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by David Albright and Corey Hinderstein

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Introduction

A year and a half after the dramatic arrest of Abdul Qadeer Khan, the father of Pakistan's gas-centrifuge program, much has been learned about his illicit, transnational nuclear smuggling network, called the "Khan network." Key questions, however, remain unanswered about this network's customers and inner workings. Understanding the Khan network is critical to ensuring that it is no longer operating and for safeguarding against a similar network emerging in the future.

This article provides a brief overview of what the Khan network offered to its customers and describe some of the efforts to fix holes in the international nonproliferation system that are being exposed by the investigations into Khan's activities.

Origin of the Khan Network

The Khan network was, first and foremost, an elaborate and highly successful illicit procurement network that Khan created in the 1970s in order to supply Pakistan's gas centrifuge program. The developing program aimed to make highly enriched uranium (HEU) for nuclear weapons. He built his centrifuge procurement network on an extensive collection of sensitive information that he stole or otherwise acquired in Europe in the middle and late 1970s. In addition, he was involved in acquiring overseas nuclear weapon technology for Pakistan and procuring equipment and materials for this endeavor.

Because of Pakistan's weak industrial infrastructure, it was unable to develop gas centrifuges or nuclear weapons without extensive foreign assistance. Khan had to rely on the support of many foreign businessmen and experts and on the supply of goods and technologies from foreign countries, especially in Europe. Pakistan's nuclear weapons program is still dependent on the foreign supply of spare parts, special materials, and instruments.

Khan and his associates slowly expanded their import operation into a transnational illegal network that exported whole gas centrifuges and production capabilities, as well as designs for nuclear weapons, mostly to Muslim countries. By the late 1990s, the Khan network had evolved

into an organization that could provide “one-stop shopping,” both for the wherewithal to produce weapons-grade uranium and for nuclear weapons designs and instructions. The motive was to turn a profit while providing additional business for their international collaborators. In addition to money, Khan was also motivated by pan-Islamism and its hostility to Western controls on nuclear technology.

Key Customers and Offers

Khan has admitted that his main customers were Iran, Libya, and North Korea. Reports indicate that other countries, including Egypt, Iraq, and Syria, were offered assistance, but they purportedly turned down the offers. However, investigators are still trying to verify these claims and determine exactly what assistance each country accepted and refused. In addition, questions remain as to whether members of the Khan network, including Khan himself, offered nuclear weapon assistance to terrorists in Afghanistan prior to the fall of the Taliban.

Iran

Khan appears to have attracted Iran as his first major customer in 1987, during a brief period in which relations between Iran and Pakistan were warming.[1] Iran reportedly told the International Atomic Energy Agency (IAEA) that it received only some of the offered items, in particular, centrifuge designs and sample centrifuges. Iran told the IAEA it did not take other items in the offer, namely, those related to the manufacture of nuclear weapons components. The IAEA has asked Iran for clarifications and additional information about the offer.

When inspectors first saw the Iranian centrifuges in February 2003, they recognized the obviously Dutch-origin centrifuge design, but noted that it had been modified in distinctive ways. The Khan network’s assistance, even if limited to drawings and a few components, was apparent and allowed Iran to skip many difficult research steps.

In 1994 and 1995 Iran received additional assistance from the Khan network. According to the Malaysian police report, Khan asked his partner, B.S.A. Tahir, to send two containers of P1 centrifuges to Iran. By this time, Pakistan is known to have replaced its P1 centrifuge with a more advanced and sophisticated P2 centrifuge. By selling the P1s, Khan, in essence, sold off surplus components that Pakistan no longer wanted. During the same time period, Iran reportedly also received additional documentation on the design and manufacture of the P1 centrifuge.

Putting in such a large order implied, however, that Iran had decided on a particular centrifuge design. It also indicated that by the mid-1990s, Iran was ready to assemble a pilot plant and build a large number of centrifuges.

By 1995 or 1996, Iran also received the drawings for the P2 centrifuge from the Khan network. Although Iran has stated that it did not work on the P2 until 2002, the IAEA has raised questions about this chronology, and its investigations continue.

