# Iran's Nuclear Facilities: a Profile

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### Bushehr (Busheir)

After years of searching for a supplier to complete its first nuclear power plant, Iran secured a contract with the Russian Ministry of Atomic Energy (Minatom) to finish the reactors at Bushehr, which will be under International Atomic Energy Agency (IAEA) safeguards. The $800 million contract, signed in January 1995 by Minatom chief Viktor Mikhailov and then Atomic Energy Organization of Iran (AEOI) head Reza Amrollahi, calls for Russia to complete the first reactor at Bushehr within four years.[1] In February 1998, Mikhailov reaffirmed that timetable, announcing that he expected the power plant to be finished "less than a year from now."[2] The 1995 protocol stipulates that the two sides will prepare and sign contracts for Russia to provide a 30–50 megawatt thermal (MWt) light water research reactor, 2,000 tons of natural uranium, and training for 10–20 Iranian nuclear scientists per year.[3] The Iranian nuclear specialists will be trained at the Russian Research Center (Kurchatov Institute) and at Russia's Novovoronezh nuclear power plant.[4] Both sides also agreed to discuss the construction of a nuclear desalination plant, a uranium mine, and a gas centrifuge uranium enrichment facility in Iran.[5] In May 1995, the U.S. government said it convinced Russia to cancel the centrifuge deal during the U.S.-Russia summit, although Russian officials later denied the deal ever existed.[6] The light water research reactor deal has also been canceled, but Russia is providing limited uranium mining assistance to Iran (see Yazd).[7]

Further Russo-Iranian nuclear cooperation involving addenda on the delivery of nuclear fuel, financing, and analysis of installations for the Bushehr reactors was discussed in August 1995.[8] The discussions led to the signing of a supplemental agreement on 24 August 1995, under which Russia will supply $30 million worth of nuclear fuel each year from 2001 to 2011.[9] According to Yevgeniy Mikerin, head of Minatom's nuclear fuel activities, the first core of low-enriched uranium (LEU) fuel for Bushehr-1 would be produced at the Novosibirsk Chemical Concentrates Plant in 1998.[10]

Construction of the Bushehr nuclear power plant has already cost Iran billions of dollars. The German firm Siemens and its subsidiary Kraftwerke Union (KWU) began work on the plant in 1974, but stopped following the Islamic revolution in 1979. At that time, Unit-One was 90 percent complete, with 60 percent of the equipment installed, and Unit-Two was 50 percent complete.[11] During the 1980 to 1988 Iran-Iraq war, the Bushehr reactors were repeatedly targeted by Iraq, which bombed the plant six times: 24 March 1984, 12 February 1985, 5 March 1985, 12 July 1986, and twice in November 1987.[12] In an unsuccessful attempt to deter Iraqi attacks in November 1987, Iran moved a small amount of nuclear fuel to the site.[13] The attacks destroyed the entire core area of both reactors; Iran then sealed the structure of Bushehr-1 and covered its dome with sheet metal.[14] According to officials from West Germany's national reactor inspectorate (Technischer Ueberwachungsverein), before the bombings, Bushehr-1 could have been completed in about three years, but following them, it would cost an estimated $2.9 billion to $4.6 billion to repair the damage.[15] KWU officials noted, however, that none of the core equipment had been installed and vital components for the two reactors were not located at Bushehr. Two steam generators were stored in Milan, Italy, and Germany's Gutehoffnungshuette (GHH) was storing the pressure vessel for Unit-One.[16]

Starting in the mid-1980s, Iran approached several nuclear suppliers about the possibility of completing the Bushehr-1 reactor. A consortium of West German, Spanish, and Argentine companies bid to complete the reactor in the late 1980s, but the deal was never completed due to U.S. pressure. In a similar deal, Iran signed a protocol in February 1990 with Spain’s National Institute of Industry (INI) and Nuclear Equipment (ENSA) to complete the Bushehr plant, and National Uranium Enterprise (ENUSA) to supply the reactor’s fuel.[17] The Spanish firms later canceled the deal citing U.S. political pressure and nonproliferation concerns.

Unable to find a Western European supplier, Iran turned to China and the Soviet Union for nuclear technology. On 6 March 1990, the Soviet Union and Iran signed their first protocol on the project, stipulating that Moscow would complete the Bushehr plant and build an additional two VVER-440 reactors in Iran.[18] The deal was delayed, however, by technical and financial problems.[19] In 1993, Minatom and the AEOI signed a contract for the construction of two VVER-440 reactors at Bushehr.[20] That contract never entered into force because Iran asked for a postponement of the fixed time limits due to financing difficulties. Iranian and Russian officials have said that once Bushehr-1 is completed, Russia could also complete the 1,000 MW Bushehr-2 reactor and eventually build two VVER-440 reactors there.[21]

Prior to the 1995 contract, Tehran made several unsuccessful attempts to procure components for the Bushehr project. Again, the United States successfully lobbied the suppliers’ governments not to provide Iran with nuclear assistance. Iranian agents tried to acquire eight steam condensers, built by the Italian firm Ansaldo under the KWU contract, but they were seized by Italian customs officials on 11 November 1993 while being shipped through Porto Marghera.[22] The Czech firm Skoda Plzen also discussed supplying reactor components to Iran, but canceled negotiations in 1994.[23] Tehran then tried to buy nuclear power reactor components from Poland’s unfinished VVER-440 reactor at Zarnowiece, but was rebuffed.[24] More recently, under pressure from the United States, the Ukrainian government abrogated a 1996 agreement between the Russian contractor for Bushehr and Ukraine's Turboatom for the supply of two turbines.[25] Minatom officials have subsequently said the turbines will be manufactured in St. Petersburg and that Ukraine's refusal to cooperate would not affect Bushehr’s progress.[26]

Currently, Minatom subsidiary Zarubezhatomenergostroy (Nuclear Energy Construction Abroad) is working on the Bushehr plant.[27] Preparation of the Bushehr-1 site is complete, the reactor vessel has been manufactured, and building of the steam generators and other equipment has begun.[28] Led by Igor Magala, Russian personnel conducted a feasibility study of the project in 1995.[29] Although there are approximately 150 Russian personnel working at the site, that number could increase to 3,000.[30]

