox design of the three power reactors built or partially built by North Korea. Progress on implementation of the Agreed Framework has been stop-start and it remains a long way from fruition as at 2002.

North Korea has a four MW(th) IRT research reactor as well as a critical assembly and a sub-critical assembly, all supplied by the Soviet Union and all under IAEA safeguards. These research reactors do not seem to have been involved in the weapons program to any significant degree. However it is likely that a small quantity of plutonium was separated in the 1970s, before IAEA safeguards were applied, using the IRT research reactor to produce the plutonium and hot cells (also supplied by the Soviet Union) to separate it.

Nassauer's summary of the North Korean nuclear program:

North Korea has claimed since early 2005 that it has built nuclear weapons. Two years before, in 2003, it became the first and only country to withdraw from the NPT. (North Korea's real nuclear status is not clear. In the second half of the 1990s, some Western intelligence sources estimated that North Korea might have one or two nuclear weapons. These estimates were based on the amount of weapons-grade nuclear materials North Korea could have theoretically produced. Meanwhile, based on a similar methodology it is estimated that North Korea could have built up to eight weapons. However, today Western intelligence sources doubt North Korean claims that the country already owns nuclear weapons. They assume that North Korea uses this claim to strengthen its position in the six-party talks over its nuclear program. North Korea's status in respect to the NPT is unclear as well. Several countries claim that North Korea did not leave the treaty since it did direct its withdrawal notice to the United Nations, but not the depositories of the treaty. Finally, the six nation talks have since reached an interim agreement, under which, if implemented, North Korea again would become a non-nuclear member of the NPT.)"

The country's nuclear program goes back to the 1950s, when North Korea cooperated with the Soviet Union and received their first small research reactor plus additional nuclear technology in the 1960s. Later the reactor was enlarged using North Korean technology. After a failed attempt to enlist Chinese nuclear support, North Korea began to acquire reprocessing technology from the Soviet Union in the 1970s and to develop indigenous nuclear technology for uranium processing. In the early 1980s uranium milling facilities, a fuel-rod fabrication facility, research and development facilities and a 5 MW research reactor were added. During these years, North Korea considered the acquisition of gas-graphite moderated or light-water reactors for electricity production. While North Korea entered a trilateral safeguard agreement with the IAEA and Russia for the Russian-supplied reactor in 1977, it joined the NPT no earlier than 1985. A safeguard agreement was not concluded before 1992. During the IAEA's initial inspections, inconsistencies about North Korean reprocessing activities came to light. When the IAEA asked the UN Security Council for the authority to conduct a special ad hoc inspection, North Korea announced its intention to withdraw from the NPT in 1993, only to "suspend" this decision after intense negotiations with the United States one day before the end of the ninety-day advance notice period. After that, safeguard inspections were allowed for the ongoing nuclear program but not for verifying the program's past. When the reactor core of the 5 MW reactor was burned up in the spring of 1994, North Korea began to remove the fuel rods without IAEA supervision in a manner which compromised the IAEA's ability to reconstruct the reactor's history. The resulting new crisis was defused by a Framework Agreement negotiated by former US President Jimmy Carter who, in October 1994, talked North Korea into accepting an IAEA-verified freeze of reactor operations and continued NPT membership in return for the supply of two light-water reactors and deliveries of heavy oil for electricity production.

This agreement successfully froze the North Korean program for almost a decade. However, when the United States, under President George W. Bush, claimed in 2002 that North Korea had a secret uranium enrichment program and stopped the heavy oil deliveries, North Korea retaliated by lifting the freeze on its nuclear facilities, ending IAEA monitoring, and again announced its withdrawal from the NPT. North Korea now claims to have built nuclear weapons which are plutonium-based. It is still unclear whether a uranium enrichment program exists in North Korea. No reliable judgement is possible about when North Korea's military nuclear intentions began. *(Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>)*

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PAKISTAN

Pakistan launched a covert nuclear weapons program in the aftermath of the Indo-Pakistani war in the early 1970s. Pakistan was able to accumulate the equipment and expertise to produce weapons with the help of weak Western export controls, the cover of civil nuclear power and research programs, and Chinese support. Pakistan is not a signatory to the NPT or the Comprehensive Test Ban Treaty.