Iran continued to receive assistance from the Khan network after 1996. Meetings with a Khan intermediary continued and included discussions on technical issues. According to Iranian information, 13 official meetings took place with the clandestine supply network between 1994 and 1999. Questions remain as to whether meetings occurred after 1999.[2]

Iran continues to deny that it received any nuclear weapons designs or manufacturing assistance from the network. Pakistan also denies such assistance. Nonetheless, investigations continue.

Iraq

In late 1990, shortly after Saddam Hussein seized Kuwait and the UN Security Council imposed an embargo on Iraq, Khan offered Iraq assistance in building centrifuges and making nuclear weapons. This offer is detailed in a set of documents found by UN inspectors at the farm of Hussein Kamel, Saddam Hussein's son-in-law, after his 1995 defection.

One of the documents, dated October 6, 1990, is a one-page memo from the Iraqi intelligence service, Mukhabarat, addressed to a contact person in Iraq's main nuclear weapons program (codenamed PC-3). It summarizes a meeting between members of the Mukhabarat and an intermediary who said he represented A.Q. Khan. The meeting took place in the offices of the Technical Consultation Corporation (TCC)—a procurement organization of the Mukhabarat.[3]

This memo states that the intermediary approached the Mukhabarat with the following offer: Khan was prepared to give Iraq project designs for a nuclear weapon and to provide assistance in enriching uranium and manufacturing a nuclear weapon. He would also acquire any necessities or materials from Western European countries through a company Khan owned in Dubai.

The intermediary requested a preliminary technical meeting to discuss the documents that Kahn was willing to sell. The memo notes that a meeting with Khan directly was not possible at that time, however, given the tense international atmosphere resulting from Iraq's continued occupation of Kuwait and the impending attack by Coalition forces. Rather, an alternative of setting up a meeting in Greece with an intermediary who had good relations with the Iraqi intelligence agents was mentioned as a possibility. In the memo, Iraqi intelligence officials said that they believed the motive was money.

Another document found by UN inspectors was PC-3's response to the Mukhabarat office. PC-3 was dubious about the offer and was concerned that it could be a sting operation. Nonetheless, PC-3 advised the Mukhabarat to try to obtain a sample of what was being offered. However, in post-1995 discussions, former leaders of the PC-3 program repeatedly told inspectors that no such samples were ever received. Given that the offer occurred just three months before the start of the Persian Gulf War, this might have resulted from lack of time rather than lack of mutual intent.

In its reporting to the Security Council in the late 1990s, the IAEA recorded its concerns about this matter, not only with respect to its potential direct effect on Iraq's endeavors to acquire nuclear weapons, but also in the global arena of nuclear weapons proliferation. The IAEA invested significant effort in attempting to resolve this matter in its interactions with both Iraqi and with Pakistani officials. When approached about this matter by the media in the late 1990s, the Pakistani government and Khan vehemently denied making any such offer. When, in December 1998, the IAEA inspectors departed from Iraq, the issue remained one of a small number of outstanding questions and concerns.

Libya

The Khan network's most ambitious sale was to Libya. It committed to supply Libya with a wide range of items, including a turnkey gas centrifuge plant, the wherewithal to make centrifuges, nuclear weapons designs, uranium hexafluoride, and the ability to make uranium hexafluoride. Fortunately, at the time Libya renounced nuclear weapons in late 2003, it had not yet received many of these items.

Unlike Iran, Libya has provided a credible accounting of the assistance it received from the Khan network. The network's first major sale to Libya was in 1997. According to a Malaysian police report, Libya contacted Khan for help and expertise in gas centrifuges.

In 1997, Libya bought 20 pre-assembled P1 centrifuges, which it called L-1 centrifuges. These surplus or retired machines from Pakistan started arriving in 1997. Khan also sold Libya another 200 P1 centrifuges, process gas-feed and withdrawal systems, uranium hexafluoride cylinders, and frequency converters.[4] The feed and withdrawal systems, the frequency converters for small cascades, and some of the centrifuge components were supplied by the network outside of Pakistan.

