



“The Khan Network”

Paper by David E. Sanger¹, White House correspondent for the *New York Times*
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The exposure in early 2004 of the nuclear trading network of Abdul Qadeer Khan, the Pakistani metallurgist who headed the Khan Research Laboratories and is revered in his country as the father of the Pakistani bomb, marked the public acknowledgement that a new era has begun in the history of nuclear proliferation.

For the first time, a single individual - not a state, not a terror group - created a multinational business than provided an entire range of nuclear technologies to any willing buyer. Through the steady trickle of disclosures, the world has discovered that a secret network that was originally created to supply Pakistan with the technology it required to become a nuclear power was re-wired, and turned to new purposes. Ideology was not important; while Dr. Khan spoke publicly about the need for an Islamic bomb to counter the West's monopoly of nuclear technology, his main motivating force appeared to be financial profit.

At this writing, the most important details about the Khan network remain unknown. Investigators still do not understand the type and quantity of the weapons it exported to some of the world's aspiring nuclear powers. They do not know how many nations, beyond Libya, received basic weapons designs. They suspect – but do not know for sure – that several other nations received the network's help. They strongly believe that the Pakistani military aided Dr. Khan, perhaps with the knowledge of the country's leadership, but so far they cannot pierce President Pervez Musharraf's denials of government involvement. They have not been allowed to interview Dr. Khan or his senior aides directly.

Yet for all the unresolved question, this much is clear: Over a period of more than a decade, the network helped arm some of the world's most unpredictable authoritarian regimes. Investigators have already determined he sold centrifuge

¹ The author is White House correspondent for *The New York Times*. Much of the reporting reflected in this paper was done in collaboration with William J. Broad and David Rohde, also of the *Times*, and has been published in a series of articles published in that newspaper beginning in January, 2004. Courtney Radsch of the Times Washington Bureau prepared a timeline of Khan network transactions that greatly aided this research.

technology to Iran, North Korea and Libya. In addition to the weapons design, now in the hands of the United States, Libya was also provided with extensive lists of additional equipment required to complete a nuclear program – and the names of middlemen and manufacturers able to fill that list.

There is no reason to believe that the list of network customers was limited to those three nations. The search is on for evidence of other nations that also dealt with the network, primarily in the Mideast. The investigation has been impeded by Pakistan's reluctance to turn over records or allow access to the key suspects; instead, the Pakistani government's passing out bits of information from its interrogation of the man it once lauded as a national hero. In Washington, Tokyo and Seoul, many government officials wonder whether key details are being omitted to avoid embarrassment of the Pakistani government.

The underlying strategy behind Dr. Khan's network was simple: He turned a collection of the Khan Research Laboratory's suppliers into a network of exporters. Under his business plan, factories spread around the world produced key parts. Malaysia became the production point for centrifuge parts. Dubai was a central transfer point. Secret flights and cargo shipments were organized to deliver the components. Dr. Khan himself led many missions abroad, including some after he was removed from his job as director of the laboratories and made a "special adviser" to the Pakistani president, a position he was forced to relinquish only after the magnitude of the network became known in the West. To this day it is unclear whether the Khan network he created has been broken up, as President Bush has suggested, whether it is merely hibernating, or whether it may re-emerge in another form. Nor is it clear that the full roster of the network's clients, or what precisely they obtained, will ever be known.

The Strategic Challenge

Even before the full scope of the network's activities are understood, the revelations of how it worked raise a series of disturbing questions – and new strategic challenges – for the United States, and for the other signatories of the Nuclear Nonproliferation Treaty.

The exposure of the details of the Khan network's operations has made clear the limitations of the NPT, and underscores the need to rethink some of its underlying precepts. Despite the Pakistani government's assertions that Dr. Khan was operating on his own, the fact remains that the largest and most dangerous example of nuclear proliferation in post-World War II era had its origins in a one of the three states that refused to sign the NPT three decades ago. (North Korea has since departed the treaty, joining the non-signatories: Pakistan, India and Israel.) That fundamental fact has profound implications for the forthcoming conference to review the NPT, and makes urgent the question of whether the treaty should be made universal, and whether other signatories need greater rights to inspect or sanction nations that refuse to sign.

