Future World of Illicit Nuclear Trade

Mitigating the Threat

David Albright

Andrea Stricker

Houston Wood

July 29, 2013

INSTITUTE FOR SCIENCE AND INTERNATIONAL SECURITY

236 Massachusetts Avenue, NE
Suite 305
Washington, DC 20002

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
29 JUL 2013		**00-00-2013 to 00-00-2013**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Future World of Illicit Nuclear Trade: Mitigating the Threat	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Institute for Science and International Security,236 Massachusetts Avenue, NE Suite 305,Washington,DC,20002**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**130**	

Acknowledgements

This material is made possible in part by support from the Project on Advanced Systems and Concepts for Countering Weapons of Mass Destruction (PASCC), Center on Contemporary Conflict, Naval Postgraduate School, under Grant No. N00244-12-1-0032. PASCC is supported by the Defense Threat Reduction Agency (DTRA).

In addition, the research and preparation of this report has been supported by a generous grant from the Smith Richardson Foundation, Inc. We would like to thank Paul Brannan and Lauren Callahan, who while working at ISIS, assisted in the research and preparation of this report. We are also grateful to Orde Kittrie and several reviewers who prefer to remain anonymous whose thoughtful reviews of this report added immense insight and expertise. Finally, we thank the participants of a November 2012 workshop who greatly informed this report.

Table of Contents

Executive Summary

Of the roughly two dozen countries that have pursued or obtained nuclear weapons during the last fifty years, almost all of them depended importantly on foreign supplies. As a short term projection over the next five to ten years, illicit nuclear trade is likely to be conducted by several nations seeking nuclear weapons or wanting to maintain existing nuclear weapons arsenals or capabilities. Additional states in regions of proliferation concern may utilize smuggling methods to acquire advanced, ostensibly civilian, nuclear technology including uranium enrichment and plutonium production and separation capabilities. And despite many recent, particularly United States-led, successes, stopping this trade will remain difficult. Absent mitigating actions, several existing or expected trends are projected to make it easier for smugglers to succeed in acquiring nuclear and nuclear-related goods and technology.

Future illicit trade can be stopped through measures taken today as long as the political will is there to foresee and address future threats. A range of countermeasures aimed at mitigating or eliminating these future threats must be employed today to stop them from emerging in the next five to ten years. Preventing the future world of illicit trade is imperative to U.S. and international security and to the creation of a world safer from the spread and use of nuclear weapons.

Projecting the Next Countries Likely to Use Illicit Trade

This report first characterizes the future world of illicit nuclear trade in the next five to ten years. Illicit nuclear trade, or trafficking in nuclear commodities or technologies, is defined as trade that is not authorized by: 1) the state in which it originates; 2) under international law; 3) the states through which it transits; or 4) the state to which it is imported. The report assesses the next countries and actors likely to use illicit nuclear trade to obtain a range of nuclear or nuclear-related goods to outfit covert or sanctioned nuclear programs. Figure i summarizes the countries that are projected in the next five to ten years pursue illicit nuclear trade.

For countries in the developing world, the pathway to obtaining and improving nuclear weapons will remain illicit nuclear trade. In the next five to ten years, more developed or newly industrialized countries will be more independent, but the fact that the global marketplace is increasingly interconnected means that countries often do not seek self-sufficiency in the manufacture of all the goods that would be needed to make nuclear explosive materials or the nuclear weapons themselves. Thus, these countries as well may seek out high-tech dual use goods abroad.

Figure i: Illicit Nuclear Trade Consumers in Next Five to Ten Years

I. Nuclear Non-Proliferation Treaty (NPT) states which may conduct some illicit trade	II. Non-NPT signatory states expected to maintain or improve nuclear arsenals via illicit trade (in violation of originating state laws and international law)	III. Nuclear Aspirant States, dependent on illicit trade	IV. Developed countries/ territories to worry about seeking nuclear weapons via illicit trade and probability of them doing so, particularly in light of North Korea's advancing nuclear program	V. Developing or emerging market countries to worry about building nuclear weapons or capabilities via illicit trade, in light of Iran's advancing nuclear program	VI. Non-state actors of concern
China; particularly with regard to improving its own nuclear weapons, targeting intellectual property and related improvement-focused technologies	Pakistan	Iran	South Korea (low probability)	Egypt (low to medium probability)	Al Qaeda
	India		Taiwan (low)	Algeria (low)	Other terrorist groups, particularly in failed states
	North Korea		Japan (low)	Turkey (medium)	Transnational smuggling networks
	Israel, on occasion			Saudi Arabia (medium)	
				Syria (low, given civil war)	
				Failed states in Africa and Asia (low)	

Smuggling in Nuclear and Nuclear-Related Commodities

What is the typical makeup of a nuclear smuggling network? Nuclear smuggling networks are usually comprised of at least several major components, entities which we term in general proliferation "nodes" or "hubs," if the node is particularly active. Many networks have some or all of the following main components (illustrated in Figure ii), such as:

- A state nuclear program or complex which compiles lists of needed goods;
- A domestic nuclear procurement organization which receives the lists of needed equipment from the state nuclear programs and organizes their procurement domestically and abroad;
- Often domestic front or trading companies working under contract for the nuclear procurement organization to obtain goods;
- Other front or trading companies or middlemen/brokers usually located abroad and further removed from the nuclear procurement organization, which are hired by the domestic front or trading company or the nuclear procurement organization for the purpose of placing orders for goods;
- Suppliers of goods;
- Intermediaries involved in shipping and logistics;
- Banks, financial institutions, or informal payment structures which wittingly or unwittingly facilitate financing for the goods.

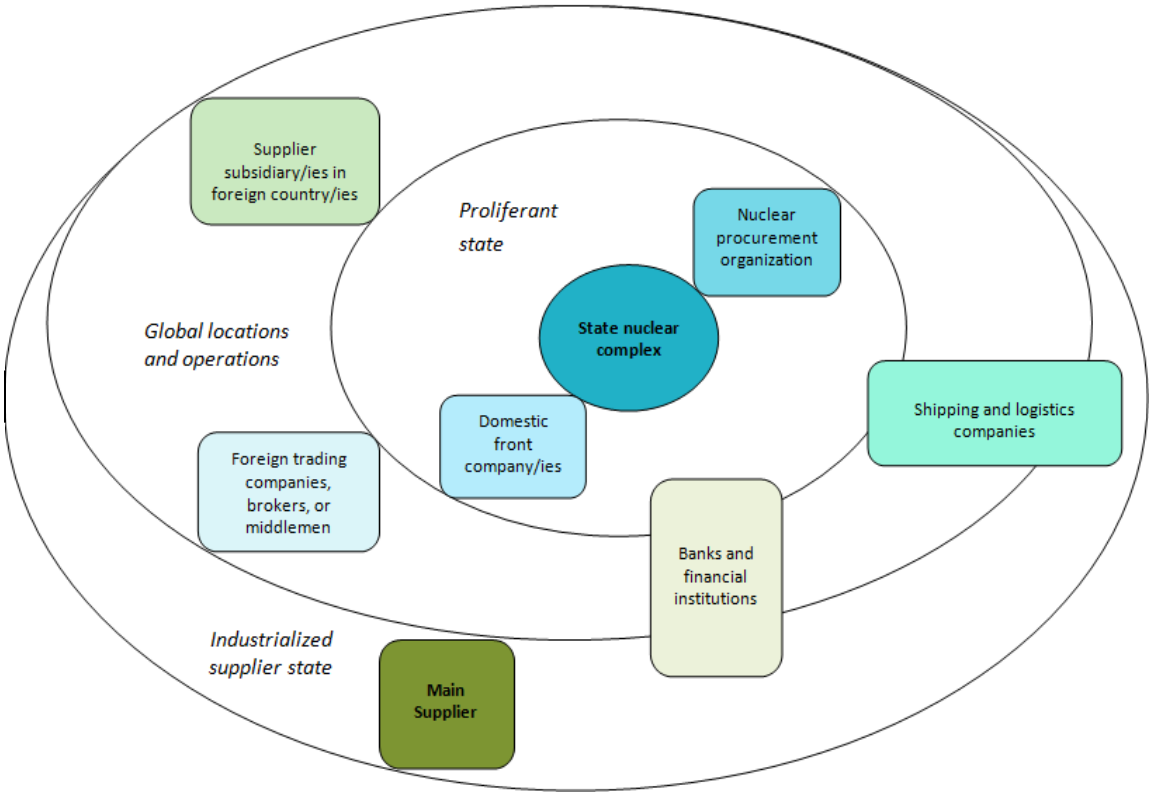

Figure ii: Depiction of actors/entities in a large illicit nuclear trade network

How do smuggling networks operate? What might they look like in the future? Nuclear smuggling operatives and networks have become very sophisticated over the last several decades. Smuggling networks have learned that suppliers in any country, including the United States with its extensive export laws, can be tricked into selling sensitive goods. Smuggling networks typically route their illegal procurements through countries with weak or nonexistent export controls. By using trading companies in third countries, international shippers, and complex payment schemes, these networks can use any country as a transshipment point, often called a "turntable." Smugglers use a wide variety of approaches to obtain goods, varying from legal to illegal methods and from straightforward to highly deceptive schemes. The simplest procurement scheme involves a nuclear program or one of its domestic agents making a direct order to a supplier, where the supplier believes that the end-user is a civilian, nonnuclear program.

The future world of illicit trade may include a pariah country, unauthorized entities in a country, or criminal elements selling nuclear facilities or capabilities to other states—actors which are termed "rogue suppliers." North Korea is a rogue supplier and has demonstrated the capability and inclination to provide nuclear goods and capabilities to customers abroad outside normal commerce and despite international norms and rules. Other states could emerge as rogue suppliers, particularly Iran. There is also growing concern that Iran and North Korea are undertaking nuclear cooperation. In the longer term, there is reason to worry that Syria under the victorious, old, or a new, radical regime could restart a secret nuclear program and emerge as a rogue nuclear supplier, or that Pakistan's government, along with its nuclear arsenal, could fall into the hands of radical fundamentalists.

The problem of illicit nuclear trade appears to be growing worse as technologies and capabilities proliferate. The world could in fact become far more dangerous. With the global spread of technology and rapid growth in international trade, traffickers could find it easier to ply their dangerous trade. It could be simpler ten years from now to obtain the materials, equipment, and know-how to produce nuclear weapons. Many countries that are considered developing nations have growing, sophisticated manufacturing and machine tool capabilities that can be exploited. These new suppliers are emerging in developing markets with few export controls and a culture of indifference to stopping the spread of nuclear weapons technology.

Future Production of Plutonium and Highly Enriched Uranium

The report turns to an analysis of the most likely future pathways for nuclear wannabe states or actors to achieve the production of fissile materials for nuclear weapons; particular focus is devoted to gas centrifuges, as one common and likely to be pursued pathway, and laser enrichment, as one that could loom on the horizon and is not being given adequate attention by governments and international control regimes. We also assess that the spread of classified or sensitive information could contribute importantly to proliferation in the near future.

Overall, we find that the likeliest to be chosen pathways to make highly enriched uranium (HEU) and separated plutonium will entail extensive foreign procurements and assistance. The methods

likeliest to be pursued by additional states in the next five to ten years to make nuclear weapons include:

- Gas centrifuges. Gas centrifuges are expected to remain a preferred pathway to making HEU. As a result, gas centrifuges warrant particular consideration. They are relatively widespread and are currently favored by proliferant states as the pathway to obtain fissile materials for nuclear weapons. Gas centrifuge procurements dominate illicit nuclear trade cases. This trend is not expected to change over the next decade.
- Nuclear reactor coupled with a plutonium separation plant. Over the next five to ten years, the main source of plutonium for nuclear weapons is expected to remain nuclear reactors and associated plutonium separation plants. Although there are other ways to produce plutonium, such as by particle accelerators, these methods are judged as less likely to be significant sources of plutonium in this time period.

Laser enrichment of uranium is also a pathway that deserves more scrutiny, despite its technical challenges. In addition, two less likely pathways considered in the report are particle accelerators to produce plutonium and the diversion of irradiated fuel from safeguards coupled with a low-tech plutonium separation plant.

The Special Challenge of the Spread of Classified or Otherwise Sensitive Information

In the future, there could be a greater availability of classified, proprietary, and other sensitive information about the technologies used to make HEU and plutonium and build nuclear weapons. For almost all proliferant states during the last several decades, their progress benefited from access to another country's classified information about nuclear weapons or the means to make HEU and plutonium. More recently, cyber-theft and espionage pose new threats of leakage of sensitive information important to the development of nuclear weapons and the means to make them. In addition, there are many dual-use technologies used in modern industries that are sensitive or proprietary and sought by other states. Some of these are critical to the development of a capability to make nuclear weapons, plutonium, or HEU.

Preventing the unauthorized spread of classified, proprietary or other sensitive information will remain a difficult challenge. States and terrorists will likely continue to try to gain access to such information in their quest for nuclear capabilities.

Future Marketplace: Suppliers of the Future

In assessing the future marketplace of illicit nuclear trade, this report finds that the most problematic future suppliers could emerge in developing countries. Figure iii is a list of countries of concern, many of which include those that today have few export controls in place and a culture of indifference to stopping the spread of nuclear weapons technology. Several more countries are identified in the report that could contribute to diversion of controlled or dual-use goods from one country to another and others yet that could specialize in facilitating proliferation financing of those goods.

Figure iii: Future illicit nuclear trade suppliers of concern
• **China**
• **Hong Kong**
• **India**
• **Pakistan**
• **Southeast Asia**
• **Turkey**
• **Brazil**
• **Argentina**
• **Russia**
• **Portions of Eastern Europe including Czech Republic, Hungary, Poland/former Soviet states in Central Asia: Belarus, Azerbaijan, Uzbekistan, Ukraine**
• **Rogue states or actors: Iran, North Korea, perhaps Syria, and possibly a Khan-type network**

One example of a country on both lists concerning future suppliers and diversion is China. China currently poses special challenges both today and in the future to stopping illicit trade in nuclear and nuclear-related commodities. As China becomes more capable of manufacturing high-tech goods, the problem could grow, unless mitigation steps are taken soon.

China will not be the only country posing such a threat. Based on current patterns, many other emerging markets are expected to gradually learn to make more sensitive goods reliably or contribute to the diversion of goods, and thus are included on our lists. Some of these countries are also lagging on implementation of controls against proliferation financing with few relevant laws and structures in place. Countries that fail to implement basic financial controls will be at risk for exploitation by financing schemes other than those relating to proliferation, such as money laundering, terrorist financing, and fraud related schemes.

Uncovering Smuggling Efforts

The report assesses that the scourge of illicit nuclear trade appears to be worsening and if left unchecked, it could emerge as one of the most significant global challenges to combating the future spread of nuclear weapons. Yet, this future world of illicit nuclear trade is not inevitable. There are important vulnerabilities that can be exploited; the expected trends can be prevented and new threats headed off.

Detection methods such as government watch lists of key goods ordered on the open market should be used more both in the United States and abroad to prevent and detect illicit trade; companies and governments will also need to cooperate more in sharing information vital to detecting and thwarting illicit procurement schemes. Watch lists often allow the detection of a suspicious combination of goods being sought by a country and permits supplier states to marshal resources more effectively in thwarting a proliferant state or sanctioned nuclear

program's illicit procurement attempts. Governments and companies can also work together to identify suspicious requests for goods and prevent sales before they are made. Governments have intelligence relevant insight into what may be behind a suspicious request and can warn companies. Companies can in turn provide suspicious information for governments to use to employ sting operations, learn more about a proliferant state's needs and plans, or otherwise take action against a network.

Findings and Recommendations

This report sets forth over 100 specific recommendations in 15 broad policy areas that the United States should implement. These countermeasures aim at mitigating or eliminating future threats posed by illicit nuclear trade. They must be employed today to stop the threats from emerging in the next five to ten years. Specific recommendations are aimed at thwarting or slowing the efforts of developing or emerging countries that will seek nuclear weapons or sensitive nuclear fuel cycle facilities. The report discusses methods to hinder developed or newly industrialized countries from acquiring the means to make nuclear weapons. Several other recommendations concern preventing emerging markets from becoming major hubs of illicit nuclear trade.

The following discussion summarizes the recommended actions in the 15 broad policy areas:

1) Build greater awareness against illicit trade:

Many countries and publics do not view export controls or sanctions as essential or give them the same priority as the United States. In order to promote greater awareness of the threats posed by illicit nuclear trade, the United States should launch a broad-based educational effort aimed at a wide overseas audience.

2) Make export controls universal and more effective:

One important tool against future illicit trade and nuclear proliferation will be the broader and more universal enforcement of export controls by developing nations. The United States should implement unilateral, international, and regional measures to support the universal, effective implementation of export controls.

3) Promote better enforcement and use of UN, unilateral, and regional sanctions:

United Nation Security Council, regional, and unilateral sanctions are important tools against illicit nuclear trade, although they currently suffer from many weaknesses. One issue is convincing countries to better enforce UN Security Council sanctions resolutions against Iran and North Korea. The United States should seek to improve the implementation and enforcement of UN Security Council sanctions by lagging countries.

4) Improve controls over sensitive nuclear information and assets:

Proliferant states and terrorists are expected to continue seeking classified and sensitive information related to the production of nuclear weapons and fissile materials. The United States

should support the development of improved national and international laws and guidelines to protect classified and sensitive information relevant to the production of fissile materials and nuclear weapons. A parallel goal should be protecting proprietary, unclassified, but sensitive information relevant to developing the wherewithal to make plutonium, HEU, or nuclear weapons.

5) Stop the money flows related to illicit trade:

International smugglers, like any other vendor, need to make and receive payments for goods acquired for their proliferant state clients. They have become adept at using the global financial system to facilitate transactions for goods purchased in contravention of national laws and international sanctions. Governments led by the United States must better leverage the financial industry as one of the last lines of defense against illicit nuclear trade and proliferation.

6) Better coordinate prosecutions and more vigorously prosecute smugglers:

Increased arrests and prosecutions of nuclear smugglers would delay or interrupt illicit procurement operations and actively shut down more networks. But to overcome many current problems with prosecuting smugglers and preventing future illicit trade, domestic legal processes in many countries must be improved to more effectively try and punish trafficking. The U.S. government, led by the Department of Justice, must therefore create or support efforts to increase cooperation among nations to overcome legal impediments to prosecuting smugglers and sanctions violators to better deter and prevent illicit trade.

7) Enhance early detection methods:

The single, most significant shortcoming of current counter illicit nuclear trade efforts is the lack of systematic, universal methods to detect nuclear trafficking. Early detection is key to preventing illicit nuclear trade. The United States should support internationally and develop or improve domestically its own efforts to better detect illicit trade.

8) Emphasize interdictions:

Increased U.S. and partner efforts to interdict goods heading to proliferant states or transit points would render proliferant states less able to obtain the goods they require and provide intelligence-usable information about their needs and activities.

9) Create a universal standard against illicit nuclear trade:

As the United States continues to seek internationally to strengthen export controls and efforts to thwart illicit nuclear trade, it should create a "Universal Standard against Illicit Nuclear Trade" for improved compliance by other states. It should also develop sets of benefits for states that improve their records and enact consequences for those that refuse to do so. Laying out clear criteria that indicates what a country must do to be considered as having come into compliance with globally-recognized counter illicit trade efforts is important to reducing confusion on this issue and incentivizing action.

10) Prevent additional developed/industrialized market nations from developing nuclear weapons:

If developed or newly industrialized countries decide to pursue nuclear weapons or build sensitive nuclear facilities, they pose a particular challenge. These nations already possess the industrial base, technological know-how, and domestic scientific capacity to build nuclear weapons within a relatively short period of time. The U.S. government should seek to detect efforts by these countries to gather certain goods on the open market for a covert nuclear weapons effort.

11) Reinvigorate a U.S. policy to discourage uranium enrichment and plutonium separation capabilities in regions of tension:

In the next five to ten years, additional states in regions of proliferation concern may seek advanced, civilian nuclear technology including uranium enrichment and plutonium reprocessing capabilities. Additional enrichment plants and reprocessing facilities are the most proliferation-sensitive parts of the fuel cycle, and more of them are unnecessary during the next decade for creating robust civilian nuclear power capabilities. The United States should as a matter of policy discourage additional countries from building enrichment or plutonium separation plants and work toward new bilateral and regional agreements banning them.

12) Gain and verify pledges to renounce illicit nuclear trade:

No matter the progress that is made on preventing the emergence of future illicit trade and transshipment outposts, the demand-side of the problem must be addressed. Most illicit nuclear trade is driven by a handful of states. As a result, the U.S. government should make it a policy to gain verifiable commitments from states that they will renounce illicit nuclear trade practices.

13) Obtain additional state commitments not to proliferate:

Additional state commitments not to proliferate are important to establish and verify. In particular, there is a need to ensure that Iran, North Korea, and Syria agree not to transfer nuclear materials, reactors, centrifuges, other nuclear facilities or equipment, or the means to make such equipment or facilities to any state, company, or other entity. The U.S government should seek these assurances as a part of any negotiated agreement with Iran and North Korea affecting their nuclear programs.

14) Prevent non-state actors from obtaining nuclear weapons via illicit trade:

These actors can have significant determination to develop nuclear weapons or sell major capabilities to others that threaten the United States. Countermeasures developed against them today to combat future threats should involve better security over nuclear explosive material and other nuclear assets and prosecuting major rogue suppliers under an international crime against humanity.

15) Implement relevant arms control agreements and extend security assurances:

As ultimate goals, the United States should increase its efforts to obtain legally-binding arms control treaties limiting or banning the creation of nuclear weapons, which will remain bedrocks of nonproliferation efforts. Through caps on fissile material production and bans on tests of nuclear weapons, international security can be more adequately safeguarded and concrete steps taken toward global nuclear reductions or disarmament.

The goal of these remedies and countermeasures is to increase the obstacles faced by states and their illicit procurement networks and reduce the chances that new states or terrorists will be able to proliferate nuclear weapons. These remedies are vital to strengthen and put in place now to close these looming new loopholes in global counter proliferation systems.

SECTION I

1. Projections of Countries Likely to Pursue Illicit Nuclear Trade

As a short term projection over the next five to ten years, several additional states in dangerous regions of the world, along with terrorist organizations, may seek nuclear weapons. Certain countries with nuclear weapons will continue improving their nuclear arsenals. Others may seek sensitive nuclear facilities, despite U.S. government opposition, but stop short of making nuclear weapons.

For most of these countries and certainly for terrorists, illicit trade in nuclear and nuclear-related commodities will remain critical to obtaining nuclear capabilities or seeking or improving nuclear weapons. Illicit nuclear trade, or trafficking in nuclear commodities or technologies, is defined as trade that is not authorized by: 1) the state in which it originates; 2) under international law; 3) the states through which it transits; or 4) the state to which it is imported. The report assesses the next countries and actors likely to use illicit nuclear trade to obtain a range of nuclear or nuclear-related goods to outfit covert or sanctioned nuclear programs.

For most countries, illicit nuclear trade has been an essential part of acquiring the wherewithal to make plutonium and highly enriched uranium (HEU) for nuclear weapons and the means to make the nuclear weapon itself, a process often called nuclear weaponization. Of the roughly two dozen countries that have pursued or obtained nuclear weapons during the last several decades, almost all of them depended importantly on foreign supplies.[1] These nations have sought complete nuclear facilities, subcomponents of facilities, nuclear materials, classified know-how, and manufacturing capabilities to make key components.

There is little risk that legitimate suppliers in the developed world will sell reprocessing or uranium enrichment plants to developing countries in regions of tension. Unable to acquire complete facilities, these developing countries instead seek nuclear subcomponents and "dual-use" goods with ostensibly civil purposes that could enable them to build and operate such nuclear facilities on their own. Control of dual-use goods is particularly challenging because proliferators try to mislead suppliers into believing they are for a civilian, non-nuclear use.

Illicit nuclear trade will likely continue well into the future. Figure 1 shows a projection of countries which may use illicit trade in the next five to ten years to create or supply covert or sensitive nuclear programs.

[1] Thomas C. Reed and Danny B. Stillman, *The Nuclear Express: A Political History of the Bomb and Its Proliferation* (Minneapolis, MN: Zenith Press, 2009); Institute for Science and International Security (ISIS), "Nuclear Weapons Programs Worldwide: An Historical Overview." http://isis-online.org/nuclear-weapons-programs/

Figure 1: Illicit Nuclear Trade Consumers in Next Five to Ten Years[2]

I. NPT states which may conduct some illicit trade	II. Non-NPT signatory states expected to maintain or improve nuclear arsenals via illicit trade (in violation of originating state laws and international law)	III. Nuclear Aspirant States, dependent on illicit trade	IV. Developed countries/ territories to worry about seeking nuclear weapons via illicit trade and probability of them doing so, particularly in light of North Korea's advancing nuclear program	V. Developing or emerging market countries to worry about developing nuclear weapons or capabilities via illicit trade, in light of Iran's advancing nuclear program	VI. Non-state actors of concern
China; particularly with regard to improving its own nuclear weapons, targeting intellectual property and related improvement-focused technologies	Pakistan	Iran	South Korea (low probability)	Egypt (low to medium probability)	Al Qaeda
	India		Taiwan (low)	Algeria (low)	Other terrorist groups, particularly in failed states
	North Korea		Japan (low)	Turkey (medium)	Transnational smuggling networks
	Israel, on occasion			Saudi Arabia (medium)	
				Syria (low, given civil war)	
				Failed states in Africa and Asia (low)	

[2] This table is a snapshot of illicit nuclear trade consumers in the next five to ten years. The countries and sub-national groups in the table buy or would need to purchase key equipment and materials illicitly to produce or improve nuclear weapons. Russia, Britain, France, and the United States do not engage in illicit trade to maintain their nuclear arsenals and are excluded. As discussed in the text, developed countries may still need or want to depend on foreign suppliers to build nuclear weapons if they decided to do so. They would use illicit procurement likely to reduce costs or increase the pace of their sensitive nuclear or nuclear weapons program.

For countries in the developing world, the pathway to obtaining and improving nuclear weapons will still require illicit nuclear trade. Other, more developed or newly industrialized countries are more independent, but the fact that the global marketplace is increasingly interconnected means that countries often do not seek self-sufficiency in the manufacture of all the goods that would be needed to make nuclear explosive materials or the nuclear weapons themselves. Thus, these countries as well may seek out high-tech, dual-use goods abroad.

Several states with nuclear weapons, including India, North Korea, Pakistan, and perhaps China, are expected to continue procuring abroad to maintain or improve their nuclear arsenals. Pakistan's smuggling operations date to the 1970s and are expected to endure. India, on one hand, seeks parts, equipment, and technology for its civilian nuclear power program, an effort facilitated by the 2008 U.S.-India agreement on civilian nuclear trade, while at the same time engaging in illicit activities to obtain key items for its unsafeguarded nuclear facilities and nuclear weapons program.[3] China appears self-sufficient in maintaining and improving its nuclear arsenal, but suspicion remains that it seeks classified know-how and advanced goods from other nations to improve its nuclear forces. Israel used to conduct extensive illegal procurements for its nuclear program, but under pressure from the United States, it largely stopped this practice in the mid-1990s. Advanced industrialized countries, such as France, the United Kingdom, and the United States, do not need illicit trade to maintain their nuclear arsenals. Less is known about Russian practices, although in general it is seen as self-sufficient.

Iran is widely suspected to be pursuing nuclear weapons. It currently conducts smuggling operations regularly to outfit its sanctioned nuclear programs, and it did so to supply its secret nuclear weapons program until at least 2004, according to information from the International Atomic Energy Agency (IAEA).[4] Its wide-ranging illicit procurement attempts center on outfitting its growing gas centrifuge program and Arak nuclear reactor project in defiance of a host of supplier countries' national trade controls and of United Nations Security Council sanctions resolutions that require Iran to suspend both programs. There is hope that the crisis over Iran's nuclear programs can be solved and it will abandon its uranium enrichment and indigenous reactor programs. However, prospects for such a comprehensive solution are currently not promising, given the failure of several rounds of negotiations between Iran and the P5+1. Without such a settlement, Iran is expected to continue illicitly seeking goods abroad for its sanctioned nuclear programs and perhaps a nuclear weapons program.

If Iran's and North Korea's nuclear ambitions remain unchecked, in direct defiance of the major powers in the United Nations Security Council and other key UN member states, the international community could face the prospect of several other states seeking nuclear weapons

[3] See David Albright, *Peddling Peril: How the Secret Nuclear Trade Arms America's Enemies* (New York: Free Press, 2010) and ISIS, "Illicit Trade: Case Studies." http://isis-online.org/studies/category/illicit-trade/

[4] Report by the Director General, International Atomic Energy Agency (IAEA), *Implementation of the NPT Safeguards Agreement and the relevant provisions of Security Council resolutions in the Islamic Republic of Iran,* November 8, 2011. http://isis-online.org/uploads/isis-reports/documents/IAEA_Iran_8Nov2011.pdf . See also David Albright and Christina Walrond, "The Trials of German-Iranian Trader Mohsen Vanaki: The German Federal Intelligence Service Assesses That Iran Likely Has a Nuclear Weapons Program," ISIS, December 15, 2009. http://www.isis-online.org/uploads/isis-reports/documents/MohsenCaseStudy_update_15Dec2009.pdf; and multiple interviews with British, French, and German officials by ISIS staff, 2008 and 2009.

and a severely weakened world order to stop proliferation. A range of countries may seek nuclear weapons capabilities, particularly in the Middle East and North Asia.