According to IAEA safeguards reports, Libya received two P2 centrifuges in September 2000 from Pakistan. Included in this shipment were small uranium hexafluoride cylinders. But, one of the P2s was not suitable for enrichment with uranium hexafluoride gas. It did not have the final surface coating necessary to prevent corrosion by the gas. In the late 1990s, Libya ordered a staggering 10,000 P2 centrifuges from the Khan network. It also placed an order for a sophisticated manufacturing center, code-named Workshop 1001, to make centrifuge components. The original plan called for this center to produce additional centrifuges—once the network delivered the first 10,000—either to replace broken ones or add to the total number. A facility containing this many machines would have been able to produce enough highly enriched uranium for more than 10 nuclear weapons annually.[5] To supply the Libyan order, the network decided to make the centrifuges and related equipment outside Pakistan. Since each P2 machine has roughly 100 different components, this order translated into a total of about one million components, a staggering number of parts reflecting the sophistication of gas centrifuge components. The network was assembling an impressive cast of experts, companies, suppliers, and workshops to make these components. It also provided Libyans with centrifuge-related training.

The Khan network intended to provide Libya with a turnkey gas centrifuge facility, something typically reserved for states or large corporations in industrialized nations with full government support and knowledge.[6] The network also offered ongoing technical assistance to help overcome any obstacles in assembling and operating the plant. If Libya had continued to pursue its nuclear ambitions and the network had not been exposed, it could have succeeded in assembling the centrifuge plant and could be producing significant amounts of highly enriched uranium by late in this decade.

P2 components started to arrive in Libya in December 2002. By December 2003, when the program ended, a large number of components had arrived, but not enough to assemble complete P2 centrifuges. For example, no maraging steel rotor tubes or bellows had been delivered under this order. Other equipment for the centrifuge plant was also ordered, but not all was delivered by December 2003.

By late 2003, Libya had received an extensive collection of equipment and materials for Workshop 1001. Most of the machine tools, furnaces, and other equipment for the center came from Europe, particularly from or through Spain and Italy. The equipment was not necessarily on the nuclear dual-use list, but it was still adequate for use in a centrifuge manufacturing program, particularly because the network also supplied detailed manufacturing information for almost all the parts. As in the Iraq case, the bulk of this equipment was sent to Libya via Dubai.

In addition to the means to produce fissile material, the Khan network also gave Libya the information necessary to build a nuclear weapon. Libya stated that it received the documents in late 2001 or early 2002, but claimed that it took no steps to act on the information or even to assess its credibility or practical utility.

The nuclear weapons documents and drawings collectively represented very dangerous information that far exceeded that found in public or on the internet. The key documents and all the drawings were in English. The information in these documents strikingly confirmed the public reports that China provided significant nuclear weapons help to Pakistan, including the A.Q. Khan

Laboratories, in the early 1980s. As such, the documents demonstrated serious nuclear weapons proliferation both by China in the early 1980s and later by Pakistan.

The set of documents turned over by Libya details nuclear weapon theory, the design and purpose of individual components, and the assembly of an implosion-type nuclear weapon, including drawings of almost all (95-97 percent) of this weapon design. The level of technical precision and detail in the documents would have allowed Libya to manufacture most of the components with a high confidence that they would work.

Although the components are discussed conceptually in the documents, their development and construction would have been challenging for Libya. The absence of these drawings would have required Libya to go back to the source for more information or to conduct a development and testing program to build them. As mentioned above, Libya has denied doing either.

The documents do not contain any direct evidence that they came from Pakistan. However, they were reportedly handed over to IAEA inspectors in two white plastic shopping bags from a Pakistani clothing shop.[7]

The design provided by the Khan documents appears to be for a Chinese warhead that was tested on a missile in 1966, has a mass of about 500 kilograms, and measures about 0.8-0.9 meter in diameter. This design includes the first steps China took to reduce the size of its nuclear weapons. Although the design is old, weapons experts judged it as “very well engineered.”[8]

The nuclear weapon described in the documents would not fit into Libya’s Scud-Bs or Scud-Cs, its longest-range ballistic missiles. It did, however, appear deliverable by North Korea’s Nodong missile, Iran’s Shahab-3 missile, and ballistic missiles Iraq was pursuing just prior to the 1991 Persian Gulf War. Thus, this design would be highly useful to countries such as Iran and North Korea.