But it also strikes at the heart of the central bargain that underlies the NPT: That the world's nuclear powers are committed to providing aid to the non-nuclear powers to promote the peaceful use of nuclear energy. Non-nuclear states have long complained, with good reason, that the nuclear powers are not living up to their end of the bargain, chiefly because they are not working toward the elimination of their own

arsenals. But the lesson of the Khan experience – especially with Iran and North Korea – is that the essential bargain of atoms-for-peace can now, more easily than ever, provide a convenient cover for atoms-for-weapons. The result is that none of the signatories is satisfied with the treaty, more than three decades after it went into effect.

Secondly, the Khan network's activities have driven home the fact that the Cold War balance of carefully-managed nuclear arsenals – with the United States and a few other declared nuclear powers matching the power of the former Soviet Union and China holding its own with a minimum deterrent – is now a relic. It has been replaced by a far more chaotic, far more dangerous era of nuclear trade. It is a world in which traditional deterrence is impossible; if a nuclear explosion occurred in a major city in the world, it might take days, weeks or months to figure out who was responsible. Even if an answer is found, a counter-strike could well prove impossible.

Thirdly, the reach and success of the network has raised fundamental questions about the quality of intelligence about nuclear proliferation. While Dr. Khan's activities were no secret to the Central Intelligence Agency and other intelligence services, it is now clear that American intelligence officials missed many key transactions, from the shipment of centrifuges to Iran to the shipment of nearly two tons of uranium hexafluoride, the raw feedstock for making enriched uranium for bomb fuel, to Libya. Similarly, it was not until the past few years that American intelligence analysts understood the nature of the links between Dr. Khan and the Iranian nuclear program. In fact, the intelligence discovery that North Korea had moved beyond the research phase to build a second, secret nuclear weapons program – based on enriching uranium – was the product of South Korean intelligence, even though American intelligence officials had carefully been watching both Dr. Khan and North Korea.²

What explains such a serious intelligence failure over so many years? Part of the answer, echoed by so many critics of the intelligence community, is that the kind of intelligence operations set up in the Cold War era have not yet adapted to the new realities. Satellite imagery is of limited use in tracking the progress of nations like North Korea and Iran. Both countries have managed to hide away significant parts of their programs. Human intelligence is critical, and it is the hardest kind of intelligence to exploit when the target is an authoritarian state. Programs like the Proliferation Security Initiative, while a laudable start, depend on excellent intelligence, willing allies, and a patchwork of national laws to enable the interception of shipments. It is hardly a firewall.

Finally, the intelligence community's mistakes in Iraq, where it declared the presence of a weapons-of-mass-destruction program that so far no one has been able to find, has complicated the politics of cracking down on true proliferators. Nations will be far more cautious about their response now when the United States or its allies declare that an urgent proliferation threat exists. Yet if the lesson of Iraq that it is dangerous to over-estimate the size and sophistication of a covert weapons program, the lesson of the Khan network is that it is equally dangerous to under-estimate it as well. The question is whether the Bush Administration has lost so much credibility over the Iraq estimates that it will have trouble convincing allies to join it in confronting the

² David E. Sanger and William J. Broad, "Evidence is Cited Linking Koreans to Libya Uranium," *The New York Times*, 23 May 2004, page A1.

programs in Iran and North Korea, or even in forcing Pakistan to reveal all that it knows about the Khan network's operations.