The Russian-Iranian contract entered into force on January 12, 1996, and calls for the reactor to be completed within 55 months.[31] However, without technical specifications for the German-supplied components, it is doubtful that Russia will be able to complete the reactor on time because existing equipment installed by Siemens may have to be replaced with Russian equipment.[32] Russia plans to install a VVER-1000 reactor which requires six horizontal VVER steam generators; the planned Siemens reactor was 1,300 MWe, designed to hold four vertical steam generators.[33] Metallurgical specifications of the German equipment differ from those of Russian primary- and secondary-side components, and the horizontal VVER steam generators are materially different from the vertical Siemens steam generators.[34] Failure to match metallurgical specifications in the equipment could lead to corrosion or other serious problems.[35] Unless Minatom can match these specifications, the cost of the project will increase greatly and completion could be delayed until at least 2003.[36]

Iran has repeatedly asked the German government to allow Siemens to ship reactor components and documentation that Tehran has paid for. Under a 1982 International Commerce Commission (ICC) ruling, Siemens is obligated to deliver all plant materials and components stored outside Iran. However, the German government has refused to grant Siemens an export license for the materials or grant permission to complete the plant.[37] In response, Iran filed a lawsuit in August 1996 with the ICC, asking for $5.4 billion in compensation for Germany's failure to comply with the 1982 ruling.[38] German officials have stated that any decision to release information or equipment related to Bushehr would be "carefully weighed" and that Bonn would most probably reject any such request.[39]

Uncertainty surrounding the work schedule, and disagreement on how much of the German equipment can be used, has caused friction between the two partners. Iran is insisting that it will not pay more than $100 million unless Russia agrees to a firm completion deadline, while Russia insists that it needs a down payment in hard currency before it can proceed.[40] Although Iran paid Russia $60 million in March 1997 and work is continuing, uncertainty over the Siemens equipment threatens to significantly delay or even derail the project.[41] Questions remain whether Russian technicians can overcome the incompatibility problems within a reasonable timeframe and budget. If the delays and costs are significantly higher than expected, Iran is not likely to be able to afford any new large-scale nuclear projects until Bushehr-1 is completed, meaning at least into the next century.

Assessment:

Russia's ability to complete the 1,000 MW Bushehr-1 reactor will have a great impact on Iran's civilian nuclear program. If successful, as many as four reactors could be built at the site, giving Tehran substantial expertise for a military nuclear program. The training in Russia and experience gained from running a nuclear power plant will give Iranian scientists and engineers a greater understanding of nuclear matters that have both civilian and military applications, potentially increasing Tehran's ability to produce weapons-grade fissile material and build a nuclear weapon over the long-term. Such training would have to be augmented with additional expertise in critical technologies such as weaponization, reprocessing, or enrichment. The large amount of materiel and technicians moving between Russia and Iran as part of the Bushehr deal could also provide cover for covert weapons-related assistance or smuggling activities.

Furthermore, the Bushehr-1 reactor and corresponding facilities would give Tehran legitimate grounds to conduct research and acquire nuclear-related capabilities that could make a clandestine military nuclear program easier to conduct and conceal.

Although the most worrisome clauses of the 1995 Russian-Iranian nuclear contract — provision of a gas centrifuge uranium enrichment plant and a large research reactor — have been halted, other concerns remain. Russian nuclear fuel cycle assistance, such as building a uranium mine and providing 2,000 tons of natural uranium, could enhance Tehran's capability. The natural uranium, which does not require safeguards, could potentially be used to feed a secret uranium enrichment program or could be fabricated into heavy water reactor fuel.

The existence of spent fuel from the Bushehr reactor, which would have to be stored on-site for several years while it cools, would also be a concern. The Bushehr plant could be capable of producing up to 180 kg of plutonium each year in its spent fuel.[42] Although it would be subject to IAEA safeguards, the spent fuel could potentially be diverted or stolen from the facility for use in a plutonium reprocessing plant. Such a scenario is a long-term concern, as Tehran does not presently have a large-scale reprocessing plant and is years away from having the technical capability to build one. Even if Iranian scientists do manage to build one, such a plant would have to be declared and safeguarded by the IAEA. Furthermore, clandestine reprocessing facilities are difficult to operate and hard to conceal due to the distinct isotopic signatures of elements released during reprocessing.

The spent fuel from Bushehr will pose further proliferation risks, as its final disposition has not yet been determined. It may eventually be sent back to Russia to be stored or reprocessed, but Minatom official Yevgeniy Mikerin said that Russia and Iran "have made no agreements" concerning the spent fuel.[43] According to Mikerin, the Russian-Iranian deal covers only the front end of the fuel cycle.[44]

The best option from a nonproliferation standpoint would be to return the spent fuel to Russia for storage at Krasnoyarsk-26 (Zheleznogorsk), in southern Siberia.[45] Russian environmental law, however, seems to preclude this. The Law on Environmental Protection, two presidential decrees, and a government decree regulate the importation of spent fuel. Article 50 of the Law on Environmental Protection (19 December 1991) prohibits storing or burying radioactive waste or materials from abroad on Russian territory. However, a contradictory law (Presidential Decree 72, dated 25 January 1995) allows Krasnoyarsk-26 to temporarily store and reprocess spent fuel from foreign plants. Following criticism of Decree 72, Presidential Edict 389 was issued on 20 April 1995, to improve oversight of importing and handling spent fuel. On 4 April 1996, the Russian Supreme Court repealed the sections of Decree 72 that provide for the importation and reprocessing of spent fuel.[46] Edict 389 requires that products of reprocessing be returned to the country of origin. Russian government Resolution 773 of 29 July 1995, also stipulates that Russia must return solid radioactive wastes and "other by-products of reprocessing not intended for further use in Russia." The law further requires that the process be safeguarded by the IAEA and that the country of origin has in place all the necessary regulatory structures as well as the ability to safely handle radioactive waste.[47]

A second option would be to separate the spent fuel at the RT-2 reprocessing plant in

Krasnoyarsk once it is completed.[48] Russian environmental law appears to allow this, but only if Moscow returns the high-level radioactive waste and separated plutonium to Iran.[49] However, the presence of separated plutonium in Iran, even under IAEA safeguards, would draw fierce criticism from the United States due to nonproliferation concerns. Furthermore, the RT-2 plant will not be completed until after Bushehr-1 is operating, meaning that sending spent fuel to Russia would be tantamount to storage and therefore violate Russian environmental law.