North Korea

Little information is available about Khan’s assistance to North Korea or the extent of the Pakistani government’s knowledge or participation in such assistance. Khan is known to have traveled to North Korea, and North Koreans are known to have visited the Khan Research Laboratories until at least 2001. Pakistani government statements about the visits, however, focus on conventional weapons cooperation and deny any official nuclear cooperation. Of the three main customers, North Korea is viewed as the one that the Pakistani government is most likely to have known about or to have approved the transfer of centrifuge assistance.

Pyongyang has denied that it has a gas centrifuge program. Despite its denials, however, evidence strongly suggests that North Korea has received centrifuge components—and other know-how—from the Khan network.

North Korea has also denied receiving nuclear weapon designs from the network. Nonetheless, as a result of the assistance provided to Libya and offered to Iraq, suspicions remain that the Khan network routinely offered these designs to its customers, including North Korea.

U.S. officials have stated repeatedly that information on North Korea’s centrifuge program is limited. The IAEA is not involved in an active investigation of Khan’s assistance to North Korea. Currently, details remain sparse about who brokered the deals—and where and when key meetings took place.

Despite growing consensus on the existence of a gas centrifuge program, governments and experts differ on the status and scope of North Korea's gas centrifuge program. U.S. government officials have stated that North Korea may be close to finishing a production plant involving thousands of centrifuges, able to make enough HEU for several nuclear weapons per year. Other governments and independent experts have debated whether or not North Korea is that close to finishing such a facility. There are also questions about whether North Korea's effort has slowed with the arrest of key players in the Khan network and with increased scrutiny of North Korea's procurements.

Non-State Actors

It is known that Khan traveled to Afghanistan between 1997 and 2003, increasing suspicions that Khan or his associates may have offered nuclear aid to al Qaeda or other terrorist organizations. In particular, concerns remain that Pakistani scientists transferred nuclear weapon designs to these groups.

Uncovering the Network

Khan's activities have been closely watched by U.S. and other intelligence agencies since the late 1970s. There were early indications of Khan's willingness to disseminate sensitive nuclear information. He co-authored a series of articles with his colleagues at the A.Q. Khan Research Laboratories (KRL) near Islamabad. The series was published in technical journals on nuclear technology in the late 1980s. In addition to expressing contempt for Western controls, these articles contained information about centrifuge assembly and components, information considered classified in the West. They may also have served to advertise what Khan was willing to offer would-be customers.

Throughout the late 1980s and 1990s, Western intelligence agencies learned of additional signs that Khan was selling his wares to others, particularly Iran and North Korea. In 1995, the IAEA obtained Iraqi memoranda that exposed Khan's offer to Iraq of centrifuge assistance and nuclear weapons design information from 1990.

By the late 1990s, intelligence agencies had indications that Khan had provided centrifuge assistance to both Iran and North Korea. But U.S. efforts to limit Khan's activities were ineffective, partly because of conflicting U.S. and Pakistani priorities, as well as an incomplete picture of the network's activities gleaned from on-going intelligence efforts.

Whenever the United States did confront the Pakistani government about Khan, Islamabad would typically deny U.S. accusations against Khan and his associates. The United States was unwilling or unable to provide sufficient evidence to leverage a change in Pakistan's views.

Complicating any crackdown on Khan was the Pakistani government's concern that such an action could seriously disrupt its own nuclear weapons program. Khan, after all, controlled the critical program that had succeeded in making large amounts of nuclear explosive materials, the most difficult step in building nuclear weapons.

In addition, by the 1990s Khan had become an almost legendary figure in Pakistan for his exploits, an image Khan carefully cultivated. He was the recipient of frequent prestigious awards and appointments. Some even expected him to seek a high political office.

By early 2003, the British and U.S. governments had become concerned enough about evidence they were collecting that they finally decided to take steps to shut down the network. The United States and Britain decided to seize a shipment of centrifuge parts aboard the *BBC China*. This

German-registered ship had earlier left Malaysia for Dubai and then was bound for Libya. In early October 2003, the ship was diverted to Italy in a coordinated intelligence operation involving U.S. and British intelligence agencies and Italian and German authorities. The seizure provided direct evidence of a secret and substantial Libyan gas-centrifuge program being supplied through an illicit black market.