There is little doubt that the intelligence shortcomings surrounding the Kahn network were also reinforced by strategic decisions made by a succession of American administrations. For at least two decades, Republican and Democrat president alike chose to put other strategic imperatives ahead of attempting to limit Pakistan's nuclear development. While a series of relatively mild sanctions were imposed against the country, the need to assure Pakistani political stability, and to win the country's cooperation against the Soviets in Afghanistan, trumped any serious effort at limiting either Pakistan's own nuclear growth, or the growth of Dr. Khan's network that it engendered. After the Sept. 11 attacks, the need to nurture Pakistani cooperation in the search for Osama bin Laden and other members of al Qaeda meant that other issues, including nuclear proliferation concerns, were given a lesser priority.³ Nor was the Pakistani government pressed to seriously investigate the network's activities until very recently, when the evidence became too overwhelming, and public, to deny.

The Bush Administration's response to these critiques so far has been to argue that no one could have known the extent of Dr. Khan's dealings until recently. His operation was hard to penetrate, and senior American officials now acknowledge that in the 1990's they lost track of its remarkable expansion. "It was not until two or three years ago that it became obvious," said one senior administration official recently. Moreover, American officials report that their Pakistani contacts, when asked, said they assumed that Dr. Khan's obvious wealth came from skimming profits from the large government budget that he enjoyed as head of the research laboratories. Whether that is true – or just a convenient explanation that deflects questions about whether government officials aided Dr. Khan – is unclear.

Without question, however, the revelation of the extent of the Khan activities has forced a fundamental re-thinking of the nuclear danger posed to the world. As the head of the International Atomic Energy Agency, Mohamed ElBaradei, said recently, "The information is now all over the place, and that's what makes it more dangerous than in the 1960's." As a result, it now seems far more likely that, sooner or later, a rogue state or terror group will be able to obtain the ingredients and the designs for nuclear weapons. "The race against time," as one senior administration official put it recently, "is whether we can play defense faster than market can play offense."

³ Interviews with senior Bush administration officials, who have insisted on anonymity. They argue that behind the scenes, continuous pressure was placed on the Musharraf government to crack down on Dr. Khan, and say that explains his forced retirement as the head of the Khan Research laboratories in early 2001. Nonetheless, they express frustration that the details about the workings of the Khan network have, in the words of one senior official, "slowed to a trickle."

The Beginnings of the Khan Network⁴

The biggest hurdle in making a nuclear weapon is not designing the warhead, but getting the fissile material to create an atomic explosion. One route is to extract plutonium from nuclear reactors and reprocess it to produce more fuel, popularly known as creating a fuel cycle. The other is to extract uranium from the ground and then enrich it. It was the second method – easier to hide than the plutonium route -- that A.Q. Khan turned into a business.

He was aided by the fact that Pakistan, along with India and Israel, is an outlier from the 1970 Nuclear Non-proliferation treaty. Pakistan's refusal to sign the treaty meant there were no international inspectors in the country, and no public accounting of its nuclear activities. That enabled Dr. Khan to operate in an environment of tremendous secrecy – secrecy that helped Pakistan deny it was working on nuclear weapons until it conducted tests in the late 1990's, and secrecy that Dr. Khan could exploit to build his network.

Uranium enrichment looked promising to him because it could take place in hidden facilities, emitting few traces. And that was the technology that Dr. Khan perfected as his laboratory raced to produce a nuclear bomb to keep up with India.

The key to the technology is the development of centrifuges. These hollow tubes spin fast to separate a gaseous form of natural uranium into U-238, a heavy isotope, and U-235, a light one. The rare U-235 isotope is the holy grail: it can easily split in two, releasing bursts of nuclear energy. But making centrifuges is no easy trick. The rotors of centrifuges, spinning at the speed of sound or faster, must be very strong and perfectly balanced or they fly apart catastrophically. To produce bomb-grade fuel, uranium must pass through hundreds or thousands of centrifuges linked in a cascade, until impurities are spun away and what remains is mainly U-235. The result is known as highly-enriched uranium.

Dr. Khan obtained his basic designs in the Netherlands, working for an affiliate of a European consortium that produced equipment for enrichment. He left the country with extremely secret centrifuge designs, a Dutch one that featured an aluminum rotor, and a German one made of maraging steel, a superhard alloy. He was later charged with stealing the designs from the European consortium, but his conviction was overturned on a technicality.

