Ringing in Proliferation

How to Dismantle an Atomic Bomb Network

Alexander H. Montgomery

The nuclear nonproliferation regime has come under attack from a group of academics and policymakers who argue that traditional tools such as export controls, diplomatic pressure, arms control agreements, and threats of economic sanctions are no longer sufficient to battle proliferation. They point to North Korea's reinvigoration of its plutonium program, Iran's apparent progress in developing a nuclear capability, and the breadth of the Abdul Qadeer (A.Q.) Khan network as evidence that the regime is failing.[1] In addition, they claim that proliferation is driven by the inevitable spread of technology from a dense network of suppliers and that certain "rogue" states possess an unflagging determination to acquire nuclear weapons. Consequently, they argue that only extreme measures such as aggressively enforced containment or regime change can slow the addition of several more countries to the nuclear club. This "proliferation determinism," at least in rhetoric, is shared by many prominent members of President George W. Bush's administration and has become the main thrust of U.S. counterproliferation policy.[2] Yet current proliferators are neither as "dead

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1. On proliferation networks in general, see Chaim Braun and Christopher Chyba, "Proliferation Rings: New Challenges to the Nuclear Nonproliferation Regime," *International Security,* Vol. 29, No. 2 (Fall 2004), pp. 5–49. On North Korea, see Jonathan D. Pollack, "The United States, North Korea, and the End of the Agreed Framework," *Naval War Review,* Vol. 56, No. 3 (Summer 2003), pp. 11–49. On Iran, see IAEA (International Atomic Energy Agency) Board of Governors, "Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran," IAEA report GOV/2004/83 (Vienna: International Atomic Energy Agency, November 15, 2004), http://www.iaea.org/Publications/Documents/Board/2004/gov2004-83_derestrict.pdf. On the A.Q. Khan network, see Gaurav Kampani, "Proliferation Unbound: Nuclear Tales from Pakistan" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, February 23, 2004), http://cns.miis.edu/pubs/week/040223.htm.
2. See, for example, Paul Wolfowitz, "Deputy Secretary Wolfowitz Q&A," International Institute for Strategic Studies, Asia Security Conference, Singapore, May 31, 2003, http://www.defenselink.mil/transcripts/2003/tr20030531-depsecdef0246.html; George W. Bush, "President Announces New Measure to Counter the Threat of Weapons of Mass Destruction (WMD): Remarks by the President on Weapons of Mass Destruction Proliferation," February 11, 2004, http://www.state.gov/t/ac/rls/rm/2004/29291.htm; Condoleezza Rice, "Remarks by National Security

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set" on proliferating nor as advanced in their nuclear capabilities as determinists claim.[3] To dismantle the network of existing proliferation programs, the administration should instead move toward a policy of "proliferation pragmatism." This would entail abandoning extreme rhetoric, using a full range of incentives and disincentives aimed at states seeking to acquire a nuclear capability, targeting the hubs of proliferation networks, and engaging in direct talks with the Islamic Republic of Iran and the Democratic Peoples' Republic of Korea (DPRK).

In practice, the Bush administration's nonproliferation policies have been more varied and less aggressive than its rhetoric would suggest. For example, it has been willing to enter talks with North Korea and Libya despite describing both as "rogues." Strong words can be used strategically to convince proliferators that accepting a settlement offer would be better than continuing to hold out. Yet the administration's unyielding rhetoric has placed the United States in a position from which it is difficult to back down;[4] combined with a lack of positive incentives, this stance has convinced proliferators that the United States will not agree to or uphold any settlement short of regime change. Moreover, the administration has not formulated any coherent counterproliferation policies other than regime change and an aggressive form of export control enforcement known as the Proliferation Security Initiative. With respect to two of the key proliferators today—Iran and North Korea—the Bush administration has shown little interest in offering any significant incentives or establishing any clear red lines. Instead, it has relied almost exclusively on China to convince the DPRK to give up its nuclear program and has declined to join the United Kingdom, France, and Germany in talks with Iran.

Proliferation determinists present two arguments. First, dense networks among second-tier proliferators such as Iran, North Korea, and Libya and pri-

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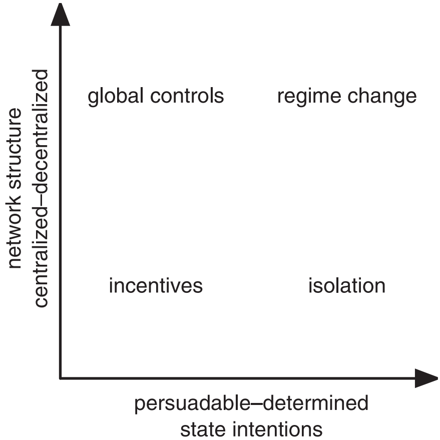
Advisor Dr. Condoleezza Rice to the Reagan Lecture," February 26, 2004, http://www.whitehouse.gov/news/releases/2004/02/20040228-1.html; John R. Bolton, "The Bush Administration and Nonproliferation: A New Strategy Emerges," panel 1 of a hearing of the House Committee on International Relations, 108th Cong., 2d sess., March 30, 2004, http://www.state.gov/t/us/rm/31010.htm; and Richard Cheney, "Remarks by the Vice President at Westminster College," April 26, 2004, http://www.whitehouse.gov/news/releases/2004/04/print/20040426-8.html.

3. John R. Bolton, "Preventing Iran from Acquiring Nuclear Weapons," remarks to the Hudson Institute, August 17, 2004, http://www.state.gov/t/us/rm/35281.htm.

4. As Vice President Dick Cheney has argued, "I have been charged by the president with making sure that none of the tyrannies in the world are negotiated with. We don't negotiate with evil; we defeat it." Quoted in Warren P. Strobel, "Administration Struggles to Find Right Approach to N. Korea Talks," Knight Ridder, December 20, 2003.

Figure 1. Network Structures and State Intentions Mapped to Nonproliferation Strategies



vate agents—including A.Q. Khan and two of his middlemen, Buhary Seyed Abu (B.S.A.) Tahir and Urs Tinner—have rapidly accelerated proliferation and lowered technological barriers.[5] Because these networks are widespread and decentralized, global measures rather than strategies targeted at individual states are necessary to slow these processes. Second, certain rogue states are dead set on proliferating and thus have no interest in bargaining. These two arguments define two variables—network structure and state intentions—encompassing four kinds of states that can be mapped to four different nonproliferation strategies (see Figure 1). Proliferation determinists argue that a number of states (e.g., Iran, North Korea, and formerly Libya) belong in the upper-right quadrant of Figure 1 (regime change); because these regimes are determined to seek nuclear weapons and are connected by effective, decentralized networks, they must be changed.

Both parts of the determinist argument are based on an interpretation of the progress of new proliferators that is at odds with publicly available docu-

5. Libya reinvigorated its nuclear program in 1995, then announced its termination in December 2003. On the roles of Tahir and Tinner, see Polis Diraja Malaysia, "Press Release by Inspector General of Police in Relation to Investigation on the Alleged Production of Components for Libya's Uranium Enrichment Programme," Royal Malaysia Police official website, February 20, 2004, http://www.rmp.gov.my/rmp03/040220scomi_eng.htm.

ments. The evidence that decentralized proliferation networks have allowed these proliferators to make great strides is contestable; the evidence that certain types of regimes are dead set on nuclear proliferation and cannot be persuaded to abandon their nuclear programs is even less compelling. Although the source of nuclear knowledge may have shifted from first-tier (advanced industrialized) to second-tier (developing industrial) states, there is no cause for proliferation panic.

In this article I propose an alternative approach—proliferation pragmatism—that rests on two premises. First, nuclear proliferation networks are highly centralized and are much less effective than determinists claim. Second, given sufficient incentives, proliferators can be persuaded to halt or roll back their programs. Consequently, most if not necessarily all states are in the lower-left quadrant of Figure 1; proliferation can be halted or slowed through proper application of country-specific incentives selected from a broad range of options. The presence of second-tier networks is indeed a new problem. Measures to deal with them should be based on an analysis of their structure and the speed of technological development. The hub-and-spoke structure of nuclear weapons and ballistic missile networks—which, I argue, developed in part because of the difficulty of passing on the tacit knowledge required to successfully build and operate these weapons—requires a policy that targets the hubs rather than a policy of systemwide coerced change. Past successes in slowing the spread of nuclear weapons through the use of targeted incentives, rather than demanding regime change, indicate that even the most seemingly determined proliferants can be slowed without resorting to extreme measures.

The two remaining quadrants in Figure 1 (global controls and isolation) differ in their policy prescriptions from pragmatism and determinism. If a proliferation network is decentralized but states that are part of it can be persuaded to halt their programs, global methods (such as those discussed by Chaim Braun and Christopher Chyba) that enhance the bargain of the nonproliferation treaty by providing more incentives and making transfers of nuclear technology more difficult are most appropriate.[6] If the network is centralized but states are determined to develop a nuclear capability, then proliferation can be

6. Global methods advocated by Braun and Chyba include universalization of export controls, extension of the Proliferation Security Initative (PSI), an Energy Security Initative to complement the PSI, a Fissile Material Cutoff Treaty, and a policy of nuclear de-emphasis by the United States. Braun and Chyba, "Proliferation Rings."

stopped by threatening to isolate a few key states, similar to the policy of dual containment of Iran and Iraq pursued by President Bill Clinton's administration.[7] Unlike regime change, these prescriptions (especially global controls) are potentially compatible with incentives targeted at specific states, although they will most likely fail if used without incentives.

In the next section, I argue that nuclear proliferation networks have not significantly altered the length of the development cycle of nuclear weapons programs and that regime type has little influence on states' desires to seek such weapons, contrary to the claims of proliferation determinists. I then examine the structure of the proliferation networks and discuss the role of tacit knowledge in shaping those structures and hindering new proliferants. In the third section, I review and critique steps taken to dismantle these networks. I then conclude with recommendations based on past successes.

New Proliferators Are Neither Advanced Nor Determined

Proliferation determinists contend that the inevitable spread of nuclear technology, combined with regimes that are dead set on proliferating, calls for a policy of regime change. Although countries' capabilities and intentions are difficult to ascertain, it is possible to compare particular claims made by determinists with publicly available data and reasonable calculations to demonstrate that the determinist case is far from certain; a policy of regime change requires much better evidence than advocates of determinism have presented. In this section I focus primarily on the cases of North Korea, Iran, and Libya. Because these countries were the primary recipients of nuclear technology from the A.Q. Khan network and have been singled out as by the United States as "rogue" states, these should be easy cases for proliferation determinism. In addition to examining the technological progress of these states, I evaluate the determinists' argument that particular regimes are dead set on proliferating, and find that the available evidence fails to support this assertion.

NUCLEAR NETWORKS: LEAPFROGGING OR FALLING DOWN?