## Bonab

The area 80 km south of Tabriz is home to the Bonab Atomic Energy Research Center, which conducts research on nuclear technology for agricultural uses.[50] The facility, run by the AEOI and headed by Hussein Afarideh, is not under IAEA safeguards but was visited by IAEA Director General Hans Blix in July 1997.[51] Although Blix found no prohibited activities and the facility has not generally been the subject of allegations, one report claimed that a nuclear reactor housed in a reinforced-concrete bunker was under construction with Chinese assistance there.[52]

Assessment:

Publicly available information on the Bonab Atomic Energy Research Center suggests that it is a minimal proliferation threat with little military application aside from providing basic nuclear training. The Blix visit and the scant amount of information on the center do not substantiate the report that a secret nuclear reactor is being built at Bonab.

## Darkhovin (also called Ahvaz, Esteghlal, and Karun)

Located on the Karun River south of the city of Ahvaz, Darkhovin was the proposed location for a nuclear power plant to be built by either French or Chinese firms. The first proposal was for France to build two nuclear reactors there in the late 1970s. In 1974, Iran signed a contract with the French company Framatome to build two 950 MW pressurized water reactors (PWRs) at the site they called Karun.[53] Although Framatome surveyed the area and site preparations had begun, construction had not yet started when Iran canceled the contract following the Islamic revolution in 1979.[54]

Iran made a second attempt to acquire a nuclear power plant at Darkhovin, contracting China to build two 300 MW PWRs for a project the Chinese called Esteghlal. On 10 September 1992, Iranian President Hashemi Rafsanjani announced that China’s Qinshan Nuclear Power Company and the Shanghai Nuclear Research and Design Institute agreed to build the reactors as part of a nuclear cooperation agreement.[55] Chinese officials said it could take up to 10 years to complete the two reactors.[56] Western analysts at the time predicted the plant would never be finished because China was not technically capable of building a 300 MW reactor without importing key components from abroad.[57] These arguments have been disproved by China’s apparently successful attempt to build the Chashma-1 reactor in Pakistan, which is nearing completion.

Although preliminary preparations, such as a seismic study, were conducted, the deal now seems to be on hold.[58] China failed to submit a detailed technical plan for the plant and failed to implement an agreement to train Iranian nuclear technicians.[59] The Iranian side was unable to provide detailed financial plans on how to raise $2 billion for the two reactors.[60] Several reports have quoted Chinese Foreign Minister Qian Qichen as telling U.S. Secretary of State Warren Christopher on 27 September 1995, that Beijing "terminated" the reactor contract.[61] Qian changed his statement on 30 September 1995, saying the deal was merely suspended "because the original site is not very appropriate for these nuclear reactors."[62] The planned site was subsequently moved from Darkhovin to near Bushehr due to Darkhovin's proximity to Iraq.[63] Since 1995, however, there have been no new developments on the proposal and it is doubtful that Iran could afford the project while paying for construction of Bushehr-1.

Assessment:

A severe shortage of hard currency, coupled with payments for the Bushehr-1 reactor, makes progress on the Darkhovin project unlikely until Iran's financial situation improves. If the project were to proceed, the two reactors would likely be built by the China National Nuclear Corporation (CNNC) near Bushehr. Although the reactors would be under IAEA safeguards, completion of a nuclear power plant at Darkhovin would provide Iran with nuclear technology from which the country's military could draw expertise and personnel. Despite the presence of IAEA safeguards, the concern remains that the reactors' spent fuel could be stolen or diverted for use in a secret reprocessing program. Furthermore, enlarging the size and scope of Iran's nuclear infrastructure could make it more difficult to detect and assess a clandestine nuclear research and development (R&D) program [though not the nuclear facilities themselves].

## Isfahan (Esfahan) Nuclear Technology Center

The Nuclear Technology Center at Isfahan was founded in the mid-1970s with French assistance in order to provide training for Bushehr reactor personnel.[64] Located at the University of Isfahan and directed by Kazem Rassouly, the center houses four small research reactors.[65] The first, a Chinese-supplied 27 kilowatt thermal (kWt) miniature neutron source reactor (MNSR), went critical in March 1994. The MNSR is used to produce isotopes and burns 900 g of highly enriched uranium (HEU) fuel supplied by the CNNC.[66] The center also has a Chinese-supplied heavy water, zero power, reactor which went critical in 1995, and two Chinese-supplied sub-critical reactors which were completed in 1992 (an open tank facility fueled by uranium metal pins and a graphite-moderated facility).[67] The CNNC supplied the MNSR and the zero-power reactor with heavy water.[68]

During a November 1996 IAEA visit to Isfahan, Iran informed the IAEA Department of Safeguards that it plans to build a uranium hexafluoride (UF6) conversion plant at the Nuclear Technology Center.[69] Tehran expects the Chinese-supplied plant, which will be placed under IAEA safeguards, to become operational sometime after 2000.[70] The plans explain the presence of 15 Chinese nuclear experts at the center in 1995, who were likely making design preparations for the facility.[71] U.S. officials subsequently convinced China to halt the transfer of anhydrous hydrogen fluoride (AHF) and other UF6-related materials as a prelude to opening nuclear exports to China.[72] Although AHF is not regulated by the Nuclear Suppliers' Group (NSG) list of controlled nuclear technologies, it is a feedstock material for converting natural uranium into UF6. Beijing may have already provided Tehran with blueprints for the UF6 facility.[73]

The planned UF6 plant prompted allegations that R&D on gas centrifuge technology was secretly being conducted at Isfahan.[74] Uranium hexafluoride gas is used to feed a gas centrifuge uranium enrichment plant. Any R&D activities at the site would likely be overseen by AEOI personnel and Isfahan University staff. Key staff at the center include: Morteza Saghalan Nejad, university chancellor; Ahmad Abrishamchi, vice-chancellor for research; Safa Isfahani, dean of physics; Fakhr-o-Din Ashrafizadeh, dean of materials science and metallurgy; Mahmood Vafaian, dean of mining engineering; H. Bassir, professor of mining engineering; and Mohammad Reza Ehsani, dean of chemical engineering.[75]