In the Middle East and North Africa region, Saudi Arabia, Egypt, and Turkey are often discussed as states that may see a nuclear armed Iran as sufficient motivation to seek sensitive nuclear capabilities, particularly uranium enrichment or plutonium separation plants, and perhaps nuclear weapons. Countries, including the United States, would be expected to oppose such efforts, and this opposition could involve efforts to block procurement of needed goods to build and operate sensitive nuclear facilities. All three of these countries, or for that matter, other Arab countries in the Middle East would today and in the future require overseas procurements to build sensitive nuclear facilities. In the next five to ten years, only Turkey is assessed as becoming fully industrialized, although even then, it will likely not be self-sufficient in all the goods needed to build the complex of facilities able to produce separated plutonium or highly enriched uranium, let alone deliverable nuclear weapons.

In North Asia, North Korea's expanding nuclear weapons program and belligerence have unsettled neighboring countries. The South Korean public and some Korean politicians and experts have begun advocating the acquisition of nuclear weapons, although there is no sign that the government would support such a move.[5] However, over the next five to ten years, that attitude could shift, particularly if North Korea overtly deploys nuclear weapons and is perceived as succeeding at being begrudgingly accepted as a nuclear weapon state, similar to the status Pakistan and India achieved. Few believe Japan would build nuclear weapons but pressures from certain domestic constituencies to do so could grow with time.[6] Similarly, Taiwan is unlikely to build nuclear weapons in the immediate future but it may feel motivated to do so in the longer term. It has attempted to build nuclear weapons twice in the past. The second attempt, in the late 1980s, included starting the construction of a small plutonium separation plant and developing a design for a nuclear weapon small enough to fit under the wing of an attack aircraft.[7] All three of these countries are industrialized, but if they decide to seek nuclear weapons, they would still likely procure certain goods from overseas suppliers as a way to reduce costs and increase their pace of building nuclear weapons.

Making predictions about additional countries is difficult. Myanmar is likely no longer interested in nuclear weapons if its apparent interest was indeed concrete. In 2012, the regime took dramatic steps that distanced it from nuclear weapons, including announcing plans to sign the IAEA's Additional Protocol, which should help allay international suspicions about past and possibly ongoing interest in nuclear weapons.[8] But its delay in actually ratifying the Additional Protocol means that it should be monitored for any future signs of interest in proliferation or cooperation with North Korea. Other south or southeastern Asian countries are not suspected of having nuclear weapons ambitions today or in the next several years.

---

[5] Denny Roy, "South Korea: Give Nukes a Chance." *Asia Pacific Bulletin* (Washington, D.C.: East-West Center, March 27, 2013), No. 204. http://www.eastwestcenter.org/publications/south-korea-give-nukes-chance; Barbara Demick, "More South Koreans Support Developing Nuclear Weapons," *The Los Angeles Times*, May 18, 2013.
[6] "More South Koreans Support," op. cit.
[7] David Albright and Corey Gay, "Taiwan: Nuclear Nightmare Averted," *Bulletin of the Atomic Scientists*, January/February 1998, vol. 54, issue 1, p. 54.
[8] "Clinton Urges Myanmar to Sever 'Illicit Ties' with North Korea," Agence France Presse. December 1, 2011.

In Latin America, despite the lack of evidence of nuclear weapons work, concerns periodically emerge of nuclear weapons ambitions among some countries, more recently Brazil and Venezuela under former President Hugo Chavez. Any such effort would be intensely opposed by the United States, the European Union (EU), and Japan, all critical suppliers and trading partners to Latin American countries. There is more concrete worry that governments will seek sensitive nuclear facilities or capabilities in order to create latent nuclear capabilities. Brazil's navy has for several decades operated a centrifuge complex, albeit safeguarded and committed to peaceful use since 1990. Brazil states it will use this facility to make enriched uranium, possibly HEU, for nuclear powered submarines. It is unlikely the United States would support such a submarine or the use of HEU fuel. However, few governments have considered trying to block acquisitions for Brazil's military centrifuge plant or nuclear powered submarines.

Of course, there could be surprises. Regional powers and tensions could shift unexpectedly and opportunities to acquire nuclear weapons could emerge that are too tempting to refuse. There remains the risk of new "nuclear wannabes" whether they are states or terrorist groups.

Terrorist Groups

Terrorist groups, such as Al-Qaeda, are expected to continue attempting to acquire the ability to build "improvised nuclear explosive devices," or crude atomic bombs. However, few would assess that a terrorist group would be able in the next decade to successfully make plutonium or HEU. Therefore, their main constraint is expected to remain having access to sufficient nuclear explosive material for a nuclear explosive or to a complete, operational nuclear weapon.

As a result, programs to better protect stocks of plutonium and highly enriched uranium are critical. Given the sheer quantity of such materials in the world and the inadequate controls over them in some countries, the constraint of lack of access is not strong enough to eliminate the possibility of a terrorist group acquiring enough fissile material for a nuclear explosive.

In order to fashion a nuclear explosive, a terrorist group would need additional technology, equipment, and materials. One concern is that terrorists could buy detailed nuclear weapon designs from black marketers or rogue suppliers, easing their task of building improvised explosive devices. Armed with a design, a terrorist group would need to acquire equipment and materials to convert the fissile material into bomb components and construct or acquire a range of other components. This effort to weaponize would likely require the procurement of a range of nuclear dual-use goods.

A terrorist group would also need a safe location to assemble the components and expertise to build the nuclear explosive. Lawless regions of the globe could hide such efforts by terrorists. Failed or quasi-failed states in Africa or Asia might be suitable locations where a terrorist group could import the equipment and materials to cobble together its own crude nuclear weapons.

Nuclear weapons are in general easier to protect than stocks of separated plutonium and highly enriched uranium. However, extreme care is needed to prevent terrorists from gaining access to operational nuclear weapons. One special concern is Pakistan. A collapsing Pakistan could offer

terrorists access to a complete nuclear weapon, whether by an internal actor smuggling such a device or through an outside takeover by a terrorist group.

Proliferation May Worsen

The problem of nuclear proliferation may augment in the next few decades. Several states can be expected to seek nuclear weapons and those that have them can be expected to work to improve them. Moreover, despite U.S. opposition, some states may seek to build sensitive nuclear facilities, such as uranium enrichment or plutonium separation plants, ostensibly for civil purposes.

Given the priority states give to nuclear weapons programs, states seeking sensitive nuclear capabilities will likely have the economic resources to pursue these goals over the next decade. One key part of this effort will remain smuggling of nuclear commodities.

2. The Scope of the Threat: Smuggling in Nuclear and Nuclear-Related Commodities

Nuclear smuggling operatives and networks have become very sophisticated over the last several decades. They have proven adept at adapting and learning to defeat national and international efforts to stop them. With illicit nuclear trade so fundamental to proliferation, those opposed to the spread of nuclear weapons have long focused on strategies to stop it. Unfortunately, these strategies often do not succeed because of the special difficulty of stopping nuclear wannabe countries which devote considerable effort to undermining these strategies. States such as Iran, North Korea, and Pakistan currently drive illicit nuclear procurement networks. Their official nuclear programs, sometimes with the help of domestic intelligence agencies, create state-sponsored procurement networks that seek to hide the true purpose of goods and identify the most effective ways to bypass or find loopholes in export regulations.

Smuggling networks themselves have learned that suppliers in any country, including the United States with its extensive export laws, can be tricked into selling sensitive goods. For example, U.S. authorities in 2012 announced the arrest of a man in the United States for allegedly sending sensitive vacuum pump equipment manufactured or sold in the United States to Dubai, which they suspect was routed to Iran's gas centrifuge program.[9] Smuggling networks typically route their illegal procurements through transit countries with weak or nonexistent export controls, or, in the case of the United Arab Emirates (UAE), such a large volume of trade with Iran that sensitive exports may slip through. By using trading companies in third countries, international shippers, and complex payment schemes, these networks can use any country as a transshipment point, often called a "turntable." Popular turntables have included the UAE and Malaysia, both well-known for lacking robust controls until recently, especially in the case of UAE which has significantly strengthened monitoring and controls over transfers to Iran. Other turntable examples that have taken steps to improve their records have included Canada, Poland, Singapore, South Korea, Taiwan, and Turkey.

The European Union faces persistent Iranian smuggling attempts. It is home to many high tech companies that make quality goods needed by Iran's nuclear and missile programs.

In one scheme, Iran sets up an agent in one EU country to buy goods made in another EU country. Because the transactions are within the EU, no export license is required and scrutiny by authorities can be weak. Once in possession of the goods, the agent smuggles the goods to Iran. A recent case highlights this problem and also shows that closer cooperation between EU countries can stop this type of smuggling scheme.

Shahab Ghasri, originally from Iran but a naturalized Swedish citizen, ran a small Swedish trading company and was convicted in 2013 for attempting to illegally export valves.[10] He attempted to

[9] David Albright and Andrea Stricker, "Major U.S. Sting Operation Arrests Iranian in Nuclear Smuggling Network," ISIS, August 12, 2012. http://isis-online.org/uploads/isis-reports/documents/US_case_gas_centrifuge_equipment.pdf

[10] Swedish indictment of Shahab Ghasri, September 24, 2011. http://www.exponerat.info/wp-content/uploads/2012/12/iranier_Smuggling-tekn-utrust-Iran-B-3487-11-stämning.pdf *; Report of the Panel of Experts on Iran established pursuant to resolution 1929 (2010)*, June 5, 2013, paragraphs 23-27 and 111.

export eleven advanced valves in 2011, some of which were highly corrosion-resistant.[11] Some of these valves are known to be used in Iran's centrifuge program, according to a centrifuge expert consulted by ISIS. Ghasri also sought dual-use vacuum pumps prepared for use with corrosive gases from a German supplier that were of a type that could be used in Iran's centrifuge program, although whether he obtained any is unknown. His company appears to have had no other purpose than to procure high quality dual-use goods from Western suppliers for Iranian entities. He was reportedly approached by Iranians to establish a trading company in a European country solely for the purpose of procuring items to be shipped to Iran.[12] He would receive a commission, which was sometimes substantial, for his exports. The attempted shipment involved changing the name and address on the air waybill of the consignee in a third country, to one in Iran, after the details had been submitted to Swedish customs for clearance procedures.[13] He did not inform Swedish customs authorities of this change in address. Media identified that consignee as located in Dubai.[14] The investigation uncovered an invoice from Ghasri's company to the Dubai company, Dragon Offshore, which was part of the Royal Oyster Group.[15]

Ghasri's activities were first detected as a result of Suspicious Transaction Reports submitted by two Swedish banks in late 2010 and early 2011.[16] Suspicions increased when German authorities alerted Swedish customs authorities to Ghasri's suspicious procurement attempts from German companies. Based on these concerns, Ghasri's shipments were inspected and the valves found. The investigation revealed that he had made many previous exports to Iran. The Swedish court ruled that Ghasri would have been aware of EU restrictions on trade with Iran. No one else involved with Ghasri appears to have been prosecuted. In May 2011, the United States designated Royal Oyster Group under U.S. sanctions against Iran, although the United States did not state whether the imposition of sanctions was related to this case.[17]

The European Union is also targeted as a turntable by proliferant states. In these schemes, the original supplier outside the EU believes it is supplying a reliable and export control compliant EU partner, but the goods are then sold to less and less reliable and compliant companies within the EU, ultimately reaching a company that is under the control of a smuggler. At this point, the proliferant state is in control of the goods and can smuggle them out of the EU. The multiple sales and transfers within the EU do not require an export license or special scrutiny by authorities

---

[11] "Man Charged for Breaking Iran Nuke Sanctions," *The Local, Sweden's News in English*, December 4, 2012; Swedish indictment, op cit. His conviction was reported in "Swedish Man Found Guilty of Breaking Iran Embargo," Agence France Presse. February 6, 2013.

[12] *Report of the Panel of Experts on Iran*, June 5, 2013, op. cit, par. 111.

[13] *Report of the Panel of Experts on Iran*, June 5, 2013, op. cit., par 24; "Man Charged for Breaking Iran Nuke Sanctions," op. cit.; and "Iranier åtalas för smuggelförsök av förbjuden utrustning till Iran," *Exponerat*, December 5, 2012. http://www.exponerat.info/iranier-atalas-for-smuggelforsok-av-forbjuden-utrustning-till-iran/#ixzz2ZVIMD3ey.

[14] "Man Charged for Breaking Iran Nuke Sanctions," op. cit.; and "Iranier åtalas för smuggelförsök av förbjuden utrustning till Iran," op. cit.

[15] Swedish Indictment, op. cit., p. 3; Royal Oyster Group Twitter page, https://twitter.com/RoyalOysterGrp. Royal Oyster Group acquired Dragon Offshore in 2008.

[16] *Report of the Panel of Experts on Iran*, June 5, 2013, op. cit.

[17] "Persons on Whom Sanctions Have Been Imposed Under the Iran Sanctions Act of 1996," Bureau of Economic, Energy and Business Affairs, September 6, 2011. http://www.state.gov/e/eb/rls/othr/2011/172350.htm. The sanctions on Royal Oyster Group became effective May 24, 2011.

because they occur internally, despite the fact that the effectiveness of export controls in individual EU states can vary dramatically. The goods are often controlled under export control lists.

In addition, when goods are sold by foreign countries to the EU, such as by the United States to an EU country, the supplier often does not pay close attention to the end user. That EU end user is typically a responsible end user in a trusted country which in turn is a member of the Nuclear Suppliers Group. This EU recipient sells the goods to a company in another EU member state, where no export license or special scrutiny is needed for the transaction.

In the case of Iran, goods purchased in the EU would typically be trucked to Iran via Turkey once in the control of a company working for Iran. In the last few years, Iran used this smuggling method to acquire significant quantities of high quality carbon fiber, a good usable in its advanced gas centrifuges. The carbon fiber, made in Japan, was sold to a U.S. company, which in turn sold it to an EU country. It was subsequently sold to other companies within the EU, and ultimately trucked to Iran via Turkey.

A far more pressing concern is China. It is the location of many subsidiaries of foreign high-technology companies and a growing number of domestic manufacturers of sophisticated dual-use goods. Iran and North Korea regularly exploit loopholes and weaknesses in Chinese trade control and sanctions enforcement efforts to obtain goods for their nuclear programs. China is discussed in greater detail in a later section.

Smugglers use a wide variety of approaches to obtain goods, varying from legal to illegal methods and from straightforward to highly deceptive schemes.[18] Box 1 below lists several common methods used in illicit schemes to obtain goods from suppliers. A few of these methods are using trading companies to hide the actual end user, identifying and exploiting countries with weak export controls, or seeking less than ideal goods, or those "just below" in quality or technical specifications of those on dual-use or direct use control lists.

The simplest procurement scheme involves a nuclear program or one of its domestic agents making a direct order to a supplier, where the supplier believes that the end-user is a civilian, non-nuclear program. Another, more complex scheme involves the use of a chain of one or more trading companies, possibly located in different countries, to buy goods. The original order from the nuclear program is first sent to a domestic trading company, which orders the goods through a succession of foreign trading companies, the last of which then contacts a supplier. Sometimes the trading companies are duped; after all, the vast majority of all trading companies are legitimate and law-abiding. Some, however, are well aware that the actual end-user is a nuclear program or at least not what it appears.

In a more devious scheme, network operatives convince manufacturing companies themselves, with clearly legitimate reasons to acquire dual-use equipment or materials, to buy the goods for them, in essence acting as trading companies but without the trading companies' questionable *bona fides*. Networks have developed a more elaborate ruse by arranging off-shore manufacturing

[18] For more in-depth studies of these strategies, see Albright, *Peddling Peril*, op. cit. and "Illicit Trade: Case Studies," op. cit. See also *Report of the Panel of Experts on Iran*, June 5, 2013, op. cit., Annex VIII, which contains a list of common indicators that an enquiry is suspicious and intended for use in a sanctioned nuclear program.

of nuclear components using materials, equipment, and subcomponents bought by trading companies, all while conniving to hide the true end-user from the suppliers, trading companies, and the off-shore company.

Box 1: List of Common Smuggling Methods, compiled from procurement cases
I. Ordering Related Schemes-
Obtaining goods from a state with weak or non-existent export controls
Seeking less than ideal goods, "just below" in quality or technical specifications of those on dual-use or direct use control lists
Seeking dual-use goods for ostensibly non-nuclear uses via front or trading companies, claiming they will go to legitimate domestic companies (important examples being Iran's petro-chemical or automobile sectors)
Using barrage approach--sending out multiple enquiries for one good to many companies or multiple subsidiaries of a single company in hopes one will make a sale
Exploiting trusted company distributors to acquire goods (they can order the goods without suspicion)
Obtaining goods from within the supplier state so that the sale looks to be a domestic sale; then shipping the goods abroad illegally with false documentation (while riskier, this method avoids the need to supply a false end use declaration)
Using aliases to obscure sanctioned or suspicious company names or locations from authorities, bank screening systems, or company compliance officials
Operating small import/export operations disguised as larger ones
II. Shipping Related Schemes-
Using trading companies abroad, even multiple trading companies located in different countries, to acquire and then transship, obscuring the actual end user
Transshipping or re-exporting goods via multiple countries to hide the actual end user
Operating in a Western country not known for illicit trade and then transshipping elsewhere
Abusing international shipping arrangements; altering customs and shipping labels to phony product descriptions, undervaluing contents, altering labels and values upon

transshipment
Sending goods to a freight forwarder in a foreign country; from this location, the goods would be illegally retransferred
III. Financing Related Schemes-
Paying a hefty premium to obtain goods and services
Abusing the international financial system by the use of aliases, fraudulent paperwork, methods of obscuring the country of origin, and by transacting via multiple banks
Using more elaborate schemes to exploit the financial system, such as hiring an accountant or financial official in a legitimate company in another country who is willing to falsify records and documents, or buying or taking control of a bank overseas
IV. Proliferant State as Supplier Schemes-
Rogue or semiautonomous illicit trade networks growing out of state illicit procurement efforts, such as the Khan network
Proliferant states outfitting others using their established procurement networks
Operating manufacturing sites in a foreign country that supply the proliferant state with key components—the offshore manufacturer may not even know who or what it is really supplying

Structure of Illicit Nuclear Trade Networks

Today, illicit nuclear trade efforts aim to procure nuclear direct-use and dual-use goods, many of which are controlled by national and international trade control regimes. The organization of these efforts has a network structure, which differs, for example, from a hierarchical structure. A hierarchical structure entails all entities subordinate to a primary entity. A network in the nuclear trafficking sense is made up of an interacting collection of companies and individuals engaged in the process of procuring nuclear goods or capabilities, with no clear hierarchical structure. A network structure includes all aspects of the activities necessary to organize the acquisition of goods and deceive suppliers, including ordering goods, paying for them, and shipping them.

A network is a collection of "nodes" which can represent a company, a person, or a state procurement organization. These nodes are connected by interactions, typically represented by lines, which can represent orders, shipments, or enquiries. A node that has many connections is referred to as a "hub." A hub could be the nuclear program itself, a domestic procurement organization operating on its behalf, or a particularly active trading company seeking many goods from a variety of suppliers. Later, the report references other "hubs," such as shipping hubs, transit

hubs, and proliferation financing hubs. Each should be understood to be a center of major activities where some loose direction or coordination occurs to ensure all of the network's nodes, whether aware or unaware of the nature of the network's activities—including companies, shipping agencies, smugglers, middlemen or brokers, and banks, for example—are effective. In other words, they must be securing the needed goods for the proliferant state's nuclear programs.

Illicit trade networks must abuse normal trade arrangements to obtain goods. However, it should be emphasized that the goods are not in and of themselves illegal or contraband and the networks are not standard criminal networks.

Nuclear smuggling networks are usually comprised of at least several of these major components—each a proliferation node, or hub, if the node is particularly active. Many networks have some or all of the following main components, such as:

- A state nuclear program or complex which compiles lists of needed goods;
- A domestic nuclear procurement organization which receives the lists of needed equipment from the state nuclear program and organizes their procurement domestically and abroad;
- Often domestic front or trading companies working under contract for the nuclear procurement organization to obtain goods;
- Other front or trading companies or middlemen/brokers usually located abroad and further removed from the nuclear procurement organization, which are hired by the domestic front or trading company or the nuclear procurement organization for the purpose of placing orders for goods;
- Suppliers of goods;
- Intermediaries involved in shipping and logistics;
- Banks, financial institutions, or informal payment structures which wittingly or unwittingly facilitate financing for the goods.

Networks of traffickers, suppliers, and trading companies are connected by requests for price quotes, orders, shipments, payments, and other communications and transactions. In network parlance, these connections are represented by lines connecting the nodes.

There are a variety of individuals who are part of an illicit nuclear trade network. Typically nuclear and procurement experts working within the nuclear complex and its nuclear procurement organizations are at the "center" or comprise a core "hub" of the network. Business, financial, and logistical people are in outer nodes surrounding the hub. They are more removed from the nuclear complex and are closer to the supplier. Figure 2 shows an illicit trade network with the key procurement agencies located at the hub. The entities and actors at the core of the network are typically removed from contact with the supplier, making them difficult to detect behind any procurement attempt.

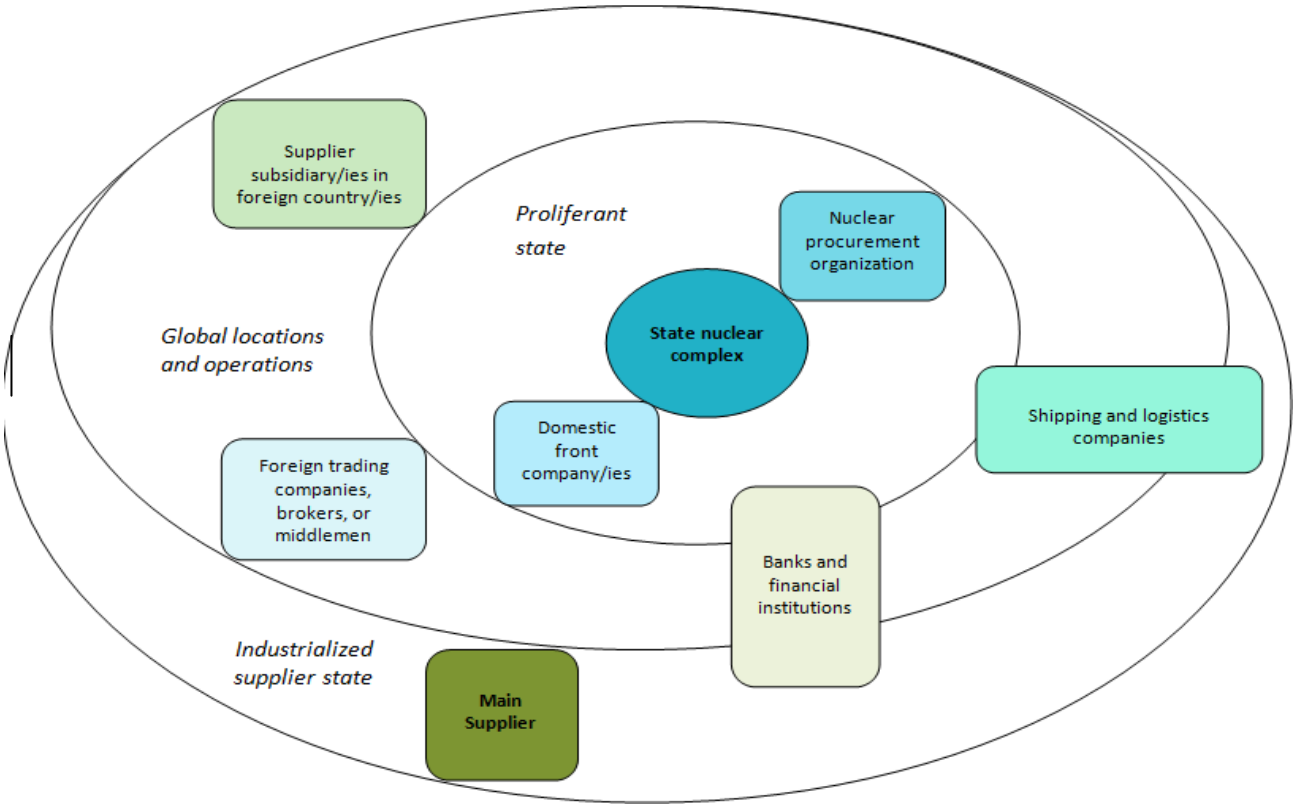

Figure 2: Depiction of actors/entities in a large illicit nuclear trade network (connecting lines are omitted for the sake of clarity)

The domestic trading company that contracts with the state's procurement organization may be engaged in a range of legitimate business activities in addition to illegal ones. It may seek goods abroad directly from suppliers or indirectly via other trading companies located in other countries. Sometimes, the domestic trading company, or its agent, will even find a legitimate manufacturer in a third country to order the goods from a supplier.

The nuclear program or its procurement organization may also establish their own front companies, either domestically or off-shore. These companies will typically conduct both legitimate and illicit business, and they could be located anywhere. They will in general know that their purchases for the nuclear organization are illegal. The front company may be little more than a postal address. The company's name may be frequently changed or it may have multiple names as a means to hide its existence from authorities and its connection to the nuclear program.

Front companies and trading companies play an important role in the ordering process. Their goal is to find a supplier of the goods, despite increasing trade controls and suppliers' internal compliance systems aimed at defeating illicit trade. To achieve that goal, they will contact the supplier, often initially via an e-mail seeking a price quotation for specific goods, where it is trying to look like a legitimate customer. At the same time, they may contact a number of suppliers and their subsidiaries, probing for a "weak link" that is willing to provide the goods. Once the front or

trading company finds a willing supplier, it needs to place an order and arrange delivery and payment. Figure 3 of a Pakistani trafficking network illustrates an illicit trade network carrying out all facets of an illicit procurement scheme—ordering, shipping, and payment. It shows many of the components described above. As stated, not all such networks will contain each of the components listed.

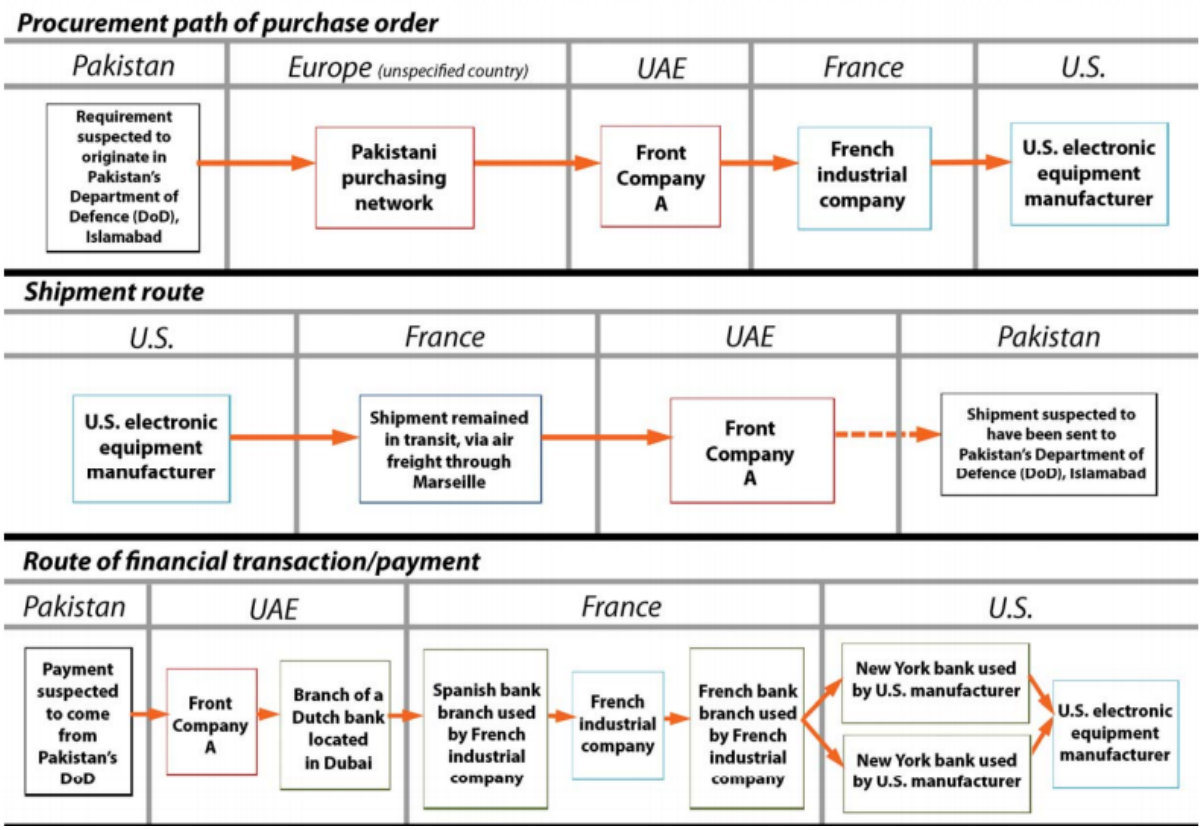

Figure 3: Pathway examples of an illicit procurement network's activities.[19] This figure shows the flow of orders, goods, and money through a network.