Determinists argue that proliferation networks are ubiquitous, interlinked, and effective. Some even group together proliferation networks and terrorist

7. Anthony Lake, "Confronting Backlash States," *Foreign Affairs*, Vol. 73, No. 2 (March/April 1994), pp. 45–55.

networks; for example, President Bush argued in February 2004 that "with deadly technology and expertise going on the market, there's the terrible possibility that terrorists groups [*sic*] could obtain the ultimate weapons they desire most."[8] The same month, National Security Adviser Condoleezza Rice noted, "We now know, however, that there are actually two paths to weapons of mass destruction—secretive and dangerous states that pursue them and shadowy, private networks and individuals who also traffic in these materials, motivated by greed or fanaticism or, perhaps, both."[9] Similarly, Vice President Dick Cheney contended in April 2004 that "our enemy no longer takes the form of a vast empire, but rather a shadowy network of killers, which, joined by outlaw regimes, would seek to impose its will on free nations by terror and intimidation."[10] But how effective are these proliferation networks? Undersecretary of State John Bolton warned in May 2004, "It is clear that the recently revealed proliferation network of A.Q. Khan has done great damage to the global nonproliferation regime and poses a threat to the security of all states gathered here today."[11] Yet the difficulties that the leadership in Pyongyang, Iran, and Libya have encountered in seeking to achieve nuclear capabilities indicate that there are still significant barriers to the development and transfer of technological knowledge.

Although North Korea has received relatively little outside help with its plutonium program, proliferation determinists cite its possession of "up to eight bombs" as a rationale for action, arguing that the leadership in Pyongyang may seek to sell plutonium to third parties.[12] Evidence suggests, however, that North Korea may have much less plutonium than is commonly claimed. In May 1994 the DPRK heightened a crisis it started in 1993 by removing nearly 8,000 fuel rods from its Yongbyon nuclear reactor. In exchange for diplomatic and economic benefits from the United States, the North Koreans agreed to place these rods in sealed canisters under International Atomic Energy Agency (IAEA) supervision; standard calculations estimate that these rods (in addition to the rods that North Korea irradiated before 1989 and may have removed

8. Bush, "President Announces New Measure to Counter the Threat of Weapons of Mass Destruction."
9. Rice, "Remarks by National Security Advisor Dr. Condoleezza Rice to the Reagan Lecture."
10. Cheney, "Remarks by the Vice President at Westminster College."
11. John R. Bolton, "Nuclear Suppliers Group Plenary," statement to the 2004 Nuclear Suppliers Group plenary meeting, Göteborg, Sweden, May 27, 2004, http://www.state.gov/t/us/rm/33121.htm.
12. Bill Gertz, "North Korea Seen Readying Its First Nuclear Arms Test," *Washington Times*, April 23, 2005.

and reprocessed) could contain as much as 41.5 kilograms (kg) of plutonium.[13] This calculation, however, assumes a high capacity factor of 80 percent for the reactor between 1989 and 1994.[14] But the North Koreans also placed about 700 broken fuel rods into dry storage, making such a robust reliability unlikely.[15] Multiple shutdowns of North Korea's reactor between 1989 and 1994, possibly caused by mechanical problems rather than regular maintenance, have also been reported.[16] Since the reactor was restarted in early 2003, it has been shut on and off multiple times, indicating that the North Koreans are still experiencing difficulties operating it.[17] Many accounts assume that the North Koreans are understating the amount of plutonium that they have produced; this ignores the significant incentives they have to overstate the amount they may possess as a greater deterrent and for greater leverage.

Since former Los Alamos National Laboratory Director Sigfried Hecker verified in January 2004 that the 8,000 fuel rods were no longer in their cannisters at the Yongbyon facility, most analysts have assumed that they were reprocessed, significantly increasing the potential nuclear material separated by the North Koreans. Yet whether the rods have been reprocessed is unclear.[18]

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13. According to David Albright, Hans Berkhout, and William Walker, if between 1989 and 1994 the plant was operated 80 percent of the time—a high estimate—it could have produced 33 kg of plutonium in addition to the 9.5 kg still in the rods if only a few rods were extracted in 1989. Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996: World Inventories, Capabilities, and Policies* (Oxford: Oxford University Press, 1997), pp. 298–299.
14. Capacity factor is equal to the actual energy produced divided by the energy that could have been produced if the reactor was run constantly for the entire time period at 100 percent power.
15. Robert Alvarez, interview with author, Washington, D.C., November 8, 2004; and Robert Alvarez, "North Korea: No Bygones at Yongbyon," *Bulletin of the Atomic Scientists*, Vol. 59, No. 4 (July/August 2003), pp. 38–45. Alvarez was a senior policy adviser in the U.S. Department of Energy who oversaw the canning of the spent fuel rods. Albright, Berkhout, and Walker note the presence of 650 rods in dry storage in addition to the rods extracted from the reactor. See Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996*, p. 294.
16. Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996*, p. 298.
17. See, for example, the images at the Institute for Science and International Security of the DPRK nuclear power plant. Corey Hinderstein, "Imagery Brief of Activities at the Yongbyon Site," July 1, 2003, http://www.isis-online.org/publications/dprk/Imagery.pdf. These photos indicate a shutdown sometime between March and June; a second shutdown occurred later that fall. Douglas Jehl, "Shutdown of Nuclear Complex Deepens North Korean Mystery," *New York Times*, September 13, 2003.
18. Hecker avoided arguing that all of the rods had been reprocessed simply by noting that they were no longer in the cooling pond. See Sigfried S. Hecker, "Visit to the Yongbyon Nuclear Scientific Research Center in North Korea," Senate Committee on Foreign Relations, 108th Cong., 2d sess., January 21, 2004, http://foreign.senate.gov/testimony/2004/HeckerTestimony040121.pdf. Any of three remote-sensing technologies could have detected reprocessing. First, satellite photos could have picked up visible emissions from the reprocessing plant. See Richard R. Paternoster, "Nuclear Weapon Proliferation Indicators and Observables," LA-12430-MS (Los Alamos, N.M.: Los Alamos National Laboratory, December 1992), p. 8. Second, steam from the power plant

But reader problems and reprocessing inefficiencies may have hindered their ability to produce enough plutonium for six to eight weapons. For example, if the reactor ran at a 40 percent capacity factor from 1989 to 1994 consistent with the operating record before the 1989 shutdown and reprocessing losses were 25 percent, North Korea would have a total of about 20 kg of plutonium.[19] Although the standard figure for calculating the amount of plutonium used per weapon is around 5 kg, 6 kg is often used as a more conservative estimate;[20] further the first weapon built by a new proliferator can require up to 8 kg.[21] With the more conservative figure, North Korea would have enough plutonium for only three weapons, not enough to sell or use in a test and still maintain a sufficient deterrent. There is also some question as to whether North Korea has produced nuclear weapons with this material.[22]

Many U.S. officials also raise concerns over North Korea's highly enriched

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connected to the reprocessing plant could be observed; this was seen briefly in January 2003 but has not been observed since. See David E. Sanger, "U.S. Sees Quick Start of North Korea Nuclear Site," *New York Times,* March 1, 2003. Third, detectors on the border could find Krypton-85 gas emissions; such emissions were reported only once, in July 2003. See Thom Shanker and David E. Sanger, "North Korea Hides New Nuclear Site, Evidence Suggests," *New York Times,* July 20, 2003. While the Central Intelligence Agency and the Defense Intelligence Agency had concluded that North Korea had reprocessed the rods, State Department intelligence was unconvinced as of mid-2004. David E. Sanger and William J. Broad, "Evidence Is Cited Linking Koreans to Libya Uranium," *New York Times,* May 23, 2004. The reprocessing might have been done instead in an unknown underground facility, which could potentially circumvent these detection methods.

19. Alvarez argues that with the large number of broken rods, the capacity factor of the reactor could have been 40 percent. This figure would also be more consistent with the operating record of the reactor before the 1989 shutdown. With 9.5 kg already in the rods, the additional amount of plutonium in the rods would then be about 16.5 kg, for a total of about 26 kg. Alvarez also points out that without skilled knowledge of the PUREX process, the amount of plutonium extracted could be significantly less than assumed. Alvarez, interview with author. The fraction by which this would decrease the amount of plutonium extracted is highly uncertain. One possible indication, however, is the amount of material North Korea itself claimed to have lost in its reprocessing—about 30 percent. See David Albright and Kevin O'Neill, *Solving the North Korean Nuclear Puzzle* (Washington, D.C.: Institute for Science and International Security, 2000), p. 88. The amount of plutonium that North Korea could potentially extract from these rods is therefore probably closer to 20 kg than 42 kg.

20. The Trinity atomic test on July 16, 1945, and the bomb dropped on Nagasaki on August 9, 1945, both used 6 kg or more of plutonium. Richard L. Garwin, "The Future of Nuclear Weapons without Nuclear Testing," *Arms Control Today,* Vol. 27, No. 8 (November/December 1997), pp. 3–12.

21. Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996,* p. 306.

22. Although the CIA's assessment in 2003 that "North Korea has produced one or two simple fission-type nuclear weapons" is widely cited, the next sentence of the assessment indicates that this conclusion may have been reached using only the vaguest of evidence: "Press reports indicate North Korea has been conducting nuclear weapon–related high explosive tests since the 1980s in order to validate its weapon design(s)." Central Intelligence Agency, "SSCI Questions for the Record: Regarding 11 February 2003 DCI World Wide Threat Briefing," SSCI 2003-3662, Central Intelligence Agency, August 18, 2003, http://www.fas.org/irp/congress/2003_hr/021103qfr-cia.pdf.

uranium (HEU) program. In particular, much has been made of Pyongyang's attempts to acquire parts for its centrifuges in Europe. The Central Intelligence Agency reported in November 2003 that "a shipment of aluminum tubing—enough for 4,000 centrifuge tubes—was halted by German authorities" in April 2003.[23] The shipment in question, however, contained only 214 tubes. If North Korea had received this shipment, these tubes could have been turned into the vacuum housings for 428 centrifuges—enough for only a pilot-sized facility.[24]

The North Koreans seem to be seeking parts for the more advanced P-2 (aka G-2) centrifuge,[25] which operates at higher speeds and requires more sophisticated materials than the simpler P-1 centrifuge. Consequently, this increases the amount of time required to construct a uranium-enrichment facility capable of producing sufficient quantities of nuclear weapons–grade HEU. As one expert has noted, "The North Koreans assumed that their path to HEU would be shortened if they procured the most advanced materials available. Iraq also 'made that mistake.'"[26] Germany's 2003 seizure of the aluminum tubing reveals that the DPRK did not have enough vacuum housings at that time for even a small pilot plant. In addition, it seems unlikely that the North Koreans would have already acquired difficult-to-manufacture maraging steel rotors or other sensitive parts if they could not manufacture the much simpler vacuum housings. Even with a simpler design, they probably would not have progressed to the point of being able to make HEU.[27]

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23. Central Intelligence Agency Nonproliferation Center, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions," January 1–June 30, 2003, http://www.cia.gov/cia/reports/.
24. Joby Warrick, "N. Korea Shops Stealthily for Nuclear Arms Gear; Front Companies Step Up Efforts in European Market," *Washington Post*, August 15, 2003. Assuming 5 separative work units (SWU)/yr. P-2 centrifuges, 428 centrifuges would take nearly two years to produce 20 kg of 93 percent enriched uranium (a standard assumption for a small-implosion nuclear weapon using HEU). But this assumes that no centrifuges break down, which is highly unlikely given the record of North Korea's plutonium program and the difficulties faced by states unfamiliar with centrifuge technology.
25. Mark Hibbs, "Customs Intelligence Data Suggest DPRK Aimed at G-2 Type Centrifuge," *Nuclear Fuel*, May 26, 2003.
26. Quoted in Mark Hibbs, "CIA Assessment on DPRK Presumes Massive Outside Help on Centrifuges," *Nuclear Fuel*, November 25, 2002, p. 1.
27. One "Western centrifuge expert" doubted North Korea's progress, arguing that the suggestion that "the North Koreans could make HEU on a consistent basis with (the CNOR/SNOR design) after, say, five years' time, is pretty unlikely, given all the challenges." Quoted in Mark Hibbs, "DPRK Enrichment Not Far Along, Some Intelligence Data Suggest," *Nucleonics Week*, October 24, 2002, p. 2. The CNOR/SNOR is a simpler aluminum-rotor design similar to the P-1 centrifuge used by Pakistan and distributed by the A.Q. Khan network.