While there have been ongoing efforts to develop plutonium production and separation capabilities, the emphasis of the covert weapons program has been on uranium enrichment. In 1978 France broke off an agreement to supply an enrichment plant, but a large scale gas centrifuge enrichment plant was built at Kahuta nonetheless, using stolen European designs, some Libyan funding and some equipment bought by "dummy" companies from European and North American suppliers. The Kahuta enrichment plant is believed to be the source of all or nearly all of Pakistan's fissile material for the weapons program. Pakistan probably has sufficient HEU for 30-52 nuclear warheads (although there is considerable uncertainty in those estimates).

In the 1970s, Pakistan planned to use power reactor/s to produce plutonium for weapons. However in 1978 France pulled out of an agreement to build a reprocessing plant because of the weapons implications. Efforts to complete the plant without further French assistance struck insurmountable obstacles.

A 50 MW(th) natural uranium fuelled, heavy water moderated research reactor has been under construction for many years at Khushab, with the potential to provide Pakistan with its first supply of unsafeguarded spent fuel. Former Prime Minister Bhutto described the Khushab reactor as "a small reactor for experimental purposes". The reactor has been built with Chinese assistance. There have been several reports in recent years that construction of the Khushab reactor has been completed, and also reports that it has begun operation. The Khushab reactor is estimated to be capable of generating 10-15 kg of weapon grade plutonium annually, enough for 1-2 weapons. The availability of unsafeguarded plutonium would permit Pakistan to develop smaller and lighter nuclear warheads which would facilitate Pakistan's development of warheads for ballistic missiles.

In addition, Pakistan might use the Khushab reactor to irradiate lithium-6 targets to produce tritium to use as a neutron initiator in weapons, for boosted fission weapons or, in the longer term, for hydrogen weapons.

In tandem with the construction of the Khushab reactor, Pakistan's capacity to reprocess spent fuel has steadily expanded, with the largest reprocessing plant located at Chasma. Weapon grade plutonium from the Khushab reactor's spent fuel could be extracted at the nearby Chasma reprocessing plant, if that facility becomes operational, or at the New Labs reprocessing facility in Rawalpindi – both unsafeguarded facilities.

Pakistan's power reactors, which are subject to IAEA safeguards, have had little or no direct connection to the weapons program in terms of plutonium production. However one possible source of heavy water for the Khushab reactor is diversion of heavy water supplied by China for the Kanupp power reactor.

Two research reactors, both significantly less powerful than the Khushab reactor, are under IAEA safeguards. One of these reactors, PARR-I, may have been used clandestinely to produce tritium for the weapons program.

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Rodney W. Jones and Mark G. McDonough with Toby Dalton and Gregory Koblentz, 1998, Tracking Nuclear Proliferation, 1998, Carnegie Endowment for International Peace.

Leonard S. Spector, Mark G. McDonough with Evan S. Medeiros, 1995, Tracking Nuclear Proliferation, Washington: Brookings Institution / Carnegie Endowment for International Peace, pp.97-102.

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ROMANIA

Romania ratified the NPT in 1970, but a covert nuclear weapons program was pursued under the Ceausescu regime. Little information is publicly available on the weapons program, but it is known that hot cells were used for experimental plutonium extraction from irradiated research reactor fuel.

After Ceausescu's overthrow in 1989, the weapons program was terminated. Supply of HEU for a 14 MW(th) Triga research reactor was terminated by the US in the late 1980s because of the possibility of HEU diversion; the reactor was shut down from 1989-91 and it was converted to enable the use of LEU fuel.