After the seizure of the *BBC China* and with Libya's subsequent cooperation, the Khan network was exposed and Pakistan came under intense pressure to deal with Khan and his associates. Nonetheless, the Pakistani government initially resisted arresting Khan. U.S. Secretary of State Colin Powell recalled in December 2004 that he had called President General Pervez Musharraf in early 2004, telling him, "We know so much about this that we're going to go public with it, and within a few weeks, okay? And you need to deal with this before you have to deal with it publicly." According to Powell, "[T]he next thing we knew, A.Q. Khan had been put in custody."[9]

After his arrest in February 2004, Khan confessed to selling sensitive nuclear technology, components, and equipment to Libya, Iran, and North Korea. He received a conditional pardon and today remains under house arrest with very little access to outsiders. Khan also maintained that he alone was responsible and had acted independently of current and previous Pakistani governments—a statement that many experts view with skepticism as an apparent attempt to prevent Islamabad's further embarrassment.[10]

Although many Pakistanis have been detained since the scandal broke, none have been prosecuted. The Pakistani government has provided the IAEA and foreign governments with information about Khan's activities, but has not allowed anyone outside the Pakistani government to interview Khan or other detainees. Although the IAEA has been allowed to submit written questions for Khan to answer, this type of exchange is not a substitute for direct access to Khan and his associates.

Awaiting major breakthroughs in Pakistan, attention has focused on investigations conducted by national authorities and the IAEA in an effort to fully understand the network, its key suppliers, and its operations, as well as the history and procurement activities of the network's customers. The striking revelation of just how widespread the network had become has led to prosecutions and investigations in many countries.

Implications for International Nonproliferation Regimes

Without extensive reforms to national and international nonproliferation systems, the risk of another illicit nuclear trade network emerging remains high. Even after the Khan network is shut down, remnants of the smuggling ring may coalesce into a new one.

In the future, North Korea could replace Pakistan as a major supplier. Iran could also begin to sell centrifuge technology if its fissile material programs are not limited by European Union or global initiatives to halt them. In addition, a new network of scientists and businessmen may decide to exploit existing loopholes in the nonproliferation system. In order to prevent new illegal networks and thwart existing smuggling rings, changes in international regimes are necessary. Already, public revelations about the Khan network have intensified support for improving those regimes already in place that address nuclear proliferation. In particular, the network's exposure has reenergized efforts to strengthen inspections and national and international export controls.

In direct response to the activities of the Khan network, President George W. Bush called for a wide set of reforms in a February 2004 speech at the National Defense University in Washington, D.C. He proposed a broad strategy to strengthen and improve both domestic and international nonproliferation efforts. In addition, he introduced new measures designed to enable the United States and the international community to increase the likelihood of detecting illicit trade in

nuclear-related materials.[11] Among these steps were expanding the Proliferation Security Initiative (PSI); strengthening the legal framework governing proliferation, in particular a UN Security Council resolution requiring states to criminalize proliferation, enact strict export controls, and secure sensitive materials; expanding efforts to secure nuclear material in the former Soviet Union and other states; denying enrichment and reprocessing technology to any state that does not already possess them; requiring countries to implement the IAEA's advanced safeguards Additional Protocol as a necessary condition for supplying equipment and materials for civilian nuclear programs; and reforming the IAEA to improve its capability to enforce states' obligations. Many international bodies have also responded by adopting various measures—UN Security Council Resolution 1540, reforms considered by the Nuclear Suppliers Group (NSG), expansion of the Proliferation Security Initiative, the G-8 Global Partnership's Action Plan on Nonproliferation, and proposed steps to strengthen IAEA investigations.

UN Security Council Resolution 1540

In April 2004, the UN Security Council passed Resolution 1540. It requires all states to criminalize proliferation to non-state actors and to establish, review, and maintain appropriate and effective export control systems. This resolution, which the United States had first proposed in September 2003, fills an important gap in existing nonproliferation regimes by including an export control law requirement for all 191 UN member states, and by targeting non-state actors. Because its requirements apply to all states, this resolution offers a remedy for some of the problems resulting from the NSG's voluntary, limited membership. Extensive assistance will be necessary because many states, however well-intentioned, will experience difficulties in enacting, implementing, and enforcing effective export control legislation.