The Libyan nuclear program had been active much longer than the North Korean program, suggesting that even with extensive help, HEU production remains difficult. According to the IAEA, Libyan authorities "made a strategic decision to reinvigorate its nuclear activities" in July 1995. Despite massive assistance from the A.Q. Khan network, including the sale of twenty preassembled P-1 centrifuges, Libya had installed only one 9-machine cascade by April 2002—and never fed any nuclear materials into it. Libya also could not develop the uranium hexafluoride (UF_6) production facilities required to feed the centrifuges.[28] Given that it requires about 1,600 P-1 centrifuges and around 4,500 kg of natural uranium to produce 20 kg of weapons-grade HEU in a year, Libya's program was far from completion.[29] Moreover, the centrifuges that Libya sent to the United States after it gave up its nuclear program lacked rotors.[30]

Iran's nuclear program has also been in existence longer than the North Korean program. Iran's centrifuge enrichment program was established in the mid-1980s. After transient and somewhat dubious successes, Iran has been unable to separate isotopes using lasers since 1994 because of "continuous technical problems." The laser-enrichment equipment Iran received from its foreign suppliers between 1975 and 1998 was for the most part incomplete or never properly functioned; the supposed success of its pre-1994 experiments was measured by the same foreign suppliers who carried out the experiments, lending some doubt as to the veracity of the results.[31] Similarly, since its acquisition of parts for 500 centrifuges (split between two shipments in 1994 and 1996) from the A.Q. Khan network, Iran has made relatively little progress in developing its centrifuge technology. Problems with the bellows required additional shipments in 1997.[32] More than half of the rotors that Iran had assem-

28. IAEA Board of Governors, "Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya," IAEA report GOV/2004/12 (Vienna: International Atomic Energy Agency, February 20, 2004), http://www.fas.org/nuke/guide/libya/iaea0204.pdf, pp. 4–5.
29. Assuming a natural uranium feed and a 0.3 percent tails assay, 4,000 SWU are required to produce 20 kg of 93 percent enriched HEU from 4,500 kg of natural uranium, enough for a first-generation implosion device. A P-1 centrifuge produces about 2.5 SWU/yr., so 1,600 centrifuges would be required. See Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996,* p. 469.
30. David E. Sanger and William J. Broad, "As Nuclear Secrets Emerge, More Are Suspected," *New York Times,* December 26, 2004.
31. IAEA Board of Governors, GOV/2004/83, pp. 6, 12–13.
32. Ibid., p. 8. Uranium centrifuges typically have one or more bellows (connectors) between individual stacked segments to prevent the centrifuges from self-destruction when passing through resonance velocities.

bled in the spring of 2004 were unusable.[33] Iran received P-2 designs in 1995 from the A.Q. Khan network, but reportedly did little work on the P-2 centrifuges because of the extensive problems it was already having with the simpler P-1 centrifuge, delaying work on the more advanced design until 2002. The owner of the private company hired to work on the P-2 centrifuges stated that Iran was not capable of manufacturing the P-2's maraging steel rotors, and began work on adapting the design to use a shorter (probably single-rotor) composite carbon tube instead.[34] These time frames are quite close to—or even significantly exceed—the ten to fifteen years that other countries have needed to develop centrifuge programs.[35]

THE IRRELEVANCE OF REGIME TYPE

In addition to arguing that proliferation networks have significantly decreased development times, proliferation determinists contend that particular regimes—referred to variously as "rogue" states, "outlaw" regimes, or members of an "axis of evil"—are inherently prone to proliferation and cannot be deterred or contained, and so must be replaced. In his State of the Union Address on January 29, 2002, President Bush singled out Iran, Iraq, and North Korea as an "axis of evil." Two days later, National Security Adviser Rice identified the same three states.[36] Secretary of State Colin Powell announced the Bush administration's policy of regime change in Iraq in testimony before Congress on February 6, 2002.[37] Discussing Iraq just days before the U.S. invasion on March 20, 2003, Bush stated, "Should we have to go in, our mission is very clear: disarmament. And in order to disarm, it would mean regime change."[38] Although the administration has sought to limit explicit calls for regime change in countries other than Iraq since Powell's testimony, a secret memo by Secretary of Defense Donald Rumsfeld leaked in April 2003 called explicitly

33. David Albright and Corey Hinderstein, "Iran: Countdown to Showdown," *Bulletin of the Atomic Scientists*, Vol. 60, No. 6 (November/December 2004), pp. 67–72.
34. IAEA Board of Governors, GOV/2004/83, p. 11.
35. Hibbs, "DPRK Enrichment Not Far Along, Some Intelligence Data Suggest."
36. George W. Bush, "State of the Union Address," January 29, 2002, http://www.whitehouse.gov/stateoftheunion/2002/; and Condoleezza Rice, "Remarks by the National Security Advisor Condoleezza Rice to the Conservative Political Action Conference," Marriott Crystal Gateway, Arlington, Virginia, February 1, 2002, http://www.whitehouse.gov/news/releases/2002/02/20020201-6.html.
37. Todd S. Purdum, "U.S. Weighs Tackling Iraq On Its Own, Powell Says," *New York Times*, February 7, 2002.
38. George W. Bush, "President George Bush Discusses Iraq in National Press Conference," March 6, 2003, http://www.whitehouse.gov/news/releases/2003/03/print/20030306-8.html.

for such change in North Korea.[39] The following month, Deputy Secretary of Defense Paul Wolfowitz demanded "fundamental change" in the DPRK's regime.[40] The investigative journalist Seymour Hersh has reported that the Department of Defense is already conducting covert operations in Iran.[41] Even without an explicit call for regime change, the logic of proliferation determinism—that new proliferants cannot be contained, deterred, or bribed into giving up their nuclear weapon programs—leads to the inevitable conclusion that regime change must occur.

This position is untenable for three reasons. First, there is little or no systematic evidence that regime type is linked to proliferation propensity. Second, proliferation desires have historically varied even while regimes in North Korea and Libya (and Iraq before the 2003 U.S. invasion) remain the same, while in Iran, the 1979 revolution temporarily halted its nuclear program. Third, the direct evidence that contemporary proliferators are dead set on acquiring nuclear weapons does not hold up to scrutiny.

Although authoritarian regimes might be more prone to obtaining nuclear weapons and ballistic missiles than other kinds of states, this is only one factor among many. Surveys of the proliferation literature emphasize security and prestige benefits or organizational pathologies as drivers of nuclear proliferation, rather than domestic political structures or particular leaders.[42] A few studies argue that economic liberalization, not particular leaders, may restrain regimes from developing nuclear weapons.[43] Ironically, because economic growth is also linked to proliferation, the net effect of economic liberalization may be to increase in the likelihood of proliferation. Statistical studies of proliferation between 1945 and 2000 found either a positive correlation between de-

39. David Rennie, "Pentagon Calls for Regime Change in North Korea," *Daily Telegraph* (London), April 22, 2003.
40. Wolfowitz, "Deputy Secretary Wolfowitz Q&A."
41. Seymour M. Hersh, "The Coming Wars," *New Yorker,* January 24–31, 2005, http://lexis-nexis.com.
42. See Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security,* Vol. 21, No. 3 (Winter 1996/97), pp. 54–86; and Tanya Ogilvie-White, "Is There a Theory of Nuclear Proliferation? An Analysis of the Contemporary Debate," *Nonproliferation Review,* Vol. 4, No. 1 (Fall 1996), pp. 43–60.
43. Etel Solingen, "The Political Economy of Nuclear Restraint," *International Security,* Vol. 19, No. 2 (Fall 1994), pp. 126–169; and Etel Solingen, "The Domestic Sources of Nuclear Postures: Influencing Fence-Sitters in the Post–Cold War Era," IGCC Policy Paper PP08 (Irvine, Calif.: Institute on Global Conflict and Cooperation, October 1, 1994), http://repositories.cdlib.org/igcc/PP/PP08.

mocracy and proliferation or no relationship at all. Factors such as diplomatic isolation, economic growth, interstate rivalries, and security threats were much more influential than how democratic or autocratic a regime was.[44] Five of the nine established or suspected nuclear weapons states (France, India, Israel, the United Kingdom, and the United States) are well-established democracies.

Although a particular leader might still make a difference at the margin, none of the cases of contemporary "rogue" state proliferators support the thesis strongly. Bolton has argued that "historically, countries have given up their nuclear weapons programs only at a time of regime change."[45] Yet this argument does not seem to hold for the states singled out as "rogue" regimes. The Iraq Survey Group, constituted by Australia, Britain, and the United States to search for evidence of nonconventional weapons programs after the 2003 Iraq war and removal of Saddam Hussein from power, found "no evidence to suggest concerted [Iraqi] efforts to restart the [nuclear] program" after the 1991 Persian Gulf War.[46] Libya gave up its nuclear, chemical, biological, and long-range missile programs while maintaining the same leader. North Korea's nuclear ambitions have varied while its leaders have been relatively constant; factors other than regime type, such as rapprochement with South Korea and U.S. promises to establish diplomatic and economic ties in exchange for a freeze on North Korea's program, have influenced its decisionmaking at various times. Iran sought nuclear weapons even as a U.S. ally under the shah; the revolution actually led to a cessation of Iran's nuclear ambitions until at least 1985.[47]

44. See Sonali Singh and Christopher R. Way, "The Correlates of Nuclear Proliferation: A Quantitative Test," *Journal of Conflict Resolution*, Vol. 48, No. 6 (December 2004), pp. 859–885; Dong-Joon Jo and Erik Gartzke, "Determinants of Nuclear Weapons Proliferation," November 2003, http://www.columbia.edu/~eg589/pdf/nuke-proliferation-112003.pdf; and Karthika Sasikumar and Christopher R. Way, "Testing Theories of Proliferation: The Lessons from South Asia," paper presented at the Center for International Security and Cooperation–Army War College Conference on South Asia and the Nuclear Future, Stanford, California, June 3–4, 2004.
45. John R. Bolton, "Arms Control and Nonproliferation Issues," press conference, July 21, 2004, http://www.state.gov/t/us/rm/34676.htm.
46. Charles Duelfer, "Key Findings of the Comprehensive Report of the Special Advisor to the DCI on Iraq's WMD," September 30, 2004, http://www.cia.gov/cia/reports/iraq_wmd_2004/Comp_Report_Key_Findings.pdf.
47. On the shah's program, see Anne Hessing Cahn, "Determinants of the Nuclear Option: The Case of Iran," in Onkar S. Marwah and Ann Schulz, eds., *Nuclear Proliferation and the Near-Nuclear Countries* (Cambridge, Mass.: Ballinger, 1975), pp. 185–204. After the revolution in 1979, Iran first constituted its centrifuge program and began construction on the Isfahan nuclear complex in 1985. IAEA Board of Governors, GOV/2004/83, pp. 6, 14.

