WORKING PAPER 1301

Tracking Nuclear Proliferation within a Commercial Power Program

Susan Voss

JANUARY 2013

NPEC

Nonproliferation Policy Education Center

Tracking Nuclear Proliferation within a Commercial Power Program

by Susan Voss

Nonproliferation Policy Education Center
Working Paper 1301

January 2013
Series Editor: Henry D. Sokolski

Nonproliferation Policy Education Center

The Nonproliferation Policy Education Center (NPEC), a 501(c)3 nonprofit organization, is a nonpartisan, educational organization founded in 1994 to promote a better understanding of strategic weapons proliferation issues. NPEC educates policymakers, journalists, and university professors about proliferation threats and possible new policies and measures to meet them.

For current publications of the Nonproliferation Policy Education Center, please visit www.npolicy.org.

Contents

About the Author

Susan Voss is the President of the Global Nuclear Network Analysis, LLC, a small, woman-owned engineering firm in Los Alamos, NM. Ms. Voss was previously employed at Los Alamos National Laboratory (LANL), where she worked on projects related to nuclear power, the nuclear fuel cycle, nuclear nonproliferation, counter-proliferation, and arms controls for the Departments of State, Energy, Defense, and Homeland Security. Prior to her career at LANL, she worked for the Air Force Weapons Laboratory in Albuquerque on space nuclear power. Ms. Voss graduated from the University of New Mexico with a Master's in Nuclear Engineering, and is currently a member of the Hyperion small nuclear reactor design team, focusing on advanced nuclear fuel design and safety.

Introduction

It requires an estimated 3,000 people to construct a large commercial nuclear power plant and 800 to 900 people to operate two 1,000 megawatt-electric (MWe) light water reactors. If a country has a reactor built by a commercial company or a consortium from another country, there is a large exchange of experts working together from both countries. This includes training for language skills, siting experts, safety experts, reactor and balance-of-plant (BOP) design, and plant operations, to name just a few. Construction and manufacturing of the reactor system requires that the plant construction contractor provide highly skilled labor and technical expertise on-site to ensure the work meets nuclear quality assurance (NQA) standards. Therefore, the construction process brings together experts with backgrounds in many different fields and varied levels of education and skill.

One of the key proliferation concerns is that a country may choose to develop a commercial nuclear power program as a means of concealing nuclear weapons development by exploiting direct contact with nuclear experts in another country in order to obtain nuclear weapons-related information and produce nuclear weapons-useable materials and equipment. There are historic cases where nuclear power development has been used as a front for a nuclear weapons program, and technology has also been transferred within the framework of nuclear research outside of formal international agreements. The purpose of this paper is to discuss the systematic tracking of information needed to follow and interdict nuclear proliferation and the difficulties in doing this work. A summary of technologies that have reportedly been transferred to Iran are provided as an example.

New Construction

During the past 15 years or so there have been a number of surprises in the field of nuclear proliferation, including the discovery of the construction of the Syrian research reactor with the DPRK's support; the recent reports that China provided Pakistan nuclear material and the design for a weapon; the Khan network providing uranium enrichment equipment and expertise, along with nuclear weapons design information, to Libya, the DPRK, Iran, and a still unnamed fourth nation; and the surprising advancements within the Iranian nuclear program that were outed by a dissident group – including heavy water production, the operation of a heavy water reactor, and uranium enrichment using centrifuge technology. These examples point to the difficulties faced by the nonproliferation community in tracking illicit nuclear agreements and transfers of technology, which have steadily grown with the advent of global trade. The potential transfer of technology is a more significant issue in nuclear weapons states where nuclear institutions and education centers work on technology that can be used for nuclear weapons materials production, nuclear weapons design, and nuclear weapons testing. Therefore, to help clarify the problem of technology transfers, the issue can be divided into three categories: nuclear materials, nuclear weapons and nuclear weapons testing.

Nuclear Materials

The construction of a nuclear power plant requires the exchange of scientists, engineers, material scientists, and technicians between two countries unless it is being built with indigenous technology. This affords a country that may have the production of nuclear material for a nuclear weapon as its ultimate goal an opportunity to have direct contact with nuclear experts in other countries and the possibility of establishing outside contracts or agreements.

Nuclear weapons materials production is a rather broad category that includes uranium mining and conversion, uranium enrichment, fuel pin manufacturing, the operation and construction of research reactors, reprocessing spent fuel, and plutonium production. Often, knowledge of these key technical areas coexists at the institutes, companies, and educational centers involved in commercial nuclear power since the processes for producing nuclear power and nuclear weapons materials utilize complementary technologies and capabilities. Also, some of the manufacturing organizations work on many different technologies and may have expertise in manufacturing what are called dual-use capabilities. What this implies is that, given a cooperative agreement to construct a nuclear power plant, a country seeking a nuclear weapons capability will have an increased probability of having access to experts, institutions, companies, and educational centers that have expertise in the production of nuclear materials that could be used for weapons.

Given the large quantity of people, equipment, and correspondence–over 1,000 people; 10,000s of pieces of equipment; and 10,000s of documents, drawings, and communications–involved in the design and construction of a nuclear power plant, it is possible that a country seeking a nuclear weapons capability could use a nuclear power plant as a cover to obtain information on nuclear materials production. That said, it is ironic to note that the Syrian research reactor, reportedly being built with the help of the North Koreans, was not noticed in part because Syria's partnership with the DPRK was unknown, and therefore Syria was not under the same scrutiny that a country suspected of developing a nuclear weapons capability would be subjected to. Examples of nuclear material pathways include the following:

1. Pakistan chose the highly enriched uranium (HEU) path based upon the illicit use of information obtained from the commercial URENCO plant. They have since built heavy water research reactors for the production of plutonium.

2. The DPRK chose a plutonium path, using spent nuclear fuel (SNF) from its 5-MWe research reactor. There are recent reports that it is pursuing the HEU option using centrifuge technology reportedly obtained through the Khan Network.

3. Syria was possibly pursuing a plutonium path using the research reactor it was developing with North Korea.

4. South Africa chose a HEU path with support from Israel.

5. Iran appears to have chosen a multi-pronged approach for HEU production–including the use of centrifuge technology obtained through the Khan Network and, early in their program, laser enrichment–while simultaneously pursuing possible plutonium production through their heavy water research reactor. Iran obtained much of its technological base through interactions with Pakistan's Khan Network, China, and Russia.