Sources and more information:

Leonard S. Spector, Mark G. McDonough, with Evan S. Medeiros, 1995, Tracking Nuclear Proliferation, Washington: Brookings Institution / Carnegie Endowment for International Peace, pp.83-86.

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SOUTH AFRICA

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South Africa initially had a civilian nuclear program to which a military one was later added. Much of the technology was indigenous with substantial secret outside help, especially from West Germany. HEU-enrichment in South Africa was based on a German technology (Becker nozzle process) officially supplied for the civilian nuclear energy program. The South African nuclear program resulted in a uranium weapon.

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SOUTH KOREA

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South Korea began a secret nuclear weapon program when it began to construct its first nuclear power plants in the early 1970s. When the United States threatened to withdraw its military support for South Korea, Seoul agreed to end the program and to join the NPT in 1975.

Since the 1980s, South Korea has launched several attempts to initiate a reprocessing program but has backed off when pressured by the United States. The 1991 denuclearization agreement with North Korea requires Seoul to refrain from uranium enrichment and reprocessing. However, in 2004 South Korea informed the IAEA about some previously unknown plutonium related experiments and thus is currently under special investigation.

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SWEDEN

Matthew Bunn writes:
"Sweden's nuclear program was originally an integrated program for both nuclear energy and nuclear weapons, based on plutonium production in heavy-water reactors. R&D on nuclear weapons was carried out in the 1950s, while the public civilian program pursued development of the heavy-water reactors. Delays in the heavy-water reactors, combined with a U.S. offer of safeguarded LWR technology and fuel, led Sweden's industry to drop its support for the heavy-water option, leaving continued development with no civilian rationale. By the mid-1960s, the weapons program had been dropped, because of lack of domestic political support. Today, all of Sweden's nuclear activities are under international safeguards." (Matthew Bunn, 2001, "Civilian Nuclear Energy and Nuclear Weapons Programs: The Record", <http://ocw.mit.edu/NR/rdonlyres/Nuclear-Engineering/22-812JSpring2004/DA39D9C3-72E5-426E-840C-712594207E23/0/prolif_history.pdf>.)

This is the abstract to an article by Thomas Johansson:
The possibility of developing a nuclear weapons potential under the cover of a civilian nuclear power program was illustrated by Sweden between the early 1950s and 1968. Indeed, this case shows that the development and use of nuclear power and the nuclear weapons proliferation problem are inextricably linked. Although Sweden's nuclear weapons option was officially closed in 1968, when the Parliament declared that it was not in the nation's security interest to procure nuclear weapons, important issues have been raised by a series of investigative reports by Christer Larsson, a reporter with the weekly technical magazine Ny Teknik (New technology). Based on

some 50 documents declassified at Larsson's request as well as interviews with about 100 people involved in the nuclear programs in the 1945 to 1972 period, the new information indicates that the weapons-related work was much more intensive and comprehensive that has previously been publicly acknowledged. This article analyzes the Ny Teknik articles and other information. (Johansson, Thomas B., 1986, "Sweden's abortive nuclear weapons project", Bulletin of the Atomic Scientists, Vol.42(3), pp.31-34.)

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SYRIA

Comments copied verbatim from the NTI website:
<www.nti.org/e_research/profiles/Syria/Nuclear/index.html>

A member of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) since 1969, and a proponent of a Nuclear-Weapon-Free Zone (NWFZ) in the Middle East, Syria is nonetheless suspected of harboring nuclear weapons ambitions. While Damascus is currently known to possess only one small operational research reactor, the Chinese built SRR-1, it has consistently pursued more advanced nuclear technologies. The military has been a stakeholder in Syria's nuclear program since the 1970s, and Damascus has both openly and covertly sought the assistance of numerous parties, including the International Atomic Energy Agency (IAEA), China, Russia, Iran, and North Korea to develop its nuclear program.
Syria's nuclear program has come under significant international scrutiny since Israel's September 2007 airstrike on Al-Kibar, a site alleged by Israeli and American officials to have been an undeclared plutonium production reactor. An IAEA investigation into the matter is ongoing, with progress hindered by limited Syrian cooperation.
Syria's adversarial relationship with Israel is the most important factor influencing its national security policies, and could motivate Damascus to pursue nuclear weapons.
...