An illicit trade network may also seek the services of a broker to obtain goods or other services. Trade control laws traditionally have been slow to control brokering of dual-use goods, unless their use in a nuclear weapons program is demonstrated. A broker may be located in one country and arrange the purchase of goods from a different country and their transport to still another country, or even the country hosting the banned nuclear program. In addition, a broker may assist in providing insurance, financing, and transportation and logistics. Brokers are often individuals operating small companies and are usually mobile and able to operate from many states.

In summary, globalization and the ease of international travel, communication, and trade has provided illicit trade networks with many opportunities to obtain goods for sanctioned nuclear programs or nuclear weapons programs. These networks try to mask their procurements as

[19] Figure from case study, David Albright, Paul Brannan, and Andrea Scheel, "Pakistan's Illicit Procurement of Missile and Drone Equipment Using Multiple Financial Transactions," ISIS, January 28, 2009. http://isis-online.org/uploads/isis-reports/documents/Pakistan_Financial_28January2009.pdf

legitimate trade. The purpose of the various intermediaries is to help hide the real end user from the supplier and authorities. Sometimes these intermediaries in the network are unaware of the actual end-use of procurements, but other times they are aware or choose to turn a blind eye to the real purpose of the goods.

Illicit trade networks place orders for goods in or from countries with weak trade controls that do high volumes of international trade, frequently using free trade zones to hide illegal retransfers of goods to the final end user. To obtain goods in supplier countries with well-developed export controls, the networks rely more on false end-user statements and fraudulent shipping documents. Shipments and payments are arranged with the intention of hiding the true end user. Box 1 above illustrates some common methods used by smugglers to illicitly obtain nuclear and nuclear dual-use goods.

For many of the types of goods sought by an illicit trade network, the false end-use statement is a critical document, required by most exporting countries. The network will try to establish for the supplier that the end use is in a third country that is seen as responsible and that the end-user is a company that has a legitimate need for the goods. Or, the smugglers will claim the end-user is in a country that has weak or nonexistent export controls, so when the goods are sent to this third country, they can be more easily retransferred to the actual nuclear program that is banned from receiving them.

The international shipment of illicitly obtained goods often involves major transportation centers where cargo is sorted and redistributed for shipment onward. Major shipping nodes have included Hong Kong, Singapore, and Malaysia. In addition, goods sometimes pass through free trade zones, such as the Jebel Ali free trade port in the United Arab Emirates. Both transportation centers and free trade zones are sometimes used as the declared end destination of goods actually destined for another country. Often, these areas have less stringent export controls, making it easier for the illicit network to retransfer goods to their final destination.

Paying for illicitly acquired goods requires access to the international financial system and the source of the money paying for those goods must be hidden from law abiding financial institutions and national authorities. Rarely does a proliferator use bags of cash. The purchases are made from legitimate suppliers which expect to conduct business, including being paid, in a normal, legitimate manner. Front companies and intermediaries also expect a decent profit for their efforts. Schemes to route money from the actual end-user to the supplier and intermediaries can be complex, involving more than one bank and multiple transfers across borders.

Iran's and North Korea's Procurements

Over three decades, Iran has become quite experienced at smuggling for its nuclear programs. Its shopping lists are likely assembled by Iranian procurement organizations within state entities, such as the Defense Industries Organization (DIO), Aerospace Industries Organization, Aircraft Industries Group, Iran Electronics Industries (IEI), and the Atomic Energy Organization of Iran (AEOI). These entities are not likely to procure goods directly from foreign suppliers, although in the past they did so. Faced with tighter controls and sanctions but seasoned in exploiting loopholes in national and international trade control laws, Iran's procurement organizations have created

networks of domestic and foreign trading companies and agents that seek the necessary goods from abroad.

Iran also relies on a range of domestic Iranian middlemen and companies to fill orders from state entities. Often, however, with increased awareness and stronger export controls, these Iranian companies have a difficult time obtaining sensitive goods directly from Western suppliers, still the main target for high-technology items for Iran's nuclear programs. These individuals and companies seek out foreign trading companies that will approach suppliers. There may be several successive middlemen abroad handling a single procurement—further obscuring from suppliers the actual person or organization behind the procurement. Sometimes, the trading companies know the true end use of the goods; oftentimes, they do not. But most are willing to certify to suppliers that the end user is civilian and the item is not intended for Iran. They falsely list, for example, Dubai, Malaysia, or China as the final destinations.

As economic sanctions on Iran have increased and Iran has created more sophisticated procurement operations, these foreign middlemen try to convince suppliers that Iran will not receive any goods. It is the foreign middlemen that typically make the purchases, take most of the risks, and serve to shield the inner, Iran-based procurement core from discovery or prosecution. There have been many arrests of these outlying network operatives, and despite how valuable they are in supplying Iran's nuclear, missile, and conventional military programs, Iran has often viewed these operatives as expendable and easily replaceable.

North Korea's smuggling efforts are highly centralized and appear to be directed by the government and nuclear programs. For example, North Korea will often use government officials stationed at embassies to conduct illicit procurement related business. It has also established North Korean entities abroad under the government's control that seek goods. It uses North Korean expatriates who own companies in China to procure needed goods that contract with private Chinese trading companies and middlemen. In the past, North Korea has also cooperated closely with other governments, such as Pakistan, that have been willing to provide training or needed goods and sensitive technologies.

Currently, North Korea concentrates its smuggling efforts in China, which has inadequately implemented and enforced trade control laws and regulations. One result is that fewer North Korean procurements are detected by Western intelligence agencies or made public.

Major Nuclear Proliferation Networks: A.Q. Khan Network

Particularly dangerous are nuclear proliferation networks such as the one headed by the Pakistani scientist Abdul Qadeer Khan that was exposed and rolled up in 2003 and 2004. The A.Q. Khan network demonstrated that it is possible for a shady transnational network of engineers, industrialists, and businessmen able to sell turn-key nuclear weapons production facilities. At its height, this network was dispersed over three continents and involved numerous individuals and companies that knowingly or unwittingly aided its actual or attempted proliferation sales to Iran, Libya, North Korea, Iraq, South Africa, India, possibly Syria, and perhaps other countries.[20] This

[20] Albright, *Peddling Peril*, op cit. and David Albright and Corey Hinderstein, "Unraveling the A.Q. Khan and Future Proliferation Networks," *The Washington Quarterly*, vol. 28, no. 2, Spring 2005, pp. 111-128.

network rivaled legitimate suppliers of turn-key nuclear facilities in its ability to sell nuclear facilities and capabilities to states.

Removing the A.Q. Khan network root and branch was very difficult. It took an extraordinary effort by the United Kingdom, the United States, and the IAEA to end the network. Nonetheless, only about ten percent of its members have been successfully prosecuted and questions still remain about its customers and the goods it provided.[21]

The Khan network did not survive, but other such transnational networks are currently operating, and new ones might arise in the future. Moreover, the conditions that led to the Khan network remain unchanged: buyers with cash and people with access to classified or critical nuclear know-how, experience with designing as well as building nuclear facilities, trafficking skills, and insensitivity to the dangers of the spread of nuclear weapons. Some may be motivated by ideology or radical religious views to form a new Khan-type network able to supply U.S. adversaries. A developing country could save years in its quest for nuclear weapons by utilizing the services of such a network.

Smuggling Persists

Trafficking networks such as the defunct A.Q. Khan network, and today, Iran's and North Korea's, for example, are flexible and resilient, making their elimination difficult. Overseas trading companies are expendable to proliferant states. Once a trading company serves its purpose, or is discovered by authorities, the illicit trade network can jettison it and find a new one either in the same country or elsewhere. Removing a supplier most likely does not disrupt the network because other suppliers typically exist. Another strength of such networks is that they tend to grow. Networks, once established, inevitably find new partners, or nodes, in an interconnected web of buyers and sellers.

The reason that there are so many willing partners is easy to understand. Companies are typically driven by new business and profits. Working for a proliferant state's procurement network can provide both sizeable profits and steady work. And for many such businessmen, greed can assuage any nagging suspicion that they are assisting a secret nuclear weapons effort. Too often, salesmen take a "don't-ask, don't-tell" attitude about suspicious sales. Some are even willing to pursue sales that they know could further nuclear proliferation, if it lines their pockets. They disassociate themselves from the real, terrifying prospect of nuclear weapons.

Rogue Suppliers

States have also been important suppliers to proliferant state programs. Sometimes these activities have been legal; sometimes they violate international laws. The risk remains that a pariah country will sell nuclear facilities or capabilities to other states. These pariah states could supply materials

---

http://www.twq.wm/05spring/docs/05spring_albright.pdf; David Albright, "ISIS Special Report- Libya: A Major Sale at Last" ISIS, December 1, 2010. http://isis-online.org/uploads/isis-reports/documents/Libya_and_the_Khan_Network_1Dec2010.pdf

[21] David Albright and Michael Rietz, "Closing the Tinners' Swiss Criminal Case," ISIS, October 26, 2012; and *Peddling Peril*, op. cit.

and technology—alone or with a network. In addition, unauthorized government entities in a pariah country, or even criminal elements, could supply a proliferant state or a country seeking nuclear capabilities without their government's knowledge. These actors are termed in this report "rogue suppliers."

North Korea. The Pyongyang regime occupies a special place as a rogue supplier and has demonstrated the capability and inclination to provide nuclear goods and capabilities to customers abroad outside normal commerce and despite international norms and rules. Based on its current trajectory and absent major breakthroughs through negotiations with the regime or other means that lead to fundamental changes in the nuclear policies of the regime, North Korea is unlikely to waver from this role in the future. It has long pursued goods for its own nuclear programs illegally, while selling nuclear or nuclear-related goods to other states. It is also suspected to have acted as an intermediary in procuring conventional military, missile, and nuclear items from suppliers for others, or at least helped facilitate those orders.

North Korea has a long history of subterfuge in carrying out its overseas sales. The May 2011 report by the United Nations DPRK Panel of Experts scrutinized North Korea's illicit, secret exports.[22] Based on interviews with member states, experts, and officials and its independent examination of a number of seized goods, the Panel concluded that North Korea used a number of masking techniques in order to circumvent Security Council sanctions, including false description and mislabeling of the contents of containers, falsification of manifests covering shipments, alteration and falsification of information concerning the original consignor and ultimate consignee of goods, diversion of cargo, and use of multiple layers of intermediaries, front companies, and financial institutions.

For many years, North Korea provided key assistance to Syria in its secret quest to build a nuclear reactor. Many key goods or components reportedly came from North Korea. However, a range of items for the reactor project also came from Western or Chinese suppliers. Although much remains unknown about the supply chain for this reactor, Syria acquired water pumps suspected to be for the secondary cooling circuit of this reactor from a Danish company, and barium sulfate that could have been intended for use in concrete shielding in the reactor or an associated plutonium separation facility from a Chinese company via a Hong Kong intermediary.[23] There is suspicion,

[22] *Report of the Panel of Experts on North Korea established pursuant to resolution 1874 (2009),* May 2011.

[23] One possible indication of construction of a plutonium separation facility was reported by the IAEA. It stated: "Large quantities of barite [mineral containing barium sulfate] were purchased by the AECS [Syrian Atomic Energy Agency] between 2002 and 2006. Syria has stated that the material was to be used for shielded radiation therapy rooms at hospitals, without providing any supporting information. However, the end use of the barite as stated in the actual shipping documentation indicates that the material was intended for acid filtration. Additionally, the delivery of the barite was stopped at the request of the AECS after the destruction of the building at the Dair Alzour [Al Kibār reactor] site and the remaining quantity was left undelivered. Given that barite is frequently used to improve radiation shielding properties of concrete, and the inconsistency concerning the end use of the barite and the involvement of the AECS in its procurement, the Agency cannot exclude the possibility that barite may have been intended for use in the construction of shielded spaces for purposes linked to nuclear fuel cycle related facilities." Report of the Director General, International Atomic Energy Agency, *Implementation of the NPT Safeguards Agreement in the Syrian Arab Republic*, May 24, 2011. One type of shielded space is a hot cell involved in the initial steps of separating plutonium from highly radioactive irradiated fuel. ISIS did not identify the company that obtained the barite beyond it being located in Hong Kong. In addition, the Syrian Atomic Energy Agency had contracted with this Hong Kong company

according to a senior U.S. official close to the IAEA, that Syria was interested in buying from a Swiss company hot cell manipulators that can be used in a plutonium separation plant.[24] While North Korea was the supplier of this reactor, its supply also depended on obtaining certain dual-use goods from other countries. North Korea procured these goods and then shipped them to Syria. In addition, Syria also procured goods, possibly with North Korean assistance. These goods were likely the ones North Korea could not make adequately or economically. Thus, although North Korea was the main supplier, Syria, either alone or in cooperation with North Korea, sought key goods from other countries.

Questions have also arisen over whether Myanmar was a past nuclear customer of North Korea. As discussed above, Myanmar is believed to have stopped any nuclear weapons programs. The United States and Myanmar have recently reestablished relations leading to the lifting of U.S. sanctions. However, there are questions about whether Myanmar's military cooperation with North Korea may still linger and lead it to buy suspect goods from North Korea or allow North Korean vessels to stop at its ports or airports before proceeding to Iran or other sanctioned countries. One media account from March 2013 reported on a ship carrying high strength aluminum suitable for use in centrifuges from North Korea via Dalian, China to Myanmar.[25] It is unclear whether Myanmar was the final destination of the cargo; the cargo may have been intended for another client. The Myanmar government subsequently denied that it was the destination of the aluminum. Nonetheless, this media account adds weight to concerns that North Korea could be selling dual-use goods to other states that are unable to acquire them legitimately. In essence, North Korea is suspected of being a broker and middleman for other countries needing sanctioned or banned goods for their nuclear programs.

North Korea could find it lucrative to proliferate gas centrifuges and their underlying technology. Its international consortium of illicit trading entities and overseas accomplices, combined with ready access to centrifuge technology and its own centrifuge experts, could over time rival the Khan network in both its sophistication and ability to provide turn-key centrifuge plants.

With North Korea recently stating that it is bolstering its nuclear arsenal and threatening to strike the United States and South Korea with nuclear weapons, expectations are low that North Korea will constrain its problematic nuclear trafficking actions that defy international norms. As a result, and because it is strapped for money and has very few licit sources of revenue, North Korea may seek additional customers for its nuclear and nuclear-related products well into the future.

Other Rogue Suppliers

Iran. Other states could emerge as rogue suppliers, particularly Iran. It has growing nuclear capabilities, is hostile to international trade control regimes, and may be motivated to sell its nuclear capabilities to other pariah states. In addition, corrupt or ideologically motivated members of Iran's nuclear program could decide on their own to proliferate in the future.

---

for the barite which it in turn acquired in China. When the Syrian Atomic Energy Agency suspended the contract in 2008, the Hong Kong company sued since it had already bought all of the required quantity in China.

[24] ISIS interview with former senior official close the IAEA, January 2013.

[25] "Japan Seizes Nuclear-Related Materials from North Korea Cargo," Agence France Presse. March 18, 2013.

Iran could emerge, as could North Korea, as a source of nuclear-related dual-use goods, even those controlled by Nuclear Suppliers Group (NSG) lists. For example, the Iranian company Fararo Paya makes frequency converters and maintains a public website in English, apparently as part of an effort to sell goods abroad. Frequency converters have a wide variety of industrial uses, including in gas centrifuges. When the computer security firm, Symantec, assessed the 2009/2010 cyber attack on Iran, called Stuxnet, which destroyed 1,000 or more Iranian IR-1 centrifuges, it found that Fararo Paya's frequency converters, also identified as variable frequency drives, were included as targets in the Stuxnet code.[26] The attack aimed to speed up or slow down gas centrifuges at the Natanz Fuel Enrichment Plant in a way that would destroy them.[27] However, the finding also revealed that this domestic Iranian company's frequency converters were adequate for use in gas centrifuge cascades and likely eligible for coverage by NSG dual use controls. The converter mentioned in the Stuxnet code was part number KFC750V3.[28] On Fararo's English language website, two types of KFC750 frequency converters were advertised. The second one, with the greater voltage and current ratings, is shown in figure 4.[29]

[26] Nicolas Falliere, Liam O Murchu, and Eric Chien, *W32.Stuxnet Dossier Version 1.4*, Symantec, February 2011, p. 39. http://www.symantec.com/content/en/us/enterprise/media/security_response/whitepapers/w32_stuxnet_dossier.pdf

[27] For background information, see two ISIS Reports by David Albright, Paul Brannan, and Christina Walrond, "Stuxnet Malware and Natanz: Update of ISIS December 22, 2010 Report," February 15, 2011. http://isis-online.org/isis-reports/detail/stuxnet-malware-and-natanz-update-of-isis-december-22-2010-reportsupa-href1/8; and "Did Stuxnet Take Out 1,000 Centrifuges at the Natanz Enrichment Plant? Preliminary Assessment," December 22, 2010. http://isis-online.org/isis-reports/detail/did-stuxnet-take-out-1000-centrifuges-at-the-natanz-enrichment-plant/

[28] *W32.Stuxnet Dossier Version 1.4*, op. cit., p. 39. According to the report: "Identification numbers are assigned to manufacturers by Profibus & Profinet International (PI) for each device type they manufacture. 7050h is assigned to part number KFC750V3 which appears to be a frequency converter drive (also known as variable frequency drive) manufactured by Fararo Paya in Teheran, Iran. 9500h is assigned to Vacon NX frequency converter drives manufactured by Vacon based in Finland."

[29] The test report of the KFC750 mentioned at the bottom of the web pages for the KFC750-10 and KFC750-20 describes the tested model as KFC750V1, implying its similarity to KFC750-10 and KFC750-20.

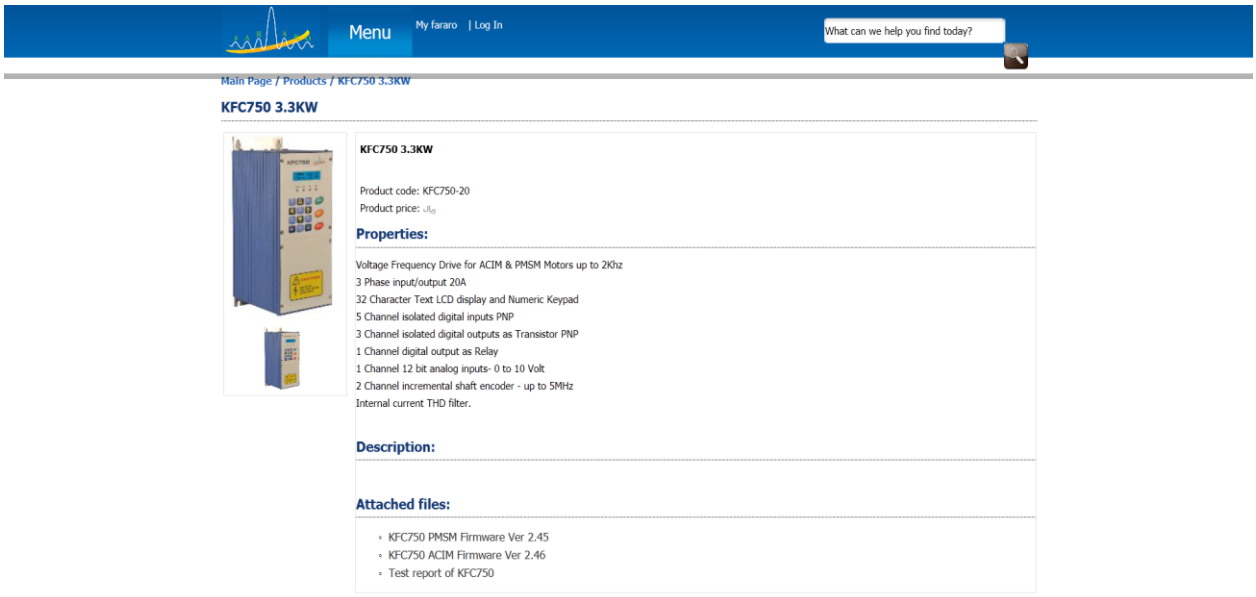

Figure 4: A frequency converter advertised on the Iranian company, Fararo Paya's web site. This model is a KFC750-20; KFC750V3 was a target of a Stuxnet attack sequence.
Source: http://fararopaya.com/en/?cnt=prdd&prdid=68

It was not determined if these models are controlled or usable to drive centrifuge cascades.[30] However, the sale of similar models as the version used at Natanz gas centrifuge plant raises the question whether this company would also supply the one used at Natanz to foreign centrifuge programs.

It is unknown if Fararo Paya makes the subcomponents for its frequency converters, buys them from other suppliers in Iran, or purchases them abroad. North Korea, Pakistan, and the Khan network needed to purchase such subcomponents overseas for their frequency converters. Thus, one would expect that Iran has done so too, likely depending on the European and Asian markets for these subcomponents. But regardless of the source of the subcomponents, this example shows that Iran may already be emerging as a supplier of controlled nuclear dual-use goods, albeit one of the easier types of goods to master.

There is also growing concern that Iran and North Korea are undertaking nuclear cooperation, including on nuclear weaponization. North Korea and Iran could mutually benefit from collaboration on their respective nuclear programs; missile cooperation has been fruitful. There are reports that North Korea provided Iran with nuclear weapons data.[31] Additionally, North Korea revealed that it signed a bilateral scientific cooperation agreement with Iran in September 2012, which the Obama administration reportedly fears could facilitate nuclear and missile

[30] The multiphase frequency output is sufficient to require control, but the stability was not given in the advertisement, which under the new NSG controls needs to have frequency control better than 0.2%. Both conditions must be met for the converter to be controlled. In addition, the one in the Stuxnet code, KFC750V3, may have a greater current and voltage than the two models advertised on the web site, which may be needed to drive the Natanz cascade composed of 164 centrifuges.
[31] Jay Solomon, "Iran-North Korea Pact Draws Concern," *The Wall Street Journal*, March 8, 2013.

advances by both countries.[32] This agreement contains similar wording—including provisions for "exchange of expertise" and "joint use of scientific research equipment"—as the scientific agreement signed between North Korea and Syria in 2002. Soon after it made that agreement, North Korea began constructing the Syrian nuclear reactor.

There are multiple areas where North Korean assistance could prove valuable to Iran. North Korea appears to have deployed centrifuges based on the Pakistani P-2 design, which is also the basis for Iran's recently installed IR-2m centrifuges. North Korea just announced that it plans to use its centrifuge facility to make weapon-grade uranium, something that would likely present technical challenges for Iran if it decided to pursue nuclear weapons. North Korean knowledge could potentially help Iran overcome significant technical challenges.

Furthermore, if North Korea continues to develop its uranium enrichment program and builds devices using weapon-grade uranium, this expertise could benefit Iran, should it decide to build nuclear weapons. Iranian scientists are rumored to be observers at every major North Korean nuclear or missile test and although North Korea has likely tested only plutonium weapons thus far, future tests could preference its uranium program. Even if North Korea never deploys and tests a uranium bomb, its experience with miniaturization and weapons components, including sensitive machining and implosion design, could be helpful to the Iranians.

Syria. Another concern is Syria. Given ongoing internal conflict, Syria is unlikely to be pursuing a secret nuclear program at this time. However, in the longer term, there is reason to worry that Syria under the victorious, old, or a new, radical regime could restart a secret nuclear program and emerge as a rogue nuclear supplier.

Currently, the threat posed by Syria's nuclear and missile proliferation is rooted in its internal instability. A report by the Financial Times raised concerns about the security of upwards of 50 tonnes of highly purified natural uranium alleged to be in Syria, formerly intended for use in fuel for the Al Kibar reactor.[33] This material, unless further enriched, is not suitable for nuclear weapons and does not pose nearly the risk of Syria's chemical weapons stockpile. However, the uranium stock could end up in the hands of terrorists who may wish to sell it on the black market. This material may also end up in undeclared nuclear programs of other states. The Financial Times in particular raised the concern that Syria could provide Iran with this secret uranium stock. For several years, Iran has reportedly tried to covertly obtain quality uranium on the international market. Although Iran mines its own uranium, it could prefer a secret stock of purified natural uranium for a parallel uranium enrichment program. Fifty tonnes of natural uranium would be enough, if enriched to weapon-grade, for 3-5 nuclear weapons, depending on centrifuge efficiency and cascade operations.

Pakistan. And what should happen in Pakistan if its government, along with its nuclear arsenal, falls into the hands of radical fundamentalists? Besides the obvious threat to the United States, a radical fundamentalist government may decide that spreading its nuclear capabilities to other nations is its duty and vital to its survival. It could even decide to provide such capability to

[32] "Iran-North Korea Pact Draws Concern," op cit.
[33] James Blitz, "Fears Grow over Syria Uranium Stockpile," *The Financial Times*, January 8, 2013.

terrorist groups. A collapse of the Pakistani state, as mentioned earlier, could also lead to terrorists acquiring or taking over government-controlled nuclear weapons complexes and assets.

Smuggling Appears to be Worsening

What makes these smugglers and networks so difficult for suppliers or governments to detect is that they are often small and dispersed within the immense network of global business. The legitimate global market in nuclear or nuclear-related dual-use goods is enormous. For a supplier or a government, detecting the illicit ones is a difficult endeavor. Less than one percent of all enquiries would be suspicious, based on what suppliers see in procurement efforts by states such as Iran.[34]

Proliferant states can continue seeking capabilities for their nuclear programs from an abundance of suppliers and intermediaries. Because of this, there is a general sense that export controls can never keep up; that proliferant states will always find a way to bypass controls or find another trading company or supplier willing to make the sale, and that these states will only be slowed, not stopped, by export controls in their steadfast efforts to acquire nuclear weapons. According to former head of the Central Intelligence Agency, George Tenet, "In the current marketplace, if you have a hundred million dollars, you can be your own nuclear power."[35] With advances in technology and a wider diffusion of knowledge, that price might come down considerably.

In fact, the problem of illicit nuclear trade appears to be growing worse as technologies and capabilities proliferate. The world could in fact become far more dangerous. With the global spread of technology and rapid growth in international trade, traffickers could find it easier to ply their dangerous trade. It could be simpler ten years from now to obtain the materials, equipment, and know-how to produce nuclear weapons.

Many countries that are considered developing nations have growing, sophisticated manufacturing and machine tool capabilities that can be exploited. These new suppliers are emerging in developing markets with few export controls and a culture of indifference to stopping the spread of nuclear weapons technology.

[34] Based on discussions with suppliers targeted by Iran.
[35] George Tenet, *At the Center of the Storm* (New York: HarperCollins, 2007), p. 287.

3. Key Technologies: Future Production of Plutonium and Highly Enriched Uranium

States seeking nuclear weapons have traditionally pursued the wherewithal to produce both plutonium and highly enriched uranium, the two major nuclear explosive materials.[36] This section discusses the methods to make these materials and those methods likely to be used in the next five to ten years to produce HEU and separated plutonium.

Proliferant states must also seek the capability to research, develop, test, and manufacture nuclear weapons. Although successfully developing such weaponization capabilities is challenging, the harder and larger task is developing the means to produce HEU and separated plutonium. Moreover, the strategies and methods to achieve weaponization in the future are expected to remain similar to those pursued today by proliferant states.

Countries seeking nuclear weapons have typically sought capabilities to make both HEU and separated plutonium, which are called fissile materials. In the case of developing states that did so, they usually succeeded with one path long before mastering the other. For example, North Korea and India first acquired an ability to make separated plutonium and many years later succeeded in building gas centrifuge plants able to make HEU. Pakistan and South Africa built enrichment plants and later pursued the plutonium path. Pakistan ultimately succeeded while South Africa cancelled the plutonium path prior to ultimately abandoning its nuclear weapons in 1989. Israel acquired the ability to make separated plutonium but is suspected of pursuing gas centrifuges as early as the 1960s. Thus, when considering proliferation, a lesson is that states should be expected to diversify and pursue more than one path to the acquisition of nuclear explosive materials, hoping that at least one method will succeed more quickly.

States with nuclear weapons, such as India, North Korea, Pakistan, and perhaps Israel, are likely to maintain and improve their ability to make HEU and separated plutonium via their existing methods. They may also seek new, more advanced methods.