6. Libya was pursuing a HEU path with centrifuge technology purchased from the Khan network.

The examples above are included to illustrate the different pathways taken by some countries pursuing nuclear material production capability. Of the countries that have pursued, or appear to be pursuing, a nuclear weapons capability during the past fifteen years, Iraq, Syria, and Libya had nuclear research programs but not a civilian nuclear power program, whereas North Korea and Iran developed fuel cycle capabilities and nuclear power programs as the cornerstone for their broader nuclear research. Both the North Koreans and Iranians received nuclear training in Russia. It is reported that "more than 300 North Korea nuclear specialists of various qualifications were trained at various Soviet institutes of higher education." These facilities included the Moscow Engineering Physics Institute (MEPhI), the Bauman Higher Technical School, the Moscow Energy Institute, and other educational establishments and some of the nuclear specialists worked at the Joint Institute for Nuclear Research (JINR) in Dubna and the Institute of Physics and Power Engineering (IPPE) in Obninsk.[1] Specific examples of Iranians training in Russia are referenced below.

Nuclear Weapons and Weapons Testing

The second category of nuclear weapons expertise represents a much smaller core group of individuals, institutions, companies and educational centers. While these groups may still be involved in the commercial nuclear power business, they are far fewer in number and generally work within a secure or classified environment.

According to Jeffrey Richelson "While thousands were involved in India's nuclear program, only fifty to seventy-five scientists were actually part of the effort to design and build an explosive device."[2] This is illustrated in Figure 1.

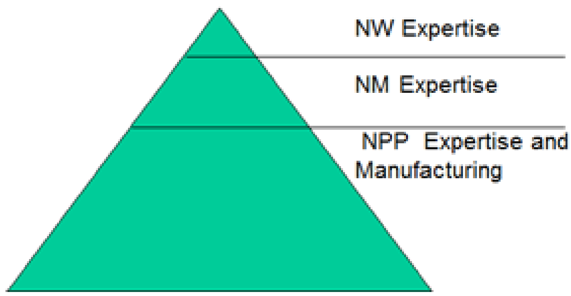


Figure 1: The number of individuals with specialized nuclear materials production and weapons knowledge is a relatively small fraction of those with knowledge in nuclear power plant construction, manufacturing, and operation.

Finally, the third category, nuclear weapons testing, also has a reduced number of people working within the civilian nuclear power business but cross-over is still possible. More difficult to trace are the affiliated organizations or front companies for the weapons laboratories that provide specialized expertise in support of nuclear weapons work and testing.

Existing and New Nuclear Power Plant Construction

According to the World Nuclear Association (WNA) there are 435 nuclear power reactors operating in 30 countries, plus Taiwan, representing 2,630 billion kWh in 2010 figures, or around 14% of the world's electricity.[3]

There are currently 60 new reactors under construction in 14 countries, including some countries with existing nuclear power capability: the U.S., Canada, Finland, France, the UK, Romania, Slovakia, Bulgaria, Russia, South Korea, Japan, China, Pakistan, and India. Nations that are far along in their planning for a commercial nuclear power capability include Poland, Kazakhstan, the United Arab Emirates (UAE), Jordan, Turkey, Vietnam, Indonesia, and Thailand.[4] Overall there are "45 countries actively considering embarking upon nuclear power programs which do not currently have it."[5] According to the WNA, the following countries are actively considering nuclear power programs (NPP):

- In Europe: Italy, Albania, Serbia, Croatia, Portugal, Norway, Poland, Belarus, Estonia, Latvia, Ireland, Turkey
- In the Middle East and North Africa: Iran, Gulf states including the UAE, Saudi Arabia, Qatar & Kuwait, Yemen, Israel, Syria, Jordan, Egypt, Tunisia, Libya, Algeria, Morocco, Sudan

- In West, Central and Southern Africa: Nigeria, Ghana, Senegal, Kenya, Uganda, Namibia
- In South America: Chile, Ecuador, Venezuela
- In Central and Southern Asia: Azerbaijan, Georgia, Kazakhstan, Mongolia, Bangladesh, Sri Lanka
- In South-East Asia: Indonesia, Philippines, Vietnam, Thailand, Malaysia, Singapore, Australia, New Zealand
- In East Asia: North Korea

Of the 14 countries with new reactors under construction, seven of them–the U.S., France, the UK, Russia, China, Pakistan, and India–are already nuclear weapons states, and two of the seven non-weapons states, Japan and Canada, have expertise in the production of weapons-usable materials. Both countries are under International Atomic Energy Agency (IAEA) safeguards. Primary reactor design, manufacturing, and construction are from private commercial or state-owned companies within the U.S., Canada, France, Russia, South Korea, and Japan.[6]

Tracking Proliferation

Therefore, given the increase in new countries seeking a civilian nuclear power program and the potential for increased interaction with individuals, companies, organizations, institutions, and educational centers with nuclear production expertise and technology, and to a lesser extent with those with expertise in nuclear weapons and testing, we have to ask, what do we need to do to track proliferation in this environment? If we estimate that there are thousands of people working on a nuclear power plant within the country building the plant, several thousands more visiting that country, thousands of pieces of equipment being shipped, and thousands of documents and communiqués being generated, is it possible to find illicit activity between nations, institutions, companies, or even between individuals?

A "systems approach" is required to set up an infrastructure to track nuclear proliferation and identify potential gaps or discrepancies. The key to the effort is gaining an understanding of the fundamental governmental and organizational structures for each country involved in receiving or transferring nuclear technology. Without an understanding of the organizational structures it is impossible to understand the relationship between people, companies, technologies, projects, and other important indicators of proliferation. Creating a detailed understanding of an organization and identifying the key people takes a significant amount of time and effort.

Once a model is established it is important to keep it current as changes are made–i.e., a dynamic systems model or living document. Once organizational structures are established additional information–such as relationships, publications, history, timelines, technologies, and projects–can be correlated. Timelines are critical for gaining a spatial understanding of the inter-relationship between technology development and a country's overall capability. Relationship charts help to map interactions between different organizations, groups, and individuals, thereby providing possible ties between military and civilian interests. Tracking past relationships can provide insights into current transactions as well. Maps, material/facility flow sheets, organization charts, and relationship charts all provide an integrated picture that incorporates thousands of pieces of information and can capture the state of knowledge at that moment.