Why did Damascus suddenly embark on a nuclear program in the 1970s? On the one hand, Syria's rapidly increasing domestic energy demand during that decade provided it with incentives to consider nuclear energy. But Damascus may also have been pursuing a hedging strategy, as it could no longer afford total military dependence on the Soviet Union. ... Given Syria's weak conventional forces, a nuclear weapons program may have seemed a viable option for achieving strategic parity with Israel

However, by the early 1980s Syria realized it was not capable of indigenously producing a single nuclear reactor, let alone six, and sought assistance from states such as the USSR, Belgium, Switzerland and France to acquire a reactor. More than thirty firms bid on the proposed reactor, including at least one U.S. firm, but Syria ultimately chose the French firm Sofratome. In 1983, both the IAEA and the USSR advised Syria on selection of the reactor site. But Sofratome backed out of the agreement following feasibility studies, as the Syrians lacked the resources to finance the reactor. Frustrated, Syria again approached the USSR in 1985, hoping its friendly relations with the superpower would translate into acquisition of a nuclear reactor. The negotiations yielded plans for construction of a 2 to10MWt research reactor and an associated research center. Progress was slow due to financial disagreements and the project was retired in the design phase in 1991.

The 1990s: Limited Progress

In 1990, Syria concluded a $100 million nuclear deal with Argentina. The state-controlled National Institute of Applied Research (INVAP) agreed to provide Syria with a 10MWt research reactor, and Argentina's Comisión Nacional de Energía Atómica (CNEA) was to provide the requisite uranium hexafluoride reactor fuel, enriched to a maximum of 20 percent U-235. The deal also included a radiological protection center and a hot cell lab for producing radioisotopes. However, the Argentinean government vetoed the deal in 1995, stating that a special nuclear cooperation treaty with Syria was a prerequisite to the implementation of the deal. Argentina allegedly received strong pressure from both the United States and Israel to block the deal. Guido Di Tella, who was then Argentina's Foreign Minister, publicly stated that he was aware of objections to the sale and that "not only do we have to judge that it is not interfering with the process or security, but both Israel and Syria must believe the same." Similarly, India's offer to provide Syria with a 5MWt reactor was shelved in 1991 under significant U.S. pressure.

Syrian nuclear ambitions finally met with limited success when China began constructing the SRR-1 research reactor in 1991 as a part of an IAEA technical assistance project. China also provided Syria with 980.4g of uranium enriched to 90.2% U-235 to fuel the reactor, intended to ensure operation for 2,000 hours per year for ten years. Fuel depletion now limits current operation to only two hours per day. The SRR-1 reactor is modeled after the Canadian Slowpoke 2 reactor and is used for neutron activation analysis (NAA), training, and small-scale radioisotope production. Syria concluded a Comprehensive Safeguards Agreement with the IAEA in 1992 and the reactor went critical in 1996.

Controversy surrounded Syrian nuclear intentions during the 1990s. As far back as 1991, Western officials, particularly from the United States and Israel, claimed China was working with Syria on weaponization projects. Whether any of these allegations were true remains unclear, but they were often directly contradicted by open source reports from the U.S. intelligence community. However, various members of the international community continued to worry about sensitive technology transfer to Syria. In 1998 for example, the intergovernmental Russia-Syria Commission on Trade and Scientific and Technical Cooperation signed a deal for the peaceful use of nuclear power, which included a desalination facility powered by a 25MW light-water reactor. The project did not progress and is likely to have collapsed under U.S. pressure, similarly to the Argentinean and Indian negotiations in the early 1990s. In 2003, Syria signed a $2 billion nuclear deal with Russia that included a nuclear power plant and a nuclear seawater desalination facility. The announcement of the deal was originally placed on the Russian Foreign Ministry website and received a considerable amount of negative attention. The Foreign Ministry spokesman quickly refuted claims that any such discussion had taken place. Currently, there is no known Russian-Syrian cooperation in the field of nuclear power.