The United States was aware of the theft, and presumably its implications. "The designs for the machines," said a State Department memo at the time, "were stolen by a Pakistani national." Those designs launched the Pakistani nuclear program, and enabled Dr. Khan to move quickly from a basic design to the "P-2," a more sophisticated, steel-rotor model that turned out to be particularly difficult to manufacture. But it could spin twice as fast, meaning it produced more fuel and did so at a faster rate. Dr. Khan's accomplishments turned him into a national hero. In 1981, as a tribute, the president of Pakistan, Gen. Mohammad Zia ul-Haq, renamed the enrichment plant the A. Q. Khan Research Laboratories.

⁴ Much of the discussion in this section appeared earlier in two articles: David E. Sanger, William J. Broad and David Rohde, "From Rogue Nuclear Programs, Web of Trails Leads to Pakistan," *The New York Times*, 4 January 2004, page A1 and William J. Broad, David E. Sanger and Raymond Bonner, "A Tale of Nuclear Proliferation: How Pakistani Built His Network," *The New York Times*, 12 February 2004, page A1.

Understanding Dr. Khan's motives, and how they may have changed over time, is difficult. A fervent nationalist, he often condemned the NPT, the embodiment of a system that limits legal nuclear weapons knowledge to the five major nuclear powers. He emphasized the hypocrisy of Western states that say little or nothing about Israel's nuclear weapons capability, while focusing on the fear of an Islamic bomb or a nuclear war that begins in South Asia. He once declared that "all Western countries, are not only the enemies of Pakistan but in fact of Islam," but some of his associates say that may have been grandstanding.

In the years before Pakistan's first test in 1998, Dr. Khan's team began publishing papers in the global scientific literature on how to make and test its uranium centrifuges. In the West, these publications would have been classified. Dr. Khan made little secret of his motive: he boasted in print of circumventing the restrictions of the Western nuclear powers, declaring in a 1987 paper that he sought to pierce "the clouds of the so-called secrecy." Papers in 1987 and 1988 detailed how to take the next, difficult steps in the construction of centrifuges -- reaching beyond first-generation aluminum rotors to produce more efficient centrifuges out of maraging steel.

A 1991 paper by his colleagues at the laboratory gave more details away, revealing how to etch special grooves on a centrifuge's bottom bearing, a crucial part for aiding the flow of lubricants in machines spinning at blindingly fast speeds. A Pentagon program that tracks foreign scientific publications has uncovered dozens of other reports, scientific papers and conference proceedings on uranium enrichment that Dr. Khan and his colleagues published. While federal and private experts agree that the blitz left much confidential -- including some crucial dimensions, ingredients, manufacturing tricks and design secrets -- Pakistan was clearly proclaiming that it had mastered the technology.

The scientific papers were soon followed by sales brochures, including one which features a rather unsubtle drawing of a mushroom cloud. The brochures touted gear marketed by the Khan laboratory that would prove vital to anyone eager to reproduce Pakistani-designed centrifuges. One such brochure, for example, included vacuum devices that attach to a centrifuge casing and suck out virtually all the air, reducing friction around the spinning rotors.

In 2000, the Pakistani government ran its own advertisement announcing procedures for commercial exports of many types of nuclear gear, including gas centrifuges and their parts, according to a Congressional Research Service report published in May. Many of the items, it noted, "would be useful in a nuclear weapons program."⁵ It is such advertisements that make it difficult to believe that the government had little knowledge of the Khan laboratory's work in marketing nuclear technology.