Much of the argument for regime change comes from a reading of these countries' intentions based on their progress. This is especially true of Iran. Similar to the North Korean case, arguments regarding the rate of Iran's nuclear acquisition are based on worst-case estimates and incomplete information. This is not to suggest that Iran's pursuit of a nuclear capability is solely for civilian purposes, as the Iranian government asserts; rather, advocates of regime change have exaggerated the military capabilities of Iran's nuclear facilities. Moreover, the slow rate of growth of Iran's nuclear program is incompatible with the notion of a regime determined to acquire weapons at any cost.

In an address to the Hudson Institute on August 17, 2004, Bolton made remarks typical of determinist claims regarding Iranian intentions.[48] He emphasizes the potential size of the Iranian pilot facility (1,000 centrifuges) and the planned production facility (50,000 centrifuges). Yet according to the IAEA, the Iranians installed only a 164-machine centrifuge cascade at the pilot plant; as of August 2005, this pilot cascade has not been operated. Uranium was fed into a small test cascade of nineteen machines at the Kalaye Electric Company only in 2002. This represents a substantial lack of progress given the receipt of parts for 500 centrifuges more than ten years earlier.[49] A regime determined to acquire nuclear weapons presumably would have attempted to move more quickly, despite any significant technical difficulties. As noted earlier, Iran has been working on laser enrichment technology even longer—since 1975. Bolton claims that Iran is developing enrichment facilities to produce weapons-grade uranium (containing 90+ percent uranium-235). But the samples acquired by the IAEA from the laser enrichment facility were enriched to just 1 percent; only gram quantities were produced at this level. Moreover, Iran had shut the facility down in response to a lack of progress and interest by May 2003.[50]

Bolton also claims that Iran has an impressive plutonium production program, highlighting the capabilities of its planned 40 megawatt nuclear reactor: "The technical characteristics of this heavy water moderated research reactor are optimal for the production of weapons-grade plutonium." Initial estimates, however, projected that this reactor would not be online until 2014—hardly a crash nuclear weapons program,[51] especially given that Iran has been planning

48. Bolton, "Preventing Iran from Acquiring Nuclear Weapons."
49. The centrifuge parts arrived in two shipments: the first in March 1994 and the second in July 1996. IAEA Board of Governors, GOV/2004/83, pp. 6–8.
50. Ibid., pp. 12–14.
51. Ibid., pp. 12–15.

this reactor since the mid-1990s.[52] More recent reports claim that it could be finished more quickly, perhaps by 2009, based on construction times of similar reactors in other countries.[53] An early completion date seems unlikely, however, given Iran's past difficulties in attempting to finish work on its Bushehr reactor, a light-water nuclear power plant originally ordered in 1975 from Germany. Iran's inexperience with nuclear technologies has produced significant delays, despite assistance from Russia; at one point, Iranian contractors had completed only five months of work on Bushehr in twenty-five months.[54] Moreover, merely starting up the reactor would require 80–90 tons of heavy water; as of November 2003, only one of the two heavy-water production lines had been completed. Production of 8 tons per year was supposed to have started in 2004,[55] but as of February 2005, even the first production line had not yet started.[56] Consequently, the reactor will not have a sufficient amount of heavy water until at least 2010.

Bolton also warns that Iran could use the Bushehr reactor to generate plutonium if it pulled out of the Nuclear Nonproliferation Treaty (NPT)—a claim true for any of the seventy countries currently or previously in possession of nuclear research or power reactors, and consequently not a useful measure of a particular regime's desire to proliferate.[57] Moreover, Iran would have to master the necessary reprocessing technology; so far, however, it has succeeded in reprocessing only milligram quantities of plutonium from irradiated targets—a very different technical challenge than reprocessing reactor fuel rods.[58] The Iranians would also have to construct a large-scale reprocessing facility that would be relatively easy to detect. It is also unclear how much knowledge Iran

52. IAEA Board of Governors, "Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran," IAEA report GOV/2003/63 (Vienna: International Atomic Energy Agency, August 26, 2003), http://www.iaea.org/Publications/Documents/Board/2003/gov2003-63.pdf, p. 9.
53. Jack Boureston and Charles Mahaffey, "Iran Pursues Plans for Heavy Water Reactor," *Jane's Intelligence Review,* November 14, 2003, http://jir.janes.com.
54. Anthony H. Cordesman, "Iran and Nuclear Weapons: A Working Draft" (Washington, D.C.: Center for Strategic and International Studies, February 7, 2000), http://www.csis.org/mideast/reports/irannuclear02072000.PDF, p. 13.
55. IAEA Board of Governors, GOV/2003/75, p. 14.
56. Institute for Science and International Security, "Iran Constructing the 40 MW Heavy Water Reactor at Arak Despite Calls Not to Do So by the European Union and the IAEA Board of Governors," March 4, 2005, http://isis-online.org/publications/iran/arakconstruction.html.
57. Bolton's presentation also includes technical inaccuracies, such as confusing deuterium (D) with heavy water (D_2O).
58. IAEA Board of Governors, GOV/2004/83, p. 17.

can gain from its work on the Bushehr reactor; Russian Minister of Atomic Energy Aleksandr Rumiantsev has claimed that Russian training of Iranian technicians is limited to operation only, without any transfer of knowledge of "actual nuclear technology."[59] Finally, the highly publicized revelation in early 2005 of Iran's small stake in a uranium mine in Namibia was, in the end, old news: Iran had acquired the stake in 1975 under the shah, and its contract does not include rights to the uranium.[60]

In sum, Iran will need years to develop a nuclear weapons capability. If the resuspension of centrifuge manufacturing that began in late November 2004 holds, the acquisition date will continue to be pushed back. Bolton's charge that Iran is "dead set on building nuclear weapons" and is proceeding with an urgency "quite consistent with a desire to produce a nuclear weapon as soon as possible"[61] seems implausible in this light, especially given that U.S. intelligence on Iran has been called into doubt.[62] Even some in the Bush administration estimate that Iran will not have a nuclear capability until sometime in the next decade.[63] Bolton argues that the June 2003 introduction of uranium hexafluoride gas into centrifuges at Iran's pilot plant and the temporary resumption of centrifuge manufacture in July 2004 are inexplicable other than by desire for rapid proliferation.[64] Yet the Iranian leadership has admitted taking these actions primarily to secure a better bargaining position,[65] which seems more plausible given their difficulties with the centrifuges and the considerable length of time before their program reaches completion.

Similar arguments hold for Libya and North Korea. Libya had about thirty people working on its program, far fewer than the thousands usually required for nuclear weapons development. Libya's nuclear activities may have been intended only as a bargaining chip rather than as part of a serious nuclear program; components were collected haphazardly, and development proceeded slowly.[66] After signing the Agreed Framework in 1994, North Korea made a deal with Pakistan to purchase materials and plans for centrifuges in 1997 at

59. I thank Sonja Schmid for bringing this to my attention and providing a translation. Aleksandr Rumiantsev, "Interview with the Minister of Atomic Energy," Ekho Moskvy, May 29, 2003.
60. Louis Charbonneau, "Iran in Rio Tinto Link," Reuters, January 31, 2005.
61. Bolton, "Preventing Iran from Acquiring Nuclear Weapons."
62. "U.S. Intelligence on Iran Seen Lacking–Experts," Reuters, February 9, 2005.
63. Nicholas Kralev, "U.S. Doubts Tehran Nukes Are Imminent," *Washington Times*, April 14, 2005.
64. Bolton, "Preventing Iran from Acquiring Nuclear Weapons."
65. Nazila Fathi, "Iran Hints It Sped Up Enriching Uranium as a Ploy," *New York Times*, December 6, 2004.
66. David Crawford, "Libya Was Far From Building Nuclear Bomb; Program Was Haphazard, But Shows How Technology Was Bought Off-the-Shelf," *Wall Street Journal*, February 23, 2004.

the earliest;[67] it embarked on an effort to develop a uranium enrichment program only by late 2000,[68] and started seeking the necessary materials in large quantities in late 2001.[69] Although these dates are ultimately uncertain, the bulk of public evidence does support them: North Korea's multiple efforts to seek parts have all occurred after 2000, with only a single effort to procure frequency converters in 1999.[70] As with Libya and Iran, the North Korean program may be intended as a bargaining chip; some observers argue that Pyongyang's confirmation of its uranium program to U.S. diplomats in October 2002 may have been intended as an offer to put the nuclear issue on the table in exchange for a grand bargain with the United States.[71]

Proliferation Networks: Star Structures and Tacit Knowledge

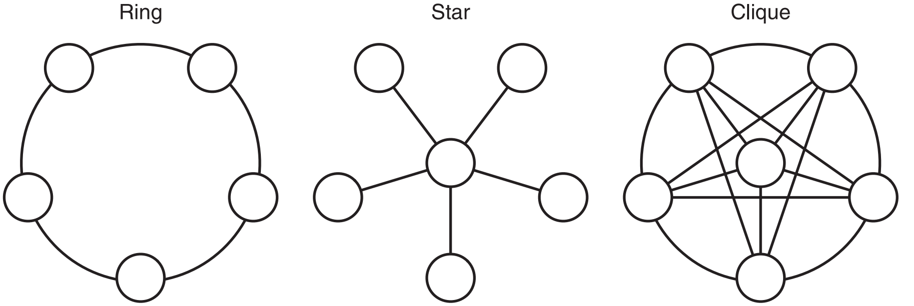
To justify a policy of regime change, proliferation determinists assume that nuclear technology is spreading rapidly through decentralized networks. Yet proliferation networks, in general, and nuclear proliferation networks, in particular, resemble a star-shaped (aka hub-and-spoke) structure. This structure is a function of the difficulty of transferring tacit knowledge through these networks, thus restricting their growth. This constraint makes these networks vulnerable to a range of counterproliferation measures that target the hub states directly.