Given the obvious need to develop not only in-depth tracking but also integrated systems thinking, why isn't this accomplished more often? Interestingly, one of the primary concerns has to do with the power dynamics and the interests of the individual analyst. A nonproliferation analyst is noted for the research he or she performs on a specific topic and therefore, in a sense, the analyst owns that "piece" of the puzzle. When an analyst surrenders it to a larger model it results in a loss of power and a place at the table. Therefore, one of the keys to developing extended systems thinking is finding a way to ensure that each analyst has a place in the larger picture.

Yet even establishing an understanding of the organizational dynamics does not guarantee there will be a clear path for action. For example, it was never clear what role former President Musharraf or the military may have played in the Khan Network. There are many similar examples where the line of information ends and it is indeterminable as to why; in other words, is it because there are no further connections and links, or might it simply be that we were unable to obtain additional information?

Example: Iran's Nuclear Program

The Iranian nuclear program is used as an example of a nation whose civilian nuclear program has been identified as providing cover for illicit activity.[7] To understand their nuclear program it is important to establish the organizational relationships of the Iranian government, the military, and the religious leadership. To gain a systems perspective of Iran's program you would need to build a model of the organizations that work with nuclear technology or nuclear policy and their inter-relationships. The Atomic Energy Organization of Iran (AEOI) has the lead for civilian nuclear development including uranium mining, conversion, fuel fabrication, research reactors, the Bushehr nuclear power plant, and uranium enrichment. The AEOI has its headquarters in Tehran and operates a number of different facilities and research centers throughout Iran. A good summary of the AEOI organization, capabilities, and facilities is provided by Dr. Ghannadi-Maragheh in his 2002 paper.[8]

Since February 13, 2011, the director of the AEOI has been Dr. F. Abbasi-Davani. He has a dual role as head of the AEOI and Vice President of Iran. The dual appointment shows the importance of the nuclear program within Iran. Information on the military dimension to Iran's nuclear program has emerged in the past ten years or so. Dr. Abbasi-Davani has been linked to the military side of Iran's government. According to the Institute for Science and International Security (ISIS), "Prior to his appointment as AEOI head, he chaired the physics department at Tehran's Imam Hossein University, which is linked to the Iranian Revolutionary Guard Corps (IRGC) and work on nuclear weaponization."[9] Dr. Abbasi-Davani's unique role of being linked to the military aspect of the weapons program and his recent placement as the head of the AEOI may indicate the Iranian government's decision to ensure closer ties between civilian and military nuclear development. Both the IRGC and regular military are subordinate to the Ministry of Defense and Armed Forces Logistics (MODAFL). MODAFL and IRGC have a number of affiliated institutions, universities, and businesses, including the Imam Hossein University in Tehran, Shahid Behreshi University, Institute of Applied Physics (IAP)–formerly the Physics Research Center (PRC)–and many others.[10] The National Council of Resistance of Iran (NCRI) provides additional background on Iran's nuclear program, and in 2004 it made the claim that the P2 centrifuge technology development program was not under the AEOI but rather the military.[11]

Developing highly advanced organization charts of both the civilian and military governmental structures with ties to companies, institutions, technologies, and key individuals makes it possible to observe patterns and relationships that would otherwise be missed. Figures 2 and 3 are organization charts prepared by the IAEA on Iran's military program. Their detail reflects a significant effort to piece together information over many years.

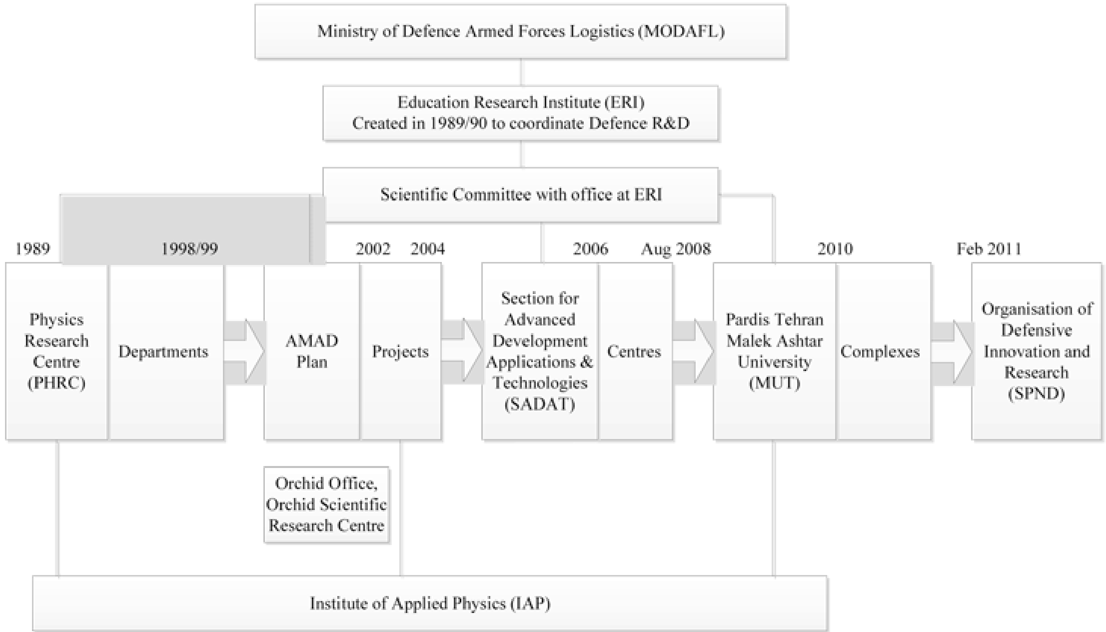


Figure 2: IAEA organization and flow chart of the military side of Iran's nuclear program.[12]