The C.I.A. was aware of some of these activities, and began tracking Dr. Khan around the time that he left the Netherlands in the late 1970's. Pakistan was cut off from economic and military assistance in 1979 because of its import of unsafeguarded nuclear enrichment technology. In 1980 it was caught seeking to re-export, through Canada, equipment that could be used in centrifuge manufacture. By 1981 it was clear that Pakistan was trying to design a nuclear test site. And by the mid-1980's, the Khan Research Laboratory itself was a source of significant intelligence interest. A 1983 State Department memorandum, recently declassified, notes "unambiguous evidence that Pakistan is actively pursuing a nuclear weapons development program.... We believe the ultimate application of the enriched uranium produced at Kahuta,

⁵ Sharon A. Squassoni, "Weapons of Mass Destruction: Trade Between North Korea and Pakistan," Congressional Research Service, The Library of Congress, 7 May 2003.

which is unsafeguarded, is clearly nuclear weapons.” Dr. Khan himself declared in February, 1984 that the accusations that he was secretly working to build a bomb was a Western fantasy. “The ‘Islamic Bomb’ is a figment of the Zionist mind.”

In retrospect, his denials were exactly what they seemed to be at the time: A cover story to allow Pakistan the political space and the time to complete its secret nuclear project. It was not until 1998, when Pakistan set off its nuclear test, that Dr. Khan freely and publicly discussed his activities, and he continued to denounce a system that he believed discriminated against developing nations, and particularly Islamic nations.

But for all the mounting evidence in the 1980’s that Pakistan was aggressively seeking to violate nuclear control regimes – its scientists and middlemen were involved in a series of nuclear export control violations involving maraging steel and beryllium, – the efforts to stop the country were only scattershot. Early hints of cooperation with Iran and Libya resulted in little action, even after American intelligence agencies concluded that Pakistan probably already possessed a workable bomb design and the fissile material to produce a weapon. And at every turn, placing overt pressure on Pakistan to close down Dr. Khan’s operations was weighed against other American strategic interests.

Interviews with former government officials indicate that while there was rising concern about Pakistan’s activities, Washington did not want to risk other aspects of its relationship with Islamabad. In the 1980’s, Washington viewed Pakistan as a critical ally in the covert war it was waging against the Soviets in Afghanistan. In 1986, despite evidence that Pakistan had already succeeded in making weapons-grade uranium, President Reagan announced an aid package to Pakistan of more than \$4 billion.

In the 1990’s, as Mr. Khan began to explore export deals, the level of alarm seems to have lessened. Interviews with senior members of the Clinton Administration indicate little sign of major intelligence warnings about Dr. Khan’s network until after the 1998 nuclear tests, and the sanctions that resulted from those tests. Gary Samore, the head of nonproliferation efforts in the Clinton national security council, reported later: “We had some intelligence successes with Iran, we knew about some of their enrichment efforts. What we didn’t know was the Pakistan connection -- that was a surprise. And the extent of Pakistan’s ties was, in retrospect, the surprise of the 1990’s.”

In fact, American intelligence officials completely missed the turn in the Khan program, the shift from import to export. The investigations that followed Libya’s agreement to dismantle its nuclear infrastructure have surprised intelligence analysts who wonder how a network that operated so broadly amounted to ship so much without detection. And it raises the question of how much is still unknown.

How the Network Worked

So far, the high-water mark of the Bush Administration’s counter-proliferation effort has been the interceptions of the *BBC China*, a German cargo ship, as it steamed toward Tripoli in October, 2003. It was, in the words of one senior intelligence official, “the perfect spy story.”

Intelligence agents had been tracking the production of components for high-speed centrifuges at a factory in Malaysia. Clearly, the factory itself had been penetrated by intelligence agencies. By the time the ship was loaded with five containers of parts, American intelligence officials knew exactly which five containers they were seeking, by serial number. With the assistance of Italian and German authorities, the ship was turned around at sea and brought into an Italian port. The parts were confiscated – they are now being held at the Energy Department’s secure Y-12 facility in Tennessee – and the event was used to convince Col. Muamar el-Qaddafi to give up his nuclear program. Since December, he has been doing exactly that, and Libyan officials have led I.A.E.A. inspectors to a huge range of nuclear facilities, turning over nearly two tons of uranium hexafluoride, components for centrifuges, and even a complete bomb design, apparently from Pakistan but Chinese in origin.⁶ Other components, apparently hidden in containers the inspectors did not know about when they inspected the ship, arrived in Libya in early 2004.⁷

In many respects, the BBC China was a huge intelligence success for the United States and its allies. Its seizure helped convince Libya to give up its entire program. It set an example of the kind of fruits born by the Proliferation Security Initiative, a loose alliance of states that have agreed to intercept and inspect suspected shipments of weapons of mass destruction, using existing domestic laws. It broke the dam on operations of the Khan network, allowing investigators to close down several of its key production and distribution nodes.