HEU Production

HEU is made in uranium isotope separation facilities, which enrich the fraction of uranium 235 relative to uranium 238. Although many ways to enrich uranium exist, few have proven reliable or economical. All of them pose daunting technical challenges to produce significant quantities of enriched uranium. Proliferant states in particular have found the deployment of enrichment plants time consuming and plagued by problems.

Proliferant states have sought several technologies to make HEU, which involves enriching uranium to a concentration of greater than or equal to 20 percent uranium 235. The most desirable HEU for weapons is enriched above 90 percent, called weapon-grade uranium (WGU). Iraq secretly pursued gas centrifuges, electromagnetic isotope separation (EMIS), chemical enrichment,

[36] Neptunium and americium are two other major nuclear explosive materials but they are outside the scope of this report. For more information on their role in nuclear weapons, see http://isis-online.org/uploads/books/documents/New%20chapter%205.pdf

and laser enrichment in the 1980s. The first two proved the most promising before Iraq's enrichment programs ended in 1991 as a result of the Gulf War. Iran was developing both gas centrifuges and laser enrichment in secret but told the IAEA in 2003 that it would stop its laser enrichment program. Nonetheless, it may still be developing a capability to enrich uranium with lasers.

Currently, gas centrifuges are the main method of producing enriched uranium, whether for civil or military purpose. For several proliferant states, gas centrifuges have proven the most successful and efficient way to make HEU. However, the challenges of building gas centrifuges are formidable. Claims that low technology centrifuges are somehow easy to build are contradicted by both centrifuge experts and states' experience. Success among developing states in particular has depended on persistence, state commitment, and outside assistance.

In more recent times, with flagging interest in nuclear power, states have not in general sought large-scale deployment of other enrichment technologies, with the exception of the consideration of the commercial deployment of a laser enrichment plant in the United States. Moreover, for developing states these other enrichment technologies have suffered from excessive costs to build and operate and technical challenges that they find difficult to overcome. Although Iraq's EMIS enrichment program was stopped following the 1991 war and subsequent intrusive inspections, the program itself was not very efficient and would likely have been eclipsed by the parallel gas centrifuge program.[37]

As far as is known, proliferant or developing states do not currently have enrichment plants using any technology other than centrifuges producing significant quantities of enriched uranium, although Iranian officials have stated that Iran possesses laser enrichment technology.[38] In addition, little is known about Israel's enrichment efforts, if any in fact exist. However, laser uranium enrichment may be reconsidered by a variety of states because of the development of the SILEX (Separation of Isotopes by Laser Excitation) method of laser enrichment, which is being evaluated in the United States for commercial deployment.

Plutonium Production and Separation

The source of plutonium for nuclear weapons has been nuclear reactors and plutonium separation plants. The latter are often referred to as "reprocessing" plants, which technically is a term used to denote only a civilian plutonium separation plant. Historically, states pursuing plutonium for nuclear weapons have used reactors dedicated to this purpose, even if sometimes these reactors were claimed to be civilian reactors.

Production. Plutonium is typically made as a byproduct in nuclear reactors that are fueled with uranium. Although most reactors produce plutonium, the amount and quality of the plutonium varies based on the type of reactor, its size, and the exact fuel used.

[37] Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996, World Inventories, Capabilities, and Policies* (Oxford: Oxford University Press, 1997), see chapter 11 on Iraq.
[38] Cited on the website of the President of the Islamic Republic of Iran, February 7, 2010, at http://www.president.ir/en/?ArtID=20255 .

Weapon-grade plutonium, or plutonium containing high concentrations of plutonium 239 (greater than 93-94 percent), is typically sought for nuclear weapons. Lesser quality plutonium can also be used in nuclear explosives, although its use causes losses in explosive yield and additional problems in handling, fabrication into weapons components, and heat dissipation during storage of the weapon.

The main types of reactors used to make plutonium for nuclear weapons have included heavy water cooled and moderated reactors, gas cooled/graphite moderated reactors, and light water/graphite moderated reactors. France has used a fast reactor, fueled by plutonium, to make plutonium for nuclear weapons.[39]

Developing states have never built nuclear reactors on their own. Several states bought complete reactors suitable for making weapon-grade plutonium, such as India's first heavy water reactor purchased from Canada, Israel's heavy water reactor purchased from France, Algeria's heavy water reactor bought from China, and Taiwan's heavy water reactor bought from Canada. Syria may have bought a complete gas graphite reactor from North Korea, although parts may have been supplied via their illicit procurement networks. Some countries did not buy complete reactors but had extensive outside help, such as Pakistan's Khushab heavy water reactors, North Korea's Yongbyon gas graphite reactor, and Iran's Arak heavy water reactor. The Arak reactor, which is slated for operation in 2014, has benefited from extensive Russian design assistance in the 1990s and foreign procurement of key parts, such as specially prepared valves acquired in Germany and India (see Box 2). Iran may still be seeking goods for this reactor abroad.

[39] *Plutonium and Highly Enriched Uranium,* op. cit.

Box 2: Valves for Iran's Arak Heavy Water Reactor[1]

Starting in 2007 and continuing into 2011, Iran sought 1,767 valves from Germany for its IR-40 heavy water reactor at Arak and planned to pay $6 million for these valves. The reactor has extensive piping to transport the heavy water, and this piping requires a large number of specialized valves.

UN Security Council resolutions require a suspension of this reactor's construction. It is suspected of being intended to make plutonium for nuclear weapons. It is large enough to make enough plutonium for more than one nuclear weapon per year.

Iran-based Modern Industries Technique Company (MITEC) is responsible for the design and construction of the Arak reactor, and it is the entity that sought the valves abroad. MITEC has been listed under United Nations Security Council sanctions since 2010.

German authorities who led the investigation into this case established that the Arak reactor was the end use for these valves. The evidence was in several documents seized by German authorities.

MITEC sought three groups of valves, each group having different technical parameters that were listed in at least one document seized by German authorities. Most of the valves were non-listed dual-use items, but a large portion of one group of valves was specially designed for nuclear purposes and thus controlled explicitly by export controls, according to German authorities.

MITEC contracted with Hossein Tanideh, a 48-year-old Iranian citizen, who was alleged to be a professional smuggler connected with numerous companies not only in Iran but also in Turkey and Azerbaijan. In 2012, he was listed in the United States as a Specially Designated National (SDN) by the Treasury Department Office of Foreign Assets Control (OFAC) for making illicit procurements.[1] Such SDNs are generally prohibited from engaging in any transactions with U.S. companies and any assets the designees may have under U.S. jurisdiction can be blocked or seized.

MITEC instructed Tanideh that it wanted high quality valves made in Germany. Thus, Tanideh involved several Germans and German-Iranians in his plan. These individuals were involved in organizing the procurement, producing the valves, financing the deal, brokering the acquisition of the valves, and exporting them. Two small companies in former East Germany agreed to provide two of the three types of valves sought. Subsets of 92 valves were sent in five shipments directly to Iran or via Turkey to Iran.

Unable to acquire the third, more sensitive set of valves in Germany, the smugglers placed orders from Germany and Turkey to an Indian valve company. Four shipments of 856 valves went from India to Turkey and then on to Iran. India makes large numbers of valves for its heavy water power reactors.

The International Atomic Energy Agency recently found that the piping system of the Arak reactor appeared largely complete, implying that Iran acquired sufficient numbers of valves. MITEC acquired 1,163 valves via this smuggling scheme, enough in the end or acquired more via other schemes.

The major players in this procurement scheme, including Tanideh, were arrested in Turkey and Germany. Authorities are still seeking several Iranian nationals.

[1] Cathrin Gilbert, Holger Stark, and Andreas Ulrich, "Operation Ventilator," *Der Speigel*, 40/2012. See also *Report of the Panel of Experts on Iran*, June 5, 2013.

India and France have also used commercial, electricity production reactors to make plutonium for their nuclear weapons. France used commercial gas graphite reactors; India used commercial heavy water reactors as a way to surge plutonium production following its 1999 nuclear tests and the formal launch of its nuclear arms race with Pakistan. These French and Indian reactors were not under IAEA safeguards or limited to peaceful uses, so their use did not involve a violation of any international agreements.

So far, no state has used a safeguarded reactor to make significant quantities of plutonium for nuclear weapons. A few, including Iran, Iraq, and North Korea have used safeguarded research reactors to produce small quantities of plutonium in violation of their international nonproliferation obligations. In the future, however, more significant misuse could take place, such as the diversion of irradiated fuel from nuclear electricity production reactors and subsequent separation of significant quantities of plutonium, albeit likely non-weapon-grade. If nuclear power reactors spread in the Middle East, for example, a state facing a national security emergency could decide to obtain plutonium for nuclear weapons by misusing safeguarded reactors.

Several states are developing newer types of civilian reactors, such as fast reactors, research reactors, and advanced light water reactors.[40] Most of these newer reactor technologies are less vulnerable to being used to make plutonium for nuclear weapons. The developers have focused on fuel that leads to the production of plutonium that is of very low quality or alternative fuels that result in little plutonium production. In addition, modern operational and control processes, including elaborate safety systems, make these reactors very difficult to copy and build without extensive outside assistance.

Separation. In a reactor, plutonium is produced in low concentrations in the uranium. Therefore, plutonium must be separated chemically from the uranium and radioactive waste in special facilities. Several methods of separating plutonium have been developed, although the dominant process is called PUREX and is widely known. However, regardless of the technology, building a reliable plutonium separation plant is difficult to accomplish because of the intensive radioactive environment and the challenge of avoiding radioactive releases and radioactive exposures to personnel while maintaining plant reliability. Many countries have encountered difficulties in building and operating them successfully. Most proliferant states have depended on foreign procurement to acquire either a whole plant, such as the case of Israel, or major components, such as the cases of Argentina, Brazil, Iran, India, Pakistan, and Taiwan.

One exception is a low-tech plutonium separation plant. As mentioned, one of the challenges facing the builder of a plutonium separation plant is achieving reliability and plant longevity while also achieving a high level of radiation protection for personnel and meeting strict environmental and safety criteria. If these goals are abandoned or severely restricted, then it is much easier to build an inferior quality, low-tech plant that may function only long enough to separate a few tens of kilograms of plutonium.

The low-tech plutonium separation plant stands in contrast to the traditional separation plant. A traditional one is characterized by a series of connected "cells," or operating rooms made of thick

[40] World Nuclear Association, "Advanced Nuclear Power Reactors," Updated May 2013. http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Power-Reactors/Advanced-Nuclear-Power-Reactors/#.Ua4b1UBwroI

concrete walls; observation ports involving thick, lead-shielded windows; sophisticated remote operating equipment such as manipulators; a shielded basin able to receive irradiated fuel; miles of piping; and a considerable amount of instrumentation. The result is typically a unique design that requires considerable procurement and involves a building that looks conspicuous, making it easier to detect by foreign intelligence agencies.

In contrast, the concept behind a low-tech plutonium separation plant is based on a simple, quick operating philosophy. The main developers of this low-tech concept were at Oak Ridge National Laboratory in the 1970s.[41] The concept focused on extracting only the plutonium from the irradiated fuel and discarding everything else. The design involved concrete-lined ditches, simple fuel cutting tools, and stainless steel drums, all of which, in theory, could be obtained domestically. In practice, however, some chemicals and equipment may be sought abroad to decrease the construction time if the chemicals or other goods are not made reliably domestically. For example, India is known to have procured on several occasions at least one of the required chemicals, tributyl phosphate (TBP), for its own program abroad rather than making the TBP itself. A less developed nation may have no choice but to procure certain goods from abroad.

The resulting facility would likely cause large negative environmental impacts from nuclear waste and expose workers to excessive radiation doses that in some cases would be large enough to cause radiation sickness. The plant would also be unlikely to function for very long. However, it would likely work long enough to extract some tens of kilograms of plutonium from commercial nuclear reactor fuel. If that effort failed, the state could build another one. Moreover, this type of plant could be built relatively quickly, possibly in less than a year, and hidden rather easily, particularly underground in a tunnel.

Future Pathways

Predicting the particular path a state may take to acquire nuclear weapons remains fraught with uncertainty. There are many ways to do so. Moreover, surprises have occurred. Few expected Iraq's choice of electromagnetic isotope separation, or "calutrons," to make HEU in the 1980s. There is always the risk that new technologies could emerge that would simplify the task of making nuclear explosive materials or nuclear weapons.

In trying to understand the future world of illicit nuclear trade, several particular pathways were evaluated as to their feasibility and attractiveness to proliferators during the next five to ten years. Several of these pathways would entail the procurement of a variety of high-tech goods. A few may involve less of such goods. But overall, the likeliest to be chosen pathways to make HEU and separated plutonium will entail extensive procurements. They are:

- Gas centrifuges
- Laser enrichment of uranium
- Nuclear reactor coupled with a plutonium separation plant
- Particle accelerators to produce plutonium

[41] See for example, Memorandum from D. E. Ferguson to F.L. Culler, *Simple, Quick Processing Plant*, Oak Ridge National Laboratory (ORNL), August 30, 1977.
http://www.npolicy.org/article_file/Simple_Quick_Processing_Plant_Culler.pdf

Another pathway to acquire separated plutonium is a hybrid involving the diversion of irradiated fuel from a safeguarded nuclear reactor and the separation of plutonium in a low-tech plutonium separation plant, as discussed above. This pathway would assume the occurrence of a national security emergency warranting such a diversion. In addition, this pathway is potentially available to terrorists, unlike those that involve building an enrichment plant or a reactor.

Gas Centrifuges

Centrifuges are expected to remain a preferred pathway to making HEU during the next five to ten years. The next section discusses the illicit procurement and production of centrifuges in more detail; here the findings about its feasibility as a future pathway to nuclear weapons are presented.

Existing proliferant state centrifuge programs are likely to continue depending on overseas procurement for a range of key goods and sensitive information. The amount and type of goods needed will likely shift as the state becomes more self-sufficient in making certain goods.

A developing state seeking centrifuges for the first time is likely to need a considerable amount of foreign assistance. Strictly indigenous production of centrifuges is rare historically and this is unlikely to change much over the next five to ten years.

A developing state with no prior experience may be able to build a gas centrifuge plant, although it may face considerable delays. It would likely settle on a centrifuge design that is more advanced than the earliest centrifuges ever built but far less advanced than modern ones being deployed by developed states. The designs would likely be similar to those built by proliferant states such as Iran, and formerly, Iraq.

It is unlikely that states in the future will opt for low-end, early Soviet-era type centrifuges. All centrifuge plants, including those involving low-end centrifuges, are difficult to build and operate. Moreover, state programs are unlikely to be successful in utilizing low-end centrifuges as a way to avoid overseas procurements and assistance. In fact, it is doubtful that developing states could build large numbers of low-end centrifuges without outside assistance and foreign procurements. Because of these constraints, it is more logical for states to pursue a slightly more advanced design requiring the same level of commitment but greater output.

In the next five to ten years, declared or undeclared centrifuge programs could develop, or re-start, in countries that are newly industrialized or in more rapidly developing countries, such as South Korea, Turkey, and South Africa. Their centrifuges may be more advanced than those built initially by proliferant states such as Pakistan, Iran, and Iraq. These programs would be expected to be mostly capable of making centrifuges indigenously. However, they are still expected to depend on overseas procurement for certain items in order to save costs and time and obtain higher quality, more reliable goods.

Terrorists may be capable of building a limited number of low end centrifuges, although they would likely need considerable outside assistance. Moreover, the production of enough weapon-grade uranium for one nuclear weapon would require a large number of centrifuges. As a result,

this scenario is unlikely, even if a terrorist group could establish itself securely and safely for years in a host state. The detection of such a plant by the outside world would likely trigger an immediate military or other draconian response aimed at immediately destroying the facility. Thus, this scenario is unlikely during the next five to ten years.

Laser enrichment of uranium

Nuclear technical experts often view laser enrichment of uranium as a latent, future proliferation threat. Future breakthroughs in this technology that allow for the easier and more reliable production of HEU are concerning and could involve the deployment of small, easy to hide sources of HEU. A covert laser enrichment facility might escape detection by the IAEA and Western intelligence services. A more complete discussion of states' ability to acquire laser enrichment capabilities via illicit trade is included in section 3b.

There does remain widespread disagreement among technical experts about developing countries' ability to build laser uranium enrichment plants. Therefore, it remains difficult to evaluate the likelihood of a state building a laser enrichment plant able to produce significant amounts of HEU for nuclear weapons.

Enriching uranium with lasers on a production-scale appears extremely complicated. Moreover, detailed technical information about uranium laser enrichment technologies remains rather limited, making any assessment as to their feasibility more complicated. Although laser enrichment appears able to make small quantities of HEU, there are disagreements about ease, reliability, and feasibility of doing so with existing methods.

Despite the difficulty of succeeding with laser enrichment, proliferant states may be motivated to look again at this option for making highly enriched uranium for nuclear weapons. These motivations include recent, major advances in laser technology, the relatively small size and the few external indicators of a laser enrichment plant, the apparent success of a new form of laser enrichment, separation of isotopes by laser excitation (SILEX), and the ability to conduct several necessary research and development activities at once under a non-nuclear cover. Over the next five to ten years, further advances could occur that would elevate the chance that a state could use laser enrichment to produce HEU for nuclear weapons.

Thus, in a five to ten year time frame, laser enrichment of uranium warrants concern as a potential way for a proliferant state to acquire significant quantities of highly enriched uranium. As a result, it is important to focus on ways of improving the detection probability of clandestine efforts in proliferant states, thwarting the progress of any secret effort, and finding ways to deter the deployment of secret laser enrichment programs among proliferant states.

Nuclear reactor coupled with a plutonium separation plant

Over the next five to ten years, the main source of plutonium for nuclear weapons is expected to remain nuclear reactors and associated plutonium separation plants. Although there are other ways to produce plutonium, such as by particle accelerators, these methods are judged as less likely to be significant sources of plutonium in this time period (but see below).

The reactors posing the largest threat are likely to remain older types, such as heavy water or gas graphite reactors (including air cooled) that depend on natural uranium fuel. Building these types of reactors does not pose the same level of engineering challenge as modern reactors, but they can still pose challenges. As a result, developing states are expected to continue seeking their purchase, or if they decide to build them, they will seek major components abroad.

Another concern is posed by research reactors fueled by low enriched uranium (LEU) or HEU that allow for the production of plutonium in natural or depleted uranium targets that are inserted secretly in the reactor. As mentioned above, Iraq, Iran, and North Korea produced small quantities of high quality plutonium in this manner. It remains a method that a state could pursue in the future.

In all cases, the state would need to establish a capability to separate the plutonium from the irradiated targets. Plants to separate plutonium likewise are expected to require outside assistance or supply, which is explained below.

Particle Accelerators to Produce Plutonium

Particle accelerators can be used to produce plutonium. The particles from the accelerators would be used to generate neutrons which would irradiate natural uranium targets. Their use internationally is increasing to make medical isotopes, which could lead to their greater availability and raise the chance of their potential misuse to make plutonium. Moreover, their construction is likewise easier than in the past. However, accelerators that would make significant amounts of plutonium remain difficult to develop and construct and would require a separation capability to separate the plutonium from irradiated material. Thus, overall, the probability of the use of accelerator to make significant amounts of plutonium is viewed as low. Nonetheless, states may calculate that their efforts would likely be missed by intelligence and inspection agencies focused on other technical approaches. As a result, despite the low chance of deployment, this proliferation approach deserves attention and policies aimed at early detection, complicating success, and deterring attempts to carry it out in the first place.

Low-tech plutonium separation plant and the diversion of irradiated fuel from safeguards

In a national emergency, a state may divert safeguarded irradiated fuel containing plutonium and separate it in a low-tech reprocessing plant. In general, this pathway appears to have a low chance of occurring because the diversion would be so momentous. Nonetheless, it should be viewed as a credible possibility in the future.

If commercial nuclear power reactors spread into developing countries in regions of tension, such as the Middle East, this low tech method of reprocessing could increase the risk of proliferation in a crisis. For example, if Iran succeeds in building nuclear weapons and one or more Arab countries follow suit, those with commercial reactors, despite Nuclear Non-Proliferation Treaty commitments or bilateral supply agreements, may be more motivated to divert spent fuel and separate plutonium for nuclear weapons via this low tech route.

A state could in theory construct a low-tech plutonium separation plant indigenously. However, this pathway requires goods that may be sought abroad instead.

Of all the pathways to producing fissile material, this one is likely the only one available to terrorist groups given their limited technical capabilities. However, they would need to acquire irradiated fuel containing plutonium and be located in a secure territory, conditions that are difficult to achieve.

3a: Digging Deeper: Gas Centrifuges

Gas centrifuges programs are relatively widespread and are currently favored by proliferant states as the pathway to obtain fissile materials for nuclear weapons. Figure 5 shows a schematic of a centrifuge of the type deployed in developing states.

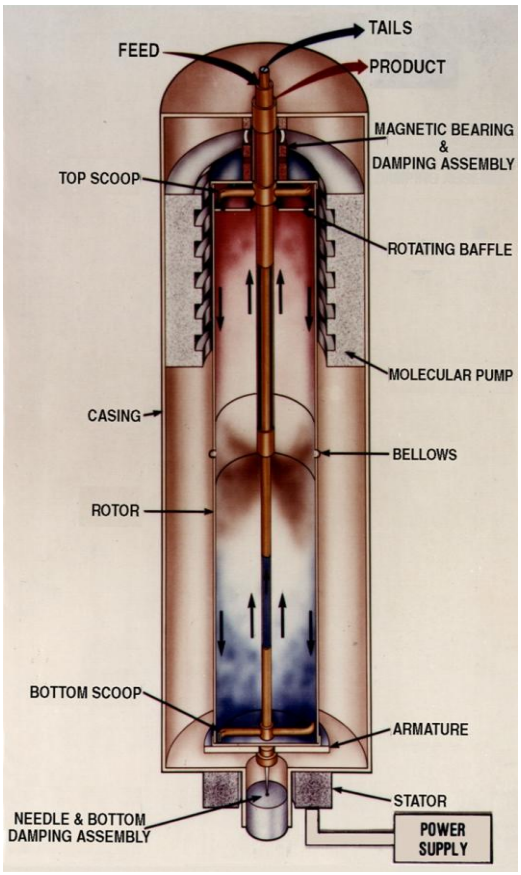

Figure 5: A schematic of a centrifuge of a type deployed in developing countries.

Gas centrifuge procurements dominate illicit nuclear trade cases. This trend is not expected to change over the next decade. As a result, gas centrifuges warrant particular consideration in this report, despite the technical nature of the discussion. Besides providing more detail about the creation and implementation of gas centrifuge plants in regions of tension, and the role of illicit procurement in those efforts, this discussion also provides insight relevant to other technologies to create the wherewithal to produce fissile materials.

A state planning to build its first gas centrifuge is strongly dependent on the information and experience it possesses and is able to obtain elsewhere. For example, does the state have access to detailed gas centrifuge designs and manufacturing instructions and individuals with extensive experience in building gas centrifuges? The path forward will be quite different for a state with neither designs nor experienced personnel. The development of centrifuges and the subsequent construction of a plant is a time consuming process. During this process, a program will need to acquire a wide variety of information and goods. Many of these items may be difficult for that

state to supply domestically. Even in the case of a developed manufacturing economy, not all goods will be readily available.

Time Frame

To understand the time needed to build and operate a centrifuge plant, two scenarios are considered. The first is a state with no head start in terms of detailed centrifuge designs or persons familiar with centrifuges. The second is a state with access to both.

The first case is a state that begins with no centrifuge designs and no individuals who have worked in the field, but it is assumed to have a domestic team of experienced engineers and scientists with adequate resources to purchase or manufacture needed items. In this case, it is likely that the team would first research open literature about gas centrifuge mechanics and processes. A considerable amount of information has been published on the centrifuge's internal fluid dynamics and the process of isotope separation, so the engineers could quickly understand fundamentals and theory of how a gas centrifuge operates. The types of material needed for the rotor, for example, have been widely discussed. The first centrifuge rotors a state would likely seek to make would be those made of high strength aluminum or maraging steel. If the state has a missile program, it would likely have knowledge of winding composite materials, such as carbon fiber, which could also be applied to manufacturing centrifuge rotors. Because of classification and proprietary issues, however, very little information is available publicly on the detailed design of gas centrifuges and centrifuge plants, the manufacture and assembly of centrifuge components and cascades, and solutions to a range of operational problems common to centrifuge plants. Information about making uranium hexafluoride, the feed gas for centrifuges, is more available. However, the production of high quality uranium hexafluoride necessary for centrifuges is less known and remains challenging to accomplish.

This scenario is not so different than the initial efforts in the former Soviet Union in the mid-20th century. In the 1930s and early 1940s, Soviet scientists, in particular German émigré Fritz Lange, worked to develop a horizontal gas centrifuge. Beginning in 1945, the Soviet Union captured German and Austrian engineers and scientists, Max Steenbeck, Gernot Zippe, and Rudolph Sheffel. They were put to work on developing gas centrifuges in the Soviet Union. Ten years later, on October 10, 1955 the USSR made a decision to construct a centrifuge pilot plant, which was commissioned in November 1957. In late 1957 or early 1958, the pilot plant became operational with about 2,500-3,000 centrifuges, each with an estimated average output of about 0.5 separative work units (swu) per year.[42] The plant's enrichment output was not enough

[42] Early Soviet centrifuges were similar to a centrifuge built by Gernot Zippe in the 1960s, which he called the SSZ 100. Zippe said that this centrifuge was a duplicate of the centrifuge that he, along with Russians and other Germans, developed in Russia after World War II. This centrifuge had a rotor made out of aluminum with a diameter of 100 millimeters, a length of 48 centimeters (cm), and a rotational speed of 360 meters per second. The length of the rotor involved in enriching uranium, called its separative length, was shorter, at 43.1 centimeters. Based on a theoretical calculation, SSZ 100's maximum possible separative capacity was 1.88 kg uranium (U) separative work units (swu)/year. This value is considerably higher than the value that can be achieved in an actual centrifuge and must be reduced by a separative efficiency, which Zippe estimated theoretically had a maximum value of 40 to 50 percent. However, he discovered experimentally that this value must be reduced further to reflect inefficiencies in operation. During actual running of the SSZ 100, Zippe obtained a separative efficiency of only about 30 percent, or a separative capacity of 0.569 kg U swu per year. He personally believed for this design, the

for a state to produce 25 kilograms of weapon-grade uranium per year, or roughly enough for one nuclear weapon. In 1959, the USSR deployed several tens of thousands of centrifuges in a larger plant, providing a capability to make weapon-grade uranium for nuclear weapons. It eventually developed more advanced centrifuge designs, but these designs continued to be relatively simple "sub-critical" centrifuges with very low output per machine.[43] However, they were precision instruments with lifetimes on the order of 20 years. Thus, to produce a first plant able to make significant amounts of weapon-grade uranium, the USSR required almost 15 years. Today, this time should be shorter, particularly since the Soviets and Germans had to also invent the modern centrifuge. In addition, with modern computers and improved manufacturing methods, the time to produce this first generation subcritical centrifuge plant might be reduced to 10 years. If a more advanced supercritical centrifuge is developed, it is difficult to see how this time frame would be accomplished in less than 10 years.

What is a Separative Work Unit (SWU?)

A separative work unit (swu) is a difficult to understand unit of measurement. A swu measures the ability of an enrichment process, such as a gas centrifuge, to separate the fissile uranium 235 isotope from the uranium 238 isotope. Canada-based Cameco provides a very helpful illustration of swu and how operators vary swu to their advantage using an orange juice analogy:

"Let's assume you are in the freshly squeezed orange juice business. By deciding first how much juice you are prepared to leave behind in the pulp, you can then decide the optimum balance between the number of oranges you require and the effort required to squeeze them. If oranges are cheap and the cost of squeezing is high you are less concerned with how many oranges you use, but you want to make your orange juice with the least amount of squeezing. If oranges are relatively expensive and the squeezing process is cheap, you will minimize costs by squeezing fewer oranges more times to get the same amount of juice.

Now think of the oranges as uranium and the effort to squeeze them as swu. If the price of uranium is relatively low, then you will use more uranium and less swu to enrich the UF_6. If the price of uranium is high and swu is relatively cheaper, you will use more swu and less uranium. Enrichment is measured both as the percentage of uranium 235 in the product and in the depletion. So the percentage of uranium 235 left behind in the tails assay is critical to the calculation of enrichment. The reactor operator always starts with the tails assay to find the best combination of UF_6 feed and swu."

See: http://www.cameco.com/uranium_101/

In the second scenario, the state has everything as in the first scenario, but also has acquired detailed drawings and manufacturing instructions for the components and has the benefit of experienced engineers or scientists with knowledge of this centrifuge design. This case is similar

maximum value achievable was 0.6 kg U swu per year. Operation in cascades would likely reduce this value further, leading to an estimate of 0.5 kg U swu/year. For sources, see Albright and Christina Walrond, *Iran's Gas Centrifuge Program: Taking Stock*, ISIS, February 11, 2010 and Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996, World Inventories, Capabilities, and Policies* (Oxford: Oxford University Press, 1997), p. 102.