Nuclear Suppliers Group Reforms

The Nuclear Suppliers Group has considered steps designed to address systemic weaknesses that contributed to the Khan network's success. At the May 2004 NSG plenary meeting in Göteborg, Sweden, the NSG decided that, as part of their national export control laws, all member states should adopt a catch-all mechanism. This useful tool, which is already in place in many countries, gives NSG members the legal authority to refuse to allow an item to be exported, even if it is not included on a control list, if that item might be intended for use in a nuclear weapons program.

The NSG also commits states to consider additional factors, such as items whose specifications fall just below those requiring controls and known information about the imports and proliferation credentials of the recipient country. In addition, NSG members debated requiring states to implement the IAEA Additional Protocol as a condition for supplying nuclear items for civilian use.

The NSG has also considered further expanding its membership, but remains hesitant to do so. The Khan network has shown that some states, such as Malaysia, that are not generally considered actual or potential suppliers of nuclear items may have advanced industrial infrastructures that can be exploited to produce direct-use nuclear items such as centrifuge components. Expanding membership in the NSG would enable other countries to improve their export control systems and allow them to receive help from more experienced members. But after significant expansion over the last decade, as highlighted by the cases of South Africa and Turkey, many current NSG members cannot implement the controls they accepted when they joined the organization. Thus, leading members of the NSG, including the United States, are reluctant to expand the group more until controls among all existing members are improved.

Proliferation Security Initiative

Another policy area undergoing change as a result of the revelations about the Khan network is the PSI, defined by the U.S. Department of State as "a global effort that aims to stop shipments of weapons of mass destruction (WMD), their delivery systems, and related materials worldwide."[12] The successful seizure of the *BBC China* demonstrated the importance of the PSI as an enforcement tool, but also highlighted some of its weaknesses and controversies. Because it is a set of activities, and not an organization, the PSI may be vulnerable to changes in administration. For example, the program is not directly funded but is supported through existing diplomatic resources.[13] In addition, the PSI can suffer from lack of intelligence. Even though the PSI was responsible for the successful seizure of Malaysian-made centrifuge parts on the *BBC China*, the ship also contained many centrifuge parts made in Turkey that were not intercepted by the United States and its allies. This incident revealed how much the PSI depends on critical intelligence that—even in optimum cases, can be incomplete.

G-8 Global Partnership

The G-8 Global Partnership reached agreement on an Action Plan on Nonproliferation at the Sea Island summit in July 2004.[14] The G-8 partners agreed that exporting "sensitive items with proliferation potential" should be allowed only in a manner consistent with nonproliferation norms and should be limited to states committed to these norms. In the action plan, the G-8 members made a commitment to pursue these goals by amending the NSG guidelines as appropriate and by working to gain widespread support for these measures. While pursuing these efforts, G-8 partners agreed not to initiate any new contracts that provide reprocessing or uranium-enrichment equipment and technologies to additional states for one year. A complete, long-term ban on such contracts will be difficult to achieve within the framework of either the G-8 or the NSG, although the United States is expected to continue to work toward achieving this important goal.

IAEA Safeguards

The Khan network confirmed the weaknesses of traditional IAEA inspections in detecting undeclared nuclear facilities and materials. It highlighted the need for all states to implement the IAEA's Additional Protocol in order to increase reporting by states and expand the rights of inspectors to verify that information. This case has also shown why the IAEA needs to receive more information from states about their exports and imports of key, sensitive dual-use items. In the cases of Iran and Libya, the IAEA has retroactively received a wide variety of information about their imports of sensitive dual-use equipment, materials, and technology. The agency is now in a much stronger position to perform its responsibilities in those states—to make a determination about their compliance with the Nuclear Nonproliferation Treaty (NPT) and to take the steps necessary to develop confidence that there are no undeclared nuclear activities or materials in these two countries.