But it was also a stark illustration of how little is known about the network, or its reach. Only after interviewing members of the network did the I.A.E.A. begin to suspect that the uranium hexafluoride turned over by Libya may have come from North Korea, though it may not have been converted to gaseous form there.⁸ Moreover, the unexpected arrival of additional components has made many investigators nervous. Was the rest of Libya’s shopping list never manufactured? Or was it manufactured and never delivered, leaving a number of nuclear components out on the open market, seeking a buyer? In short, the successful mission has also laid bare the limits of international controls on nuclear proliferation.

Those controls clearly did little to restrict the Khan network’s activities. “It was an astounding transformation when you think about it, something we’ve never seen before,” a senior American official told the New York Times. “First, he exploits a fragmented market and develops a quite advanced nuclear arsenal. Then he throws the switch, reverses the flow and figures out how to sell the whole kit, right down to the

⁶ “Implementation of the NPT Safeguards Agreement of the Socialist People’s Libyan Arab Jamahiriya,” International Atomic Energy Agency, 28 May 2004, Restricted Distribution. The bomb design – which was crude and by some accounts incomplete – was among the first items from the Libyan program flown out of the country to the United States. It is unclear whether other clients of the Khan network received copies of the same or similar designs.

⁷ William Broad and David E. Sanger, “After Ending Arms Program, Libya Reveals a Surprise,” *The New York Times*, 29 May 2004, page A6.

⁸ David E. Sanger and William Broad, “Evidence is Cited Linking Koreans to Libya Uranium,” *The New York Times*, 23 May 2004, page A1.

bomb designs, to some of the world's worst governments." ⁹

Interviews conducted on three continents -- from Islamabad to to Kuala Lumpur to Dubai to Washington -- suggest that it took years to put together even a rough understanding of the far-reaching organization of scientists, engineers and business executives who operated on murky boundaries between the legal and the illegal, sometimes underground but often in plain view. The interviews indicated that the participants were little encumbered by international agreements that prohibit trafficking in nuclear technology.

North Korea was among the first customers, eager for a more surreptitious way to build nuclear weapons after the United States had frozen the North's plutonium-production facilities in Yongbyon. By the late 1990's Libya was also a major customers, ordering \$100 million or more in goods. Iran was also a major customer for many years.

Dr. Khan turned some of the business over to aides like Bukhari Sayed Abu Tahir, a businessman in Dubai, who, investigators say, placed the order for the Libyan equipment. President Bush once described him as "the network's chief financial officer and money-launderer." Among other partners, American officials believe, was Peter Griffin, a British engineer who said in an interview that he had been a supplier to Pakistan for two decades, in the period when Dr. Khan was building nuclear weapons.

In fact, Dr. Khan drew heavily on Dutch lists of nearly 100 companies that supplied centrifuge parts and materials for Pakistan's Kahuta site. In 2001, Dr. Khan said "they literally begged us to buy their equipment." German, Dutch and French middlemen, flocked to Pakistan to offer price lists for high-technology goods and learn what Pakistan needed.

Africa became a source of raw materials. Europe became a source of high-tech machines. While Dr. Khan argued it was no crime to ship these goods to another Muslim country, it also turned out to be highly profitable. He became a rich man, with homes and hotels around the world. A family friend of the Khans said Dr. Khan spoke of the centrifuge designs he perfected as if the technology belonged to him personally, not to Pakistan. A senior politician said that in meetings with Chaudry Shujat Hussain, leader of a pro-Musharraf political party, Dr. Khan never spoke of selling the technology, only of "sharing" it.