Assessment:

The facilities currently operating at the Nuclear Technology Center are not a direct proliferation threat because they are safeguarded, because the research reactors can not produce significant amounts of plutonium-bearing spent fuel, and because only minor amounts of heavy water and HEU are present. However, Iranian attempts to buy a 30 MWt heavy water research reactor from China in 1991 raised concerns.[76] A deal to build the reactor at Isfahan, which would have been capable of producing significant quantities of plutonium in its spent fuel, never materialized due to technical and financial problems. Coupled with the rapid build-up of nuclear facilities at Isfahan, the proposed reactor deal raised concerns that the center may be conducting research on nuclear technology with military applications; a worry exacerbated by the fact that part of the center is apparently built underground.[77]

The planned UF6 production plant fuels additional suspicion. There is no logical explanation for Iran to build such a plant, the product from which is used to feed a uranium enrichment facility. Iran does not have a declared uranium enrichment facility, nor does it require one for its civilian nuclear program. The country's lone commercial reactor, at Bushehr, will use nuclear fuel imported from Russia. Due to the absence of commercial nuclear power plants and the high investment costs associated with building nuclear facilities, the development of fuel cycle facilities such as the UF6 plant suggests that Tehran may wish to use them for non-peaceful purposes.

## National Iranian Steel Company

The National Iranian Steel Company (NISCO) in Isfahan, which produces steel for a Defense Industries Organization (DIO) munitions plant, could provide a number of nuclear-related metallurgical products.[78] With help from Japan's Nippon Steel, the Italian firm Danieli built four specialty steel plants for NISCO that could have the capability to produce maraging steel and other corrosion-resistant alloys useful in a nuclear program and in the construction of ballistic missiles.[79] The Isfahan Alloy Steel Complex, of which the plants are a part, officially opened on 20 August 1996, and has a capacity of 30,000 tons of alloy steel per year.[80]

Assessment:
The status of the NISCO plants is questionable. In 1996, British customs officials seized a shipment of 55 kg of maraging steel, used to make uranium enrichment centrifuges as well as components for missiles and other military hardware, that was bound from the United States to Iran.[81] If the plants are operable and can produce maraging steel, the Iranian government would

be unlikely to waste valuable oversees procurement assets to acquire this high-strength alloy. Danieli's participation in the project is of additional concern due to the firm's past involvement in building a maraging steel plant for Iraq's Taji uranium enrichment centrifuge production facility.[82]

## Gorgan (also called Neka)

Iran had planned to build two Russian VVER-440 MWe power reactors at a facility in Gorgan, sometimes referred to as either the Gorgan al-Kabir Center or Neka.[83] The deal was part of a 6 March 1990, protocol between the Soviet Union and Iran, which stipulated that Moscow would complete Bushehr-1 and -2, as well as build two VVER-440 reactors at an unnamed site, later identified as Gorgan.[84] Russian technicians conducted a geological survey of the area, but determined that it was unsuitable for nuclear facilities due to seismological instability.[85] It was then decided to build the proposed reactors at Bushehr.[86]

Despite the location change, allegations persist that the area is home to a secret nuclear weapons-related facility.[87] According to one report, Iranian, Ukrainian, Russian, and Kazak scientists are working at the Gorgan al-Kabir Center, earning up to $20,000 a month each.[88] The facility, said to be one of Iran's largest nuclear research centers, is allegedly supervised by AEOI Deputy Chairman Mansour Haj Azim. Two Russian scientists, Dr. Larichenkov and Dr. Ayshrov, reportedly led the research efforts there.[89] Other sources have said that Israel threatened to bomb the facility in 1996, ostensibly due to its involvement in Iran's nuclear weapons development efforts.[90]

Assessment:

Although this facility has not been declared to the IAEA, and therefore was not inspected as part of the agency's 1992 trip to Iran, there is no available evidence to justify allegations of nuclear activities in the area. The allegations, which originated with the Iraqi-based Mojahedin-e Khalq resistance group, are likely founded on the now canceled plan to build two Russian reactors at Gorgan. These sources likely confused the presence of Russian technicians conducting the site survey for more dubious activities.

## Center for Agricultural Research and Nuclear Medicine

Inaugurated on 11 May 1991, by Iranian Vice President Hassan Habibi, the facility at Karaj is a nuclear medicine and agricultural research center run by the AEOI.[91] A 30 Mega-electronvolt (MeV) cyclotron accelerator supplied by Belgium's Ion Beam Applications, and a small (one milliamp (mA) Chinese-supplied and -installed calutron are located there.[92] The existence of these devices has led to allegations that, in 1995, China was installing a uranium enrichment facility using calutrons at Karaj.[93] A large hydro-electric dam located nearby could provide the facility with the large amounts of electricity it would require.[94] However, the Chinese-supplied calutron is housed in a gymnasium-sized building that uses an unprotected ventilation system, precluding its work with radioactive substances.[95]

Assessment:

Allegations of a secret uranium enrichment plant at Karaj are likely misinterpretations of the Chinese-supplied calutron's capabilities. Aside from the configuration of the ventilation system, the desktop-sized machine has the wrong technical specification to be used in a uranium enrichment program; it is used to produce stable isotopes of zinc for biological research.[96] The device is too small to enrich uranium to weapons grade, and Iranian scientists have experienced problems operating it correctly, although some progress has been made.[97] Furthermore, IAEA inspectors visited the facility in 1992 and determined that its activities were consistent with civilian nuclear research.[98]

Although the Karaj facility does not currently violate IAEA safeguards obligations and is not an immediate proliferation threat, it does present some long-term concerns. Iranian technicians could use the calutron and cyclotron to gain knowledge of electromagnetic isotope separation (EMIS) technology. Such technology could be used to build or reverse-engineer larger versions of the devices to clandestinely enrich uranium in another facility. However, an EMIS enrichment plant would require large amounts of electricity, making it difficult to conceal.