Because Iran and Libya lied to the IAEA about their nuclear activities, they were under intense international pressure to be more transparent with the IAEA. Under normal circumstances, however, the IAEA receives limited information about countries' exports and imports. The IAEA's Additional Protocol does require states to report on exports of direct-use nuclear items; however reports of exports of dual-use nuclear items would be more useful. Dual-use items are more likely to be exported with a license, albeit with a false end-use declaration. They would be reportable to the IAEA and subject to scrutiny aimed at revealing undeclared activities in a country of concern. Requiring states to report on a wider variety of exports and imports would be a logical extension of the current safeguards that place great emphasis on developing a broader picture of a state's nuclear and nuclear-capable infrastructure.

A New System to Improve Export Controls

Beyond current reforms, IAEA Director El Baradei has called for a formal international arrangement to control exports and imports. In January 2004, El Baradei said that “export controls must be dramatically improved and, in contrast to the past, must be carried out within an international framework.”[15] A month later, he urged the establishment of universal, “binding, treaty-based controls.”[16] El Baradei did not provide any details about a potential treaty, and he also apparently recognized the difficulty of actually achieving such a treaty. Nonetheless, his proposal warrants further study because it could solve many of the problems in the current system of export controls, making it significantly more difficult for nuclear smuggling to occur.

Conclusion

The successes of the Khan network should shatter any complacency about how effective national and international export controls have been in stopping trade in illegal nuclear or nuclear-related materials. Some countries that participated in the illicit trade, such as South Africa and Turkey, were even NSG members. Investigations have shown that these countries did not adequately implement their national export control and nuclear nonproliferation laws, despite their commitments as NSG members. Indeed, because of their countries’ NSG membership, companies assisting the Khan network could receive items from other NSG members essentially without checks on their potential end uses. The failure of these NSG countries to stop the illicit manufacture of centrifuge components is one of the most embarrassing aspects of this scandal.

The Khan network was also masterful in identifying countries that had sufficient industrial capability and an eagerness to make direct-use nuclear items, but had little knowledge of nuclear technology or inadequate national export laws, thus making them oblivious or indifferent to the actual nature of items. Revelations about the network have highlighted the risk posed by states such as Malaysia that are outside the NSG. Because these states were not members, their governments and companies were poorly prepared to resist the Khan network’s lucrative offers. Many of the network’s suppliers were not aware of the actual purpose of the materials they provided, or the parts they were contracted to make. They often were located in countries whose authorities were unlikely to scrutinize exports carefully or encourage curiosity about the actual end use of an item. In many cases, the companies themselves had little motivation—arising from either conscience or threat of punishment—to confirm the cover stories they were given by members of the network.

Members of the network even knew how to exploit loopholes in the much more stringent European export control systems in order to obtain necessary subcomponents, materials, machine tools, and other manufacturing equipment. For instance, the network depended on complicated transportation arrangements to confuse suppliers about the true end use of the item, to evade prying intelligence agencies, and to deceive them about the final destination for its products. The international free trade zone in Dubai—through which shipments are still subject to few meaningful controls—was particularly critical to the network. Indeed, most items found in Libya were transported through Dubai, in some cases more than once.

The A.Q. Khan network exploited loopholes in the existing nationally based system and created a network of suppliers, manufacturers, and shippers that provided secret nuclear technology to Iran, Libya, North Korea, and perhaps others. Iran and Libya would have been severely hindered in their efforts to achieve nuclear weapons capability absent assistance from the Khan network. These transfers went largely undetected, and any hints of these dangerous activities were not pursued aggressively until relatively recently. With the international community increasingly aware of the damage done by the Khan network, it is taking further steps to uncover all aspects of the network and prevent future nuclear smuggling.

At this point, many questions about the extent of the network remain unanswered. While a number of individuals have been arrested or identified, investigators worldwide believe that other

key participants remain at large. Questions also remain about the full extent of these individuals' activities in manufacturing and supplying centrifuges and associated equipment. This task has become more complicated because many investigations started slowly, giving the network a chance to cover its tracks or destroy evidence. There is a growing recognition that network members may have destroyed many key internal documents and records.

Whether or not all the key workshops and companies have been identified also remains unknown. Moreover, it is possible that components for uranium-enrichment plants have been produced for, but not delivered to, Libya. Perhaps they have been sent to other, unknown customers.