There was little open source basis for concern about a Syrian nuclear weapons program prior to the 2007 revelation of an alleged nuclear facility at Al-Kibar. However, Syria's other WMD endeavors, namely in the chemical weapons arena, led countries such as the United States to closely monitor its activities and oppose sensitive technology transfers. Furthermore, a 2004 CIA report found that Pakistani nuclear scientist A.Q. Khan may have provided Syria with nuclear information and equipment. According to a 2007 statement by President Bashar al-Assad, while Khan approached Syria in 2001 with an offer to provide it with nuclear equipment, he rejected the offer.

Recent Developments and Current Status

On 6 September 2007, Israel destroyed a facility near the Euphrates River in the Northeastern region of Dar az Zwar. Commonly referred to as "Al-Kibar," the facility is alleged by U.S. and Israeli intelligence to have been a partially completed 25MWth gas-cooled graphite-moderated nuclear reactor, which would have been capable of producing enough plutonium for one or two weapons per year.

The strike precipitated a flurry of media interest and speculation; Israeli authorities maintained silence on the issue, while Syria adopted the tone of aggrieved victim and claimed the site had been an unused military building. Problematically for IAEA inspections, and in a move guaranteed to make some question if it had something to hide, Syria leveled what remained of the Al-Kibar site and built over it only three days after the airstrike. In April 2008, the U.S. released photos reportedly taken at the Al-Kibar site prior to the airstrike, whose striking similarity to images of Yongbyon suggested that the facility had been a nuclear reactor developed with North Korean assistance.

The IAEA was finally provided unrestricted access to the Al-Kibar site on 23 June 2008, which enabled inspectors to decipher its layout, dimensions, containment structures, and water-pumping infrastructure. In its subsequent report, the agency found that the containment structure and overall size of the building could be sufficient for a nuclear reactor, and the water pumping capacity was "adequate for a reactor size referred to in the allegations." Inspectors also found natural uranium particles, which Syria claimed derived from Israeli munitions, an allegation swiftly denied by Israel.

However, the June 2008 visit ultimately raised as many questions as it answered. In November 2008, the IAEA Board of Governors sent letters to both Israel and Syria requesting more information on Al-Kibar. The agency also asked Syria for access to additional sites, which Syria had refused during the June 2008 inspection. Syria's February 2009 response reiterated that Al-Kibar had been a military site, and did not permit additional inspections access. That same month the IAEA released a second report on Al-Kibar that did not produce new information about the site's infrastructure, but revealed that environmental samples had yielded additional traces of anthropogenic (or manmade) uranium and rejected Syrian claims that the uranium derived from dropped Israeli munitions. The February 2009 report states, "there is low probability that the uranium was introduced by the use of missiles," and it further indicates that the uranium particles were not of a type found in Syria's declared inventory. Again on 5 June 2009, the IAEA reported that its inspections had revealed the presence of undeclared anthropogenic uranium particles, this time from a hot cell facility at the SRR-1 research reactor in Damascus.

Syria continues to deny that it was ever involved in illicit nuclear activities and to insist that the Al-Kibar site was and remains a non-nuclear military installation. However, Damascus also persists in refusing further inspections access. As of July 2009, the investigation therefore remained inconclusive.