PHRC Departments	AMAD Plan Projects	SADAT Centres
Department 01 Nuclear Physics Department 02 Centrifuge Enrichment Department 03 Laser Enrichment Department 04 Uranium Conversion Department 05 Geology Department 06 Health Physics Department 07 Workshop Department 08 Heavy Water Department 09 Analytical Laboratory Department 10 Computing Department 20 Analysis	Project 110 Payload Design Project 111 Payload Integration Project 3 Manufacture of Components 3.12 Explosives and EBW detonator 3.14 Uranium metallurgy Project 4 Uranium Enrichment Project 5 Uranium Mining, Concentration & Conversion 5.13 Green Salt Project 5.15 Gchine Mine Project Projects 8, 9 and 10 Project Health and Safety Project 19 Involvement of IAP Project/Group 117 Procurement and Supply	Centre for Readiness & New Defence Technologies Centre for R&D (1) of Explosion & Shock Technology Centre for Industrial Research & Construction Centre for R&T (2) of Advanced Materials – Chemistry Centre for R&T of Advanced Materials – Metallurgy Centre for R&D of New Aerospace Technology Centre for Laser & Photonics Applications

(1) R&D = Research & Development
(2) R&T = Research & Technology

Figure 3: IAEA chart of the Iranian military program departments, projects, and centers.[13]

What is interesting about the MODAFL organization structure developed by the IAEA, as shown in Figures 2 and 3, is that it implies that nuclear research, although considered to be under the AEOI, the civilian branch of the Iran nuclear program, may fall either completely or in part under the military organization, MODAFL, instead. The implications of this governmental structure are that the technologically critical infrastructure to producing weapons material is actually part of the "military infrastructure" rather than the civilian infrastructure. This is a wonderful example of integrating information over time and across different venues including organizations and technologies. It provides a powerful overview of Iran's nuclear program in two simple charts.

Iran's Nuclear Program and International Agreements

Iran has worked primarily with Pakistan's Khan Network, China, and Russia in establishing its broad based nuclear capability. To understand Iran's proliferation pathways would require establishing detailed knowledge of the Pakistani nuclear program; the Khan network with associated people and businesses; and Russia and

China's civilian and military nuclear complex, institutions, companies, and technologies. This is a thoroughly complex and daunting task.

Consider Russia. Its nuclear organization, Rosatom, is a highly complex organization consisting of governmental offices, technical and research institutes, design institutes, large scale manufacturing and testing, materials development, nuclear reactor operation, nuclear weapons stockpile maintenance, materials production, universities with expertise in nuclear training, banks, and many other entities. During the 1990s, Russia was in a state of transition and economic chaos and had less control over its nuclear institutes, which opened up possibilities for technology transfer.

Their current organization chart is diverse and multifaceted. Many of the technical institutes also have affiliated private companies called Limited Liability Companies (LLC). The predecessor organization to Rosatom signed the agreement with Iran to complete the unfinished Bushehr nuclear power plant back in the mid-1990s. This baseline agreement resulted in additional agreements for language training, nuclear physics and engineering education, reactor operations, nuclear safety, and others.

Training was included as part of the Bushehr Nuclear Power Plant agreement between Russia and Iran. The following list provides just a few specific examples of the sites and number of people identified for training and construction at the Bushehr Nuclear Power Plant (BNPP):

- July 22, 1989 and August 25, 1992: Russia and Iran establish training agreement with Zarubezhatomenergostroi (later to become part of Rosatom) contract to train up to 100 Iranians/year.[14]
- 1993-1995: eighteen Iranians reported to have completed their Masters degrees at the Russian All-Union Research Institute for Power Plant, Moscow (possibly NIKIET).[15]
- 1995: Within the 1995 Bushehr reactor agreement 10-20 students trained per year in Russian schools such as the Kurchatov Institute of Atomic Energy (KIAE), MEPhI, and Novovoronezh NPP.[16]
- 1998: began training Iranians on reactor operations at the Novovoronezh NPP; by 2001 a total of 342 Iranians have been trained.[17]
- 1998: Iranian student trained at the Mendelev Institute of Chemical Technology.[18]
- 2003: up to 200 Iranians trained at Obninsk Atomic Energy University, where they learned basic skills in operating the BNPP.[19]

Published estimates of the number of workers at the BNPP construction site:

- 1998: 700 Russians working at the BNPP site.[20]
- 2002: approximately 3,900 Russians and Iranians working on the BNPP; another source reports there were 1,200 Russians and Ukrainians.[21]

Published estimates of the amount of equipment shipped to Iran from Russia:

- By the end of 2002: 5,000 tons of equipment had been delivered to the BNPP.[22]
- 2003: 7,000 tons of equipment had been delivered.[23]

- 2000-2005: the large pieces of equipment were shipped to Iran. This includes the reactor vessel, steam generators, turbine, piping, and other large equipment needed for the system.
- By 2008: A total of 82 mtons of fuel enriched up to 3.62% U-235 were delivered to the BNPP.[24]

In summary, given the number of Iranians receiving training at Russian nuclear institutes, the number of Russians traveling to and living in Iran for the construction of the BNPP, and the massive amount of equipment shipped from numerous manufacturing centers throughout Russia, it was possible for nuclear proliferation activity to go undetected and unchecked within the civilian nuclear power umbrella. Quite simply, the amount of exchange of people, equipment, and documentation between two nations engaged in the purchase and construction of a nuclear power plant is large. Tracking nuclear proliferation is highly complex, difficult to unravel, and time- and personnel-consuming.

Issues with Technology Transfer

According to the Intelligence Community (IC) unclassified report to Congress in September 2001:

These projects [referring to Russian projects with Iran] will help Iran augment its nuclear technology infrastructure, which in turn would be useful in supporting nuclear weapons research and development. The expertise and technology gained, along with the commercial channels and contacts established—particularly through the Bushehr nuclear power plant project—could be used to advance Iran's nuclear weapons research and development program.[25]

This document specifically flags the U.S. concern over the use of the BNPP to support Iran's nuclear weapons program.