As Pakistan's own technology became more sophisticated, Dr. Khan began to sell Pakistan's stock of old centrifuges and parts. A Pakistani military official involved in the investigation of Dr. Khan said foreign requests for technology "came on paper, in person, through third parties, in meetings with Khan himself." The scientist then used the vast logistic system available to him, which included government cargo planes, to ship the components to middlemen, who passed the equipment through other countries to veil its origin. The use of official Pakistani government transport is, for now, the strongest evidence that some in the Pakistani government may have known what Dr. Khan was doing. One military official told the New York Times that "The same

⁹ Some parts of this section have been published previously in William Broad, David E. Sanger and Raymond Bonner, "A Tale of Nuclear Proliferation: How Pakistani Built His Network," *The New York Times*, 2 February 2004, page A1.

network, the same routes, the same people who brought the technology in were also sending it out." In the final stages of his export career, Dr. Khan simply used his middlemen to order large shipments of parts for foreigners, even if Pakistan had no apparent role in the transaction.

An example of how the network operated became clear when Scomi Group Berhad, in Malaysia, was identified as a major supplier. Its executives said later they signed a contract with a front company, called Gulf Technical, in December 2001 to supply the components. Dr. Khan provided the blueprints for machines and parts, according to a close aide to General Musharraf. Scomi Precision made its first shipment to Gulf Technical in December 2002 and the last in August 2003. Investigators concluded later the shipments were largely P-2 centrifuge parts. The company said its shipment consisted only of "14 semi-finished components." Company officials told reporters they never knew of the intended use of the parts.

The United States believes the Libyans planned on making at least 10,000 of the machines, though they did not get near that figure when the shipments were intercepted. Clearly the country was years away from producing a bomb. Still, a complex of the size the Libyan's envisioned would make enough highly enriched uranium each year for about 10 nuclear weapons, and over time could produce many more.

Iran, North Korea and the Challenge Ahead

Less is known about Iran and North Korea, because unlike Libya they have not agreed to let inspectors pick through their program in great detail. Iran, which initially denied relying on foreign sources, now appears to have received Pakistan's older models and was forced to slog ahead slowly for two decades, foraging around the world for parts, building experimental facilities involving a few hundred centrifuges, but apparently failing to produce enough fissile material for a bomb. That program has now accelerated considerably, largely with help from the Khan network. I.A.E.A. inspectors have discovered previously undeclared centrifuges, programs that would seem to suggest an interest in weapons triggers, and uranium hexafluoride of uncertain origin.¹⁰ A recent I.A.E.A. report listed a number of outstanding questions that Iranian officials have been reluctant to address, including questions about Iran's suppliers. Iran has denied that it is seeking to build a weapon, and the I.A.E.A. has not yet publicly charged that what it has discovered is weapons-related. But there seem to be few other plausible explanations. Investigations into links between North Korea and Iran, among other nations, are continuing.

It is the North Korean program itself, however, that may be the cause of the greatest concern. North Korea's first major program was a plutonium one, based on Yongbyon, where it has both reactors and a reprocessing facility. These were monitored by the I.A.E.A. until the end of 2002. Inspectors were ejected, however, after the United States charged the North with pursuing a separate uranium program, with Dr. Khan's help, and cut off fuel supplies provided under the 1994 Agreed Framework. The North then exited the NPT. Subsequent negotiations have made little to no progress.

¹⁰ "Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran," International Atomic Energy Agency, 1 June 2004, Restricted Distribution.

The North apparently began dealing with Pakistan in the nuclear arena in the mid-1990's, during negotiations on providing North Korean missile technology to Pakistan. Dr. Khan appears to have traveled to North Korea, though it is not clear how often. During those visits, it appears that North Korea offered to exchange centrifuge technology for North Korean missile technology, enabling Pakistan to extend the reach of its missile fleet across India. The exact nature of these transactions remains murky. President Musharraf insists that Pakistan paid for its missiles separately, and never traded nuclear technology for missile technology.