Syria's uncooperativeness in resolving agency questions about its nuclear program has contributed to the firestorm of criticism surrounding the efficacy of the nonproliferation regime. While Damascus's refusal to join the IAEA Additional Protocol means inspectors lack powerful authorities to visit undeclared nuclear facilities, the IAEA does have the right to invoke special inspections and end the Al-Kibar stalemate. However, the checkered history of special inspections, last invoked unsuccessfully against a defiant North Korea in 1993, has left this potentially powerful tool hostage to diplomatic politics.

In 2007, high-level Syrian officials, including Syrian Electricity Minister Khalid al-Ali announced Syria might pursue nuclear power to satisfy domestic energy demand. However, Syria has not asked the IAEA for assistance or made an official decision on future nuclear power plans. Given Damascus's limited financial and technological resources, its refusal to join the Additional Protocol, and unresolved allegations that it was building a clandestine plutonium production reactor at Al-Kibar, it is unlikely that Syria will find investment in a nuclear power program feasible anytime in the near future.

More information on Syria's nuclear programs and ambitions:
* http://isis-online.org/countries/category/syria/
* www.globalsecurity.org/wmd/world/syria/nuke.htm

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TAIWAN

Taiwan launched a nuclear weapons program in the 1960s in response to China's weapons program. A plan for a dedicated weapons program – involving the purchase of a heavy water reactor, a heavy water production plant, and a plutonium separation plant – was rejected in favour of a nuclear program more easily portrayed as having peaceful intentions.

Taiwan signed the NPT in 1968. Work on the Canadian supplied 40 MW(th) natural uranium fuelled, heavy water moderated Taiwan Research Reactor (TRR) began in 1969 and the reactor began operating in 1973. The reactor had the capacity to produce more than 10 kilograms of weapon grade plutonium annually, although actual production was less. The limited scope of the research program associated with the reactor caused international consternation.

In 1969, work also began on a plant to produce natural uranium fuel, a reprocessing facility, and a plutonium chemistry laboratory.

A small reprocessing facility was built adjacent to the TRR reactor. Its declared purpose was to process spent fuel from a zero power reactor that used US supplied HEU fuel and/or the TRR reactor. Another, still smaller reprocessing laboratory was built, which could have been used to research various aspects of reprocessing irradiated material. A small number of spent fuel elements may have been reprocessed, but the amount of plutonium involved was far short of the amount required for a nuclear weapon. Taiwan also tried to purchase a large reprocessing plant but was unsuccessful.

The so-called "Plutonium Fuel Chemistry Laboratory" was used for experimental scale production of metallic plutonium using 1075 grams of separated plutonium that Taiwan had received from the US in 1974. Plutonium in metallic form is rarely if ever used in civil nuclear programs.

In the late 1970s, under pressure from the US, most of the reprocessing facilities were dismantled, and 863 grams of US supplied plutonium were returned to the US.

In 1987 Taiwan began secretly building hot cell facilities in violation of safeguards commitments. In early 1988, after a visit to the facility, US officials pressured Taiwan to dismantle it. Evidently no plutonium had been separated. The TRR reactor was also shut down in the late 1980s, again under pressure from the US. Spent fuel elements from the TRR reactor, containing about 78 kilograms of plutonium, had been shipped to the US by 1997, although some spent fuel from the TRR reactor remained in Taiwan.

Nassauer writes: "Taiwan received a heavy-water reactor from Canada along with heavy water and some separated plutonium from the United States for civilian and research purposes. Reprocessing technology was coming from France and also sought in the United States, West Germany, and other countries. When IAEA and US inspections in the 1970s suggested that Taiwan intended to divert material from its safeguarded facilities to a secret military facility next door, the United States successfully pressured Taiwan to abandon the military program, to dismantle its reprocessing facility, and then sent the separated plutonium to the United States. However, by 1987 Taiwan constructed new hot cells and only after intense US pressure, the program was stopped again." (Otfried Nassauer, December 2005, "Nuclear Energy and Proliferation", Nuclear Issues Paper No. 4, <www.boell.de/ecology/climate/climate-energy-1350.html> or direct download: <www.boell.de/downloads/ecology/NIP4NassauerEndf.pdf>)

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Dr. Ta-you Wu, "A Footnote to the History of Our Country's 'Nuclear Energy' Policies", translation from Chinese article in Biographical Literature, May 1988, <www.isis-online.org/publications/taiwan/ta-youwu.html>

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YUGOSLAVIA

Covert weapons programs were pursued on two occasions in Yugoslavia, under cover of nuclear research and nuclear power programs, though on neither occasion did the program reach an advanced state.