Were Iran to try to domestically produce its own calutrons, it would need precision machining facilities to make the large magnets that powerful calutrons require. Although Iran has little indigenous capacity to build precision machine-tools, it imported high-capacity computer-numerical-control (CNC) lathes and vertical turning machines from the Czechoslovak firm Strojimport in 1982-83. The Iranian state-owned heavy manufacturing firm Machine Sazi Arak bought eight vertical turning and boring machines (three Model SKJ-12A, three Model SKJ-20A, and two SKD-32A), and the Czech firm TST Kovosvit Semimovo Usti provided Machine Sazi Arak with at least five CNC drilling machines.[99]

Iran could acquire more machine-tools from turn-key factories that foreign firms are establishing in Iran, several of which are scheduled to be completed in the late 1990s. To augment this capability, the Iranian minister for mines and metals signed a letter of intent on 5 December 1996, pledging Tehran's interest in buying the ailing former East German machine-tool manufacturer Sket Magdeburg.[100] Such a move would be similar to Iraq's former arrangement with British machine-tool maker Matrix Churchill, from which Baghdad procured machine-tools used in its weapons of mass destruction programs. Acquisitions from any of these suppliers, in conjunction with the Czech-supplied CNC machines, would give Iran the capability to manufacture the necessary large magnets for a calutron.[101]

**Moallem Kaleyah (Mo'allem Kalayeh, Moa'alem Kelayeh, also called Ghaziv (Ghazvin), Qazvin, and Alamout)**

Located in the mountains northwest of Tehran, Moallem Kaleyah was the proposed site for a 10 MWt research reactor India was going to build under a 1991 agreement with Iran.[102] Although New Delhi canceled the deal under U.S. pressure, allegations remain that Iran has a secret nuclear facility in the area. The Iranian Revolutionary Guard Corps (IRGC) allegedly oversees a gas centrifuge uranium enrichment plant at Moallem Kaleyah, said to be Iran's primary fissile material production center.[103] This facility was reportedly established in 1987 using equipment acquired from French, German, and Italian companies.[104] Other sources claim the area could be where weaponization and design work is conducted.[105]

IAEA inspectors visited the site in February 1992, but found only a small training and recreation facility being built for AEOI staff.[106] Skeptics argue that the inspectors were taken to the wrong location, far away from the intended site.[107] These critics charge that because the inspectors were not carrying navigation equipment to determine their precise location, they were easily led to an alternative facility that was not the intended inspection site. IAEA officials said those allegations are "just plain wrong."[108]

Assessment:

There is a lack of verifiable open-source evidence to prove that Moallem Kaleyah is anything more than a small AEOI training and recreation facility. Iran has not demonstrated an ability to build even a pilot-scale centrifuge facility and it is unlikely that Tehran could build and hide a large-scale uranium enrichment plant (see Sharif University of Technology). The allegations could stem from past activity in the area associated with the proposed reactor deal with India.

## Amir Kabir University of Technology

Founded in 1958 as Tehran Polytechnic, Tehran's Amir Kabir University of Technology offers doctorates in nuclear science and technology and conducts research into theoretical and high-energy physics.[109] The school has allegedly been used as a front to procure nuclear components, including attempts by university representatives to purchase neutron-shielding equipment from the U.S. firm Reactor Experiments.[110] Individuals involved in nuclear-related activities at Amir Kabir would likely include: Mohammed Hussein Salimi, chancellor; Jafar Milimmon-Fared, deputy vice-chancellor; F. Afshar Taromi, head of polymer engineering; H Modarres, head of chemical engineering; and M. Salari, head of mining and metallurgical engineering.[111]

Assessment:

Aside from the nuclear-related training that Amir Kabir could provide, the school could be used as a front for Iran to obtain dual-use technology for its nuclear program. Had it been successful, the neutron-shielding equipment would have likely been located at Tehran University and could be used in a plutonium reprocessing R&D program.

## University of Tehran

The Tehran Nuclear Research Center (TNRC), located at the University of Tehran and overseen by the AEOI, is Iran's primary open nuclear research facility. It is also the nucleus of many secret Iranian atomic programs, including plutonium reprocessing, laser enrichment, and weapon design R&D efforts. The TNRC houses a safeguarded 5 MWt pool-type research reactor, supplied by the United States in 1967, that can produce up to 600 g of plutonium per year in its spent fuel.[112] In 1987, the AEOI paid Argentina's Applied Research Institute (INVAP) $5.5 million to convert the reactor from using 93 percent enriched uranium fuel to burning 20 percent enriched uranium fuel.[113] The Argentine Nuclear Energy Commission (CNEA) has subsequently supplied the reactor with 115.8 kg of safeguarded 20 percent enriched uranium fuel.[114]

During the former Shah of Iran’s reign, the TNRC experimented with chemically extracting plutonium from spent fuel, a former head of the AEOI said.[115] According to a former TNRC technician, Iran completed and cold tested a plutonium extraction laboratory at the center in 1988 but did not reprocess any plutonium.[116] The status of this facility is uncertain, although it is believed to be inoperable. The TNRC has hot cells, supplied by the United States in 1967, which can be used to reprocess gram quantities of plutonium from spent fuel.[117] Iranian representatives may have approached Argentina about buying additional hot cells, but a deal was never completed.[118] Also, Iran acquired tributylphosphate (TBP) from China, a chemical used in the plutonium separation process.[119] China may have further supplied Iran with data on chemical separation technology.[120]

In support of its reprocessing program, Iran tried to acquire the capability to produce heavy water and nuclear fuel for a reactor. Such attempts could have been part of a long-term program to clandestinely build and operate a heavy water reactor to produce plutonium-bearing spent fuel for separation in a reprocessing plant. Iran negotiated with Argentina for a fuel fabrication pilot-plant and a pilot-scale heavy water production facility, but the deals were canceled by Argentine President Carlos Menem due to U.S. pressure.[121] Iran does have a lab-scale uranium mill at the TNRC, used to produce yellowcake from raw uranium ore, but IAEA inspectors visited the site in 1992 and found that it was not operable.[122]

Iran does have a lab-scale uranium mill at the TNRC, used to produce yellowcake from raw uranium ore, but IAEA inspectors visited the site in 1992 and found that it was not operable. In addition, China is providing Tehran with a plant to produce zirconium tubes which are used to clad nuclear fuel in a reactor's core.[123]

The TNRC may have also been the center of Iran’s nuclear weapon design program. The shah assembled a nuclear weapon design team as part of his government’s atomic research efforts, which could have included computer modeling and basic research of a nuclear explosive device.[124] Following the 1979 Islamic revolution, the new government was able to keep or lure back key TNRC personnel and therefore probably inherited most of the nuclear weapon design team’s data and knowledge.