THE STRUCTURE OF PROLIFERATION NETWORKS

In their study of "proliferation rings," Braun and Chyba examine second-tier proliferation, in which developing states aid each other in their ballistic missile and nuclear programs.[72] Although these proliferation networks have undercut

67. Joseph Bermudez Jr., "Lifting the Lid on Kim's Nuclear Workshop," *Jane's Defense Weekly*, November 27, 2002; and Seymour M. Hersh, "The Cold Test: What the Administration Knew about Pakistan and the North Korean Nuclear Program," *New Yorker*, January 27, 2003, http://jdw.janes.com.
68. Central Intelligence Agency Nonproliferation Center, "Untitled CIA Estimate to Congress," November 19, 2002, http://www.fas.org/nuke/guide/dprk/nuke/cia111902.html.
69. Central Intelligence Agency Nonproliferation Center, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions," July 1–December 31, 2001, http://www.cia.gov/cia/reports/.
70. North Korea unsuccessfully sought two frequency converters, used for timing centrifuges, in 1999, then tried again in 2002 and 2003. Part of the 2003 shipment was delivered, but the others were stopped. Mark Hibbs, "Procurement by Iran, DPRK Focuses Attention on 'Catch-All' Controls," *Nucleonics Week*, May 29, 2003.
71. Hibbs, "DPRK Enrichment Not Far Along, Some Intelligence Data Suggest."
72. Braun and Chyba, "Proliferation Rings."

Figure 2. Simple Network Structures



NOTE: To isolate all nodes, the center node in the star network can be removed, but many more nodes must be removed from a circle or clique structure.

existing export control measures, they have been less successful than proliferation determinists contend. The optimal strategy to halt the growth of these networks depends on their structure, which can take various forms, including rings or circles (where the connections between nodes—in this case, states—form a circle), stars (where every node is connected through a central hub), or cliques (where all of the nodes are directly connected). Simple examples of these three structures are diagrammed in Figure 2. If the structure is a ring or a clique, then the shutdown of any single node would not unravel the entire network; consequently, global strategies that seek to eliminate all nodes or all connections between nodes might be more effective in dissolving the network than strategies that aim at key connections or nodes. Densely connected, decentralized networks where no single node holds a crucial position in the network are easier in one sense to shut down: connections to additional nodes in the network are easier to discover, although this is balanced by the number of nodes and connections that need to be eliminated to dissolve the network. But if the structure is starlike, then the network is highly centralized; efforts are best concentrated on eliminating the central node and preventing other nodes from becoming hubs.[73]

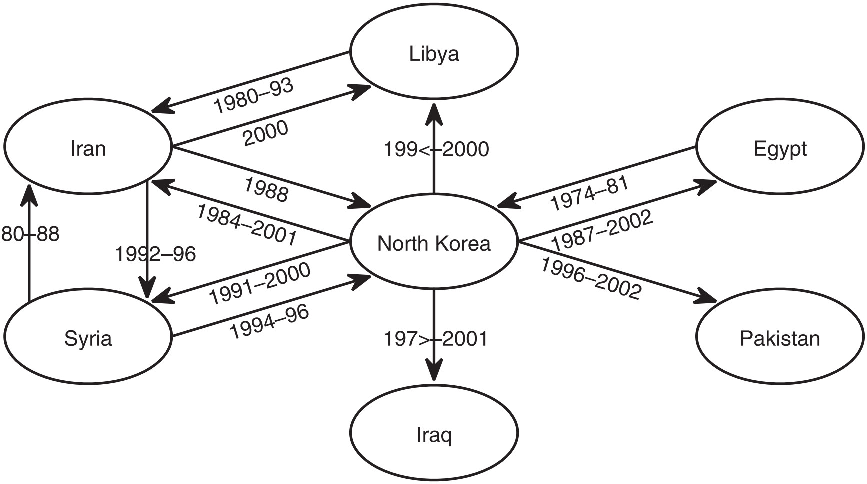
73. These are ideal types and do not by any means exhaust potential network structures; centralization and density are only two possible network measures. See Stanley Wasserman and Katherine Faust, *Social Network Analysis: Methods and Applications* (Cambridge: Cambridge University Press, 1994).

Existing ballistic missile and nuclear proliferation networks appear to closely resemble stars, in which North Korea and Pakistan are the hubs or central nodes for each network (see Figures 3a and 3b, respectively). No nuclear transactions between the spokes in the nuclear network have been confirmed as of mid-2005.[74] Interestingly, the missile network seems to be closer to a clique than does the nuclear network; however, only Iran and North Korea form hubs.[75] A.Q. Khan delivered plans or parts to Iran, Libya, and North Korea and offered assistance to other countries such as Iraq and possibly Syria. Although the extent of the Pakistani government's knowledge about the nuclear network remains unclear, there is no doubt that A.Q. Khan enjoyed unprecedented operational autonomy; shutting down the network requires convincing the Pakistani government to reestablish bureaucratic control over its program, obtain relevant information from Khan, and stop technology leaks. Consequently, from a policy perspective, Pakistan is the central hub rather than A.Q. Khan himself. Similarly, North Korea forms the center of a missile proliferation network, delivering missile technology to Egypt, Iran, Iraq, Libya, Pakistan, and Syria, among others. Iran forms a smaller hub for missile sales, linking Libya, North Korea, and Syria.

Braun and Chyba also cite other sources of missile technology (e.g., China and Russia), but these nodes are less central and, in any case, less likely to take on a central role if the existing hubs are shut down. Since joining the Missile Technology Control Regime (MTCR) in 1995, Russia has decreased its proliferation of missile technology, although it is still suspected of assisting North Korea and Iran, but at a lower level than before. China agreed to abide by the MTCR and pledged not to assist in the development of nuclear-capable missiles in 2000, then passed related domestic regulations in 2002. Some Chinese companies were still assisting Pakistan and Iran as of 2002, but the Chinese government has made progress in curbing missile technology exports since then, although it has still not become a full member of the MTCR.[76]

74. An uncorroborated report alleges that North Korea and Iran have assisted each other since the late 1990s. Louis Charbonneau, "N. Korea Provides Nuclear Aid to Iran–Intel Reports," Reuters, July 6, 2005.
75. Braun and Chyba also argue that China, Russia, Taiwan, Macedonia, and Belarus also assisted Iran. Braun and Chyba, "Proliferation Rings." According to the Nuclear Threat Initiative, China has also given assistance to Iraq, North Korea, Pakistan, Saudi Arabia, and Syria; Russia (or the Soviet Union previously) has also helped Egypt, Iraq, Libya, North Korea, and Syria. See Nuclear Threat Initiative, *Country Profiles*, January 8, 2005, http://www.nti.org/e_research/profiles/.
76. On China's missile exports and dates, see Nuclear Threat Initiative, *Country Profiles*. On its bid

Figure 3a. The Network Structure of Second-Tier Ballistic Missile Proliferation, 1974–2002

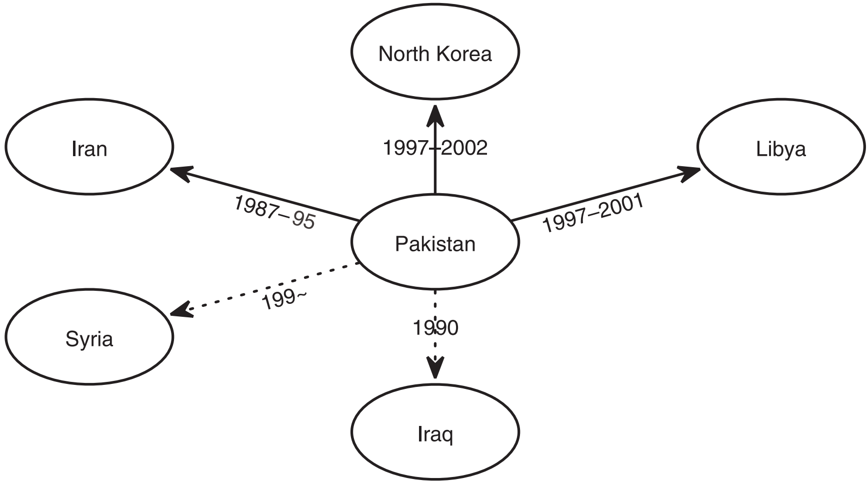


SOURCES: Missile proliferation data are from the Nuclear Threat Initiative, *Country Profiles,* and extend through 2002. Individual and minor incidents were discarded.
NOTE: Only the core second-tier proliferators appear in this figure; other countries that received only limited assistance (e.g., Sudan and Yemen) are excluded. Uncertain dates are marked as < (beginning of decade) or > (end of decade). Minor nodes are excluded; nodes are placed for clarity.

The missile proliferation network shown in Figure 3a exhibits a more dynamic structure than its nuclear counterpart. North Korea received assistance from Egypt from 1974 to 1981, importing Scud missiles that were reverse-engineered by North Korean scientists. In 1988 Iran gave the North Koreans the wreckage of al-Hussein missiles launched by Iraq in the war with Iran. North Korea reciprocated by assisting both Egypt and Iran with their development of ballistic missiles, then later Libya. Syria gave North Korea information on its SS-21 Scarab missiles from 1994 to 1996, and North Korea exported variants of the Scud and Nodong between 1991 and 2000 back to Syria. North Korea also exported Nodong technology to Pakistan, possibly in exchange for nuclear technology, while unconfirmed reports identify exports to Iraq, possibly as recently as 2001. Libya and Syria assisted Iran early in its program by supplying

to join the MTCR, see Wade Boese, "Missile Regime Puts Off China," *Arms Control Today,* Vol. 34, No. 9 (November 2004).

Figure 3b. The Network Structure of Second-Tier Nuclear Proliferation, 1987–2002



SOURCES: Nuclear proliferation data are from Gaurav Kampani, "Proliferation Unbound: Nuclear Tales from Pakistan" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, February 23, 2004), http://cns.miis.edu/pubs/week/040223.htm.

NOTE: Declined offers of assistance are dotted; uncertain dates are marked as ~ (mid-decade). Minor nodes are excluded; nodes are placed for clarity.

Scud-B missiles; Iran later reciprocated by sharing Scud-C technology with Syria and development assistance with Libya. Missile technology appears to be more transferable than nuclear technology; many of the relationships in Figure 3a involve these reciprocal exchanges.[77] This may in part be a result of the many small technical challenges posed by ballistic missiles, which allows for more decentralization and specialization than does nuclear weapons technology.[78] The density of ties among the participating nodes makes the total shutdown of such networks much more difficult, but it also makes it easier to trace relationships and discover additional nodes in the network.