[43] *Plutonium and Highly Enriched Uranium*, op. cit., p. 105-7.

to Pakistan and Iraq, both of which benefited from extensive foreign technology. It is also similar to two older cases involving developed countries, namely the United States when Gernot Zippe visited the University of Virginia 1958 to 1960 and Germany when Zippe returned there in 1960. In both of these cases, the states developed centrifuge demonstration cascades with centrifuges capable of several separative work units per year within about 7-10 years from initiating their projects. So the time was significantly reduced from that of the USSR's experience in building its first plant. Pakistan had extensive help from engineers experienced in centrifuges, but it needed about ten years to build an adequately functioning plant able to make enough weapon-grade uranium for a nuclear weapon. Its first centrifuge was a supercritical machine with an output estimated as about 1.5-2.0 swu per year per machine. Pakistan encountered many difficulties. Its first plant contained six production-scale cascades of P1 centrifuges and all of them failed within six months after starting operation. Iraq, which had the assistance of 3-4 highly experienced German centrifuge engineers and technicians, was on track to have a finished plant in about 7-10 years which would be capable of making enough weapon-grade uranium for a bomb each year.

In the first scenario, the time necessary to build a working gas centrifuge plant was about 10 years. In the second scenario, a plant could be built quicker, or in about 7-10 years.

However, the example of Pakistan highlights that developing states can run into significant additional problems, even with the advantage of critical foreign assistance. In fact, the time to build a first plant has been considerably longer for other developing countries, as the case of Brazil and Iran shows.

Brazil needed over ten years to successfully develop a centrifuge and build a plant with about 1,000 centrifuges.[44] Its first plant started in 1988, about nine years after this program was formally launched by the military government as a secret program parallel to Brazil's safeguarded nuclear programs. The first plant involved only about 50 poorly performing centrifuges. It needed several more years before it operated a plant with 1,000 centrifuges.

Iran started its centrifuge effort in 1985 and took until the early 2000s to build its first plant, involving IR-1 centrifuges. Figure 6 shows a model of an IR-1 centrifuge. However, it planned on a rapid ramp-up in capability, having ordered 10,000 IR-1 centrifuges in 2001.

[44] *Plutonium and Highly Enriched Uranium*, op. cit., p. 374.

Figure 6: A photo of a model of the IR-1 centrifuge in Iran, showing four aluminum rotor tubes and three bellows. The top and bottom tubes are painted black, possibly intended to help control the temperatures along the rotor assembly. The small tubing wrapped around the outside of the centrifuge is for water flow related to controlling the temperature along the rotor assembly. The IR-1 centrifuge is the same as Pakistan's P-1 centrifuge. Iran obtained this centrifuge design from the A.Q. Khan network.

Even developed states, which have forgone significant outside assistance, have encountered significant obstacles to developing optimally performing centrifuges. Australia, which proceeded indigenously with a limited number of engineers and technicians, took years to produce a functioning centrifuge program. Sweden spent 1969 to 1979 developing centrifuges but did not build even a functioning prototype before cancelling its program. And the effort was well funded with many excellent participants. In the 1990s, China decided to drop its indigenous centrifuge program in favor of buying centrifuges from Russia. The technical challenges to building centrifuges are very large and the construction of a functioning plant usually takes longer than expected.

An advantage of developed countries, such as Britain and Germany, was that they already had a deep reservoir of technology awareness or culture inherent in their workforce and management. As a result, centrifuge programs in these countries could rely upon engineers and technicians who could be trained more easily to produce high specification centrifuge parts. Despite that technical culture, some parts turned out to be challenging to make even for these technicians. In the German centrifuge program in the late 1960s and early 1970s, few technicians could make the most sensitive centrifuge parts. Britain's centrifuge program took another approach. It hired low skilled personnel to make the non-sensitive rotating parts but contracted with the highly skilled Ministry of Defense's Royal Ordinance Factories to make the rotating parts. They had the most advanced machine tools in the United Kingdom, including the only flow-forming machine in the country, and skilled technicians able to make the high specification parts. For example, the bottom bearing of a centrifuge involves a pin with a ball at the end that spins within

a cup. The ball and cup had to match within seven microns, a tolerance difficult to achieve at that time. Later, as British centrifuges become more advanced and heavier, the British program moved to a bottom bearing with a spiral grooved ball and pin design. Instead of making these bearings, it contracted with a German company that had become expert in building them for the German centrifuge program.

With regard to developing countries, such as Iraq, Iran, and Brazil, a technical culture was lacking. These countries experienced significant obstacles in reproducing the more sophisticated procedures needed to develop and make high-specification centrifuge components and build a successful centrifuge plant. These problems persisted even with the introduction of computer numerically controlled (CNC) machine tools in the 1980s.[45] The Iraqi program in the 1980s did not create adequate cleanliness in the manufacturing areas, for example, leaving windows open that allowed sand to enter flow forming machines slated to make centrifuge rotors out of maraging steel. Similar problems were encountered by Iran. Iranian technicians tracked in mud to the Natanz centrifuge plants rather than changing shoes and putting on clean booties. They handled centrifuge components with their bare hands, leaving corrosive residues on the parts, rather than using gloves. They also made simple mistakes in assembling centrifuges. Iraqi designers over-specified centrifuge parts, making them harder to manufacture and creating more rejected parts, according to the German Karl Heinz Schaab, who aided the Iraqi effort. Brazil encountered considerable trouble in flow forming maraging steel centrifuge rotors in the mid-to-late 1980s, despite considerable help from the German supplier of the flow forming machine. [46]

Although technical advances have occurred globally, for developing countries, inexperience is expected to remain a problem for any future centrifuge program. Developing countries seeking centrifuges for the first time are expected to encounter difficulties.

Reliance on Illicit Procurement

Throughout history, many countries building centrifuge plants have been heavily reliant on illicit nuclear trade. Starting in the 1970s, Brazil, Iran, Iraq, North Korea, Pakistan, India, and South Africa all sought key goods and technology from abroad. Iran, North Korea, Pakistan, and likely India still depend on illicitly obtaining goods. In recent times, based on records of attempted and actual procurements, these countries have sought vacuum measuring equipment, vacuum pumps, fast-acting valves, ring magnets, specialized oils, specialized epoxy resins, computerized control equipment, high-grade maraging steel, high-strength aluminum, high-strength carbon fiber, CNC machine tools. In some cases, countries have sought items that they could have made themselves in order to save costs and time and obtain higher quality, more reliable goods. This trend is not expected to change in the next five to ten years. As an example, Figure 7 lists many of North Korea's known, attempted or successful procurements for its centrifuge program in the 2000s. This list is by no means complete.

[45] See for example, ISIS, "Preventing Illegal Exports: Learning from Case Studies," http://ecbiz108.inmotionhosting.com/~export14/case_studies.htm

[46] ISIS, "Preventing Illegal Exports: Learning from Case Studies," op. cit.

Figure 7: North Korea's Known Illicit Procurements for its Centrifuge Program in 2000s (excluding goods from Pakistan and earlier procurements)

- Aluminum tubes (low strength for outer casings), ring magnets for use in a centrifuge upper bearing, specialized uranium hexafluoride resistant oil, epoxy resins used in assembling centrifuge parts (sold commercially as Araldite), and a range of equipment important to operating centrifuges individually or in cascades, such as vacuum pumps, valves, specialized uranium hexafluoride resistant oils, uranium hexafluoride cylinders, uranium hexafluoride flow meter, and frequency converters or their subcomponents.
- Flow-forming machine usable to make centrifuge rotors and an electron beam welder for centrifuge assembly. State-of-the-art computer numerically controlled (CNC) machines for making centrifuge parts.
- Spare parts for centrifuge-related equipment.
- Computerized control equipment used to run a plant composed of centrifuge cascades. (The equipment is also used in the petrochemical industry, but it was the same as that acquired by Iran to run its centrifuges.)
- Pressure transducers, which are used to measure the vacuum pressure in individual centrifuges and cascades.

In fact, most proliferant states have depended on foreign technical assistance to master centrifuges. This alone shows the damage done as a result of poor controls on classified and sensitive centrifuge information and data. Pakistan's centrifuge program was going nowhere until A.Q. Khan brought back stolen Urenco centrifuge technology from Europe in the mid-1970s. In the 1980s, India used European centrifuge design information as the basis of its program, although the evidence does not support that India obtained anywhere near the amount of classified designs and information as Pakistan.[47] Iran's centrifuge program, which started in 1985, depended on foreign assistance from its beginning. Its technical leader went to Europe in 1985 seeking assistance from Western suppliers. However, this program hesitated to accept all that the Khan network offered in 1987, and this refusal contributed significantly to the program suffering delays. It progressed much further in its centrifuge development in the 1990s after finally accepting more substantial aid from the Khan network. South Africa in the 1980s also depended on Urenco information in the development of its centrifuge program, including information about the winding angle for a carbon fiber rotor. Brazil depended on German expertise to develop its centrifuges in the 1980s, first focusing on a maraging steel model before switching to carbon fiber rotors in the early 1990s. In both endeavors, Brazil received significant help from German centrifuge experts.

Number and Type of Centrifuge

States that would seek to build a gas centrifuge plant capable of producing HEU for a nuclear weapon program can settle for a relatively small centrifuge plant, compared to one dedicated to

[47] Albright and Susan Basu, "India's Gas Centrifuge Enrichment Program: Growing Capacity for Military Purposes (Rev. 1)," ISIS, December 1, 2006. For example, the bellows was not an exact copy of an Urenco centrifuge bellows and in fact had technical problems that hindered its operation.

making low enriched uranium for a nuclear power reactor program. For example, the Natanz Fuel Enrichment Plant was designed to hold 50,000 IR-1 centrifuges, which are enough centrifuges in theory to provide the Bushehr nuclear power reactor's annual supply of low enriched uranium. In contrast, one tenth of this number, or 5,000 IR-1 centrifuges, would be sufficient in theory to produce 25 kilograms of weapon-grade uranium per year, sufficient for one nuclear weapon per year.[48]

A country would need to carefully decide on the type of centrifuge to build. Figure 8 lists a range of centrifuges deployed or planned by developing states in their plants and the enrichment output of the centrifuges. Every one of them depended on foreign assistance.

As can be seen in Figure 8, the centrifuges deployed in the first plants have ranged in enrichment output but most of them have had an output of between one and about five swu per year. Interestingly, these states did not choose centrifuges with expected outputs of less than one swu per year. In addition, the proliferant states worked on developing more than one centrifuge type relatively early in their programs, reflecting the tendency of centrifuge programs to start early on the development of centrifuges with greater output. This reflects the nature of centrifuges, which can in a straightforward manner be made longer and to spin faster, providing incremental increases in enrichment output as a result. For comparison, Figure 8 on the next page lists centrifuges in some advanced programs. The much greater output of the U.S. centrifuge is partly due to its much greater length (see figure 9).

[48] This estimate assumes about 1 swu/year and a requirement of roughly 200 swu per kilogram of weapon-grade uranium. The actual values can vary substantially from these nominal values.

Figure 8: Characterizing Gas Centrifuges

Survey of Gas Centrifuge Programs in Developing Countries

Type	Rotor Properties			Output (kg U swu per year)	Foreign Procurement of Goods
	Material	*Bellows*	*Speed*	*Single Machine*	
Soviet (1950s)	Aluminum	0	350?	0.6	No
P1 (Pakistan)	Aluminum	3	350	1.5-2.0	Yes
IR-1 (Iran)	Aluminum	3	330	1.3-1.4	Yes
Model ? (Brazil)	Maraging steel	0	?	0.5-1.0?	Yes
Model 0 (Brazil)	Maraging Steel	?	?	1.8	Yes
G1 (Iraq)	Maraging steel	0	455	2.0-2.7	Yes
G1 (Iraq)	Carbon fiber	0	455	2.0-2.7	Yes
G1 (Iraq, possible)	Carbon fiber	0	530	3.7	Yes
G1 (Iraq, possible)	Carbon fiber	0	650	5.5	Yes
Model 1 (Brazil)	Carbon fiber	?	?	3-4	Yes
IR-2 (Iran, target)	Carbon fiber	0	480	3.3	Yes
P2 (Pak., DPRK, Libya)	Maraging steel	1	450	5.24	Yes
IR-2m (Iran)	Carbon fiber	1	480-500	6.2-6.4	Yes
IR-4 (Iran)	Carbon fiber	1	?	~6	Yes
Indian (~2007)	Maraging steel	1	?	5?	Yes
IR-2m (target)	Carbon fiber	1	700	11	Yes
S1 (South Africa)	?	0	?	5?	Yes
P3 (Pakistan)	Maraging steel	3	450	9-10	Yes
Brazilian (~2005)	Carbon fiber	?	?	10?	Yes
S-2 (S. Africa, 2 meter)	Maraging steel	?	450	10	Yes
P4 (Pakistan)	?	?	?	?	Yes
TC-11 (Iraq-target?)	Carbon fiber	6	530	20	Yes
TC-11 (URENCO 1980s)	Carbon fiber	6	650	30	Yes
S-? (South Africa; 3 m rotor, target)	Carbon fiber	?	550	30	Yes
U.S Centrifuge (generic)	**?**	**0**	**?**	**350**	**No**

Notes: Gray shading represents a centrifuge deployed in production-scale cascades. Iraq operated only a single G1. In Pakistan, the P4 may be deployed as well, although little is known about its properties.
The bellows are made from maraging steel, except in the IR-4 which reportedly uses a carbon fiber bellows. The average separative work of a centrifuge in a cascade is less than when operating alone. Urenco's TC-11 and the U.S. centrifuges are for comparison.
Source: ISIS

Figure 9: A U.S. centrifuge facility.

The reason that centrifuge programs seek to increase output above one swu per year are straightforward to understand, as illustrated in figure 10. If a country wanted to build a centrifuge plant able to make enough weapon-grade uranium for one nuclear weapon per year, it would need about 500 centrifuges, each with an output of 10 swu per year, but 10,000 centrifuges, each with an output of 0.5 swu per year. At 2 swu per year, about 2,500 centrifuges would be needed. A low performance centrifuge may in theory be somewhat easier to build, but many more would have to be built and operated successfully in cascades. The amount of raw materials, components, and equipment would be proportionately greater.

Figure 10: Centrifuge Output vs. Goods Required

		Examples of Amount of Equipment	
Centrifuge Output (swu/year/cent.)	**Number Centrifuges (produce 25 kg WGU/yr)**	**Bottom Bearings(a)**	**Fast-Acting Valves(b)**
0.5	**10,000**	**10,000**	**30,000**
1.0	**5,000**	**5,000**	**15,000**
2.0	**2,500**	**2,500**	**7,500**
5.0	**1,000**	**1,000**	**3,000**
10	**500**	**500**	**1,500**

Comments:

(a) For comparison purposes, the production of 25 kilograms of weapon-grade uranium (WGU) is taken as requiring 5,000 swu, or 200 swu per kilogram of WGU; so the plant would produce enough WGU for one nuclear weapon per year.

(b) One way to protect centrifuges against crashing is to have a computer control system that allows for the rapid shut off of feed, product, and tails gas in each centrifuge. In designs used by Pakistan and Iran, each centrifuge has three fast acting valves. Additional bellows sealed valves are used in each cascade; up to 25 per cascade is not unusual. Since low end centrifuges would also need more cascades, they would also need many more bellows sealed valves than higher output centrifuges.

A higher performance centrifuge can be the same size as a low performance one, but it would require more sophisticated materials that are more difficult to obtain or to manufacture to achieve higher rotational speed. However, low performance centrifuges still require high precision manufacturing of the rotating components and the acquisition of high strength materials and much greater amounts of cascade equipment, such as vacuum pumps, valves, and measuring equipment. Few countries can make this equipment to the standards of quality and reliability needed in a centrifuge program. Moreover, these low-tech centrifuges are also hard to develop and build in large numbers, where each one must be built to high standards in order to minimize centrifuge failure during operation.

Some have tried to trivialize the difficulty of building and operating low output centrifuges.[49] But in fact, it is unlikely that states in the future will opt for low-tech, early-Soviet-era type

[49] Scott Kemp, "Centrifuges: A New Era for Nuclear Proliferation" (Washington, D.C.: Nonproliferation Education Policy Center, June 5, 2012). http://www.npolicy.org/article_file/Centrifuges-_A_new_era_for_nuclear_proliferation.pdf
This article, which ISIS had reviewed by several centrifuge experts in the United States and abroad, contains several historical inaccuracies which if corrected undermine fundamental points of the report. It also understates the engineering challenges in building centrifuges individually and in cascades and fails to accurately include the role of foreign assistance to several centrifuge programs.

centrifuges, as suggested by one analyst. Moreover, assertions that developing countries can avoid illicit procurement by building low-end centrifuges are unfounded.

Although predictions about the exact type of centrifuge sought by a state is uncertain, it is reasonable to assume that developing states in choosing a centrifuge during the next decade will balance costs, output, available knowledge and experience, and supply. In most cases, these countries are expected to pursue illicit procurement to develop their centrifuges and build plants.

Given the difficulties of building gas centrifuges, one has to ask why so many states try to build them. One answer is that many countries have had access to an extensive amount of sensitive and classified centrifuge information and data about centrifuges, and illicit procurement has proven effective in allowing states to acquire the wherewithal to make and operate centrifuge plants. It is difficult for a state, particularly one building a clandestine nuclear program, to start from scratch. These factors are expected to continue affecting states' calculations in deciding to pursue or improve centrifuges during the next decade.

Findings on Gas Centrifuge Pathway

During the next five to ten years, proliferant and other states are likely to continue to pursue gas centrifuges. Many of these centrifuge programs are likely to continue depending on overseas procurement for a range of key goods and sensitive information. Strictly indigenous production of centrifuges is rare historically and is unlikely for any new developing states seeking nuclear weapons.

State programs are unlikely to utilize low-end centrifuges as a way to circumvent the need for overseas procurements. In fact, it is doubtful that developing states could build even the low-end centrifuges without outside assistance and foreign procurements. A future initial effort by a developing state to build its first gas centrifuge plant able to make enough weapon-grade uranium for a nuclear explosive may be limited to centrifuges with an output of between one and five swu per year per centrifuge. However, most such programs can be expected to seek centrifuges in the range of 2-5 swu year per centrifuge, partly in order to limit the size of the plant and vast overseas requirements for goods (see also figure 10). Some established programs, such as Pakistan, Iran, Brazil, and North Korea could achieve centrifuges in the range of 10-20 swu per year per centrifuge five to ten years from now. Proliferant states are unlikely to achieve centrifuge outputs significantly higher than 30-40 swu year per centrifuge in this time period.

Declared or undeclared centrifuge programs could develop, or re-start, in countries that are newly industrialized or in more rapidly developing countries, such as South Korea, Turkey, and South Africa. Their centrifuges may be more advanced than those built initially by proliferant states. They could likely achieve outputs of 5 swu per year per centrifuge but they may seek a centrifuge with an output of 10 swu per year. These programs would be expected by then to be mostly capable of making centrifuges indigenously. However, they are expected to depend on overseas procurement for certain items in order to save costs and time and obtain higher quality, more reliable goods.

Terrorists Building Centrifuges. Terrorists may be capable of building a limited number of low-end centrifuges. However, the production of enough weapon-grade uranium for one nuclear weapon would require a large number of centrifuges. As a result, this scenario is unlikely, unless a terrorist group can establish itself securely and safely for years inside a host state. In that endeavor, a terrorist group developing gas centrifuges would likely require significant outside help, including enlisting experts in centrifuge technology. For such a group, the production of enough weapon-grade uranium for one nuclear weapon would likely suffice, and the device would be delivered by basic methods, such as by truck or boat. However, it would take many years to build such a plant and produce the necessary amount of HEU. The detection of such a plant by the outside world would likely trigger an immediate military or other firm response aimed at immediately destroying the facility and the effort. Thus, this scenario is unlikely during the next five to ten years.

3b: Digging Deeper: Laser Enrichment of Uranium

For several decades, countries have sought to perfect laser enrichment as an economical and efficient path to producing enriched uranium. If properly engineered, laser enrichment has the potential to dramatically advance the capabilities of proliferant states to secretly enrich uranium. To date, however, no nuclear program is known to have successfully used laser enrichment to produce kilogram quantities of HEU or quantities of LEU suitable for a civil nuclear reactor program.

It remains very difficult to evaluate the likelihood of a state building a laser enrichment plant able to produce significant amounts of HEU. Enriching uranium with lasers on a production-scale appears extremely complicated. However, detailed technical information about uranium laser enrichment technologies remains rather limited, making any assessment as to their feasibility more complicated. Although laser enrichment appears able to make HEU, there are disagreements about the feasibility of doing so with existing methods.

This project is not able to assess technically the ease or practicality of using existing laser uranium enrichment technologies to produce significant amounts of highly enriched uranium. However, in a five to ten year time frame, laser enrichment of uranium warrants concern as a potential way for a proliferant state to acquire significant quantities of highly enriched uranium. A covert laser uranium enrichment facility might escape detection by the IAEA and Western intelligence services. As a result, this project focuses on ways of improving the detection probability of clandestine efforts in proliferant states, thwarting the progress of any secret effort, and finding ways to deter secret laser enrichment programs among proliferant states.

Potential Proliferation Threat of Laser Enrichment

Laser enrichment of uranium is often viewed as a proliferation threat. Despite the difficulty of succeeding with laser enrichment, proliferant states may be motivated to relook at this option for making highly enriched uranium for nuclear weapons. These motivations include major advances in laser technology, the relatively small size and the few external indicators of a laser enrichment plant, the apparent potential of a new form of laser enrichment, separation of isotopes by laser excitation (SILEX), and the ability to conduct several necessary research and development activities under a non-nuclear cover. Over the next five to ten years, further advances could occur that would elevate the chance that a state could use laser enrichment to produce HEU for nuclear weapons.

Types of Laser Enrichment

Currently, there are three main types of laser enrichment: atomic vapor laser isotope separation or AVLIS, molecular laser isotope separation or MLIS, and separation of isotopes by laser excitation or SILEX. However, as there is little published information about the SILEX process, this report focuses on AVLIS and MLIS.

Atomic vapor laser isotope separation (AVLIS) is based on varying electronic energies of different isotopes. AVLIS typically subjects vaporized natural uranium metal to a laser beam

tuned to the right frequency and wavelength to excite the electrons in the uranium 235 isotopes.[50] When the isotope absorbs enough energy from the laser, it emits an electron, becoming a positively charged ion. The ion is then deflected electrostatically to a collector where it is gathered on charged plates as an enriched product. The uranium 238 atoms, unaffected by the tuned laser beam, remain uncharged and pass through the product collector section to be deposited on a tails collector. The laser system used in the AVLIS process of uranium enrichment consists of pump lasers and dye lasers. The pump lasers, traditionally copper vapor lasers, optically energize the dye lasers. Argon-ion or neodymium: yttrium-aluminum-garnet (Nd:YAG) lasers can also be used in place of the copper vapor lasers. The dye lasers produce the light used for isotope separation in two steps: the dye master oscillator first provides control of the laser beam's frequency, timing, and quality and one or more dye laser amplifiers then increases the power of the light from the dye master oscillator.

In molecular laser isotope separation (MLIS), lasers irradiate uranium hexafluoride gas and a carrier gas, such as hydrogen, nitrogen, or argon, in a two-step photo-dissociation process after being cooled by a supersonic nozzle.[51] In the first step, a raman shifter converts the wavelength of a carbon dioxide laser from 10.6 micrometers to 16 micrometers, which selectively excites the uranium 235 isotope of uranium hexafluoride. Photons from a second laser system then preferentially dissociate the uranium 235 isotope of uranium hexafluoride to a uranium 235 isotope of uranium pentafluoride and a free fluorine atom. The enriched uranium pentafluoride precipitates and can then be separated from the tails or waste. This process must be repeated several times to produce the desired concentration of enriched uranium and the uranium pentafluoride must be fluorinated before each subsequent stage. A typical MLIS cascade will contain anywhere from 5 to 30 separate stages to produce useful levels of enriched uranium.

Separation of isotopes by laser excitation (SILEX) is reportedly the most promising laser enrichment technology of the three. In this method, a laser is tuned to a very specific frequency and ionizes a uranium 235 isotope in a mixture of natural uranium molecules in a carrier gas so that the uranium 235 is easily separated from the mixture.[52] General Electric (GE) and Hitachi have pursued a joint venture called Global Laser Enrichment (GLE) using technology licensed from Australian Silex Systems Ltd. and are seeking federal licensing to build a full scale plant in the United States. The technology itself remains classified under a 2000 U.S.-Australian Agreement for cooperation for the development of SILEX technology, giving the United States control over its export. Analysts have suggested that SILEX could be less expensive than

[50] See for example, Lawrence Livermore National Laboratory under the auspices of the U.S. Department of Energy, "Overview of Uranium Atomic Vapor Laser Isotope Separation," August 1993. http://www.osti.gov/bridge/servlets/purl/10102839-PDTP1e/native/10102839.pdf; Hendrik Strydom, "Mass Spectrometry Characterisation of Laser Produced Products" (PhD diss., University of Natal, 1999), p. 77; and U.S. Department of Energy, Nuclear Transfer and Supplier Policy Division, "A Handbook for Annex 3," *Iraq Watch*, April 1998, pp. 61-62. http://www.iraqwatch.org/government/US/DOE/DOE-CHAPTER3.PDF

[51] "A Handbook for Annex 3,", pp. 62-63. http://www.iraqwatch.org/government/US/DOE/DOE-CHAPTER3.PDF ; Strydom, "Mass Spectrometry Characterisation of Laser Produced Products," p. 114.

[52] Sharon Weinberger, "Laser Plant Offers Cheap Way to Make Nuclear Fuel," *Nature*, July 2012. http://www.nature.com/news/laser-plant-offers-cheap-way-to-make-nuclear-fuel-1.10945

uranium enrichment by centrifuges[53] and GE claims it would be commercially economical to make LEU.

Proliferant State Uranium Laser Enrichment Programs

According to public accounts, at least 27 countries have attempted laser isotope separation as a form of uranium enrichment, including Argentina, Australia, Brazil, China, France, Germany, India, Iran, Iraq, Israel, Italy, Japan, the Netherlands, Pakistan, Romania, Russia, South Africa, South Korea, Spain, Switzerland, the United Kingdom, the United States, and Yugoslavia.[54]

Iran, Iraq, and South Korea operated small, secret laser uranium enrichment programs, according to the IAEA.[55] Iran and South Korea produced small amounts of enriched uranium. All three programs were in violation of their safeguards agreements with the IAEA. The Iranian program was most successful of the three, when its program was exposed by the IAEA and shutdown (see Box 3). While none of the programs found it feasible to produce kilogram quantities of HEU, all three countries were able to make strides in laser enrichment while avoiding detection until they were detected by the IAEA and intelligence agencies.

[53] Francis Slakey and Linda Cohen, "NRC Should Perform Non-Proliferation Assessment of Laser Enrichment Technology," *Physics & Society* (The American Physical Society), vol. 39, no. 3, July 2010, p. 16.
[54] Sandra Upson. "Laser Uranium Enrichment Makes a Comeback," *IEEE Spectrum,* October 2010. http://spectrum.ieee.org/energy/nuclear/laser-uranium-enrichment-makes-a-comeback/0 .
[55] Report of the Director General, International Atomic Energy Agency, *Implementation of the NPT Safeguards Agreement in the Republic of Korea,* November 26, 2004. http://www.iaea.org/Publications/Documents/Board/2004/gov2004-84.pdf; Report of the Director General, IAEA, *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, November 10, 2003. http://www.iaea.org/Publications/Documents/Board/2003/gov2003-75.pdf ; Report of the Director General, IAEA, *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, September 1, 2004. http://www.iaea.org/Publications/Documents/Board/2004/gov2004-60.pdf ; and National Monitoring Directorate, Republic of Iraq, *Draft Full, Final and Complete Declaration of the Iraqi National Nuclear Program*, February 1996.

Box 4: Major Foreign Assistance to Iran's Pre-2004 Laser Enrichment Program[1]

The Atomic Energy Organization of Iran started a laser enrichment program in 1975 at the Tehran Nuclear Research Center (TNRC) in Tehran. It depended heavily on foreign assistance. In total, this program had four foreign laser isotope enrichment contracts, most of which were not declared to the IAEA until late 2003.

German Contract

In 1975, the AEOI acquired a laboratory to study the spectroscopic behavior of uranium metal. It abandoned this laboratory in the 1980s since it did not function properly.[2] The laboratory also had two mass spectrometers. These spectrometers were used later to analyze undeclared samples of enriched uranium at Kalaye Electric Company, Iran's centrifuge research and development facility in the late 1990 and Lashkar Ab'ad, a pilot laser enrichment plant built in the early 2000s (see below).