Although there is a paucity of publicly available information on current nuclear weapon design activities in Iran, such activities would likely involve personnel from the TNRC. Iran has attempted to acquire equipment that could be used to fabricate weapon parts and assist in design efforts. Tehran sought high-speed cameras and flash x-ray equipment which may have been shipped to Iran through the U.K., and purchased an oscilloscope and pulse generators from a U.S. firm (see Sharif University).[125] Such equipment could be used to measure and calibrate the shock wave of an implosion device. Also, Tehran may have procured a vacuum arc furnace (see Sharif University) and acquired precision machine-tools (see Karaj), which can be used to cast and machine weapon cores, respectively.

The TNRC houses the Laser Research Center and its subsidiary the Ibn-e Heysam Research and Laboratory Complex, which was officially opened on 13 October 1992.[126] Headed by A. Hariri, the center has been the focal point of Iran’s program to enrich uranium using the laser isotope separation (LIS) method since the mid-1970s.[127] It has production lines for red helium-neon lasers and $CO_2$ gas lasers, a glass-tube manufacturing unit, an optical manufacturing unit, a nitrogen laser laboratory, a solid laser laboratory, a precision laser laboratory, semi-guided laser laboratories, and a polymer laser laboratory.[128] In addition to these indigenous LIS development efforts, Iran received at least one copper-vapor laser from China.[129] During the 1970s, Tehran sought LIS equipment and technology from U.S. scientist Jeffrey Eerkens, who had worked on a classified U.S. government project researching laser enrichment. Eerkens latter said that the laser designs and the more than four lasers he sent to Iran were not suitable for enriching uranium; Iran sought 16 µm lasers, and Eerkens concentrated on 5 µm lasers.[130] Both of these wavelengths are suitable for enriching uranium, but 5µm wavelength lasers are preferable.[131]

In support of their R&D efforts, Iranian nuclear specialists have received training from the International Center for Theoretical Physics in Trieste, Italy.[132] In 1991, up to 77 Iranian scientists, along with researchers from other developing countries, conducted advance nuclear research at the Trieste center, where they had access to a U.S.-made supercomputer and laser equipment.[133] Some of these scientists are among the 91 TNRC staff researching nuclear physics, chemistry, plasma physics, and laser technology.[134] Key personnel at the TNRC include: Chancellor Gholam Ali Afrooz; Mousavi Movahedi, vice-chancellor for research; H. Ghafourian, director; A. Owlya, deputy director; M. Naraghi, head of plasma physics; N. Banai, head of spectroscopy; E. Ziai, head of physical chemistry; F. Farnoudi, head of reactor research and development; M. Zaker, head of reactor research and operation; Fereydun Soltan-Moradi, deputy head of laser research; Ehsanollah Ziai, who headed the laser isotope separation program under the shah; and researcher S.M. Hamadani.[135]

Tehran University has other affiliated institutes that could conduct research useful in a nuclear weapons program. The Electrotechnical Institute, run by M. Rahimian and Deputy Director A. Sabet, has a staff of 200 conducting electrical engineering research.[136] The Institute of Electric Engineering, headed by R. Mirghaderi, has a graduate research staff of 30.[137] With an annual R&D budget of approximately $700,000, the Institute of Electric Engineering’s clients include Iran’s Ministry of Post, Telegraph, and Telephones (PTT), Ministry of Defense, and Defense Industries Organization (DIO).[138]

Assessment:

Under the guise of seeking civilian nuclear technology, the TNRC is conducting a variety of R&D activities with military applications. Some of these, such as operating a research reactor and training a cadre of nuclear technicians, are consistent with the peaceful development of nuclear energy. In the absence of a large civilian nuclear power program, activities such as plutonium reprocessing and laser enrichment research are hard to justify unless they are for weapons-related purposes.

The TNRC has been, and remains, the center of Iran’s plutonium reprocessing efforts. Although the hot cells and other lab-scale reprocessing activities there can produce only small amounts (0.6 kg per year) of plutonium, Iranian technicians could use the facilities to gain the scientific knowledge and competence necessary to operate a larger-scale plant.[139] Iran has already demonstrated an interest in acquiring further capabilities, having approached Argentina and

China for reprocessing technology.[140]

Despite these efforts, even small-scale reprocessing activities appear to be currently beyond Iran's technical competence. Furthermore, Tehran is years away from having the capability to build and operate a larger-scale separation plant. Recent Iranian procurement activities suggest that its plutonium reprocessing program is not a priority, possibly due to the sophisticated technical knowledge a reprocessing plant would require. Moreover, Tehran may be deterred by the IAEA's enhanced safeguard program, called 93+2, which will make it more difficult to hide a clandestine reprocessing plant due to the distinct isotopic signatures of elements released during the process.

If Tehran were to build a secret plutonium reprocessing facility, it would need a supply of unsafeguarded spent fuel to feed it. Although Iran could attempt to divert safeguarded spent fuel from its research reactors or the Bushehr plant, scheduled to begin operating in 2000, large quantities could not be diverted without being detected by the IAEA inspection regime. Iran could also try to procure spent fuel on the black market. However, there are no documented cases of significant amounts of spent fuel being smuggled internationally, and without an indigenous source of spent fuel, Iran's nuclear weapons program would be at the mercy of smugglers.

A more likely scenario would be for Tehran to secretly build a research-sized heavy water reactor for producing spent fuel with a high plutonium content. Not only do heavy water reactors produce relatively more plutonium in their spent fuel than light water reactors, they can burn natural uranium fuel, obviating the difficult step of enriching the uranium fuel. Tehran's approach to Argentina for heavy water and fuel fabrication technology may have been in preparation for commencing such a program. This would be a long-term objective, however, as Iran does not have a facility to produce heavy water or fabricate nuclear fuel and does not possess the capability to build and operate a reactor of even modest size.