Evidence that the nuclear proliferation network continues to be centralized was provided in early 2005. In February the U.S. government contended that North Korea had sold uranium hexafluoride to Libya. The "alarming intelli-

77. For details on these trades, see Nuclear Threat Initiative, *Country Profiles.*
78. I thank Dean Wilkening for pointing this out.

gence" that North Korea was "actively exporting nuclear material" was deduced "not on a murky intelligence assessment but on hard data."[79] The evidence that led U.S. "government scientists to conclude with near certainty"[80] that the uranium was from North Korea was either from uranium isotopic ratios or from plutonium contaminating the three cylinders of uranium hexafluoride that Libya had received in 2000 and 2001.[81] This would indicate that the network was becoming more decentralized, as nuclear trading was taking place between the separate nodes rather than through the hub. One recently retired Pentagon official described the trade as "huge, because it changes the whole equation with the North. . . . It suggests we don't have time to sit around and wait for the outcome of negotiations."[82] In March the U.S. government disclosed additional evidence regarding large financial transfers from Libya, which the United States claimed implicated North Korea.[83]

Contrary to U.S. claims, the plutonium, uranium, and financial evidence in the Libyan case is far from conclusive. The IAEA had performed similar analyses and found no plutonium traces on the cylinders.[84] The precision of the method used to determine the potential source of uranium has also been called into question, because the isotopic ratio measured (U-234 to U-238) can vary as much as 10 percent.[85] Yet the United States' contention that the uranium must be from North Korea "with a certainty of 90 percent or better" is belied by the admission that the U.S. inspection team had no sample of North Korean uranium.[86] Additionally, these concentrations can differ greatly even within a single mine, making it hard to identify a distinctive fingerprint.[87] The uranium in two of the three cylinders was natural uranium, while the other held depleted uranium; the latter is generally useless for creating either nuclear weapons or

79. Glenn Kessler, "North Korea May Have Sent Libya Nuclear Material, U.S. Tells Allies," *Washington Post*, February 2, 2005.
80. David E. Sanger and William J. Broad, "Tests Said to Tie Deal on Uranium to North Korea," *New York Times*, February 2, 2005.
81. Sanger and Broad reported isotopic ratios; Kessler reported plutonium. Ibid; and Kessler, "North Korea May Have Sent Libya Nuclear Material, U.S. Tells Allies."
82. Quoted in Sanger and Broad, "Tests Said to Tie Deal on Uranium to North Korea."
83. David E. Sanger and William J. Broad, "Using Clues from Libya to Study a Nuclear Mystery," *New York Times*, March 31, 2005.
84. Glenn Kessler and Dafna Linzer, "Nuclear Evidence Could Point to Pakistan," *Washington Post*, February 3, 2005.
85. Steve Fetter, "Nuclear Archaeology: Verifying Declarations of Fissile-Material Production," *Science and Global Security,* Vol. 3, Nos. 3–4 (1993), pp. 237–259.
86. See Sanger and Broad, "Tests Said to Tie Deal on Uranium to North Korea."
87. Jon B. Wolfsthal, "No Good Choices: The Implications of a Nuclear North Korea," House Committee on International Relations, 109th Cong., 1st sess., February 17, 2005.

fuel, while the total extractable weapons-grade uranium content of the former was about 7 kg, far too little for a first-generation nuclear weapon.[88] Given that the North Koreans had not even started attempting to acquire enrichment capabilities in 2000,[89] the depleted uranium is most likely the by-product of Pakistani enrichment. This is additional evidence that the uranium must have at least passed through Pakistan on its way to Libya, consistent with the existing structure of the nuclear network. One of A.Q. Khan's middlemen, B.S.A. Tahir, reported that the cylinders had been flown to Libya aboard a Pakistani airplane in 2001. With respect to the financial evidence, U.S. and foreign officials who had seen the documents in question said that they did not show that payments went directly to North Korea.[90] Nor were the payments necessarily for nuclear materials; they could equally have been for missile transfers.[91] The suppression of information by the United States that Pakistan was the likely intermediary in the deal and the high probability that the container originated in Pakistan upset U.S. allies,[92] because it appeared that the U.S. government was manipulating intelligence information to put pressure on North Korea.[93]

TACIT KNOWLEDGE AND THE SPREAD OF NUCLEAR WEAPONS

Nuclear proliferation networks are more likely to adopt star structures than ring or clique structures in part because nuclear proliferation has greater tacit

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88. Two of the three cylinders delivered to Libya (one small and one large) contained natural uranium hexafluoride (UF_6); the other small cylinder contained depleted UF_6 at 0.3 percent enrichment. The large one had 1,600 kg of UF_6; the small ones had 25 kg each. Libya received the large cylinder in February 2001 and the small ones in September 2000. See IAEA Board of Governors, *Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya*, IAEA report GOV/2004/33, International Atomic Energy Agency, May 28, 2004, http://www.fas.org/nuke/guide/libya/iaea0504.pdf, p. 3; and IAEA Board of Governors, *Implementation of the NPT Safeguards Agreement of the Socialist People's Libyan Arab Jamahiriya*, IAEA report GOV/2004/59, International Atomic Energy Agency, August 30, 2004, http://www.fas.org/nuke/guide/libya/iaea0804.pdf, p. 4. Based on a natural uranium percentage of 0.71 percent, this would give a total of 11.6 kg of U-235; assuming a standard tails assay of 0.3 percent and an HEU enrichment of 93 percent, 7.2 kg of HEU could be extracted, about a third of the amount necessary for a small first-generation implosion weapon. Depleted uranium can be put in a blanket around a reactor core to produce plutonium or as a tamper in a nuclear weapon, but it cannot be usefully enriched.
89. Central Intelligence Agency Nonproliferation Center, "Unclassified Report to Congress on the Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions," July 1–December 31, 2001.
90. Sanger and Broad, "Using Clues from Libya to Study a Nuclear Mystery."
91. I thank Paul Kerr for pointing this out. See Jeffrey Lewis and Paul Kerr, "A Financial Link in That AQ Khan–North Korea–Libya UF6 Daisy Chain?" April 1, 2005, http://www.armscontrolwonk.com/index.php?id=509.
92. Kessler and Linzer, "Nuclear Evidence Could Point to Pakistan."
93. Dafna Linzer, "U.S. Misled Allies About Nuclear Export: N. Korean Material Landed in Pakistan, Instead of Libya," *Washington Post*, March 20, 2005.

knowledge requirements. Tacit knowledge is knowledge that cannot be formulated in words or symbols, but must be learned through trial and error, potentially under the direct tutelage of someone who has already learned it; nuclear weapons design and production in particular depends heavily on such knowledge. Both Britain and the Soviet Union attempted to replicate the U.S. design from documents that they possessed, yet they had to devote major resources before they proved useful. Every nuclear program has required more time than the three and a half years the Manhattan Project took to build the world's first atomic weapon, despite the transfer of information and even scientists from one program to another.[94] One of the major preoccupations of the U.S. nuclear weapons complex is to retain tacit knowledge in the absence of testing.[95] Ballistic missile development, while also requiring some tacit knowledge,[96] would seem to be easier to transfer. If tacit knowledge was not restricting transfers of nuclear technology, the missile and nuclear networks would have connections between the same states; for example, because Libya and Iran trade missile technology, they would be likely to trade nuclear technology as well. Yet this has happened in only one case, between Pakistan and North Korea.

This constraint structures the proliferation networks. Only the central hub can dispatch experts to train new proliferants in constructing and operating equipment, whereas satellite states might be able to help each other with acquiring equipment but not with providing tacit knowledge. The hub might also have financial incentives to restrict information transfer: for example, selling parts for centrifuges but not instructions on how to build them. Individual satellite nodes are usually likely to form ties (nuclear or not) with each other through their common connections with the hub, thus decreasing chances of a potential dismantlement of the network by eliminating the hub. Such actors—called "structurally equivalent" in network terms—have a propensity to act in similar ways, often forming ties or networks between themselves when direct

94. Donald MacKenzie and Graham Spinardi, "Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons," *American Journal of Sociology,* Vol. 101, No. 1 (July 1995), pp. 44–99.
95. Alexander H. Montgomery, "Reconstructing Reliability: Confidence in Nuclear Weapons under Science-Based Stockpile Stewardship," master's thesis, University of California, Berkeley, May 1999.
96. Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, Mass.: MIT Press, 1993).

competitive pressures are weak.[97] Tacit knowledge requirements, however, help to suppress these ties.

Although some nonstate actors (e.g., Tahir and Tinner) involved in nuclear proliferation networks have been able to individually supply a few parts for centrifuges, they cannot provide the crucial tacit knowledge required to operate them. Parts from the A.Q. Khan network manufactured by the Malaysian company SCOPE were seized en route to Libya in October 2003 by a coalition of Western states. Yet these parts only constituted about 15 percent of the total number of parts for Libya's centrifuges, and none of the most sensitive parts.[98] While decentralized manufacturing may be efficient in some ways, both the lack of a direct connection and an inability to rapidly supply parts and feedback on their performance further hinder nonstate actors from properly supplying parts, let alone providing a complete proliferation solution. Iran, for example, reported that "many difficulties had been encountered as a result of machine crashes attributed to poor quality [imported] components."[99]

Although A.Q. Khan supplied both plans and parts, it appears that without the tacit knowledge required to produce nuclear weapons, the successful development of a nuclear capability requires much trial and error. Indeed, this seems to have been North Korea's problem. As Mark Hibbs has noted, "One official said that some information suggests the DPRK may have 'slavishly followed a recipe' calling for some more advanced components or materials, as called for in the design package provided by its helpers."[100] Although Iran has not fallen into this trap, the numerous problems it has encountered in its program underscore the difficulty of transferring tacit knowledge. The parts that Iran bought on the black market for its centrifuges (outside the A.Q. Khan network) were of highly variable quality; neither the sellers nor the Iranians knew how to judge their quality.[101] Iran is building a yellowcake-to-UF_6 conversion plant at Isfahan based on Chinese blueprints. Yet it has had difficulties produc-

97. Competitive pressures or direct negative ties can overcome the tendency of structurally equivalent actors to cooperate unless faced with a greater threat—for example, animosity between Iran and Iraq.
98. David Albright and Corey Hinderstein, "Libya's Gas Centrifuge Procurement: Much Remains Undiscovered," March 1, 2004, http://www.isis-online.org/publications/libya/cent_procure.html.
99. IAEA Board of Governors, GOV/2003/63, p. 7.
100. Hibbs, "CIA Assessment on DPRK Presumes Massive Outside Help on Centrifuges."
101. Mehdi Mohammadi, "Iran Press: Official Interviewed on Nuclear Activities since 1970," BBC Monitoring International Reports, Keyhan (Tehran), translated from Persian, April 28, 2005.

ing high-quality UF_4 (uranium tetrafluoride) and converting it into UF_6.[102] Although less evidence is available from Libya's program, the lags in time between receiving parts from the A.Q. Khan network and constructing its facilities as well as other difficulties seem to indicate the presence of similar problems. According to one observer, these problems suggest that Libya bought "nuclear technology without actually knowing how it worked."[103]

Yet materials acquisition is only one step in the nuclear weapons acquisition process. Even with a bomb design, many intermediate steps are required to develop a nuclear arsenal. Being able to cast fissile materials and high explosives into the necessary shapes requires extensive experience.[104] As Siegfried Hecker has noted, "The real secrets are in the details of the metallurgy, the manufacturing and the engineering."[105] A.Q. Khan apparently attempted to pass on these secrets, offering "uranium re-conversion and casting capabilities."[106] His success in describing the necessary processes in sufficient detail, however, appears to have been limited. These weapons also require a delivery system; although some of the countries discussed here have advanced ballistic missile programs, miniaturizing, toughening, and fitting a nuclear device that can be used as a nuclear warhead on a missile is not a straightforward task.