U.S. Company Contract

In the late 1970s, Iran signed a contract with Jeff Eerkens and his associated companies to study another method of enriching uranium with lasers that is similar to MLIS.[3] Most of the equipment, including four carbon monoxide lasers and vacuum chambers, was delivered. But the 1979 revolution ended this collaboration.

China Contract

In 1991, Iran signed a contract with China for the establishment of two laser laboratories at the Tehran Nuclear Research Center, with one laboratory for the spectroscopic study of uranium metal and the second one for carrying out uranium enrichment on a laboratory scale (involving milligrams of uranium). Under this contract, Iran obtained two small vacuum chambers from China. The contract also provided for the delivery of 50 kg of undeclared natural uranium metal for use in laser enrichment development. The contract provided for "getting one milligram uranium enriched with 3% concentration of U235 in no longer than 8 hours".[4] Iran's program achieved enrichment of uranium with an average of 8 percent uranium 235 with a peak enrichment of 13 percent. Again, these enrichment activities were not reported to the IAEA, as required. Ultimately, Iran viewed the experiments as unsuccessful because of continuous technical problems with the copper vapor lasers, electron beam guns, and dye lasers.

Russian Contract

In 1998, Iran signed a contract with Russian entities to obtain information related to AVLIS and for the supply of the relevant equipment for an undeclared pilot enrichment facility at Lashkar Ab'ad. However, as a result of U.S. pressure, the Russian government would not grant the Russian supplier with export permits for some of the equipment, in particular the copper vapor laser (up to 150 kW) and dye lasers, some collector parts, the electron beam gun, and the power sources.

The St Petersburg Yefremov Institute (NIIEFA), which is part of Rosatom, delivered one large vacuum chamber (5 meters long, 1 meter in diameter) equipped with some diagnostic equipment and diffusion pumps to create the high vacuum inside the chamber. The Russian supplier also provided some training and documentation. The fourth contract specified the delivery of a system that could produce enrichment levels of 3.5-7 percent and to "have actual production of at least 5 kg of a product within the first year after installation."[5]

IAEA experts assessed that the system in the fourth contract could have made highly enriched uranium, albeit in very small quantities, if the entire package of equipment had been delivered.[6] The AVLIS vacuum chamber had a number of features specific to HEU separation work, including an ion trap for the extraction of ion impurities for increased HEU yield and a collector assembly designed for the relatively low throughput of HEU.

Lashkar Ab'ad-Pilot AVLIS Plant in Iran

The failure to obtain export permits for the Russian-made lasers did not stop Iran. Independently, of these four contracts, Iran had obtained from European suppliers a range of lasers, including dye and copper vapor lasers. It already had a supply of 50 kilograms of natural uranium metal to use as the feed material for the AVLIS plant.

Iran installed its existing copper vapor lasers and dye lasers with the large vacuum vessel at Lashkar Ab'ad In 2002. Iran conducted a total of four runs with uranium feed using a total of 500 grams of uranium metal from October 2002 through January 2003, achieving enrichment levels of 0.8 percent. The equipment was dismantled in May 2003 and transferred together with the uranium metal to Karaj, where it was inspected by the IAEA.

---

[1] Unless otherwise cited, the sources are *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, November 10, 2003, op. cit. http://www.iaea.org/Publications/Documents/Board/2003/gov2003-75.pdf ; and *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, September 1, 2004, op. cit. http://www.iaea.org/Publications/Documents/Board/2004/gov2004-60.pdf
[2] Anton Khlopkov, "Creation of Laser Enrichment Laboratory in Iran: A True Story of Jeff Eerkens" (Moscow: Center for Energy and Security Studies, September 12, 2012).
[3] "Creation of Laser Enrichment Laboratory in Iran" op cit.
[4] *Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran*, September 1, 2004, op. cit., Annex, p. 7.
[5] *Implementation of NPT Safeguards Agreement in Iran*, September 1, 2004, op cit, Annex p. 8.
[6] *Implementation of NPT Safeguards Agreement in Iran*, September 1, 2004, op cit, Annex p. 8.

There are resurgent worries about a secret Iranian laser enrichment program. Iran has not provided information, as requested by the IAEA, in connection with its announcement on February 7, 2010 that it possessed laser enrichment technology.[56]

Iran's laser enrichment program benefited enormously from foreign assistance particularly from China and Russia in the 1990s. South Korea' program depended on foreign assistance. Iraq's program was inhibited by a lack of foreign assistance.

[56] Report of the Director General, IAEA, *Implementation of the NPT Safeguards Agreement and relevant provisions of Security Council resolutions in the Islamic Republic of Iran*, February 21, 2013, p. 6.

Independent of its contracts with Russian and Chinese entities, Iran used its overseas procurement networks to seek needed goods for its laser enrichment programs. Similarly, Iraq did so. The details of how South Korea obtained its capability are not publicly known.

Many, but not all, of the key goods procured abroad by Iran and Iraq appear to be on export control lists, either Part 1 or Part 2 of the Nuclear Suppliers Group control list, or INFCIRC/254. In addition, one would expect that countries pursuing laser enrichment would attempt to buy goods abroad with specifications just "under" the limit that requires explicit control and modify them for use in an enrichment program. This strategy has proven effective in other enrichment programs and in nuclear weaponization efforts. To avoid purchases abroad of certain equipment, Iran and Iraq invested in developing the capability to make their own lasers and associated equipment.

Findings, Constraints, and Additional Concerns

One potential constraint on a state choosing to pursue uranium laser enrichment is that it may instead pursue a better known and more reliable alternative, such as gas centrifuges. Moreover, much about laser enrichment remains classified by governments. They are taking precautions to ensure that the companies which develop this technology prevent it from proliferating. The companies themselves view laser enrichment technology as proprietary and do not want it available to competitors.

Nonetheless, leakage of secrets is a persistent problem, as evidenced by past leakage from reactor and gas centrifuges programs. One concern is that if laser enrichment becomes more successful at producing enriched uranium in the next several years, classified information could leak or be stolen. In addition, its widespread development may lead experts to help proliferant states as they have helped proliferant states' centrifuge programs.

On balance, in a five to ten year time frame, despite the technical uncertainties, laser enrichment of uranium warrants additional attention as a way whereby a proliferant state could acquire significant quantities of highly enriched uranium. A priority is improving the detection probability of clandestine efforts in proliferant states, thwarting the progress of any secret effort, and finding ways to deter secret laser enrichment programs. One valuable tool in that effort will be detection of illicit procurements, since a developing state is unlikely to be able to proceed on this pathway without outside assistance.

4. Key Information: The Special Challenge of the Spread of Classified or Otherwise Sensitive Information

In the future, there could be a greater availability of classified, proprietary, and other sensitive information about the technologies used to make fissile material and build nuclear weapons. For almost all proliferant states during the last several decades, their progress benefited from access to another country's classified information about nuclear weapons or the means to make HEU and plutonium. They have acquired relevant secret information via theft, purchase, or state-to-state transfer.

In the future, building a gas centrifuge plant or a reliable nuclear weapon without access to classified or other sensitive information is likely to continue being extremely time consuming and plagued by problems. The same likely also applies to laser enrichment technologies and reactor construction and operation.

The problem of controlling classified and sensitive information was highlighted by the vast amount of such information disseminated by the A.Q. Khan network. Authorities found a huge collection of sensitive and classified information in the hands of members or customers of the Khan network when it was busted in 2003 and 2004. Considering just the Tinner family, the Swiss node of the Khan network, they had two complete centrifuge designs, considerable information about building a centrifuge plant, a great deal of sensitive or classified centrifuge manufacturing instructions and operating manuals, and even a complete nuclear weapons design and portions of more advanced ones. Most of this information was found by Swiss investigators on the Tinners' computer hard drives. No one would have expected this information to end up on the internet and it did not because the smugglers wanted this information to remain scarce so that they could sell it at a high price. Copies or the originals of this sensitive information may still be in the hands of members of the Khan network or others associated with it. They may eventually sell it or pass it on to others who would make it more available.

One of A.Q. Khan's more dangerous innovations was ingeniously marketing designs and manufacturing instruction booklets for centrifuges and nuclear weapons, developing packages containing key equipment and, often times, digitized documentation. He made the information more user-friendly and eased its dissemination. These instructions were sufficient to achieve the many steps in the process of building a nuclear weapon.

Khan himself depended on stealing a vast amount of sensitive and classified centrifuge information from URENCO in the 1970s. Pakistan would have been unlikely to have ever produced much HEU without Khan's and his colleague's espionage against Urenco and subsequent illicit procurements of materials, equipment, centrifuge components, and more sensitive information.[57]

Iraq also acquired a great deal of German Urenco centrifuge information in the late 1980s.[58] This information in the form of documents and expert aid was critical to Iraq's relatively rapid progress on centrifuges up to the 1991 Gulf War.

---

[57] *Peddling Peril*, op. cit.
[58] *Iraq's Acquisition of Gas Centrifuge Technology*, ISIS, 2002. http://exportcontrols.info/case_studies.htm

More recently, cyber-theft and espionage pose new threats of leakage of sensitive information important to the development of nuclear weapons and the means to make them. Information is vulnerable when located on computer networks and hard drives. In addition, there are many dual-use technologies used in modern industries that are sensitive or proprietary and sought by other states. Some of these are critical to the development of a capability to make nuclear weapons, plutonium, or HEU.

China has emerged as a state dedicated to purchasing or stealing through cyber attacks and espionage a wide variety of sensitive information and intellectual property, including "technology blueprints, proprietary manufacturing processes, test results, business plans, pricing documents, partnership agreements, and emails and contact lists."[59] It actively seeks sensitive information from governments and corporations. The cyber security firm Mandiant estimated that since 2006, the Chinese People's Liberation Army cyber attack unit alone had compromised "141 companies spanning 20 major industries, from information technology and telecommunications to aerospace and energy…"[60]

When setting up subsidiaries in China, high-tech companies now have to exercise extreme care to prevent their proprietary and often sensitive information from falling into the hands of the Chinese government or private Chinese entities. Joint ventures in China are posing significant risks of the leakage of sensitive information and expertise.

China is markedly augmenting its efforts on a global scale to purchase whole companies, buying up strategic assets and major companies.[61] In the future, how many of these purchases will provide China with sensitive technologies that it seeks access to? But China is not alone in pursuing such information. Iran's nascent cyber capabilities have raised alarm with the brazenness of recent attacks against Western interests, according to a former U.S. CENTCOM commander.[62] In the future, Iran could also seek access to classified nuclear relevant information if it felt it could remain anonymous in doing so. These efforts are likely to continue by many other states and result in the more widespread leakage of sensitive, nuclear related information.

Another concerning phenomenon is the growing availability of experts with experience in producing nuclear explosive materials and nuclear weapons. They provide a growing reservoir of expertise for building nuclear weapons, uranium enrichment, and plutonium production.

Although the vast majority of these experts would not proliferate or knowingly help proliferant states, some have done so, mainly for financial gain but also ideological reasons. Others simply turn a blind eye to the state's intentions. A.Q. Khan and his Pakistani colleagues are a well-known example of a group of experts who violated their own countries' classification laws to help foreign nuclear weapons efforts.[63] Another case involves a former Soviet nuclear weapons expert who is

[59] Mandiant, "APT 1: Exposing One of China's Cyber Espionage Units," undated report. http://intelreport.mandiant.com/Mandiant_APT1_Report.pdf
[60] "APT 1: Exposing One of China's Cyber Espionage Units," op cit.
[61] Heriberto Araujo and Juan Pablo Cardenal, "China's Economic Empire," *The New York Times,* June 1, 2013.
[62] Josh Gerstein, "Mattis: U.S. Flubbed Response to Iranian Bombing Attempt," *Politico,* July 21, 2013.
[63] *Peddling Peril,* op. cit.

alleged to have helped Iran's nuclear weapons efforts in the early 2000s. In the August 30, 2012 safeguards report on Iran, the IAEA identified a foreign expert who is alleged to have contributed to Iran's high explosive activities at the Parchin military complex that were part of a nuclear weapons development effort. ISIS earlier identified this expert as the former Soviet nuclear weapons expert Vyacheslav V. Danilenko.[64]

Preventing the unauthorized spread of classified, proprietary or other sensitive information will remain a difficult challenge. States and terrorists will likely continue to try to gain access to such information in their quest for nuclear capabilities.

[64] Albright and Robert Avagyan, "Revisiting Danilenko and the Explosive Chamber at Parchin: A Review Based on Open Sources," ISIS, September 17, 2012
http://isis-online.org/isis-reports/detail/revisiting-danilenko-and-the-explosive-chamber-at-parchin-a-review-based-on/

5. Future Marketplace: Suppliers of the Future

For governments and responsible suppliers seeking to stop the spread of nuclear weapons and their production capabilities, detecting illicit nuclear trade will remain a difficult endeavor. Proliferant states will continue seeking capabilities for their nuclear programs from an abundance of suppliers and intermediaries. Even if no new suppliers emerge in the future, much still needs to be done to better detect and thwart illicit nuclear trade. These efforts must compete with the simultaneous spread of technologies and capabilities around the world. Many countries that are considered developing nations have growing and sophisticated manufacturing and machine tool capabilities that could be exploited by smugglers seeking to outfit nuclear programs. These new suppliers are emerging in developing markets with few export controls and a culture of indifference to stopping the spread of nuclear weapons technology.

The time when only a few states had access to the most advanced technologies is over. Dual-use technologies and the scientific and engineering personnel who design and use them are circulating more in our globalized economy. In the next several years, the number of high technology suppliers is expected to increase globally, particularly in what are today called emerging markets.

Many of these emerging countries have a poor history of implementing trade controls and U.N. Security Council sanctions. They often have a culture of indifference to stopping the spread of nuclear weapons technology. In China and other parts of Asia, export controls laws and regulations are both weak and poorly enforced. Businesses there often do not question the buyer or the purpose of the declared end-use. In the future, there could be more countries hostile to export controls or international norms against the sale of the wherewithal to make sensitive nuclear facilities. A combination of lax export controls and an increasing ability to manufacture reliable nuclear and nuclear-related dual-use components will make these emerging states popular targets for illicit procurement attempts similar to how certain European manufacturers outfitted a large number of aspiring nuclear weapons programs in the 1970s and 1980s.

Newly industrialized countries could become important suppliers of sensitive goods for nuclear programs. The situation in these countries may appear better than in the emerging markets, but their trade control culture is unlikely to be as strong as in many traditional supplier states. For example, both Taiwan and South Korea have had difficulties in preventing smugglers from acquiring controlled goods for Iran or North Korea.[65]

In the next five to ten years, which regions and countries could pose the greatest risks? This section discusses the most likely countries to do so.

Trends

For most states, including in emerging markets, a priority is developing advanced manufacturing sectors. As a result, more sophisticated manufacturing capabilities, requiring more skill and technology intensive activities, will spread globally.

[65] See for example, Andrea Stricker, "United States Busts Likely North Korean Transshipment Scheme," ISIS, May 24, 2013. http://isis-online.org/isis-reports/detail/case-study-united-states-busts-likely-north-korean-transshipment-scheme/; *Peddling Peril*, op. cit., pp. 240-241; see also Box 4 below.

Manufacturers in developed countries will continue to play an important role in the development of manufacturing sectors in emerging markets. Their subsidiaries will continue to be major local suppliers of high-tech equipment. The technology to make critical dual-use and other sensitive goods will also spread more widely.

There will be many more multinational companies based in these emerging markets. In time, they may do more business with other emerging markets than with the currently developed world. The supply chain will become much more internationalized with richer information technology and communications. In the future, suppliers of high-tech goods in developed countries will have competitors in the emerging markets for these goods.

At the same time, proliferant states, such as India and Pakistan, and possibly former proliferant states, such as Brazil, which have depended or did depend on overseas, illegal procurements for their nuclear programs may resist reforms in trade control systems and rigorous enforcement of trade control laws. In addition, China poses a special concern.

Example: China

China poses special challenges both today and in the future to stopping illicit trade in nuclear and nuclear-related commodities. In five to ten years, private Chinese companies will be able to make many more of goods to sufficient quality and reliability for use in sensitive nuclear facilities, including gas centrifuge plants. As China becomes more capable of manufacturing these high-tech goods and if its poor export control implementation record persists, the illicit trade problem in China could grow substantially unless mitigation steps are taken soon.

Current Situation. Iran and North Korea have bought a wide variety of goods for their gas centrifuge programs in China. Some goods are made in China but many are not. Many high-tech goods are made in Europe, the United States, or Japan and are in essence transshipped through China to either Iran or North Korea illicitly. Although Chinese companies can make many of these products, their goods are not of the same high quality as Western products, and Iran and other proliferant states have demonstrated through their actual and attempted procurement that they want the higher quality goods for their nuclear facilities. Key vacuum pumps used in gas centrifuge programs, high quality carbon fiber, and pressure transducers are but some examples of goods that China does not make in sufficient quality to attract proliferant state centrifuge programs.

In scrutinizing proliferant states' illicit procurement efforts, a pattern is that proliferant states want the higher quality goods for their nuclear facilities. This pattern is not surprising given the difficulty of building certain nuclear facilities where quality and reliability are paramount.

Most of the illicit trade in China involves private Chinese companies, more so than state-owned companies. However, some of these private companies contract with state-owned companies. These private companies often play a key role in facilitating illegal sales to North Korean and Iranian nuclear programs. It is likely, in fact, that increasing privatization in China will augment illicit trade due to the lack of adequate government scrutiny of their exports.

The Chinese government today does not do enough to enforce trade controls and U.N. Security Council sanctions. China has done little in recent years to stop North Korea's shopping for its nuclear programs. Perhaps, it is changing in the aftermath of North Korea's provocative actions in early 2013, including a missile launch and an underground nuclear test. As a result of concern about these developments, China has reportedly stepped up inspections of cargo bound for North Korea at ports and cities near their shared border.[66] Whether this signals a fundamental shift or just a way to temporarily show displeasure is unclear.

Iran is more constrained than North Korea in China, but it can still obtain dual-use goods and raw materials from Chinese suppliers or by working through private Chinese companies that approach U.S. and European high technology subsidiaries with locations in China. In the latter case, China acts essentially as a turntable, or country of transit concern, where the goods pass through China from the supplier country to a proliferant state.

One typical example of such a diversion occurred in 2011 and involved an Iranian smuggling effort for equipment likely intended for its gas centrifuge program. The illicit procurement attempt started with an Iranian front company that was located in Iran and was known to be a broker for Iran's ballistic missile and nuclear programs. (This Iranian company was sanctioned by the European Union in 2013.) The Iranian company contracted with an Iranian-controlled entity in China, which in turn contracted with a Chinese private company to obtain sensitive goods that are well-known to be used in Iran's gas centrifuge program. While China makes these particular goods, the Chinese-manufactured goods are not reliable or of high enough quality for nuclear use. As a result, Iran wanted to obtain Western manufactured goods available via China and was searching widely for such goods there under the pretense of seeking the lowest price. The private Chinese company told the Western suppliers' subsidiaries that the goods would be used domestically in China, despite being intended for export to Iran.[67]

This is not an isolated case nor is it the only way Iran uses China to acquire needed goods for its nuclear programs. As the world leader in investigating and prosecuting Iran's nuclear smuggling efforts, the United States often identifies Chinese suppliers or middlemen and the goods they help Iran acquire. In 2012, a major U.S. sting operation led to the arrest of an Iranian working with a Chinese company to send or attempt to send U.S. and European-origin goods to Iran and Iranian companies or entities via transshipment through China. The sought-after goods, which included tons of maraging steel, vacuum pumps, pressure transducers, mass spectrometers, and accessories, were dual-use items intended for and critical to the operation and advancement of Iran's gas centrifuge program.[68] According to a senior U.S. official interviewed by *The Washington Post*, Iran was detected in 2010 trying to buy carbon fiber in China, a material used in fabricating advanced gas centrifuges.[69] Between 2006 and 2008, the United States investigated another Chinese company's sales of missile and nuclear related materials to Iran, during which the

[66] Charles Hutzler, "China Punishes North Korea for Nuclear Tests as US Asks for More," Associated Press. March 24, 2013.
[67] Interview by ISIS authors of this report.
[68] David Albright and Andrea Stricker, "Major U.S. Sting Operation Arrests Iranian in Nuclear Smuggling Network," ISIS, August 12, 2012. http://isis-online.org/uploads/isis-reports/documents/US_case_gas_centrifuge_equipment.pdf
[69] John Pomfret, "Chinese Firms Bypass Sanctions on Iran, U.S. Says," *The Washington Post*, October 18, 2010.

company illegally accessed the U.S. financial system to receive payments from Iran.[70] In 2006, a private Chinese manufacturing company under false pretenses acquired vacuum pump systems from a European company's Chinese subsidiary. These pumps were manufactured in Europe and intended for use exclusively in China. Nonetheless, the Chinese manufacturing company in fact sent them to Iran without official approval.[71]

In another high profile case, the United States cracked down in the summer of 2012 on a major nuclear smuggling network run by an Iranian and Chinese individuals. The Iranian was arrested in the Philippines and should be extradited to the United States but there is no indication that China will take action against, investigate, or arrest the Chinese individuals.[72]

In late 2011, an Iranian trading company, Jahan Tech Rooyan Pars Co., sought via a commercial Chinese web site 100,000 ring magnets, whose dimensions matched those of ring magnets of Iran's IR-1 centrifuge.[73] This number of ring magnets was enough for 50,000 IR-1 centrifuges. The enquiry was surprising in that the Iranian company appeared to feel comfortable in openly seeking goods illicitly for Iran's nuclear programs from these commercial Chinese websites.

On balance, cracking down on illegal exports has not been a priority for China. Many parts of the Chinese government bureaucracy are aware of these cases and the problems in its trade control system. However, internal reform is hampered by the sheer size of the problem and by other economic priorities. Some Chinese officials are motivated to make changes for the better, but they say that change is slow, given the sheer size of the country and the huge number of companies that need to be controlled. Chinese government officials state that China has about 500,000 private companies, mostly small or medium in size. Many of these companies have little or no awareness of trade control laws or dual-use lists. Trade control officials make some efforts to educate these companies but are provided limited resources for education or enforcement actions. Some officials also acknowledge privately that a large amount of corruption among Chinese officials with business interests complicates getting companies to comply with Chinese trade control laws and regulations.

Another competing challenge is that the government does not want to put at risk China's critical export emphasis; exports are a major part of its economy. This emphasis, however, has the unfortunate consequence of encouraging private Chinese companies to make sales regardless of laws. The lack of resources to enforce export control laws means that smuggling efforts carry little risk.

---

[70] Andrea Stricker, "A Smuggler's Use of the U.S. Financial System to Receive Illegal Payments from Iran," ISIS, October 23, 2009, updated February 11, 2011. http://isis-online.org/uploads/isis-reports/documents/Limmt_Li_Fang_Wei_23Oct2009_update9Feb2011.pdf

[71] David Albright, Paul Brannan, and Andrea Scheel, "How Cooperation between a Company and Government Authorities Disrupted a Sophisticated Illicit Iranian Procurement," ISIS, January 12, 2009. http://isis-online.org/uploads/isis-reports/documents/Pumps_China_12January2009.pdf

[72] David Albright and Andrea Stricker, "Major U.S. Sting Operation Arrests Iranian in Nuclear Smuggling Network," ISIS, August 12, 2012. http://isis-online.org/uploads/isis-reports/documents/US_case_gas_centrifuge_equipment.pdf

[73] Albright, "Ring Magnets for IR-1 Centrifuges," ISIS, February 13, 2013.

The Chinese government appears to lack the political will to fully implement and enforce its laws aimed at stopping smuggling activities. Thus, unless more action is taken today, the problem may grow worse, as China masters the production of more and more high-tech goods.

Future. Today, Western companies with subsidiaries in China typically provide much higher quality goods than Chinese companies. This gives Western suppliers a major advantage over indigenous Chinese companies making similar goods. As discussed above, this is a major reason why China today is a country of transit concern.

But China is increasing its ability to make more sophisticated products. This increase is being accelerated by policies and practices of non-Chinese suppliers. Companies from industrialized countries have sold or are selling the technology to make sensitive goods to Chinese companies. If a good is not controlled, the technology is (or is widely perceived by Western companies) to be exportable without a license to Chinese companies. Their subsidiaries in China are often training Chinese engineers in making high-tech goods at their factories. Moreover, as discussed earlier, China has aggressive programs to steal or otherwise illicitly acquire intellectual property, which includes the technology to make more sensitive dual- or direct-use goods, from companies in advanced industrialized nations.

As a result, there are many reasons to believe that in five to ten years private Chinese companies will be able to make many more of goods to sufficient quality and reliability for use in sensitive nuclear facilities, including gas centrifuge plants. This development could be very serious for counter illicit nuclear trade efforts, given China's poor record on controlling its exports. Chinese companies could be able to produce, for example, high quality vacuum equipment, carbon fiber, and machine tools that countries like Iran and North Korea require for their centrifuge programs. Though these states now seek these goods through Chinese middlemen, China could come into its own as a direct supplier with respect to sophisticated, high technology goods.

Unfortunately, China will not be the only country posing such a threat. Based on current patterns, emerging markets are expected to gradually learn to make more sensitive goods reliably.

Future Suppliers of Concern

There are many countries that over the next five to ten years could develop the wherewithal to become high-tech suppliers to nuclear programs. This section seeks to define a list of countries that pose this concern, in the sense that they are projected to become suppliers and have inadequate export control practices or even hostility toward such controls. This list is developed in steps.

The first step is identifying the countries that could be future suppliers. Broadly, organized by region, they include:

- Relatively Newly Developed Countries and Territories, such as Israel, South Korea, Singapore, and Taiwan province.
- Emerging Markets. Emerging markets comprise up to 50 countries based on combining several standard lists of such countries. This study is considering a subset of about 20 such countries, in particular in:

    - Middle East and North Africa: Egypt, Morocco, South Africa
    - Americas: Argentina, Brazil, Chile, Columbia, Mexico, Peru
    - Asia: China, India, Indonesia, Malaysia, Kazakhstan, Pakistan, Philippines, Thailand, Turkey, Azerbaijan, Uzbekistan
    - Europe: Czech Republic, Hungary, Poland, Russia, Ukraine, Belarus
- Re-sellers of high technology equipment, such as Hong Kong province.
- Rogue Suppliers—Iran, North Korea, perhaps Syria, and a Khan-type network.

This list identifies those countries or entities that could be sources of direct use or dual-use goods for nuclear programs in five to ten years. This does not mean that each country will inevitably emerge as having developed such a capability. In addition, many of these countries that do develop such a capability may be able to produce only a few sensitive goods on a commercial scale.

It should also be noted that this project cannot identify all the countries that could become major suppliers or countries of concern; there are too many uncertainties and thus this study has sought to identify a group of countries based on current information and judgments about future developments. Some countries undoubtedly have been left off these lists; some will turn out not to develop as expected. With these uncertainties, these lists serve to identify and highlight the major countries of concern.

The second step is to consider within the above list emerging nations more carefully. Not all the emerging states in the first list will develop a robust manufacturing sector able to provide key goods to nuclear programs. Based on knowledge of illicit nuclear trade today and a judgment about future manufacturing capabilities, ISIS selected a subset of the emerging market countries for further consideration. The following is a set of emerging market countries organized by region that are more likely to become potential major suppliers of sensitive dual-use goods relevant to proliferant states, based on past illicit procurement cases, past proliferation related activities in the state, or current and emerging industrial capabilities:

- Africa: South Africa
- Americas: Brazil, Argentina
- Asia: China, India, Pakistan, Southeast Asia (in particular Malaysia, Thailand, and Indonesia), Turkey
- Eurasia: Russia, Ukraine, Belarus, Azerbaijan, Uzbekistan, Eastern Europe including Czech Republic, Hungary, Poland

These emerging market countries are expected to have manufacturing industries that can provide direct use or dual-use goods important to gas centrifuge programs, possibly laser enrichment programs, other uranium enrichment programs, and reactor and plutonium separation programs. They are expected to place emphasis on developing more advanced manufacturing sectors and to stress exports along with domestic sales.

The third step is to choose those countries on the first and second list that are projected to poorly implement trade controls, or have attitudes that emphasize increasing economic activity with too little regard for non-proliferation responsibility. This list then becomes the final list of countries of

concern. In some cases, the countries remaining on this report's list are generally considered to be cooperative under U.S. export control determinations, but procurement cases and political considerations led to their inclusion on this final list.

This step is fraught with uncertainty and largely based on judgments by ISIS, its consultants, and reviewers. For example, South Africa was dropped from the final list because it has had a good record of export control and sanctions practices over the last ten years; it was also tested severely in the 1990s by embarrassing smuggling cases and learned important lessons from them. Israel, South Korea, and Taiwan were also dropped from the final list for similar reasons. It should be noted however that this assessment involves whether the country would have poor export controls practices, or become a supplier of concern to other countries. It is not a determination about that country having or seeking nuclear weapons.