In addition to plutonium, nuclear weapons can be built using highly enriched uranium. Iran has pursued both paths to the bomb, hoping that at least one of the programs would succeed. Although the Ibn-e Heysam Research and Laboratory Complex's production facilities are impressive on paper, the uranium enrichment program using laser isotope separation technology has not been successful. LIS technology, which has not been mastered by many of the most developed countries, is probably beyond Iran's technical and scientific capacity. The need to keep the research secret further inhibits Iran's scientific growth in the nuclear field. Tehran may continue research on advanced laser technology, however, because it has military applications other than uranium enrichment.

Iranian attempts to acquire the capability to weaponize a fissile material stockpile have been equally rudimentary. Although Iran has some equipment which could be used in a weaponization effort, it lacks much of the sophisticated dual-use measurement equipment that building a nuclear weapon requires. Furthermore, given its lack of technical experience, Iranian nuclear weapon designs would be limited to simple fission devices that are low yield (about 15 kilotons), heavy, and cumbersome. However, Tehran does have the technical capability to produce the non-nuclear components of the weaponization package. The University of Tehran's electrical-related research institutes could be used to develop some of these components.

## Sharif University of Technology

Tehran's Sharif University of Technology is an important nuclear procurement front and R&D center. Western intelligence officials allege that the Physics Research Center (PHRC) is the site of attempts to produce fissile material and the German intelligence agency Bundesnachrichten-dienst (BND) lists it as an Iranian procurement front.[141] The PHRC is where Iran has tried to buy or build uranium enrichment centrifuges since at least the early 1990s. Such activities likely involve key personnel at Sharif, including: president Saed Sohrabpour; Abdullah Afshar, vice-president of research; Davood Rashtchian, chemical engineering department chair; Hossein Zadeh, metallurgical engineering department chair; and Abbas Anvari, physics department head.[142]

Following a strategy similar to Iraq's and Pakistan's nuclear development programs, Iran has attempted to acquire a uranium enrichment capability by purchasing centrifuge components piecemeal from Western European suppliers. Tehran established a network of front companies to procure dual-use and prohibited items, with Sharif University as the intended destination. As part of this program, they have used design information for Urenco G-1 and G-2 type centrifuges which the BND said was obtained through Pakistan.[143] In 1991, Sharif University officials tried to buy specialized ring magnets from the German firm Thyssen, but were rebuffed because the end-user was not specified.[144] The officials then approached Germany's Magnetfabrik Bonn (MFB) about "alnico" (a combination of aluminum and nickel) type ring magnets, which can be used in gas centrifuges.[145] When questioned, MFB officials admitted that they had sold Iran ferritic ring magnets since 1993, but denied the deals included either alnico magnets or Sharif University.[146] The MFB officials added that Germany's Federal Export Control Office (BAFA) approved the ferretic ring magnet deal because the devices could not be used for enriching uranium. Also in 1991, Germany's Leybold corporation negotiated the sale of a vacuum arc furnace with Said Kareem Ali Sonhani, an official at the Iranian embassy in Bonn.[147] Leybold further negotiated the sale of vacuum pumps to a university in Tehran from 1990 to 1991, although these may not have been delivered.[148] Another supplier of the Iranian program is the company Karl Schenck of Darmstadt, which sent at least one balancing machine to Sharif University before canceling the rest of the order.[149] The balancing machine, which can be used to produce gas centrifuges, was sent after Schenck was assured in writing that it would not be used for military purposes.

Iran procured equipment for its gas centrifuge development program from other Western suppliers as well. In 1991, several British firms sent Sharif University a supply of fluorine gas, which is used to make UF6 to feed a centrifuge plant.[150] In August of that year, Reza (Ray) Amiri and Mohammed (Don) Danesh were arrested for selling to Iran an oscilloscope purchased from the U.S. firm Tektronix.[151] U.S. federal prosecutors allege that Amiri and Danesh also sent Iran logic analyzers and pulse generators.[152] Swiss companies may have supplied Iran with gas centrifuge technology in 1991 as well.[153] Additionally, Iran acquired electrical discharge machinery (EDMs) from the Swiss firms AGIE and Charmilles Technologies in 1993.[154] EDMs cut heavy metals with a high degree of accuracy and can be used to produce gas centrifuge components and to fabricate nuclear fuel.

These activities raised concerns that Tehran has an active nuclear weapons program and is seeking gas centrifuge technology. The proposed Russian supply of an enrichment plant (see Bushehr) heightened this concern. However, Russia has denied that its contract to complete work at Bushehr has anything to do with the supply of centrifuges.[155] Russia has the world's largest centrifuge enrichment capability which uses a relatively unsophisticated design, meaning that Iran could conceivably reverse-engineer them or gain clandestine assistance for its centrifuge program. The proposed centrifuge deal was especially worrisome considering the poor economic situation in Russia and the existence of many unused centrifuges and centrifuge components there.[156]

In addition to the PHRC, Sharif University has other centers that conduct R&D potentially applicable to a nuclear weapons program. The Electronics Research Center, headed by Mahmoud Tabiani, conducts research of electronic circuit and systems communication, as well as design and development of microcomputers.[157] It has a staff of 12 researchers and seven technicians, who could work on the non-nuclear electronic parts of a nuclear weapon.[158]

Assessment:

Iranian activities at Sharif University, including attempts to acquire equipment that could be used to build gas centrifuges, is a clear indication that Tehran has an active nuclear weapons program. Despite these efforts, evidence suggests that Iran does not yet have a centrifuge enrichment facility, even on a laboratory-scale. While Tehran has made some progress, it does not possess sufficient quantities of vital production equipment and materials such as maraging steel, and the program appears to have stalled since 1993. The tightening of export controls in supplier countries following revelations that Iraq was close to building a nuclear weapon has greatly hindered Iran's ability to acquire this material. Even if Tehran were able to build a small enrichment facility, operating the complex centrifuges may be beyond Iran's scientific and technical capability without external assistance, at least over the short-term. External assistance from a knowledgeable partner such as Russia or China, however, could allow Iran to build and operate an experimental-scale enrichment facility.

The focus of Tehran's current program is on developing and bench-testing gas centrifuges; these activities are likely being conducted at Sharif University.[159] These efforts do not specifically violate Tehran's safeguards obligations because they have not reached the threshold of having to be reported to the IAEA. It is not likely that Iran has a supply of UF6 gas or has enriched uranium in centrifuges, which require reporting under Iran's safeguards agreements. If it were to build a lab-scale enrichment facility or to enrich uranium, such activities would have to be reported to the IAEA.