The bomb in the design that Libya acquired from the A.Q. Khan network was too large to fit on any of its ballistic missiles[107]—or, indeed, possibly on any missile in development by North Korea or Iran, both of which may have also received copies of the design. Accounts describe the design as "crude" and incomplete.[108] Some sources note that the core device has a mass of about 500 kg;[109] most attribute the design to the fourth Chinese nuclear test in 1966.[110] Yet the total mass of the core device, reentry vehicle, and ballast is much greater; the warhead that most closely fits this description is the one on

102. Joseph Cirincione, personal communication, June 3, 2005, from conversations with Western officials and IAEA experts.
103. Quoted in Crawford, "Libya Was Far From Building Nuclear Bomb."
104. MacKenzie and Spinardi, "Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons."
105. Quoted in William J. Broad and David E. Sanger, "Pakistani's Black Market May Sell Nuclear Secrets," *New York Times*, March 21, 2005.
106. Pierre Goldschmidt, IAEA deputy director-general and head of the Department of Safeguards, "Implementation of Safeguards in the Islamic Republic of Iran," statement to the IAEA Board of Governors, March 1, 2005.
107. Crawford, "Libya Was Far From Building Nuclear Bomb."
108. David E. Sanger, "The Khan Network," paper presented at the Conference on South Asia and the Nuclear Future, Stanford, California, June 4–5, 2004.
109. Albright and Hinderstein, "Iran: Countdown to Showdown."
110. Sanger and Broad, "As Nuclear Secrets Emerge."

the Chinese DF-2A, a 32-ton, 21-meter-long, 1.65-meter-wide missile deployed from 1966 to 1979. This warhead, a 12-kiloton device, weighs 1,290 kg; with a 200 kg reentry vehicle, the total payload would be almost 1,500 kg.[111] By contrast, all of the missiles currently or previously owned or in development by Libya, Iran, and North Korea are designed with a maximum intended payload of at most 1,000 kg.[112] Although range can be traded for payload, whether the warheads are small enough to fit on the missiles is unclear; Scud-based missiles have a diameter of 0.88 meters; the missile with the largest diameter available to these new proliferants—North Korea's Nodong 1—is 1.32 meters wide, 16 meters long, and weighs 16.25 tons, making it a third of a meter narrower and half the mass of the DF-2A.[113] South Korea's National Intelligence Service reported in 2005 that North Korea lacked the technology to put warheads on missiles.[114] Even though other methods could still be used for delivery (e.g., from an aircraft, in a shipping container, or in a truck), they are all considerably less desirable. For example, if Iran wants to deter a state with advanced air defenses such as Israel, a ballistic missile is likely to have far more success; it has significant command and control advantages as well.

Past and Future Counterproliferation Efforts

Numerous strategies for dissuading proliferants and dissolving proliferation networks have been attempted, but few have been successful. Threatening regime change has been minimally effective, and isolating or containing "rogue" states has been counterproductive, coinciding with the growth of networks between them. By contrast, offering benefits that closely mirror some of the core motivations of these states to proliferate has met with some success.

A policy of regime change is unlikely to encourage cooperation and is very likely to convince proliferators that they need nuclear weapons to deter the United States. It is self-defeating: U.S. threats of forcible regime change are

111. John W. Lewis and Hua Di, "China's Ballistic Missile Programs: Technologies, Strategies, Goals," *International Security*, Vol. 17, No. 2 (Fall 1992), pp. 5–40.
112. Daryl Kimball, "Worldwide Ballistic Missile Inventories" (Washington, D.C.: Arms Control Association, May 2002), http://www.armscontrol.org/factsheets/missiles.asp.
113. Joseph Bermudez Jr., "A History of Ballistic Missile Development in the DPRK," Occasional Paper 2 (Monterey, Calif.: Monitoring Proliferation Threats Project, Center for Nonproliferation Studies, Monterey Institute of International Studies, 1999), http://cns.miis.edu/pubs/opapers/op2/op2.pdf, p. 27.
114. Jeong-ho Yun, "North Korea Can't Put Nuke Warheads on Missiles: NIS," *Choson Ilbo* (Seoul), February 15, 2005.

likely to increase the number of states that seek a nuclear capability and bolster existing proliferators' programs as a defensive reaction. North Korea reacted to the invasion of Iraq by claiming that it was reprocessing all of its 8,000 spent fuel rods in late April 2003;[115] then in late August 2003, it threatened to test a nuclear device.[116] The Bush administration touts Libya's disarmament as an example of the threat of regime change working, yet this argument does not hold up under scrutiny. Libya had been attempting to rehabilitate itself for years, and a final agreement was well in the works before the invasion of Iraq or the interception of the BBC *China*.[117] Indeed, one Western diplomat suggested that Libya tipped off the United States about the shipment, perhaps as a good-faith gesture; others have speculated that Libya made the order expecting or intending it to be intercepted to exaggerate the size, worth, and progress of its nuclear program.[118]

A policy of isolation or containment, such as that applied to Iran and Iraq by past U.S. administrations, is a strategy that falls short of regime change. Indeed, the threat of isolation itself can be an important bargaining tool. Yet like economic coercion,[119] threatening isolation is more effective than carrying it out. The immense efforts made by the United States to isolate and contain Iran proved successful in delaying completion of the Bushehr nuclear reactor in the 1990s, but this strategy gave Iran no incentive to cooperate and did little to prevent the transfer of technology from second-tier suppliers.

The practice of isolation can even be counterproductive. Many of the states in the current second-tier proliferation networks (as well as those in past networks, for example, South Africa and Israel)[120] are isolated from the rest of the international system, whether through their own choices or through deliberate policies by the United States and other powerful actors. Isolation has been identified as a possible correlate of nuclear weapons programs.[121] If "rogue"

115. David E. Sanger, "North Korea Says It Now Possesses Nuclear Arsenal," *New York Times*, April 25, 2003.
116. David E. Sanger and Joseph Kahn, "North Korea Says It May Test an A-Bomb," *New York Times*, August 29, 2003.
117. Flynt L. Leverett, "Why Libya Gave Up on the Bomb," *New York Times*, January 23, 2004.
118. Crawford, "Libya Was Far From Building Nuclear Bomb"; and Michael Roston, "Polishing Up the Story on the PSI," *National Interest*, June 9, 2004, http://www.inthenationalinterest.com/Articles/Vol3Issue23/Vol3Issue23RostonPFV.html.
119. Daniel W. Drezner, "The Hidden Hand of Economic Coercion," *International Organization*, Vol. 57, No. 3 (July 2003), pp. 643–659.
120. David Albright and Mark Hibbs, "South Africa: The ANC and the Atom Bomb," *Bulletin of the Atomic Scientists*, Vol. 49, No. 3 (April 1993), pp. 32–37.
121. Jo and Gartzke, "Determinants of Nuclear Weapons Proliferation."

states are stopped from connecting with the rest of the world, they will be likely to connect with each other instead—with potentially disastrous consequences. The United States has facilitated connections between isolates by marginalizing them both in its rhetoric and policy and, since Ronald Reagan's administration, grouping them as "rogues," "pariahs," or "outlaws."[122] The Clinton administration slowly moved away from this policy in 1997 after the appointment of Madeleine Albright as secretary of state, who shifted U.S. rhetoric to "states of concern" in June 2000.[123] The Bush administration quickly returned to the "rogue" state rhetoric, then escalated it by referring to Iran, Iraq, and North Korea as members of an "axis of evil."[124] Later, John Bolton expanded the "axis" to include Libya, Syria, and Cuba.[125] This uncompromising rhetoric limits U.S. policy options and places the United States in a difficult negotiating position. The United States and the United Kingdom could not reach an agreement with Libya until the Bush administration complied with a request by high-level British officials to remove Bolton from the U.S. negotiating team; Bolton's unwillingness to compromise was preventing Libya from accepting a deal.[126]

By contrast, diplomatic incentives and economic benefits including aid and suspension of sanctions, have been successful in the past in an unexpected place—North Korea. Given its security relationships, the DPRK might seem to be a "hard case" for using these tools for counterproliferation.[127] Yet two of North Korea's three main demands for eliminating its nuclear program are for the United States to "recognize the DPRK's sovereignty" and to "not hinder [its] economic development."[128] North Korea has consistently responded positively to U.S. diplomatic overtures, economic benefits, and threats of economic

122. See Robert S. Litwak, *Rogue States and U.S. Foreign Policy: Containment after the Cold War* (Washington, D.C.: Woodrow Wilson Center Press, 2000); and Robert S. Litwak, "Non-proliferation and the Dilemmas of Regime Change," *Survival,* Vol. 45, No. 4 (Winter 2003), pp. 7–32.
123. Madeleine K. Albright, "Secretary of State Madeleine K. Albright Interview on the Diane Rehm Show, WAMU-FM," June 19, 2000.
124. Bush, "State of the Union Address."
125. John R. Bolton, "Beyond the Axis of Evil: Additional Threats from Weapons of Mass Destruction," remarks to Heritage Foundation, Washington, D.C., May 6, 2002, http://www.state.gov/t/us/rm/9962.htm.
126. Michael Hirsh, "Bolton's British Problem," *Newsweek,* May 2, 2005, http://www.msnbc.msn.com/id/7614769/site/newsweek/.
127. North Korea is unique in the world; it is geographically surrounded by two nuclear powers (Russia and China) and two latent powers (Japan and South Korea), and has U.S. troops are deployed on its border.
128. "Conclusion of Non-aggression Treaty between DPRK and U.S. Called For," Korean Central News Agency, October 24, 2002.

sanctions when deemed credible, and when combined with clear red lines. For example, during the 1993–94 crisis, threats of sanctions were met with North Korean bellicosity. The North Koreans believed that, with its ally China on the Security Council, multilateral sanctions would never pass. Quiet diplomacy combined with a good-faith effort by the United States to negotiate with North Korea convinced China to warn the DPRK on June 10, 1994, that it might not veto sanctions. This threat and a clear delineation by the United States of red lines that would trigger sanctions brought the North Koreans to the bargaining table.[129] Similarly, diplomatic and symbolic gestures by the United States—for example, making joint statements with the DPRK after meetings and replacing its gas-graphite nuclear plants with light-water nuclear reactors rather than with conventional power plants—were key to North Korean concessions during the crisis. These gestures were effective because they allowed North Korea to maintain its status as an equal of the United States and as a nuclear state, albeit not a nuclear weapons state.[130]

The Bush administration should adopt a policy of proliferation pragmatism that balances credible threats of force with promises of benefits to convince the current hubs of North Korea and Pakistan and potential new hubs such as Iran to cooperate. Incentives must be matched with states' underlying motivations for proliferation. Such incentives could include recognition by important states and membership in international organizations as well as economic benefits, including aid and suspension of sanctions.

NORTH KOREA

North Korea should be offered a grand bargain in which its security, economic, and diplomatic concerns are treated as legitimate rather than secondary matters to be resolved after disarmament;[131] the United States has not yet attempted to test North Korea in this way. Convincing the North Koreans that it is not going to be invaded is more likely to prod them into voluntarily giving up their program than is the threat of regime change.