Adding back the other countries in the first table leads to a list of countries of concern. They could have commercial suppliers of a significant number of dual-use or direct-use goods usable in nuclear programs. On their own, the countries on this list may not have adequate trade controls to limit sales to proliferant states or other buyers that could in turn sell the goods to sanctioned, banned, or unsafeguarded nuclear programs, or they are rogue actors:

- China
- Hong Kong
- Southeast Asia
- India
- Pakistan
- Turkey
- Brazil
- Argentina
- Russia
- Portions of Eastern Europe including Czech Republic, Hungary, and Poland/former Soviet states in Central Asia: Belarus, Azerbaijan, Uzbekistan, Ukraine
- Rogue states or actors: Iran, North Korea, Sudan, perhaps Syria, and possibly a Khan-type network

It should be noted that many other countries will likely struggle to prevent illicit trade, despite being expected with high confidence to have adequate implementation of trade controls today and in the future. Proliferant states target countries widely and any supplier country can be expected to be targets of those efforts. But this list serves to identify a set of priority countries that require special attention.

Turntable Countries in the Future

As discussed earlier, any country could become a turntable country, or a country of diversion concern. The concern, however, remains that the problem of nuclear smuggling could both spread and increase in activity and number of actors involved. Therefore, it is useful to consider future possible turntable countries or countries of diversion concern, as the global economy and its

transport networks grow. However, a comprehensive projection cannot be conducted. Nonetheless, examples of future countries of transit concern are, by region:

- Asia: Malaysia, Hong Kong, China, India, Thailand, Taiwan, Vietnam, Singapore
- Europe: South East Europe (Albania, Serbia), Bulgaria
- Middle East and Africa: Oman, Turkey, UAE, Egypt, Tunisia, South Africa
- Central Asia
- Americas: important sea ports in the Caribbean and Central America, Panama, Venezuela
- Sudan, or other countries with ties to terrorist groups or that are ranked very low in the Corruption Perceptions Index

Future Proliferation Financing Turntables and Problem Countries

Many smaller, underdeveloped and developing countries currently lag on implementation of controls against proliferation financing with few relevant laws and structures in place. Proliferation financing involves providing funds or financial services to illicitly manufacture, transfer, or procure restricted WMD commodities. In 2013, the Financial Action Task Force (FATF) demanded action from 14 high-risk or non-cooperative jurisdictions and worked with 18 jurisdictions on an on-going basis to improve implementation of anti-money laundering (AML)/counterterrorism financing (CTF) measures. Of the latter, Algeria and Antigua and Barbuda were deemed to be making insufficient progress.[74] The financial institutions of these countries could be at risk for being used as turntables by illicit procurement networks to route payments from proliferant states and entities to suppliers. Getting basic enforcement mechanisms in place, including creating agencies, training government bureaucrats to enforce proliferation financing laws, and informing employees of financial institutions what is required of them and getting them to act are necessary steps for countries to move toward implementation.

Implementation of anti-proliferation financing provisions of UN Security Council resolutions on Iran and North Korea is incomplete according to the respective UN Panels of Experts overseeing compliance with sanctions. On Iran, implementation by member states diverges widely. The Iran Panel of Experts in 2011 noted that "…Different jurisdictions have implemented financial restrictions using a variety of methods."[75] Of the UN Security Council states, China and Russia remain important financing nodes for North Korean and Iranian proliferation activities because of their failure to fully implement U.N. resolutions. China's role as a supplier of dual-use goods with lax enforcement of export control laws makes its banks continued targets of sanctioned nuclear programs. Developing or burgeoning economies with lax enforcement or implementation of basic financial controls such as some South American countries, European countries such as Austria and Ukraine; Central Asian states such as Turkey and Azerbaijan, and many South and East Asian countries and territories see their banks exploited as conduits for illicit payments. They are regularly used by illicit procurement networks as "financial turntables" to disguise the origin of

[74] Financial Action Task Force, *Public Statement: High-Risk and Non-Cooperative Jurisdictions,* June 2013. http://www.fatf-gafi.org/topics/high-riskandnon-cooperativejurisdictions/ ; FATF, *Improving Global AML/CFT Compliance: on-going process,* February 16, 2012. http://www.fatf-gafi.org/topics/high-riskandnon-cooperativejurisdictions/documents/improvingglobalamlcftcomplianceon-goingprocess-16february2012.html

[75] *Report of the Panel of Experts on Iran established pursuant to resolution 1929 (2010),* May 8, 2011, unpublished, circulated in 2011, pp. 52.

payments from sanctioned countries to supplier countries. Yet, given the complex schemes of proliferant states and their networks, even developed nations such as the United States, major European economies, and Canada, Australia, Japan, and South Korea, which strive to fully implement UN sanctions and have sophisticated financial controls in place to prevent proliferation financing, still fall victim to facilitating transactions.

Figure 11 identifies current and projected problematic proliferation financing countries and regions. This list is considerably larger than the one above for turntable countries. Part of the reason for this is that many more countries are engaged in banking than in trade in high tech commodities and the sheer number of financial transactions conducted each day augments the possibility that one of these countries could fall prey to or help facilitate a proliferation financing transaction. Financial controls and sanctions also remain in their infancy globally. The countries on the list may also be at risk for exploitation by financing schemes other than those relating to proliferation, such as money laundering, terrorist financing, and fraud related schemes.

Figure 11: List of currently and potentially problematic proliferation financing countries and regions, including those having inadequate financial controls in place and lagging on enforcement of UN resolutions[76]
Americas: Antigua and Barbuda*, Argentina*, Cuba*, Ecuador, Nicaragua*, Venezuela*
Eastern Europe: Austria, Bolivia*, Russia, Ukraine
Middle East and North Africa: Algeria*, Iran, Kuwait*, Morocco, Syria, Sudan*, Yemen
Sub-Saharan Africa: Angola*, Ethiopia, Ghana*, Kenya, Namibia*, Nigeria, Sao Tome and Principe, Tanzania, Zimbabwe*
South and Central Asia: Afghanistan*, Albania,* Azerbaijan, Bangladesh*, Kyrgyzstan*, Mongolia*, Nepal*, Pakistan, Tajikistan, Turkey
South and East Asia: Brunei Darussalam*, Cambodia*, China, Indonesia, Myanmar, North Korea, Philippines*, Sri Lanka*, Thailand*, Vietnam

Comment
* indicates country is taking action by working with the FATF to implement financial controls and is considered to be cooperating.

[76] These countries or territories are routinely seen in cases involving proliferation financing, are named frequently by experts, or are included in the reports of the FATF and UN Panels of Experts. See FATF lists of high risk and non-cooperative jurisdictions: http://www.fatf-gafi.org/topics/high-riskandnon-cooperativejurisdictions/documents/fatfpublicstatement22february2013.html; http://www.fatf-gafi.org/topics/high-riskandnon-cooperativejurisdictions/documents/improvingglobalamlcftcomplianceon-goingprocess-22february2013.html

6. Uncovering Smuggling Efforts

Currently, the scourge of illicit nuclear trade is expected to grow. But as difficult as illicit nuclear trade in commodities is to control, it has certain weaknesses which provide opportunities to intervene to stop its growth and in some cases completely disrupt it. One weakness is that the activity to obtain goods for a particular nuclear program is distinctive and detectable to authorities and suppliers. Another is that smugglers must interact in a globalized economy where the suppliers are often legitimate and responsible, creating opportunities for detection and disruption. Maintaining these advantages while the number of suppliers grows is a central challenge.

Smuggling Efforts are Detectable

A developing state needs to acquire a range of materials, equipment, components, and sensitive information and expertise in order to put together the facilities to make separated plutonium or highly enriched uranium. If it wanted to actually build nuclear weapons, the state would require another set of goods.

A proliferant state would need a procurement organization able to mobilize domestic resources and establish a smuggling network aimed at acquiring needed goods abroad. A state could develop indigenously the necessary knowledge and expertise, but this would require long lead times. Alternatively, and being the choice most likely, the state can seek to steal or purchase from abroad needed technology, saving significant time. Developing states will need to acquire a wide variety of goods overseas, either to use directly in a particular nuclear facility or in a new manufacturing complex that makes the necessary items. For these nations, going abroad for the goods is usually required because they can rarely develop on their own the required technology and goods for nuclear facilities. More developed states may decide not to make all that they need for a particular nuclear program and instead choose to depend on the global marketplace to acquire goods. It may pursue this choice even though that country, with effort and cost, is capable of producing the items themselves. The avoidance of bearing costs also plays a role in the choices of developing countries in deciding which goods to seek abroad.

Watch Lists

A nuclear program needs hundreds or thousands of specialized goods. A list of all the items needed by just one nuclear program is beyond the scope of this report, and many of the items are rather commonplace. One way to understand these key goods is to consider what is called a "watch list" (also referred to as a "chokepoint list"), which refers to a list of critical goods used in a particular nuclear program. Typically, a watch list serves as a guide to suppliers or governments of the most important goods to monitor for export with the goal of preventing sales, identifying smuggling networks, and learning more about covert or sensitive nuclear programs.

Monitoring a smaller set of goods needed by a nuclear program is feasible and offers several advantages. Governments can identify the existence of a covert nuclear program or learn more about the activities of an existing, sanctioned program by detecting a proliferant state's attempts to procure key goods used to build and operate such programs. By studying procurements of key goods, for example, governments have uncovered important intelligence relevant information

about the status, needs, and planned activities of Iran's, (formerly) Iraq's, Pakistan's, India's, and North Korea's gas centrifuge programs. Watch lists also aid efforts to stay ahead of the goals of proliferant states. By detecting attempts to procure certain quantities and types of goods and materials, governments can track the origin of any suspicious requests made to suppliers, leading to opportunities for remedial action.

Governments can work with cooperating suppliers to better track those seeking these goods and thwart sales and shipments and prosecute violating companies. Using intelligence information about attempted or actual procurements, governments can warn responsible companies about illicit procurement schemes. This approach prevents proliferant states from obtaining goods they require and forces illicit procurement networks and agents to seek supplies from other regions, countries, and companies, often delaying their progress in outfitting or expanding their nuclear programs.

Careful monitoring for critical goods also tends to force the proliferator to seek less quality goods or make changes to the design of nuclear items, such as centrifuges. Sometimes, these changes can cause delays or increase the risk of the program not working effectively. Overall, the strategy contributes to creating barriers to proliferation and forcing the proliferators to use other, slower, less efficient choices in their nuclear programs.

Elements of a Watch List. A good on a specific watch list may or may not be on a dual-use control list. One of the most common is the Nuclear Suppliers Group dual-use control list, called INFCIRC/254/PART 2. In fact, the watch list is not developed as a control list.[77] If a good on a watch list is not on a corresponding control list, it is on the watch list typically because proliferant states have often sought this item for one of their nuclear programs. Control lists, which are developed through time-consuming negotiations among NSG members, have several loopholes and other limitations, meaning that items deserving listing are not always included. When some are finally included, years may have passed during which proliferant states have been able to obtain large quantities.

It is often the detection of a suspicious combination of goods being sought by a country that causes extra scrutiny about its proliferation intentions; a watch list therefore makes it easier for governments to detect a secret nuclear program. Moreover, this approach allows supplier states to marshal resources more effectively in thwarting a proliferant state or sanctioned nuclear program's illicit procurement attempts.

Figure 12 shows a non-exhaustive watch list for gas centrifuges. The goods can either be related to the centrifuge itself, such as magnets, high and medium strength aluminum, or carbon fiber, or to cascades of centrifuges, such as roots pumps or bellows sealed valves. One lesson of studying the illicit procurement patterns of proliferant states is that goods related to both individual centrifuges and cascades should be on the watch list. Often, the relatively large number of goods required for cascades, such as vacuum measuring equipment, vacuum pumps, and valves, can be linked to a sanctioned or secret centrifuge plant that is either operational or under construction.

[77] Other items not on government control lists are covered by "catch-all" controls. These controls provide a legal or regulatory basis to require government permission for exporting unlisted items when there is reason to believe such items are intended for a missile program or for the development of weapons of mass destruction. In practice, catch-all is very hard to implement without government assistance.

(ISIS has also developed draft watch lists for laser enrichment of uranium and nuclear weaponization).

Figure 12: Watch List for Gas Centrifuges (illustrative, not exhaustive)

- Vacuum roots pumps or roots and rotary vane pump system
- Vacuum measuring equipment, such as pressure transducers and pirani gauges adapted for corrosive gases
- Corrosive gas flow meters
- High strength maraging steel
- Flow forming machines
- High strength aluminum alloy
- Aluminum extrusions of medium strength and of certain dimensions
- Frequency converters
- Bellows sealed valves
- Small fast acting air shut-off valves
- Fibrous or filamentary materials
- Filament winding machines
- Perfluorinated oils
- Ring magnets
- Semi- hard magnetic alloys in strip form

Although some of the goods on a watch list are advertised for sale by domestic companies in emerging markets, such as roots pumps or power supplies offered by Chinese companies, these goods often suffer from poor quality or reliability. In some cases, goods such as high strength maraging steel and carbon fiber cannot be made by companies in developing countries. As a result, one advantage of monitoring critical goods is that there are a limited number of suppliers making high quality, reliable goods needed in a nuclear program. This situation could look very different in five to ten years with the advent of many more suppliers of high quality goods.

Vulnerabilities of Smuggling Commodities

One vulnerability of illicit trade schemes centers on the ordering process. Proliferation entities leave visible traces as they try to acquire nuclear and dual-use goods and services from the open market. Companies and governments can detect these traces. One of the most visible traces is an enquiry or request for a price quote. Enquiries are communications to a supplier, typically faxes or e-mails, from potential purchasers or third-party contacts. These enquiries can provide an early indication of current and possible future covert illicit trade. They can reveal both state and non-state actors since they contain names of individuals and trading companies, insight into a network's *modus operandi*, the type and amount of items sought, and end-users. A military nuclear program may need to procure thousands of individual items, but will likely use far fewer trading companies to attain them.

Enquiries from smuggling networks, however, make up a tiny fraction of the total number of enquiries a supplier receives. One large European company, which covert nuclear programs have often approached, put the fraction as less than one-tenth of a percent. The small fraction of suspicious enquiries makes detecting them challenging. To increase the chance of detecting suspicious enquiries, responsible companies establish centralized trade control offices and train their personnel to spot suspicious procurement attempts and patterns.

Identifying suspicious enquiries can improve the chance of early detection of trafficking networks before an order is made or any goods are shipped. If suppliers and governments cooperate on spotting suspicious enquiries, governments can use the information gained from companies to disrupt a network's operations. For example, a European vacuum manufacturer received multiple enquiries over several months in 2002 and 2003. The first ones coincided with the public exposure of the Natanz gas centrifuge plant in Iran in the fall of 2002 and provided independent support that Iran was seeking to scale up its gas centrifuge program. The enquiries came from trading companies in Iran, Italy, and South Korea, and some European countries. Sometimes an enquiry was routed through more than one trading company.[78] The enquiries from the European trading company could have appeared as a domestic transaction, not even involving an export since these trading companies have the ability to shield the proliferator's nuclear program from the supplier. But in this case, the supplier was alert and suspected that the end-user was Iran's nuclear program. It ignored the enquiries and turned them over to authorities. Discretion and expertise about the company's specialized products helped the manufacturer's trade control office bring the enquiries to the attention of a European government agency, which eventually agreed that the valves could be for gas centrifuges, and alerted other companies and governments. This process, however, took over a year. In the meantime, Iran obtained the valves elsewhere from less vigilant suppliers. But this example shows how early detection, if acted upon, can thwart Iran's attempt to obtain critical goods for its enrichment program.

Similarly, in late 2006, the export control office at a large European manufacturer noticed a suspicious pattern of enquiries from trading companies in Pakistan and the UAE (mainly in Dubai) for dual-use equipment.[79] The manufacturer's export control office suspected that the items were for use in Pakistan's gas centrifuge uranium enrichment program and ignored the enquiries. This office received and analyzed suspicious enquiries from the manufacturer's many subsidiaries and sales agents located throughout the world. It functioned as a hub of its own network aimed at detecting and stopping potential illicit procurement attempts, in short, a "detection hub." For many years, Pakistan has recognized that its enquiries will often be met with skepticism and that suppliers will ignore many of them. As a result, its agents send out enquiries for the same items to many manufacturers, and often to several offices of the same company located in different countries, in essence using a "barrage approach" to procurement in order to increase its chances that one order will slip through controls. This strategy also attempts to exploit any lack of communication among a single manufacturer's sales agents by sending a large number of enquiries within a short period of time, or all at once. Without a centralized export control office, the

[78] See David Albright, Paul Brannan, and Andrea Scheel Stricker, "A Company's Discretion Detects Large Iranian Valve Orders by Scrutinizing Items and End-Users Instead of Lists," ISIS, January 28, 2009. http://www.isis-online.org/uploads/isis-reports/documents/Iran_Valves_28January2009.pdf

[79] See David Albright, Paul Brannan, and Andrea Scheel, "Detecting the Barrage Approach to Illicit Procurement," ISIS, January 12, 2009. http://www.isis-online.org/uploads/isis-reports/documents/PakistanBarrageApproach.pdf

individual sales offices of a manufacturer would be unaware of the identical enquiries sent by the same trading company to other sales offices.

These examples show that this network of traffickers, suppliers, and trading companies interconnected by enquiries tends to have a structure of a few dominant nodes with many connections to other nodes. A large number of nodes are on the periphery with few connections.[80] Many enquiries originate from these dominant nodes. This type of network has demonstrated success in being able to secure orders from a wide range and number of suppliers throughout the world, and is difficult to disrupt.

A network of this type also has characteristics of a "small world" network, which in this case means that the supplier is not "far" from those nodes acquiring the items for a nuclear program.[81] This helps explain the importance of cooperation between governments and suppliers: these suppliers can provide governments with valuable, real-time information about traffickers and their associated trading companies, allowing governments to disrupt their activities.

Eliminating nodes inside proliferant states is extraordinarily difficult, since the state will protect the individuals working on such efforts. Even if these individuals are identified, the state is unlikely to extradite them or otherwise make them available to foreign prosecutors. An innovative approach pursued by the United States, at least in the case of Iran, is to lure these individuals overseas to friendly countries where authorities can arrest and extradite them. U.S. authorities lured Ali Hossein Ardebili, a prolific procurement agent of U.S. military equipment, to Tbilisi, Georgia, where he was arrested and later extradited to the United States and pled guilty to charges.[82] Another Iranian agent, operating from Iran, was arrested in Germany for allegedly illegally transshipping vacuum pump equipment bought in the United States.[83]

Leveraging the International Financial System

As illuminated earlier, smugglers must also find ways to pay for their orders. Few suppliers will accept bags of cash. International smugglers, like any other vendor, at certain points of the ordering process must make and receive legal payments for goods acquired for their proliferating clients. They often need to use the global financial system. The financial system provides another opportunity to detect and disrupt smugglers' ordering schemes. Proliferators must finance a range of activities, including the purchase of goods, brokering and middlemen fees, the shipment of the goods, and various other costs. This web of financial activity is also detectable. Suspicious activity reports filed by banks are an important tool to detect and thwart proliferation financing and illicit trade networks.

---

[80] On a much smaller scale, this type of illicit trading network appears to have some of the characteristics of a scale-free network, For background on scale-free networks, see Mark Newman, "The Physics of Networks," *Physics Today*, November 2008, and Mark Newman, Albert-La´szlo´ Baraba´si, and Mark Newman, *The Structure and Dynamics of Networks* (Princeton, NJ: Princeton University Press, 2006).

[81] "The Physics of Networks," op cit. and *The Structure and Dynamics of Networks*, op cit. .

[82] David Albright, Paul Brannan, and Andrea Scheel Stricker, "Inventive U.S. Sting Operation Catches Iran-Based Military Equipment Smuggler," ISIS, February 16, 2010. http://isis-online.org/isis-reports/detail/inventive-u.s.-sting-operation-catches-iran-based-military-equipment-struggl/

[83] Andrea Stricker, "United States Busts Likely North Korean Transshipment Scheme," ISIS, May 24, 2013.

Anti-proliferation financing standards are being developed on a global basis and many countries and smaller institutions are starting to implement them. Financial controls and sanctions improve detection and prevention, and they increase obstacles against proliferators ultimately getting the goods they seek, as well as augment pressure aimed at convincing a country to halt nuclear efforts.

The resolutions passed by the United Nations Security Council lay the international legal basis for transnational efforts to block or seize proliferation related transactions and assets. These resolutions require member states to enact financial sanctions against proliferation financing and entities and individuals affiliated with nuclear programs in specific countries. UN Resolution 1540 (2004) is more comprehensive and requires states to adopt laws prohibiting non-state actors from obtaining WMD commodities and entities from financing their procurement. To reinforce and supplement UN resolutions, countries unilaterally and in regional efforts enact national sanctions. These campaigns are having significant successes in efforts against Iran and North Korea. They constrain the ability of proliferant states to obtain the goods they require and institute a chilling effect on doing business with these countries because of the risk of facilitating their illicit transactions. They also add a risk component that the proliferant state assets will be frozen and those caught violating will be prosecuted.

Box 4: Pressure Transducers and Iranian Smuggling

On May 18, 2012, Qiang Hu, aka Johnson Hu, a Chinese citizen, was formally charged in the District of Massachusetts with one count of conspiracy for violating U.S. export controls by allegedly selling thousands of pressure transducers, which measure pressure, to unnamed customers through his position of sales manager at MKS Instruments Shanghai Ltd. in China.[1] MKS Instruments is headquartered in Andover, Massachusetts but holds worldwide subsidiaries that distribute its products. Between 2007 and 2012, Hu allegedly worked with unnamed accomplices (co-conspirators), two of whom were employed at MKS Shanghai, and two phony Chinese trading companies, to fraudulently obtain U.S. export licenses for over $6.5 million worth of pressure transducers. Hu and the co-conspirators allegedly arranged their unlawful export to unauthorized Chinese end-users or to other, unnamed country end-users.[2] MKS Instruments is not being investigated in the case and appears to have fully cooperated with authorities. Hu was arrested on May 17, 2012 at an Andover hotel and faces up to 20 years in prison and a $1 million fine. The end user of all these pressure transducers is not listed in the court documents, although China, Iran and Pakistan are suspected end users.

Pressure transducers have a wide variety of uses but they are frequently used for measuring the gas pressure inside centrifuge piping and cascades. Many pressure transducers are used in cascades designed by Pakistan based on early Urenco cascade designs. These designs called for hundreds if not thousands of pressure transducers in a centrifuge plant. The exact purpose of the pressure transducers in the Pakistani-designed cascades is unclear, although they may be part of a computer-controlled cascade monitoring system, perhaps part of a safety system to prevent centrifuges from breaking or crashing. These Pakistani designs, and the need for many pressure transducers, later spread to Iran, North Korea, and other countries via the Khan network. However, reliable, accurate pressure transducers are very difficult to manufacture, and as a result there are few suppliers, leading proliferant states to smuggle these goods.

In the early 1980s, Pakistan sought thousands of MKS pressure transducers in the United States, likely for its centrifuge program. The sale required an export license, which was denied by the U.S. government. Subsequently, Pakistan tried more circuitous methods. Many succeeded, although some were discovered. Henk Slebos, a Dutch member of the Pakistani A.Q. Khan network, was convicted in the Netherlands in 2005 for illegally exporting MKS pressure transducers to Pakistan.[3]

The Hu case likely sheds light on a mystery involving large quantities of MKS pressure transducers seen in Iran's gas centrifuge program. Two photographs taken of Iranian president Mahmoud Ahmadinejad during a 2008 tour of the Natanz pilot fuel enrichment plant show installed MKS pressure transducers (figures 13 and 14). In the background of figure 14, there are several MKS pressure transducers visible in a cascade of IR-1 centrifuges. Although the end users of the pressure transducers in the Hu case were not specified, a likely end user was Iran.

[1] Department of Justice Press Release, "Chinese National Charged in Massachusetts with Illegal Exports of Sensitive Technology to China," May 23, 2012. http://www.justice.gov/usao/ma/news/2012/May/HUQiangchargesPR.html. MKS pressure transducers are classified as "dual-use equipment" controlled for export under national export laws because of the specialized materials contained in them. Not all pressure transducers are controlled in this manner because they use non-controlled materials. However, U.N. Security Council sanctions on Iran ban the sale of all pressure transducers to Iran's centrifuge program. In addition, the Nuclear Suppliers Group is in the process of eliminating this loophole. See for example, http://www.nuclearsuppliersgroup.org/Leng/NSG%20Part%202%20August%202012%20Update%20Track%20Changes.pdf

[2] *Affidavit of Catherine L. Donovan, Special Agent of the Department of Commerce*, May 18, 2012.

[3] *Peddling Peril*, op. cit., pp 147-148.

Iran has launched many other efforts to obtain pressure transducers. A U.S. company, Mattson, settled with U.S. authorities for unlicensed exports of 47 pressure transducers between 2006 and 2008 to countries such as Malaysia, China, Singapore, and Taiwan.[4] Although the end users of that equipment were not made public, these countries were frequently turntables for goods going to Iran. In 2009, Canada successfully prosecuted middleman Mahmoud Yadegari for illegally buying and attempting to export through Canada to Iran two pressure transducers procured in the United States.[5] That year, the United States through a sting operation tracked the efforts of an Iranian procurement agent, Parviz Khaki, to attempt to order from a Chinese middleman, Zongcheng Yi, equipment for centrifuge plants including two MKS Baratron pressure transducers.[6] Iran likely continues trying to obtain MKS pressure transducers.

Iran has also sought different types of pressure transducers, including a type that was not subject to the same export controls as the MKS pressure transducers. (However, both types can be banned for sale to Iran under U.N. Security Council sanctions and the NSG is fixing this loophole in the dual-use list.) MKS pressure transducers have specialized metals that are resistant to corrosive gases, such as uranium hexafluoride. It is these special metals that led to these pressure transducers being on export controls lists. However, alternative brands can work adequately in gas centrifuge cascades, and Iran has also sought these alternatives for its centrifuge program. Like in the case of less corrosion-resistant, fast-acting valves, these alternative brands work well enough in a centrifuge plant, despite their weaknesses. In 2009, a Chinese company, Roc-Master Manufacture and Supply Company, working on behalf of an Iranian client brokered a deal for 108 European-made pressure transducers with a distributor of this equipment located in Taiwan.[7] The Taiwanese distributor misled the European manufacturer Inficon that the end user was in China, but instead forwarded the pressure transducers to Iran. He did so at the specific request of the Chinese company, which stated that it would be illegal for them to send the equipment to Iran. As an incentive for the Taiwanese distributer to send the pressure transducers directly to Iran, the Chinese company offered him a significant cash inducement. Because of Taiwan's delay in implementing U.N. Security Council sanctions, the sale from Taiwan was legal at that time. However, China is not known to have pursued any charges against Roc-Master for its role in the deal.

In a one year period in 2008 and 2009 more than 40 requests for price quotes, or enquiries, for these lesser controlled pressure transducers went to German manufacturers from Iranian agents. The German government tracked these enquiries and worked closely with those suppliers to prevent any sales to Iranian procurement networks.

U.N. Security Council sanctions on Iran are adequate to ban all pressure transducers being sold to Iran's nuclear programs. However, delays in implementing national legislation, such as what occurred in Taiwan, and poor enforcement, as in the case of China, have meant that Iran has continued to successfully procure pressure transducers. Because of the efforts of countries which do enforce Security Council sanctions, Iran has experienced a much greater difficulty in acquiring pressure transducers from responsible suppliers.

[4] U.S. Department of Commerce, Bureau of Industry and Security, *Order Relating to Mattson Technology, Inc.*, April 23, 2012. http://efoia.bis.doc.gov/exportcontrolviolations/e2263.pdf The court document does not state whether the pressure transducers are MKS goods, but it does say that they required a license to be exported.

[5] Sam Pazzano, "Man Guilty of Sending Nuke Devices to Iran," *The Toronto Sun*, July 6, 2010. http://www.torontosun.com/news/torontoandgta/2010/07/06/14624771.html

[6] United States District Court for the District of Columbia, *Grand Jury Indictment: United States of America v. Parviz Khaki and Zongcheng Yi*, May 7, 2012, unsealed July 12, 2012. http://content.govdelivery.com/attachments/USDHSICE/2012/07/13/file_attachments/141298/Khaki%2B_Yi_Superseding_Indictment.pdf

[7] "How Nuclear Equipment Reached Iran," The Associated Press. March 1, 2010. The supplier was the Liechtenstein company Inficon. http://www.ynetnews.com/articles/0,7340,L-3856130,00.html

Figure 13: Iranian president Mahmoud Ahmadinejad examines an advanced gas centrifuge test stand at the Natanz pilot fuel enrichment plant during a 2008 visit. An MKS pressure transducer can be seen.
Source: Website archive of the president of Iran, www.President.ir

Figure 14: President Ahmadinejad examines gas centrifuge equipment, which includes an older MKS pressure transducer (next to his right hand) during a visit to the Natanz pilot fuel enrichment plant in 2008. In the background is an IR-1 gas centrifuge cascade which contains many more recent (mid-2000s) models of MKS pressure transducers. The MKS pressure transducers are controlled on dual-use lists; the white pressure transducer on the right in the foreground was not on the dual use list at the time it was sold to Iran.
Source: Website archive of the president of Iran, www.President.ir

SECTION II: FINDINGS AND RECOMMENDATIONS

Over the next five to ten years, illicit nuclear trade is likely to be conducted by several nations seeking nuclear weapons or wanting to maintain or expand existing nuclear weapons capabilities. Additional states in regions of proliferation concern may utilize increasingly sophisticated smuggling methods to acquire advanced, ostensibly civilian, nuclear capabilities, including uranium enrichment and plutonium production and separation wherewithal. These smugglers will be seeking controlled goods as well as those that fall below the thresholds for control established by the major export control regimes.