Questions remain about the network's customers. Are all the customers known? In addition, only in the case of Libya do investigators have a relatively complete understanding of the items supplied by the Khan network.

The key to the success of Khan's network was its virtual library of centrifuge designs and detailed manufacturing manuals. An important task for investigators is to retrieve as much of this information as possible. That effort requires, in turn, tracking down and prosecuting the members of the network. Given the ease of copying and hiding documents and digital files, this centrifuge information may form the core of a future network aimed at secretly producing or selling gas centrifuges.

About the Authors

David Albright, a physicist, is President of the Institute for Science and International Security (ISIS) in Washington, D.C. He directs the project work of ISIS, heads its fundraising efforts, and chairs its board of directors. In addition, he regularly publishes and conducts scientific research. He has written numerous assessments on secret nuclear weapons programs throughout the world. Albright has published assessments in *Science, Scientific American, the Bulletin of the Atomic Scientists, Arms Control Today, The Washington Post, Newsday, The New York Times, The Public Interest Report,* and *Forum for Applied Research and Public Policy*. Research reports by Albright have been published by the Environmental Policy Institute in Washington, D.C. and Princeton University's Center for Energy and Environmental Studies.

Albright, in collaboration with Frans Berkhout, of Sussex University, and William Walker, of the University of St. Andrews, published World Inventory of Plutonium and Highly Enriched Uranium, 1992 (SIPRI and Oxford University Press). A second, greatly-expanded edition entitled Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies was published in March 1997. He is also a co-editor and contributor to Challenges of Fissile Material Control and Solving the North Korean Nuclear Puzzle, published by ISIS Press in 1999 and 2000, respectively. Albright cooperated actively with the IAEA Action Team from 1992 until 1997, focusing on analyses of Iraqi documents and past procurement activities. In June 1996, he was the first non-governmental inspector of the Iraqi nuclear program. On this inspection mission, Albright questioned members of Iraq's former uranium enrichment programs about their statements in Iraq's draft Full, Final, and Complete Declaration. He received a 1992 Olive Branch Award for a series of articles he wrote, along with Mark Hibbs, on the Iraqi nuclear weapons program for the *Bulletin of the Atomic Scientists*. He is also a Bulletin contributing editor and has been a guest editor of special editions of the magazine.

Albright has testified many times on nuclear issues before the U.S. Congress. He has spoken to many groups, technical workshops and conferences, briefed government decision- makers, and trained many government officials in non-proliferation policy making. Prior to founding ISIS, he worked as a Senior Staff Scientist at the Federation of American Scientists and as a member of the research staff of Princeton University's Center for Energy and Environmental Studies. In the early 1980s, he taught physics at George Mason University in Virginia. He has served as a

consultant or contractor to the Environmental Policy Institute, the Congressional Research Service, the International Task Force on Prevention of Nuclear Terrorism, Los Alamos National Laboratory, and the International Atomic Energy Agency. Albright holds a Masters of Science in physics from Indiana University and a Masters of Science in mathematics from Wright State University.

Corey Hinderstein is Deputy Director and Senior Analyst at the Institute for Science and International Security (ISIS), a Washington D.C.-based research organization whose efforts focus on stopping the spread of nuclear weapons and bringing about greater transparency of nuclear activities worldwide. Her work includes key research and analytical contributions to state-specific proliferation assessments and case studies. Hinderstein's efforts have included assessments of nuclear activities in Iraq, Iran, Algeria, Taiwan, and North Korea. She also studies the operations of illicit nuclear procurement efforts. As part of her contribution to ISIS's state specific proliferation analyses, Hinderstein analyzes high-resolution satellite imagery in order to identify and assess potential nuclear weapons-related facilities. Hinderstein is a member of the U.S. Committee of the Council for Security and Cooperation in the Asia Pacific, Women in International Security, American Society of Photogrammetry and Remote Sensing, and serves on the Northeast Regional Board of the Institute for Nuclear Materials Management. Ms. Hinderstein graduated cum laude from Clark University in Worcester, MA, where she was elected to Phi Beta Kappa. She has been with ISIS since January 1996.

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