The IC has since changed its position, stating that since 2003 it believes that Iran has ended nuclear weapons development. From the 2007 IC unclassified assessment to Congress:

> Analysis of events and activities associated with the Iranian nuclear program during the reporting period has yielded the following conclusions: We assess that Iran had been working to develop nuclear weapons through at least fall 2003, but that in fall 2003 Iran halted its nuclear weapons design and weaponization activities, and the military's covert uranium conversion- and enrichment-related activities. We judge that the halt lasted at least several years, and that Tehran had not resumed these activities as of mid-2007.[26]

Since the BNPP agreement in 1995, there have been a number of projects reported in the press and by non-governmental organizations (NGO) as illicit technology transfers between Iran and Russia, China, and the Khan network for nuclear materials production and nuclear weapons design and testing. Nuclear materials production projects include: atomic vapor laser isotope separation (AVLIS), heavy water (HW) production, HW research reactor (HWRR), centrifuge enrichment technology, and uranium-hexafluoride (UF_6) gas for a centrifuge cascade. Weapon-related capabilities identified include: high explosives (HE) technology and expertise, high speed cameras, and containment vessels for weapons testing. A short summary of each is provided below.[27]

Nuclear Material Production Technologies

- <u>Russia-Iran AVLIS</u>: During early 2000 the U.S. and Russian governments engaged in discussions concerning the transfer of an AVLIS system from Russia to Iran. According to the IC unclassified report to Congress: "A component of the Russian Ministry of Atomic Energy (MINATOM) contracted with

Iran to provide equipment clearly intended for AVLIS. The laser equipment was to have been delivered in late 1999 but continues to be held up as a result of U.S. protests. AVLIS technology could provide Iran the means to produce weapons quantities of highly enriched uranium."[28] Minatom, the predecessor organization to Rosatom, had evaluated that the equipment could not be used for uranium enrichment but agreed to stop the transfer to Iran under U.S. pressure. Reportedly the AVLIS equipment was designed and manufactured at a Rosatom Institute, the Yefremov Scientific Research Institute for Electrophysical Apparatus (NIIEFA) in St. Petersburg.[29] Discussions in laser technology were part of the Russia-Iran technical agreement from 1995.

- Russia-Iran HW Production and HWRR: It was reported that prior to 1999 the Mendeleyev Russian Chemical-Technological University provided information on HW technologies to Iran[30] and in "December 1998 …press articles citing U.S. intelligence sources reported that Russia's Research and Design Institute of Power Engineering (NIKIET) and the Mendeleyev University of Chemical Technology (RHTU) were negotiating to sell Iran [a] 40 MWt heavy-water research reactor and a UF_6 uranium conversion plant."[31] Mendeleyev University, as noted above, was also training an Iranian student.

  - NIKIET was identified as the U.S. focus of concern.[32] NIKIET and the Mendeleyev institute were subsequently placed under U.S. sanctions in January 1999; they have since been removed from U.S. sanctions. Since these earlier revelations in the early 1990s, ISIS released a technical note in 2009 with information on Iran's HWRR, claiming that "Based on interviews with knowledgeable officials, NIKIET and a Russian company in Obninsk provided technology for the Arak reactor. This assistance included modifying the design of a RBMK fuel rod bundle for use in the Arak heavy water reactor. As a result of U.S. pressure, this assistance for Arak stopped in the late 1990s."[33] This provides further confirmation of NIKIET's role in the HWRR and identifies a Russian company in Obninsk as providing technology.

  - As noted earlier, in 2003 there were up to 200 Iranians trained at Obninsk Atomic Energy University where they learned basic skills in operating the BNPP.[34] This places Iranian students in the same town as the company that ISIS identifies as providing technology for the HWRR at Arak. Both the HW production plant and HWRR project were kept hidden from the IAEA through the use of front companies until outed by an Iranian opposition group in August 2002.[35] Tehran claims it needs the Arak facility to produce isotopes for medical purposes[36] and that "as of October 2008, Iran had not yet installed equipment in the hot cells, including manipulators and specialized windows"[37] that could be used for isotope production.

- China-Iran Uranium-Hexafluoride: In February 2003, the IAEA director general Mohamed el-Baradei was shown the 164-centrifuge cascade uranium enrichment facility at Natanz, and it was revealed that the Iranians had received 1,000 kg of natural UF_6 gas from China in 1991.[38] This information had previously been concealed.[39] The Chinese provided a significant amount of expertise, technology, and facility design for Iran's civilian nuclear complex within the Iranian IAEA safeguards agreement. Yet, the transfer of the UF_6 gas is an example of nuclear material transferred outside of the legal IAEA declaration.

- Pakistan Khan Network-Iran Centrifuge Uranium Enrichment: Perhaps one of the more surprising stories of proliferation was the transfer of technology and expertise from the Khan network to Iran's nuclear program, which began as early as 1985 when Dr. Khan met with the Iranians in Dubai and provided detailed construction plans and two centrifuges diverted from Kahuta.[40] This was followed by the supply of "two containers of surplus Pakistan centrifuge equipment to Iran in 1994 and 1995 for a payment of $3 million."[41] The centrifuges have been the basis for Iran's uranium enrichment program, which has continued to advance technically.

- It is interesting to note that during nuclear negotiations with the Russians in 1995 the Iranians requested the purchase of a centrifuge uranium enrichment facility. Reportedly the Russians had planned on providing the centrifuge technology but opted not to after the U.S. pressed them to end the agreement.

- Later, in December 1998, NIKIET and Mendeleyev University of Chemical Technology were reportedly negotiating with Iran over the sale of a facility to convert uranium into UF_6 after the Chinese canceled work on a UF_6 facility with Iran.[42] During the same time, the Iranians were purchasing an AVLIS system for uranium enrichment from Russia.

- It would appear there might have been some overlap within the Iranian nuclear program. This is where it would be interesting to trace each purchase and negotiation by organization, institution, company, and individual to see if the military and civilian sides of the nuclear program were working together or not. Recent studies by ISIS show that there were parts of the Iranian government purchasing equipment and materials for the centrifuge enrichment program in the late 1980s, and it is not clear how the civilian and military programs were split.[43] It is difficult to ascertain whether or not the technology transfers completed by the Khan network had the official involvement of the Pakistani government, or not. The centrifuge uranium enrichment work was well hidden within Iran's larger nuclear program until it was outed by the Iranian opposition group NCRI in August 2002. The IAEA Director General visited the uranium enrichment plants for the first time in 2003.[44]