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129. On China's threat, see Don Oberdorfer, *The Two Koreas: A Contemporary History*, rev. ed. (New York: Basic Books, 2001), p. 320. On establishing clear red lines, see Joel S. Wit, Daniel Poneman, and Robert L. Gallucci, *Going Critical: The First North Korean Nuclear Crisis* (Washington, D.C.: Brookings, 2004).
130. See Alexander H. Montgomery, "A Tale of Two Crises: U.S.-DPRK Nuclear Dynamics," paper presented at the annual conference of the American Political Science Association, Chicago, Illinois, September 2–5, 2004.
131. On this topic, see Michael E. O'Hanlon and Mike Mochizuki, "Toward a Grand Bargain with North Korea," *Washington Quarterly*, Vol. 26, No. 4 (Autumn 2003), pp. 7–18.

The North Korean declaration on February 10, 2005, that it had "manufactured nukes for self-defence" seemed to be a new twist in the North Korean crisis.[132] Rather than being an abrogation of the talks, this statement was largely a set of requirements for continuing negotiations, as elaborated by North Korea's representative to the United Nations on February 19.[133] The South Korean government played down the announcement as being short of declaring nuclear weapons–state status.[134]

Although some observers argue against rewarding North Korea or other states for bad behavior for fear of emulation,[135] it is unlikely that any other country would ever aspire to be in North Korea's position, isolated from the rest of the world, dependant on others for basic needs, and desperate enough to attempt to sell its security. Moreover, given the lack of other credible options, making a deal with North Korea is better than threatening regime change or relying on China to pressure it.[136] Six-party talks between China, Japan, North Korea, Russia, South Korea, and the United States began in August 2003 after North Korea withdrew from the NPT and ground to a halt after the third session in June 2004. South Korea's offer in June 2005 to provide electricity to North Korea (despite previous objections from the Bush administration to including additional inducements) is widely credited with bringing North Korea back to the six-party talks.[137] Others argue that pacts such as the Agreed Framework can be easily violated because covert programs can continue out of view.[138] Yet this argument highlights the problem that countries must ultimately comply willingly with the terms of disarmament—and therefore inducements must be offered that tackle the fundamental incentives that countries have to proliferate. As U.S. State Department official Paula DeSutter notes, "If we go into this and North Korea has not made such a deci-

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132. "DPRK Ministry of Foreign Affairs Statement," Korean Central News Agency, February 10, 2005.
133. Chan-ho Kang and Myo-ja Ser, "North's Envoy Lists Conditions," *Joong-Ang Ilbo* (Seoul), February 19, 2005.
134. "North Korea Not Yet a Nuclear Weapons State: Seoul," Reuters, February 13, 2005.
135. Ari Fleischer, press briefing, James S. Brady Press Briefing Room, April 29, 2003, http://www.whitehouse.gov/news/releases/2003/04/20030429-3.html.
136. As Robert Gallucci, the Clinton administration's chief negotiator with the North Koreans during the 1993–94 crisis, put it, "Listen, I'm not interested in teaching other people lessons. I'm interested in the national security of the United States. If that's what you're interested in, are you better off with this deal or without it? You tell me what you're going to do without the deal, and I'll compare that with the deal." Quoted in Scott Stossel, "North Korea: The War Game," *Atlantic Monthly*, July/August 2005, pp. 97–108.
137. Joel Brinkley, "Rice Claims U.S. Role in Korean About-Face," *New York Times*, July 14, 2005.
138. Bolton, "The Bush Administration and Nonproliferation."

sion, this is going to be like pulling teeth and our confidence at the end may not be what we would like it to be."[139] Unlike North Korea's plutonium program, even a production-scale centrifuge facility would be difficult to detect via technical means. Given the challenges of remote sensing, willing compliance is necessary for disarmament.

Threats of force alone cannot stop North Korea from trading either its missile or nuclear technologies. It is not a member of the MTCR, and its missile exports do not violate any laws; a shipment of Scuds from the DPRK was stopped by Spanish commandos acting on U.S. intelligence in December 2002 but had to be permitted to reach its destination in Yemen.[140] Now that North Korea is no longer a de facto member of the NPT, it is similarly unconstrained to trade in nuclear technology, although recipients that are members of the NPT would be in violation if they accepted nuclear technology for the purpose of pursuing a weapons capability. Yet the North Koreans have been willing to trade both its nuclear and missile programs for recognition, symbolic rewards, and economic assistance.[141] North Korea should be tested to see if it will accept a credibly backed bargain including these three elements.

PAKISTAN

The Bush administration has claimed success in shutting down the A.Q. Khan network that supplied both Pakistan and other proliferators, but its lack of cooperation with the IAEA and an unwillingness to push Pakistan have hampered U.S. efforts.[142] Not only is Pakistan's network continuing to operate, but it may be re-creating parts of it with new middlemen. Joseph Cirincione, director of nonproliferation at the Carnegie Endowment for International Peace, argues, "The network hasn't been shut down. . . . It's just gotten quieter. Perhaps it's gone a little deeper underground."[143] Pakistan continues to seek parts for its nuclear program abroad; Swiss authorities stopped two attempts by the A.Q. Khan network in 2004 to purchase aluminum tubes from Russia for Pakistan's use.[144] The existence of any network of suppliers not within

139. Quoted in Reuben Staines, "Verifying NK Nuke Dismantlement Tough Task: U.S.," *Korea Times* (Seoul), January 31, 2005.
140. Thom Shanker, "If the Scuds Were Going to Iraq," *New York Times*, December 15, 2002.
141. On North Korea's willingness to trade its nuclear program, see Selig S. Harrison, "Inside North Korea: Leaders Open to Ending Nuclear Crisis," *Financial Times* (London), May 4, 2004. On its missile, program, see Oberdorfer, *The Two Koreas*, pp. 439–440.
142. Sanger and Broad, "As Nuclear Secrets Emerge."
143. Quoted in Louis Charbonneau, "Pakistan Reviving Nuclear Black Market, Experts Say," Reuters, March 15, 2005.
144. "Khan's Nuclear Network Still Trying in 2004 to Buy Nuclear Technology: Swiss Report," Associated Press, May 26, 2005.

Pakistan's direct control makes proliferation more likely; suppliers who fill orders for Pakistan's program can fill the same orders for other proliferants. A strong U.S. effort to establish a fissile material cutoff treaty (FMCT) that includes Pakistan would undercut these suppliers; if Pakistan stops producing fissile materials, demand for centrifuge parts will drop significantly.

Although Pakistan is unlikely to roll back either its nuclear or missile programs, the United States and the other members of the MTCR should make it a high priority to ensure that it joins the MTCR and adopts domestic controls on nuclear and missile technologies. Pakistan (as well as India and Israel) should be brought inside the nuclear nonproliferation regime, possibly by relaxing the membership standards for nuclear export control consortia, including the Zangger Committee and the Nuclear Suppliers Group. More information about the extent of the A.Q. Khan network and other potential buyers (as well as the actual recipients) is also needed; the United States should push Pakistan to reveal the identity of the "fourth country" that Khan's network may have supplied or demonstrate that this country is fictional.[145]

IRAN

If the North Korean and Pakistani hubs are effectively shut down, the next logical step would be to turn to nodes that could evolve into new hubs. The advanced state of Iran's missile and nuclear programs, as well as its active participation in both networks, would suggest that it is a likely candidate to take over the central role of spreading nuclear/missile technologies. Indeed, as is shown in Figure 3a, Iran has already formed a mini-hub of missile proliferation between Libya, North Korea, and Syria. The positive response of Iran to potential diplomatic and economic benefits offered by the EU in exchange for the temporary suspension of its uranium enrichment program in November 2004 pending a final agreement is another indication that these tools can be very useful in a context that is normally dominated by security considerations. Suggestions that the United States should continue to play the "bad cop" to Europe's "good cop" with respect to Iran miss the point of the analogy: the good cop is convincing only if he can credibly restrain the bad cop; without a clear signal from the United States that it will accept the outcome of negotia-

145. Evidence found in shipping records indicates a possible fourth country beyond North Korea, Iran, and Libya. Barton Gellman and Dafna Linzer, "Unprecedented Peril Forces Tough Calls; President Faces a Multi-front Battle against Threats Known, Unknown," *Washington Post*, October 26, 2004.

tions and not take military action, Iran is unlikely to accept an offer from the EU to restrict its nuclear activities.

The United States should send such a signal—and soon, before Iran gives up on negotiations entirely. President Bush's assertion that "this notion that the United States is getting ready to attack Iran is simply ridiculous" was undermined when he continued: "And having said that, all options are on the table."[146] The minor concessions of airplane parts and support for World Trade Organization membership offered by Secretary of State Rice are insufficient; these gestures appear to be "hawk engagement," where offers over the last year in support of the EU's efforts (promptly rejected by Iran) are made to legitimize coercive action later.[147] Instead, the United States should take seriously the feelers sent out by former Iranian President and head of the influential Expediency Council Hashemi Rafsanjani to open diplomatic channels and deal directly with Iran.[148] The election of Mahmoud Ahmadinejad as president of Iran instead of Rafsanjani in June 2005 should not be used by the United States as a reason to avoid talks. The election does not change Iran's underlying reasons for pursuing nuclear technology, which are intertwined with factors such as international prestige and national pride as much as anything else.[149] As a result, it will be difficult to eliminate Iran's nuclear program completely (just as North Korea required nuclear power reactors in 1994 to save face), but creative applications of technology and diplomacy could produce a lasting compromise that keeps Iran short of the nuclear weapons threshold.

Conclusion

States are neither as determined nor as advanced in their pursuit of nuclear capabilities as proliferation determinists suggest. Part of the reason for this is the difficulty of transmitting tacit knowledge to new proliferators, which restricts the structure of nuclear proliferation networks. Two main implications flow

146. Quoted in Elisabeth Bumiller, "Bush Says Europe Should Not Lift China Arms Ban," *New York Times*, February 22, 2005.
147. Victor D. Cha, "Hawk Engagement and Preventive Defense on the Korean Peninsula," *International Security*, Vol. 27, No. 1 (Summer 2002), pp. 40–78.
148. "Region: Tehran Wants U.S. to Open Diplomatic Channel," *Daily Times* (Lahore), March 27, 2005.
149. George Perkovich, "Iran: Nuclear Power as National Pride," *Khaleej Times* (Dubai), March 26, 2005; and Neil MacFarquhar, "Across Iran, Nuclear Power Is a Matter of Pride," *New York Times*, May 29, 2005.

from this analysis. First, existing proliferation networks should be shut down by eliminating the hubs while preventing new ones from emerging. Second, a full range of incentives, instead of the threat of regime change, should be used to convince hub states to stop nuclear transfers.

Both time and diplomatic energy are in short supply, however; the immediate need is to cap and roll back the proliferation of networks created by Pakistan and North Korea and to keep new hubs, such as Iran, from taking their place. Tailored incentives and disincentives must be applied to these states. These policies require both carrots and sticks and need to be broadened beyond security-minded proposals to include diplomatic, symbolic, and economic incentives and disincentives.

This does not mean that policymakers can become proliferation procrastinators and wait until the time is ripe to eliminate these networks. Nor does it mean that they should become proliferation determinists clamoring for regime change and taking drastic steps (e.g., military action against North Korea, Iran, or Pakistan) that could have severe consequences. Policymakers have both the time and the tools to stop these hubs. By acting like proliferation pragmatists, policymakers can dismantle these hubs before they form a network of ties so dense that it will be impossible to pull apart.