Iran could attempt to build a clandestine enrichment plant separate from its safeguarded facilities once it masters centrifuge technology. This would be a long-term objective, as Tehran is years away from having the capability to build even a small, safeguarded, centrifuge plant. In addition to building and operating the centrifuges themselves, a secret enrichment facility would require an unsafeguarded supply of UF6 gas. Iran does not yet have even a safeguarded UF6 conversion plant (see Isfahan), nor does it have the ability to build a clandestine one. In short, Tehran will not have the capability to build an unsafeguarded uranium enrichment plant using gas centrifuges for many years, unless it receives large amounts of clandestine foreign assistance.

## Applied Research Center of Iran (MTK Iran)

The Applied Research Center of Iran, which is also known as MTK Iran, is affiliated with the Ministry for Heavy Industries and the Iranian Defense Research Organization (IDRO). Located in Tehran, the facility is listed as an official research center and conducts R&D on steel alloy production, processing non-ferrous metals, corrosion resistant technology, and metal casting.[160]

Assessment:

Although the technologies MTK Iran develops have civilian applications, many could also be used in a military program. In particular, developing the ability to produce maraging steel and corrosion resistant alloys could allow Iran to manufacture materials used to build uranium enrichment centrifuges. Although it is unclear how much progress Iran has made in these efforts, the 1996 seizure of maraging steel in the U.K. (see NISCO) suggests that Iran does not yet have the capacity to produce the high-strength alloy in sufficient quantities.

## Azad University

Azad University has a HT-6B tokamak fusion research reactor, which was supplied by the Chinese Academy of Sciences' Institute of Plasma Physics under a February 1993 agreement.[161] In 1994, Chinese technicians assisted with the installation and initial operation of the reactor.[162] According to former AEOI head Reza Amrollahi, Iran plans to build a second tokamak at an undisclosed location.[163]

Assessment:

The HT-6B tokamak is a fusion research reactor which uses magnetic fields to confine and heat deuterium and tritium plasma fuel. As part of their normal operations, most tokamaks remove and recycle small amounts of tritium, a vital nuclear weapon component. Such a device would give Iranian technicians experience working with fusion technology, which is potentially applicable to a thermonuclear weapon design program.

## Institute for Studies in Theoretical Physics and Mathematics

Established by the AEOI in 1989, this Tehran-based center researches theoretical, particle, and high energy physics applications.[164] The institute is primarily a training facility for Iranian nuclear scientists, and may be known as the Jabit bin al-Hayyan Laboratory.[165]

Assessment:

This institute could provide training in the fundamentals of nuclear science for Iranian technicians and researchers. Although the school is not directly involved in a nuclear weapons program, it could train those who conduct such activities.

## Yazd Province

Iran's attempts to mine and mill uranium ore have largely been conducted in the Saghand region of Yazd province. In 1985, AEOI specialists located over 5,000 t (metric tons) of uranium in the desert region of eastern Yazd province, making it one of the biggest deposits in the Middle East.[166] They also found 4,000 tons of molybdenum, a mineral which is mixed with steel to make hardened alloys that have nuclear applications. Although numerous allegations claim there is an operational uranium mine and mill nearby, IAEA inspectors visited Saghand in 1992 but found only a small uranium ore drilling rig that was at least five years from production.[167] Any AEOI uranium mining and milling activities would likely be assisted by University of Yazd experts, including: Jalil Shahi, chancellor; Mohammad Ali Barkhordari, dean of engineering; and Amir Hussein Koohsari, head of mining engineering.[168]

Having failed to indigenously mine and mill uranium on a large scale, Iran has sought foreign assistance with these efforts. China's Beijing Research Institute of Uranium Geology (BRIUG), a division of the CNNC, helped Iran explore for uranium deposits.[169] The AEOI also tried to buy $18 million worth of machine-tools from INVAP, but the deal was blocked by Argentine President Carlos Menem in February 1992 due to nonproliferation concerns.[170] The machine-tools were part of a contract for a pilot-scale uranium mill and a pilot-scale fuel fabrication plant.[171] According to U.S. intelligence reports, Tehran received further advice and assistance about mining and milling uranium ore from Russia.[172] This assistance may be continuing despite Moscow's assurances to the contrary. It is not clear, however, whether the Russian assistance is controlled by the central government or whether it is being provided by rogue individuals and Minatom bureaucrats.[173]

Due to the province's remote location and the presence of nuclear-related equipment, opposition groups have claimed that more nefarious activities are being conducted in the area. The Mojahedin-e Khalq resistance group claims that there is a major IRGC nuclear research center located underground in tunnels near the uranium mines. According to the Iraqi-based group, "the [Revolutionary] Guard Corps operates one of the regime's largest secret nuclear research centers which has been built underground near the city of Yazd."[174]

Assessment:

While allegations of secret nuclear facilities in Yazd can not be substantiated, reports of uranium mining and milling development activities appear valid. Iranian efforts to mine the province's vast uranium deposits have not born fruit, forcing Tehran to seek external assistance. Although Argentina blocked cooperation from one of its firms, China and Russia have either been unable or unwilling to do likewise. Further assistance will likely allow Tehran to acquire the capability to mine natural uranium ore and mill it into a powder form called yellowcake ($U_3O_8$) within a few years. The yellowcake could then be fabricated into heavy water reactor fuel or converted into uranium hexafluoride gas for use in a uranium enrichment plant. If Tehran continues plans to build a UF6 conversion facility at Isfahan, it would need a steady supply of yellowcake. Iran could probably complete a uranium mine and mill before the UF6 facility becomes operational, but if it does not, Tehran could use yellowcake it acquired from South Africa in the 1970s.[175]

**Tabas**

Located northeast of Saghand, Tabas is the alleged site of a secret nuclear reactor built with Chinese and North Korean assistance. North Korea is allegedly helping to build the reactor under the direction of General Myong-Rok.[176]

Assessment:
There is no open-source information to verify these claims. If North Korea is providing Iran with military assistance at a location in Tabas, it is likely for the production of ballistic missiles or conventional weapons.

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