Weapons Design and Nuclear Testing

- <u>Russia-Iran Explosives Testing</u>: According to news reports, Vyacheslav Danilenko–a former scientist from Chelyabinsk-70, a weapons laboratory under Rosatom–contacted the Iranian embassy to enquire about possible joint ventures and later worked for the head of Iran's Physics Research Center (PRC) (see Figure 1). Per the IAEA organization chart, the PRC worked for the military side of Iran's nuclear program.[45] Danilenko claimed he was in Iran training on nanodiamond technology from 1995 to 2001. In the summer of 2003, Tehran engineers reportedly conducted test detonations based upon a Russian method using information obtained from Danilenko.[46]

- <u>Russia-Iran Containment Vessel for Explosive Testing</u>: Based upon a recent news reports, the explosive vessel at the Iranian Parchin military site was designed with the help of Danilenko.[47] Danilenko denies he worked on the vessel.[48]

    - According to the IAEA, "the HE vessel, or chamber, is said to have been put in place at Parchin in 2000. A building was constructed at that time around a large cylindrical object. The IAEA was able to confirm the date of construction of the cylinder and some of its design features… and that it was designed to contain the detonation of up to 70 kg of HE" for hydrodynamic experiments consistent with possible weapons development.[49]

    - While a former IAEA inspector has insisted that 70 kg is beyond a plausible design for a containment vessel, a report on the Comprehensive Test Ban Treaty (CTBT) states that the Russian nuclear design laboratories, which would include Arzamas-16 and Chelyabinsk-70, conducted weapon-related experiments using large containment vessels. The CTBT report continues that based upon a paper from Arzamas-16 (VNIIEF) they described a need by the design laboratory in the late 1970s and early 1980s to develop explosive-resistant chambers "capable of hermetically holding inside its volume an explosive release of energy equivalent to 150 to 200 kilograms of TNT…Development of these vessels–called Kolba in Russian–was completed by 1983."[50]

- It is reported that the Parchin vessel is a vacuum vessel with a diameter of 4.6m and a length of 18.8m. In the early 1990s, I had the opportunity to visit the Russian Research Institute of Chemical Machine Building in Zagorsk where they had large vacuum vessels for testing space equipment. One was large enough to test the Russian space shuttle with its wings clipped to fit within the chamber. This is to say, Russia has designed and built impressive facilities and large vacuum chambers consistent with the reported design of the Parchin vessel.
- Therefore, if the Iranians did receive help from the Russians in the design of containment vessels for high explosive testing of implosion systems then 75 kg of HE is well within the design limits of Russian technology. What is not clear is whether or not the Russian weapons labs helped in the design of the Iranian vessel at Parchin or not.

- Russia-Iran High-speed Camera Diagnostics for HE Testing: According to ISIS,[51] the BIFO company, a subsidiary to the Russian Institute for Optical and Physical Measurement (VNIIOFI), sold two high speed cameras, K008 stream and "uniframe" camera and K011 "nineframe" camera to a German trading company who had purchased them for an Iranian front company. A technical description of each camera can be found in a VNIIOFI publication.[52] The cameras were purchases for $42K[53] and can be used for the diagnostics of HE implosion testing as described above with operating time scales in nanoseconds. It is worth noting that according to the ISIS report, VNIIOFI has joint publications on weapons testing with Arzamas-16, one of Russia's two nuclear weapons design laboratories.

In summary, there are a number of examples where nuclear materials, nuclear materials production technology, and nuclear weapons-related technology may have been transferred to Iran while hidden within its larger civilian nuclear power program. While it is plausible that these transfers occurred as a result of contacts made as a result of training or within the larger technical agreements, it is difficult to prove without more substantial information. During the 1990s Russia was undergoing a significant transformation and it created openings that may no longer be open. Since the mid-2000s, Rosatom management has established a clear vision for creating a professional organization aimed at meeting national and international needs in the nuclear field and implemented it through the Russian government energy program. Similarly, China has moved to the international standards for nonproliferation and export controls with the goal of becoming an international supplier of nuclear technology. The competitive economic and technical basis between nations raises the bar regarding when proliferation activities can tarnish a country's reputation. The above examples of proliferation primarily took place during the 1990s and demonstrate what can occur within a larger commercial program if governmental oversight is not strictly enforced.

Iran's nuclear program extends over thirty years and a timeline of its program would help provide a foundation for understanding technology developments and transfers. A timeline can be used to track interactions and changes in relationships and agreements. There are literally thousands of people and interactions within the Iranian nuclear umbrella, including all four countries, spanning back to the 1980s. Iran also has a large number of technology development programs where the inter-relationships between people, companies, organizations, and educational centers if tracked could provide insights into their activities. A systems model keeps building and building, as this is the type of complex and detailed framework needed to track potential proliferation activity.

What is clear from the above example is that a few people can provide invaluable support to a nation seeking a nuclear weapons capability. A. Q. Khan created and directed an effort to provide centrifuge-based uranium enrichment technology to several nations, and Danilenko is reported to have provided training on implosion technology and the design of an explosive vessel. These specific examples demonstrate how difficult it can be to trace nuclear proliferation within a larger commercial nuclear power program. It is the proverbial needle in a haystack.

A Few More Thoughts

- Technical expertise is critical to understanding proliferation pathways and how seemingly uninteresting information can be passed on without a second look by someone who lacks a deeper understanding of the materials, technologies, and types of technology that are used in materials production, and nuclear weapons design and testing. Unfortunately, many of the U.S. experts who know much of the more obscure information are retiring.

- Curiosity, time, and a healthy environment for "failure" are all needed to allow analysts time to track odd information down the rabbit hole. Failure needs to be encouraged.

- The initial question is of great importance in framing the research and in determining the final product. Questions should encourage seeking the answer from multiple views and perspective. Every question requires a new tact and approach and thereby brings in new insights.

- Physical space to do systems work is needed for sharing ideas, putting charts on the wall, and for spreading information out.

- And finally, cultural knowledge and insights, not from books, but from experience in country, is essential.

More often than not, a country chooses a civilian nuclear power program not as a cover for a nuclear weapons program but for energy. In the cases where it does occur, a nation's pursuit of a weapons program may be accompanied by signs of noncompliance with the Nuclear Nonproliferation Treaty (NPT) agreement. Also, there might be a sense of a defense imbalance in the region that would become balanced if that nation obtains a nuclear weapons capability. When you consider the list of nations that are currently considering new nuclear power programs or expanding their existing program it is clear that their trade and economic roles in the international community are of great importance to them and may serve as an incentive not to develop a nuclear weapons capability.