Whatever the terms of the deal, the result was that North Korea successfully started a second, secret nuclear program, based on uranium enrichment, in violation of the 1994 accord. Intelligence agencies still disagree on the question of how much progress that uranium program has made, but most agree it has not yet begun industrial-scale production. North Korea has never shown that program to inspectors, and American intelligence officials say that they still do not know where it is located, although they have suspicions about several sites. After what appears to have been an initial acknowledgement of the uranium program, North Korean officials now deny the program exists.

Whether it exists or not, the belief that the North has a second program vastly complicates the efforts to disarm the country and begin negotiations for economic aid and a lifting of sanctions. Because the plutonium program is well understood and obvious from the sky, it can be monitored, and it would be clear whether or not the North is dismantling it. But the uranium program could be located under any mountain, or spread across several locations. That makes it far more difficult to put together what the Bush Administration called complete, verifiable, irreversible disarmament. One cannot inspect a program that may be buried under the next mountain, or any mountain. Within the Bush Administration, hawks have used this argument to make the case that no agreement with the North is truly verifiable.

The North Korean program is also another vivid example of the limits of American intelligence capabilities in an age of commercial proliferation. In the North Korean case, American intelligence agencies missed many of the signals of trade with the Khan network. They knew of an experimental program, but it took evidence of specific transactions, gleaned from South Korea intelligence agencies, to demonstrate that North Korea was moving toward industrial-level production. The most concrete evidence did not come until the summer of 2001, where American spy satellites spotted missile parts being loaded into a Pakistani cargo plane near Pyongyang, the North Korean capital. The parts were assumed to be missile technology, and they were assumed to be the quid pro quo for the nuclear technology. But again, there is no hard evidence, just suspicious trading activity.

In the spring of 2003, a few months after the deal was revealed in The New York Times, the State Department announced some sanctions against the Khan laboratory but cited the illegal missile transactions. The State Department said it had insufficient evidence to issue sanctions for a nuclear transfer, a move some dissenting officials suspected was a concession to avoid embarrassing General Musharraf, who had denied that any nuclear transfers ever occurred.

The previously-cited Congressional report on the Pakistan-North Korea trade notes that over the years "Pakistan has been sanctioned in what some observers deem, an 'on again, off again' fashion," mostly for importing technology for unconventional weapons, and later for its 1998 nuclear tests. Those sanctions, which were also issued against India, were waived shortly after the Sept. 11, 2001, terrorist attacks, when the United States suddenly needed Pakistan's cooperation.

It is unclear whether the Pakistan-North Korea connection has been cut off. But new evidence suggests that North Korea is still moving forward. In April, 2003 a ship carrying a large cargo of superstrong aluminum tubing was stopped in the Suez Canal after the German authorities determined that it was destined for North Korea. The precise size of the tubes, according to Western diplomats and industry reports, suggested that they were intended for making the outer casings of G-2 centrifuges, the kind whose rotors are made of steel, and that Dr. Khan wrote about. The C.I.A. estimates that by 2005, if unchecked, North Korea will begin large-scale production of enriched uranium. But again, this is based on best guesses, not hard evidence.

The New Era

For now the world is left watching a terrifying race -- one that pits scientists, middlemen and extremists against Western powers trying to intercept, shipload-by-shipload, the technology as it spreads through the clandestine network. There have been a number of new proposals to limit the production of fissile materials, from a broad concept put forward by Mr. ElBaradei to more limited plans advocated by President Bush and his opponent in the 2004 presidential race, John Kerry.

Some consensus appears to be building around those concepts, though many countries will be loath to give up their rights to reprocess nuclear materials, or to put that capability into the hands of an international consortium. Many other countries, including Pakistan, will object to any system that allows sanctions against non-signatories of the NPT. But clearly the Khan network's discovery has put in stark relief the shortcomings of a non-proliferation system that has, at best, broken down. At worst, it could allow the creation of a number of new nuclear states in the coming decade and, worse yet, make it far easier for terror groups and non-state actors to obtain the fissile material they have hungered after for many years.