The first covert program was conceived in the late 1940s and was pursued until the mid 1960s. Yugoslavia pursued a program of nuclear research consistent with the ambition to become a nuclear weapons state. The cornerstones of the early program were three nuclear research centers established from 1948-50. The research/weapons program included the construction of a zero power critical assembly (built to acquire reactor expertise if Yugoslavia were to pursue the plutonium path) and a Soviet designed and built 6.5 MW(th) heavy water moderated "RA" research reactor capable of using uranium fuel enriched to 80% uranium-235. Heavy water and HEU for the reactors were provided by the Soviet Union. As a step towards independence from foreign suppliers, the Vinca Laboratory developed the capability to fabricate uranium oxide fuel elements for the RA research reactor.

Reprocessing technology was also pursued. Intensive negotiations between Yugoslavia and Norway took place with a view to the supply of a reprocessing plant, ostensibly to reprocess spent fuel from the RA research reactor. The engineering blueprints for the plant were delivered to Yugoslavia in 1962 but the reprocessing plant had not been built by the time Yugoslav political leaders lost interest in the weapons program in the mid 1960s.

Nevertheless, a laboratory scale reprocessing facility, equipped with four hot cells, was in operation by 1966. Small scale separation of plutonium from spent fuel from the RA reactor took place.

Although the emphasis was on developing the means to produce and separate plutonium, uranium enrichment was also studied using a small cyclotron to research electromagnetic isotope separation techniques, and a calutron. (A civil particle accelerator research program also provided useful cover for Iraq's pursuit of electromagnetic enrichment technology.)

A second push towards a nuclear weapons capability began in 1974, partly in response to the Indian test explosion of that year. The covert weapons program was pursued despite Yugoslavia's formal accession to the NPT in 1970. It was decided to pursue weapons under the cover of an expanded nuclear power program. (At the time, one power plant was under construction in Slovenia.)

Two parallel nuclear programs were pursued – one military, one civil. The program dedicated to weapons included projects into the nuclear explosive components for weapons including a neutron source to initiate the chain reaction, computer modelling, and exploratory studies of aspects of underground nuclear testing.

The "peaceful" program involved 11 projects. Its major activities were clearly related to the weapons program, including the design of a plutonium production reactor (referred to as an experimental research reactor), uranium metal production, development of an expanded plutonium reprocessing capability, design and construction of a zero power fast breeder reactor, and heavy water production.

The nuclear weapons program was effectively terminated in 1987 for reasons which remain unclear. The extent of the progress made between 1974-87 also remains unclear.

Yugoslavia retains highly skilled physicists, chemists, and engineers who obtained extensive experience in a broad range of nuclear activities during the first and second phases of the covert weapons program.

Although Yugoslavia continues to receive IAEA inspectors, the country's status as a NPT signatory remains unclear. Belgrade resists formally acceding to the NPT, arguing that it should be accepted as the sole successor to the Socialist Republic of Yugoslavia.

The largest of the research reactors has been shut down, and the plutonium reprocessing program appears to be inactive.

In addition to its experienced work force, Yugoslavia's greatest weapons asset today is its 48.2 kilograms of fresh 80% enriched HEU fuel and 10 kilograms of lightly irradiated HEU. In addition, reprocessing of spent fuel could yield more than five kilograms of plutonium. All of this material is under IAEA safeguards.

Sources and more information:

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