There are two camps on how to move forward on nuclear power when considered within the reference frame of nonproliferation:

1. Limit the transfer of any and all nuclear power technology, or

2. Provide the technology for nuclear power production, but empower the IAEA and United Nations (UN) to track and enforce any anomalies or illicit activity.

There are arguments for both perspectives and neither has worked "perfectly." For example, in trying to limit the transfer of technology to Iran and Libya, the door was opened for the transfer of illicit technology by other nations and the establishment of a shadow organization outside of governmental purview–a much more difficult and dangerous issue to track and control. In cases where nuclear technology was provided and kept under IAEA control, it has been difficult for the IAEA to limit the growth of a nation's nuclear weapons program, including programs in North Korea, Iraq, and Iran. One of the contributing factors is the varying level of concern over proliferation activities among nations. The U.S. has a much more conservative idea of what limiting proliferation should be than, say, Russia or China does. Therefore, where the U.S. may not be willing to engage with a specific nation due to concerns of nuclear proliferation–for example, in Iran, Burma, or North Korea–Russia or China may be willing to step in.

Conclusions

Overall it takes much time and funding to develop a systems perspective on nuclear proliferation. It requires a dedicated team with a passion for digging deeper and pursuing the question longer. It also requires policy representatives who want a greater understanding of the issues of nonproliferation and who are willing to push the experts in nonproliferation to do more and perform at a higher level. It is a highly complex process, but given the complexity of the global interactions and concerns over nuclear proliferation, it is the only possible way to establish a framework to track nuclear interactions and find the inconsistencies that may signal a country is seeking more than civilian nuclear technology. This type of systems approach will be needed as the number of new countries seeking commercial nuclear technology expands.

Endnotes

1. J. C. Moltz and A. Y. Monsourov, The North Korean Nuclear Program: Security, Strategy and New Perspectives from Russia (New York: Routledge, 1999).

2. Jeffrey Richelson, Spying on the bomb: American nuclear intelligence from Nazi Germany to Iran and North Korea, (New York: Norton, 2006).

3. "Plans for New Reactors World Wide," World Nuclear Association, May 2012, http://www.world-nuclear.org/info/inf17.html.

4. "Plans for New Reactors World Wide," World Nuclear Association; and "Emerging Nuclear Energy Countries," World Nuclear Association, 2012, http://www.world-nuclear.org/info/inf102.html.

5. Empasis added. "Emerging Nuclear Energy Countries," World Nuclear Association.

6. It may be possible to reduce the number of people required for planning, construction, training, and operation by moving to small or medium reactors (SMR) for nations that currently do not have a nuclear power program. Small reactors can be manufactured, built, and transported as complete units to the operating site where they are installed in the facility. At the end-of-life, the complete unit is shipped back to the originating country after a few years of cool down within the reactor compartment. The other advantage to SMRs is that they allow a developing nation to build up power at the location it is needed and expand as more power is needed within the region.

7. Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions: 1 July Through 31 December 2000, Unclassified Report to Congress from the Director of Central Intelligence, 2001, https://www.cia.gov/library/reports/archived-reports-1/july_dec2000.htm, heretofore DCI, Acquisition of Technology, 2000.

8. M. Ghannadi-Maragheh, "Atomic Energy Organization of Iran," in World Nuclear Association Annual Symposium, London, 2002, http://www.world-nuclear.org/sym/2002/pdf/ghannadi.pdf.

9. David Albright, Paul Brannan, and Andrea Stricker, "Will Fereydoun Abbasi-Davani lead Iran to nuclear weapons? (Rev. 1)," Institute for Science and International Security, June 24, 2011, http://isis-online.org/isis-reports/detail/will-fereydoun-abbasi-davani-lead-iran-to-nuclear-weapons.

10. Ibid.

11. Mohammad Mohaddessin, "New Nuclear Revelations: Text of the Press Conference of Mohammad Mohaddessin, Chairman of the Foreign Affairs Committee of the National Council of Resistence of Iran," Iran Watch, Wisconsin Project on Nuclear Arms Control, September 10, 2004, http://www.iranwatch.org/privateviews/NCRI/perspex-ncri-nuclearprogram-091004.htm.

12. "Implementation of the NPT Safeguards Agreement and relevent provisions of Security Council resolutions in the Islamic Republic of Iran," International Atomic Energy Association, November 8, 2011, http://www.iaea.org/Publications/Documents/Board/2011/gov2011-65.pdf.

13. Ibid.

14. Judith Perera, "Nuclear Industry of Iran," April 2003.

15. Mark Gorwitz, "Iranian Nuclear Science Bibliography: Open Literature References," September 2003.

16. "Specialists to Train Iranians for Bushehr Nuclear Plant," in NTI: Russia: Nuclear Exports to Iran: Training and Know How, ITAR-TASS, 1996.

17. J. Perera, "Nuclear Industry of Iran," 4/2003 2003; S. Sergievskiy, "Iranskiye stazhery na Balakovskoy AE" (Iranian trainees at Balakovo AE), Nezavisimaya Gazeta online edition, 1999.

18. Perera, "Nuclear Industry of Iran."

19. Nick P. Walsh, "Russian Lessons," The Guardian, June 16, 2003.

20. Perera, "Nuclear Industry of Iran."

21. Ibid.

22. Ibid.

23. Ibid.

24. "Bushehr: Fueling the Reactor," GlobalSecurity.org, http://www.globalsecurity.org/wmd/world/iran/bushehr-fuel.htm

25. Emphasis added. DCI, Acquisition of Technology, 2000.

26. Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions: 1 January to 31 December 2007, Unclassified Report to Congress from the Deputy Director of National Intelligence for Analysis, 2007, heretofore DDNI, Acquisition of Technology, 2007.

27. It is worth noting that the details of the stories are much richer and interesting than what I am able to provide these short summaries.

28. Acquisition of Technology, 2000.

29. Perera, "Nuclear Industry of Iran"; Michael Knapik, "Russia tells U.S. officials it will not export lasers to Iran," Nucleonics Week, 42, March 8, 2001.

30. Michael R. Gordon, "Russia to Offer U.S. Deal to End Iran Nuclear Aid," New York Times, March 17, 1999.

31. J. Perera, "Nuclear Industry of Iran."

32. Gordon, "Russia to Offer U.S. Deal."

33. David Albright, Paul Brannan, and Robert Kelley, "Mysteries Deepen Over Status of Arak Reactor Project," Institute for Science and International Studies, August 11, 2009, http://www.isisnucleariran.org/assets/pdf/ArakFuelElement.pdf; David Albright, Paul Brannan, and Robert Kelley, "Update on the Arak Reactor in Iran," Institute for Science and International Studies, August 25, 2009, http://www.isisnucleariran.org/assets/pdf/Arak_Update_25_August2009.pdf.

34. Walsh, "Russian Lessons."

35. "Iran Nuclear Milestones," Iran Watch, Wisconsin Project on Nuclear Arms Control, February 2011, http://www.iranwatch.org/wmd/wmd-nukemilestones.htm.

36. James Phillips, "Iran's Nuclear Program: What Is Known and Unknown," The Heritage Foundation, March 26, 2010, http://www.heritage.org/research/reports/2010/03/iran-s-nuclear-program-what-is-known-and-unknown.

37. Albright et al., "Mysteries Deepen Over Status of Arak Reactor Project."

38. Mohammad Sahimi, "Iran's Nuclear Program. Part I: Its History," October 2, 2003, http://www.payvand.com/news/03/oct/1015.html

39. John R. Bolton, Surrender is not an option: defending America at the United Nations and abroad, (New York: Threshold Editions, 2007).

40. Erich Follath and Holger Stark, "The Birth of a Bomb, A History of Iran's Nuclear Ambitions," Der Spiegel, June 17, 2010, http://www.spiegel.de/international/world/0,1518,701109,00.html; "Pakistan: Dr. Abdul Qadeer Khan Discusses Nuclear Program in TV Talk Show," Karachi Aaj News Television in Urdu, from "Islamabad Tonight" discussion program hosted by Nadeem Malik, August 31, 2009.

41. Chaim Braun and Christopher F. Chyba, "Proliferation Rings," International Security, 29, no. 2, (Fall 2004), pp. 5-49.

42. "Russia: Nuclear Exports to Iran: Enrichment, Mining and Milling," NTI, June 22, 2011.

43. David Albright and Paul Brannan, "Iranian Smuggling for Military Nuclear Programs: From Shahid Hemmat Industrial Group to the Physics Research Center," Institute for Science and International Security, May 16, 2012.

44. "Iran Nuclear Milestones," Iran Watch.

45. Joby Warrick, "Iran - Russian scientist Vyacheslav Danilenko's aid to Iran offers peek at nuclear program," Washington Post, November 13, 2011; Mark Gorwitz, "Vyacheslav Danilenko – Background, Research, and Proliferation Concerns," Institute for Science and International Security, November 29, 2011, http://isis-online.org/isis-reports/detail/vyacheslav-danilenko-background-research-and-proliferation-concerns/.

46. Follath and Stark, "The Birth of a Bomb."

47. "Parchin chamber raises nuclear test suspicions," AP, May 19, 2012, http://gulfnews.com/news/region/iran/parchin-chamber-raises-nuclear-test-suspicions-1.1024807.

48. Ibid.

49. "Implementation of the NPT Safeguards Agreement and relevent provisions of Security Council resolutions in the Islamic Republic of Iran," IAEA, 11/8/11, 2011.

50. Kathleen Bailey and Thomas Scheber, The Comprehensive Test Ban Treaty: An Assessment of the Benefits, Costs, and Risks, National Institute for Public Policy, March 2011, http://www.nipp.org/CTBT%203.11.11%20electronic%20version.pdf.

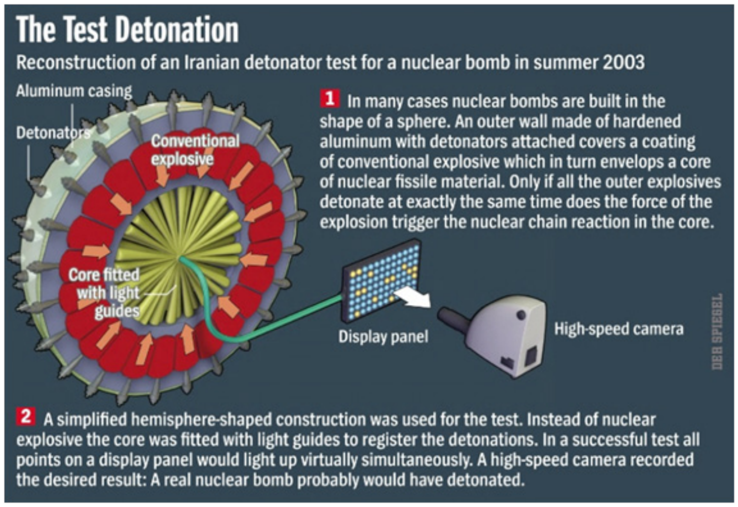
51. David Albright and Christina Walrond, "The Trials of the German-Iranian Trader Mohsen Vanaki: The German Federal Intelligence Service Assesses that Iran Likely Has a Nuclear Weapons Program " Institute for Science and International Security, December 15, 2009, http://isis-online.org/isis-reports/detail/the-trials-of-the-german-iranian-trader-mohsen-vanaki-the-german-federal-in/.

52. Vyatcheslav S. Ivanov, Yuri Zolotarevsky, Vladimir Krutikov, Vitaly B. Levedev, and Grigory G. Feldman, "High-speed image converter instrument engineering of VNIIOFI is 40 years old," presented at the 27th International Congress on High-Speed Photography and Photonics, Xi'an, China, 2007.

53. Albright and Walrond, "The Trials of the German-Iranian Trader Mohsen Vanaki."

Possible Nuclear Weapons-Related Technology Transfers Hidden within Iran's Civilian Nuclear Power Program

In 2003, Iran reportedly conducted exlosives test detonations for imposion devices based upon a Russian model.



Iran's explosives containment vessel was designed using information from a former scientist at a Russian weapons laboratory.

Two high speed cameras used for explosive test diagnostics were sold to a German company on behalf of an Iranian front company.

NPEC Nonproliferation Policy Education Center

1601 North Kent Street, Suite 802, Arlington, VA 22209
Phone: (571) 970-3187 Email: info@npolicy.org
Web: www.npolicy.org