Despite many recent, particularly U.S.-led, successes, stopping this trade will remain difficult. Absent mitigating actions, several existing or expected trends are projected to make it easier for smugglers to succeed in acquiring nuclear and nuclear-related goods and technology.

One of the most significant trends is the expected growth of suppliers in emerging markets. Currently, many of these states do not have adequate trade controls in place or awareness of the risks posed by illicit nuclear trade to U.S. or international security, and they often resist improving their trade control systems. Many emerging markets – even if they do not seek nuclear weapons – are prime targets for becoming new illicit trade outposts and diversion hubs. Emerging supplier countries may offer high technology industries and facilities, advanced machining capabilities, free trade zones, and a wide range of trading companies or import/export businesses, any of which may either be taken advantage of or choose to become involved in illicit trade for profit. Rogue suppliers and middlemen may exploit weaknesses in governmental and company oversight to conduct illicit trade.

Rogue suppliers may grow in number as sanctioned countries develop greater nuclear capabilities. North Korea is already a nuclear supplier of last resort, and Iran may become one.

In the next decade, several technologies will be available to states seeking to acquire significant quantities of highly enriched uranium or separated plutonium. The most likely methods are expected to remain gas centrifuges and nuclear reactor-based methods. As a result, many of the recommendations are focused on these technologies. However, other methods to make fissile material could emerge, such as laser enrichment of uranium or possibly accelerator-based production of plutonium. These programs could exploit existing loopholes in export controls or they may simply be missed by intelligence and inspection agencies focused on other technical approaches. As a result, the recommendations in this section also focus on ways of improving the detection probability of any clandestine effort, thwarting the progress of secret military nuclear activities, and finding ways to deter these programs.

It should also be recognized that countries may seek to declare their nuclear programs as civil and under IAEA safeguards, even though these programs are intended to provide a nuclear weapons capability that can be exploited at a desirable time. The recent proliferation cases of Iran and Syria provide important insights into this challenge and the need to seek to block these programs. These cases are also discussed in the recommendations.

The future could include additional, unanticipated challenges to thwarting illicit nuclear trade. On balance, the United States and its allies are racing against a clock where illicit nuclear trade could become more widespread and nuclear proliferation far easier.

However, this future world of illicit nuclear trade is not inevitable. The world of illicit nuclear trade contains important vulnerabilities that can exploited. As a result, these trends can be prevented and the threats headed off. This section discusses a range of countermeasures aimed at mitigating or eliminating these threats.

The overarching goals of these countermeasures against illicit nuclear trade are the achievement of universal, well-enforced nuclear and nuclear-related trade controls and regulations, effective UN Security Council sanctions when needed, the rule of law predominating throughout the world, more transparency in international shipping and financial dealings, and stronger nonproliferation norms and institutions. The remedies and countermeasures in this section will also increase the obstacles faced by states and their illicit procurement networks and reduce the chances that new states and terrorists will be able to proliferate nuclear weapons.

Several specific recommendations are aimed at thwarting or slowing the efforts of developing or emerging countries that will seek nuclear weapons or sensitive nuclear fuel cycle facilities, such as uranium enrichment facilities, indigenous reactors, plutonium separation plants, or possibly other, less common types of methods to make significant amounts of fissile materials. In the next five to ten years, these nations are likely to rely heavily on illicit nuclear trade to outfit unsafeguarded or sanctioned nuclear programs. While their growing industrial capacities may in the next five to ten years be able to produce some high technology goods, they will still need to acquire most equipment and materials for fuel cycle or weapons facilities via illicit procurement. Their scientists and technicians would also likely rely on gathering knowledge and know-how from abroad and looking for classified or sensitive information in other countries.

This section also discusses methods to hinder developed or newly industrialized countries from acquiring the means to make nuclear weapons. In the next five to ten years, some developed countries may seek nuclear weapons or sensitive fuel cycle facilities which will threaten U.S., regional, and international security. Because these programs could still seek goods abroad, this section addresses a number of recommendations for those cases.

Several recommendations concern emerging markets – even if they do not seek nuclear weapons. Their goal is to prevent these countries from becoming major hubs of illicit nuclear trade.

In parallel to these efforts, the United States and its allies must maintain and reenergize their commitment to ending those security problems in the Middle East, South Asia, and Northeast Asia that can contribute to nuclear proliferation. The countermeasures set forth in this report can slow down or thwart almost any nuclear program and also expose secret nuclear programs to the international community. The combination of slowing down and exposing programs is a powerful contribution to stopping nuclear proliferation and limiting the development of nuclear arsenals. But in the end, a state determined to obtain nuclear weapons can make progress, albeit more slowly, despite these methods. Thus, these countermeasures work best when pursued in parallel to efforts based on addressing security concerns where appropriate, changing cost-benefit analyses,

and achieving a negotiated settlement that ends the risk of a state proliferating or improving its nuclear arsenal. To that end, the United States and its allies must do more through negotiations and other means to resolve regional tensions that motivate nuclear proliferation.

Absent addressing fundamental drivers of proliferation, the following countermeasures can contribute importantly to a more secure world and offer a practical way to reduce significantly the threat posed by illicit nuclear trade. The recommendations are organized into several sections:

Chapter 7: Controls and Sanctions

1) Building greater awareness against illicit trade;
2) Making export controls universal and more effective;
3) Promoting better enforcement and use of UN, unilateral, and regional sanctions;
4) Improving controls over sensitive nuclear assets and information;
5) Stopping the money flows related to illicit trade;

Chapter 8: Detection/Interdiction/Enforcement Measures

6) Better coordinating prosecutions and more vigorously prosecuting smugglers;
7) Enhancing early detection methods;
8) Emphasizing interdictions;
9) Creating a universal standard against illicit nuclear trade;

Chapter 9: Other Measures Aimed at Developed and Developing States

10) Preventing additional developed/industrialized market nations from developing nuclear weapons;
11) Reinvigorating a U.S. policy to discourage uranium enrichment and plutonium separation capabilities in regions of tension;

Chapter 10: International Cooperative Measures

12) Gaining and verifying pledges to renounce illicit nuclear trade;
13) Obtaining additional state commitments not to proliferate;
14) Preventing non-state actors from obtaining nuclear weapons via illicit trade; and
15) Implementing relevant arms control agreements and extending security assurances.

These remedies are vital to strengthen and put in place now to close these looming new loopholes in global counter proliferation systems.

While some of these measures can be deployed effectively through international cooperation, many will need to be implemented through unilateral and regional efforts when international consensus is difficult or impossible. The United States must commit to taking the lead in deploying these remedies. U.S. diplomatic, economic, and political might coupled with its strong historical commitment to nonproliferation and countering illicit trade offers the best chance to stop the emergence of a much more dangerous world increasingly plagued by nuclear trafficking.

Chapter 7. Controls and Sanctions

1) Building Greater Awareness Against Illicit Nuclear Trade

Many countries and publics do not view export controls or sanctions as essential or give them the same priority as does the United States. One issue is that in many parts of the world, commercial interests are not counterbalanced by an understanding of the need for corporate responsibility; this is especially true in the case of China. Political will, a technical understanding of the problem, and the unique challenges posed by countries with a vast and growing number of small and medium-sized enterprises are all factors. These persistent problems can be characterized as an overall lack of awareness of the threat posed by illicit nuclear trade and the economic and security benefits of establishing effective, transparent systems against such trade. Because this lack of awareness appears so profound internationally, the first section addresses the need for more effective norms, while recognizing that improving norms is a long term effort. The following sections focus much more on specific policy recommendations.

This does not mean there has been an absence of progress. There have been significant improvements. The closing down of the A.Q. Khan network and the development and implementation of more effective sanctions on Iran and North Korea were watershed events in revealing the sophistication and risk of illicit nuclear trade and improving efforts to stop it. Many nations have developed a greater awareness of the importance of illicit nuclear trade to sanctioned nuclear programs or nuclear weapons efforts and the need to prevent that type of trade. The Nuclear Suppliers Group continues to be a reservoir of robust controls.[84] United Nations Security Council Resolution 1540 established the requirement that all countries must have export controls.[85] Many supplier states maintain robust trade control systems and numerous companies regularly undertake extensive reviews of their exports of high-tech goods to ensure responsibility and compliance with the law. In the end, efforts against illicit nuclear trade are a valuable part of creating a world ruled by law and secure against the use of nuclear weapons.

Gaps in the system remain. Many countries wrongly view export controls as unduly inhibiting economic activity. Some also falsely argue that they are inherently unfair and reflect a divided world of "haves" and "have-nots." Some countries still do not have export control law, such as Vietnam and Thailand; many more have inadequate ones. These challenges are expected to persist well into the future. By not implementing stronger counter illicit trade measures, these countries are likely to be vulnerable to exploitation by nuclear smuggling networks. A key problem will remain that many countries will not give a high priority to stopping illicit trade in direct use and dual-use commodities for nuclear programs.

In order to promote greater awareness of the threats posed by illicit nuclear trade, the United States should launch a broad-based educational effort aimed at a wide overseas audience. In coordination with its allies, it should:

---

[84] Nuclear Suppliers Group, *Nuclear Suppliers Group Guidelines*, http://www.nuclearsuppliersgroup.org/A_test/01-eng/09-guide.php?%20button=9

[85] "UN Security Council Resolution 1540," Description on website of U.S. Department of State, http://www.state.gov/t/isn/c18943.htm

- Devote substantially more resources to public diplomacy that can reach political figures, experts, the media, and publics in current problem countries and emerging markets that pose the greatest future concern. The goal should be to build a global norm against illicit nuclear trade and greater awareness of the need to instill robust measures against it in their domestic governance structures. An aim should be to urge and assist countries to create adequate export control laws and regulations, effective enforcement, and a proactive government strategy aimed at defeating illicit nuclear trade.

- Work with allies through the media, nongovernmental organizations, and international institutions and forums focused on nonproliferation such as the NSG and NPT Review Conference process to develop over the next five to ten years a stronger global norm against nations allowing illicit nuclear trade to take place on their territories. This effort should focus on showing the threat posed to international security and the benefits of improving the records of all states.

- Make lagging countries aware of negative and lasting consequences faced by countries and companies that supply nuclear weapons programs and highlight tangible, concrete benefits received by countries that create and implement robust export control programs.[86] Impress upon these countries the importance of their reaching out to small and medium-sized enterprises, often lacking internal compliance divisions or in some cases even rudimentary knowledge of export controls on dual-use goods. The State Department should name these countries publicly, if they remain uncooperative, in an annual report on the status of illicit nuclear trade worldwide.

- Add nuclear trafficking in commodities to the agenda of the 2014 Nuclear Security Summit in The Hague. The two previous summits failed to address this issue to an appropriate degree.

- Expand U.S. government outreach and training programs to other governments and major foreign supplier companies aimed at raising technical awareness about which goods are used in sensitive nuclear programs and how they are used. This outreach should also focus on precursors of dual-use or direct-use goods that are sought by proliferant states.

- Support politically and financially Track Two dialogues that convene officials and experts from high priority regions on a not-for-attribution basis to discuss the need to fight illicit nuclear trade and best methods to prevent it.

- Conduct outreach to companies in other countries, particularly in current problem countries and emerging markets, on the growing role of companies in sharing responsibility with governments to ensure that goods do not end up in unsafeguarded or sanctioned nuclear programs. A key part of this is raising awareness about the need for companies to reject business if they suspect that the declared end use is not accurate and to report such suspicions to national authorities. Another focus is the need for companies to institutionalize corporate social responsibility (described further under recommendation 2).

[86] See detailed proposals in Recommendations 2 and 9.

2) Making Export Controls Universal and More Effective

One important tool against future illicit trade and nuclear proliferation will be the broader and more universal enforcement of export controls by developing nations. Developing and emerging market states must better enforce export control laws in order to break up illicit nuclear trade networks and prevent the emergence of new networks. The foundation for these controls is already embedded deeply in the NPT and its emphasis on ensuring the peaceful use of nuclear energy and they are at the core of efforts of the Nuclear Suppliers Group.

More widespread implementation of nuclear and nuclear-related export controls has occurred in the last few decades following revelations of illicit procurements for secret nuclear programs by Iran, North Korea, Libya, and Iraq. As a result, the number of nations with national export control systems has greatly expanded. UN Security Council Resolution 1540 has contributed significantly to establishing national controls throughout the world. Resolution 1540 requires that all member states "establish, develop, review and maintain appropriate effective national export and trans-shipment controls . . . including appropriate laws and regulations to control export, transit, trans-shipment and re-export and controls on providing funds and services related to such export and trans-shipment such as financing, and transporting that would contribute to proliferation, as well as establishing end-user controls." Resolution 1540 also requires that all member states establish and enforce "appropriate criminal or civil penalties for violations of such export control laws and regulations."[87] Resolution 1540 aims to help integrate countries that are not members of the NSG into a broader, rules-based export control system.

However, implementation of these trade controls still varies greatly by country. The situation appears to be worsening with the rise of more suppliers in regions that do not have effective controls and have not been amenable to U.S. diplomatic pressure. Unfortunately, many countries remain unmotivated to implement trade controls. Only one Arab League member state, the United Arab Emirates, has a comprehensive strategic trade control law, and Morocco is now creating laws. Membership in the NSG has not ensured the effectiveness of implementation of controls. Moreover, while important, "catch-all regulations" are often evaded by determined proliferant states. An exporter rarely has adequate knowledge to suspect, let alone conclude, that an export will contribute to a banned program. There remains therefore a tremendous need to improve the implementation and enforcement of trade controls globally.

Unilateral, International, and Regional Measures

The United States should implement several unilateral, international, and regional measures to support the universal, effective implementation of export controls:

Unilaterally-focused measures:

- Re-launch U.S. export control training, assistance, and outreach programs on a massive scale. U.S. export control training programs have been scaled back in recent years due to

[87] "UN Security Council Resolution 1540," op cit.

budget constraints, with many combined into regional efforts rather than assisting individual countries.[88] The United States should commit to re-expanding these programs and include results-oriented, clear targets for assisted countries, ambitious timelines, and well-defined end goals of improved compliance. Priorities include emerging markets that are currently a problem and countries that can be identified as potential, future illicit suppliers. Similarly, turntable countries deserve special consideration. In Section I, the priority emerging markets are identified as China, Hong Kong, Southeast Asia, India, Pakistan, Turkey, Brazil, Argentina, Russia, portions of Eastern Europe, and Ukraine. To support these measures, improved compliance could result in the benefits and other economic incentives elucidated in recommendation 9.

- Encourage companies to report on suspicious approaches to purchase controlled or sensitive goods by potentially illicit customers to a central authority and provide legislative safe harbor for making these reports. Doing so would provide the U.S. government with actionable intelligence on illicit networks. A precedent for this would be the U.S. Bank Secrecy Act which requires all companies to report on suspicious transactions.[89] The Act requires financial institutions to help the government "detect and prevent money laundering" by making Suspicious Activity Reports (STRs) about potentially criminal financial transfers to the Treasury Department's Financial Crimes Enforcement Network. See also recommendation 5.

- To facilitate coordination, resolve differences, and implement the President's export control initiative, establish at the National Security Council (NSC) a point person wholly focused on export control coordination, implementation, and enforcement matters. Relevant officials are typically focused on these issues in addition to other nonproliferation related matters. The U.S. government should improve interagency coordination mechanisms for export control and contact between the law enforcement side of export controls and the policy implementation side.

- Create a line item in the national budget for funding the Export Enforcement Coordination Center (E2C2), an agency set up to coordinate export control enforcement activities of all relevant U.S. government agencies. E2C2 currently relies on funding from these agencies, which themselves have experienced cuts and have reduced their E2C2 contributions. E2C2's mandate would be more effective if it had more reliable and adequate funding.

- Establish watch lists, as described in Section I, for major nuclear technologies based on existing nuclear and nuclear-related control lists and proliferant state smuggling efforts. The United States should initiate an effort to make key goods on the watch lists licensable under export controls.

- Launch a U.S. government study, with both unclassified and classified sections, on the multiple methods that proliferant or sanctioned states could use in the future to make fissile materials for nuclear weapons. The study should assess the requirements for success, the

[88] Interview with U.S. official, December 2012.
[89] Financial Crimes Enforcement Network, U.S. Department of the Treasury, "FinCen's Mandate from Congress," http://www.fincen.gov/statutes_regs/bsa/

likelihood of each technology being pursued by various types of states (both developing and developed), and the role of international trade facilitating them acquiring such capabilities. It should include recommendations of reforms needed to increase the probability of detecting any such secret efforts, thwarting progress, and deterring a country from launching such an effort in the first place.

Internationally-focused measures:

- Encourage the Security Council to enhance the mandate and functions of the Resolution 1540 Committee. A new resolution should give the Committee an enhanced budget and administrative support system with trained officials who can regularly visit countries to report on and identify needs and allocate member state resources for export control training and assistance. It should call for deadlines by which member states must reach certain export control and criminal or civil penalty implementation related milestones. The United States should explore how to create both positive and negative economic and political incentives for attaining or failing to meet these milestones.

- Seek the establishment of an independent, international export control implementation task force if the United States cannot gain a UN Security Council resolution as described above due to entrenched political obstacles and the economic motivations of some Security Council members. An "Export Control Implementation Task Force" ("ECITF") would be an inter-governmental body composed of member states similar to the membership-based Financial Action Task Force.[90] It would be tasked with making recommendations and reporting on the progress of individual countries to create and implement export controls. It would facilitate assistance to countries that request it. Ideally, the "ECITF" would have the authority granted by its members to impose deadlines on countries to reach certain landmark achievements in export control implementation under comprehensive implementation plans. A study of the dynamics of the founding of the FATF would be useful to understanding how to set up an independent export control body.

- Encourage more communication transnationally, including international conferences, among U.S. and foreign counterparts working on specific export control related issues to share best practices and lessons learned relevant to national efforts to detect and thwart smuggling attempts.

- Encourage the development of voluntary disclosure clauses in the export laws and regulations of other countries which mandate that companies must report to the government on accidental export control lapses and in return receive reduced fines or penalties.

- Support the creation of a publicly available, global ranking of effectiveness of national export control systems. One model could be the Global Corruption Index. An Export Control Implementation Task Force (described above) or a non-governmental organization could manage this ranking.

[90] Financial Action Task Force, "Who We Are," http://www.fatf-gafi.org/pages/aboutus/

Regionally-focused measures:

- Encourage countries in regions of current and future illicit trade concern to meet regionally on export control implementation and enforcement. Officials from these countries should share best practices and lessons learned. In addition, these regional groupings should focus on methods aimed at preventing smuggling networks from establishing key transshipment hubs. They should encourage and facilitate communication among countries attempting to prevent becoming key transshipment points for smuggling networks, either through facilitating introductions or meetings, or more large-scale events, such as hosting conferences.

- Allocate funding for special prizes and challenges in emerging market regions to spur innovation on solving export control and enforcement related problems. These competitions can establish ambitious goals without the need to predict the ideas that will be chosen as the best, increase the number and types of minds tackling the issue, increase cost effectiveness and allow better decision making about which set of ideas to pursue, and pay for only one set of ideas deemed to hold the promise of success.[91]

- Encourage enhanced trade control coordination among European Union Member States. While EU members share common trade control rules, each country is responsible for its own implementation of these rules. As a result, inconsistencies occur between how different countries implement those rules, including with regard to proliferation-sensitive dual-use goods. More uniformly rigorous implementation of trade controls would prevent countries such as Iran from taking advantage of states where enforcement of EU laws and regulations is lax.

- Encourage the European Union to develop an information exchange mechanism so that relevant officials in countries across the European Union can access a central trade control database and efficiently share information related to preventing dual-use goods from being transferred illegally.

- Work to ensure that states in the EU have adequate resources for export control implementation and enforcement. Even some major states lack adequate resources.

- Press the EU to establish more effective border controls along its eastern border aimed at stopping the illegal flow of controlled and sanctioned goods to Iran via land routes.

Special Issues Requiring Attention:

Shipping:

There is a need for more transparency over shipments coming in and out of countries to make it more difficult for proliferant states to ship illegally obtained goods. This is inherently difficult to

[91] David Albright, Mark Dubowitz, Orde Kittrie, Leonard Spector, and Michael Yaffe, *U.S. Nonproliferation Strategy for the Changing Middle East* (Washington, D.C.: Project on Middle East Nonproliferation Strategy, January 2013), pp. 17. http://isis-online.org/uploads/isis-reports/documents/FinalReport.pdf

achieve given the concealed nature of packaged goods and the sheer amount of worldwide shipments sent and received each day. Air shipments are increasingly of concern because countries can send goods illicitly aboard official airlines and less time is available with air shipments than maritime cargo for states to detect an illicit shipment, intervene, and perhaps stop and search a cargo under the Proliferation Security Initiative (PSI).[92]

Viewed as a long term goal, the United States could seek to enact several measures:

- Seek better transparency and regulation over commercial shipping worldwide.

- Encourage and train worldwide more customs and border control officials to have expertise in identifying sensitive and dual-use equipment, including at airports. Such experts could work in conjunction with their own domestic intelligence and export control enforcement agents and coordinate with foreign counterparts to identify and stop flagged or suspicious shipments.

- Establish communication and information exchanges between relevant country authorities at borders, ports, and airports with the goal of making intelligence and interdiction relevant information available on short order to other countries. Doing so would allow countries to cooperate altogether or cooperate more quickly and effectively on making an interdiction.

- Broaden outreach to shipping companies internationally to ensure that they understand and are compliant with export control and anti-diversion measures.

- Encourage the universal adoption of electronic advance manifest data (as recommended by the World Customs Organization and employed by many states) that informs port authorities of what is coming into their ports in time for them to conduct any appropriate inspections. Also, false statements or other fraud committed in connection with data in such manifests should be made punishable offense under domestic authorities. As a matter of policy, the United States should urge states to require permits or foreknowledge of dual-use items transshipping through their ports.

End-Use Checks:

The United States is a world leader in verifying that sensitive goods exported by U.S. companies end up at their correct destination and are not diverted to other countries and end-users. However, more needs to be done. The U.S. government should:

- Continue and increase the frequency of overseas end-user checks on sensitive U.S. exports to ensure that these goods are not transshipped or sold to other parties. The United States has several programs through different agencies to verify the attributes of unknown or suspicious trading companies before approving an export license or to check on a good's ultimate use by paying visits to these companies or sending embassy personnel to

[92] Rachel Oswald, "Smugglers Turn to Air Transport to Evade Maritime WMD Policing," *The National Journal*, July 11, 2013.

investigate them. For example, the State Department Office of Defense Trade Controls Compliance (DTCC) Blue Lantern program's "end-use monitoring entails pre-license, post-license, or post-shipment inquiries or 'checks' undertaken to verify the bona fides of proposed foreign consignees and end-users, to confirm the legitimacy of proposed transactions, and to provide reasonable assurance that i) the recipient is complying with the requirements imposed by the U.S. government with respect to use, transfers, and security of defense articles and defense services; and ii) such articles and services are being used for the purposes for which they are provided."[93]

- Make U.S. end-use verification checks mandatory in the case of key nuclear-related dual-use goods on watch lists (see previous bulleted recommendation). To this end, the United States should issue a list of these goods subject to end use verification.

The United States could also consider empowering industries to establish their own end-use checks using specialized technology. It should consider:

- Working with or urging companies to install on certain critical equipment on a watch list or export control list a GPS coordinate system. The operator would be required to enter a GPS coordinate specifying his or her location and the machine would only work if the location corresponded with the location of the declared end use.

Government oversight would be needed if companies undertook their own end-use verification measures. If these ideas worked effectively, the United States could encourage other countries with similar suppliers to undertake such end-use verification measures.

Encouraging Foreign Companies' Compliance:

To complement the establishment of a global norm against nuclear smuggling described in recommendation 1, companies will require guidance on what it means to be compliant on export controls. The United States should consider creating a new program to encourage implementation by foreign companies of a uniform industrial standard for company compliance with internationally-accepted export control practices (see also recommendation 9 on a Universal Standard).

The U.S. C-TPAT program (Customs Trade Partnership against Terrorism), operated by U.S. Customs and Border Protection, offers a useful precedent for this approach. Membership in this program, which is voluntary, requires foreign companies whose work frequently operates at the intersection of security and border and customs checkpoints to verify their cargo security credentials. U.S. customs agents certify them as secure and verified importers, manufacturers, logistics companies, customs brokers, and rail, sea, and air transporters and carriers. As members,

[93] Report by the U.S. State Department Directorate of Defense Trade Controls, *End-Use Monitoring of Defense Articles and Defense Services, Commercial Exports, FY 2012*, http://pmddtc.state.gov/reports/documents/End_Use_FY2012.pdf

they are inspected as to their security procedures and commit to upholding a high level of cargo security practices which enhance the fight against terrorism.[94]

One major international company headquartered in Europe that was contacted by ISIS reported high satisfaction with its membership in C-TPAT and highlighted the benefit of its shipments moving through U.S. customs more quickly and with fewer bureaucratic obstacles compared to other freight. It believed gaining membership was worth the initial effort of becoming certified in addition to undergoing periodic audits. The company noted that, helpfully, CBP maintained the same officials on its account as points of contact since it signed up for the program about eight years ago.[95]

The United States should:

- Create, using the C-TPAT model, a program that would either invite or induce membership by foreign companies which produce certain goods targeted by smugglers; these companies would need to prove that they implement strong **internal compliance systems** that result in high levels of compliance with export controls and laws. In return, they would receive such benefits as fast-tracked U.S. export license approvals, less scrutiny over their exports and imports by enforcement and customs officers, and reputational advantages.

- While the C-TPAT initiative is voluntary, the United States could also consider compelling foreign companies which are faltering or do not have stellar records for enforcing export controls and strong internal compliance efforts to join such a state-of-the-art industrial standard export control program, if they want to export goods to the United States. The United States could threaten to temporarily cut off from doing business with the U.S. economy those targeted industries or companies which do not comply with internationally-recognized export control standards. This type of approach would temporarily circumvent the failure or refusal of some developing nation governments to fully implement and enforce export controls.

What is an internal compliance system?

Internal compliance systems (in the counter proliferation sense) are used by company trade control departments to ensure internally and throughout a company's foreign subsidiaries that the company's products are not exported to entities of proliferation concern. While internal compliance efforts are primarily concerned with national and international sanctions or export control lists, strong internal compliance systems also exercise due diligence to determine the *bona fides* of a potential customer who is not on a list or located in a sanctioned country but raises proliferation concerns by his or her location with respect to diversion, affiliations, queries, or suspicious types and quantities of goods sought.

[94] U.S. Customs and Border Protection Agency, "What is C-TPAT?" http://www.cbp.gov/xp/cgov/trade/cargo_security/ctpat/ctpat_program_information/what_is_ctpat/

[95] Private e-mail communication with supply chain and logistics manager of major international company that preferred to share their experience off the record, March 26, 2013.

3) Promoting Better Use of UN, Unilateral, and Regional Sanctions and Related Measures

United Nation Security Council, regional, and unilateral sanctions are important tools against illicit nuclear trade, although they currently suffer from many weaknesses. One issue is convincing countries to enforce more effectively UN Security Council sanctions resolutions against Iran and North Korea. The United States can try to use diplomatic pressure to convince hold out and lagging countries to fully implement these sanctions. However, in the future, more suppliers will rise in regions that do not have effective trade controls or a history of adequately enforcing Security Council sanctions and are not amenable to U.S. diplomatic pressure. China, notably, does not adequately enforce sanctions resolutions and so far appears insufficiently unresponsive to diplomatic pressure to significantly improve implementation against both Iranian and North Korean smuggling. Several options can improve their implementation and enforcement of UN Security Council sanctions.

UN Security Council sanctions implementation:

Enhancing the mandate of and granting more autonomy to the Iran and North Korea Sanctions Committees and Panels of Experts would be beneficial. These highly respected bodies are made up of experts from Security Council and other UN member states and are tasked with overseeing member state implementation and sanctioned country compliance with relevant UN resolutions. However, their ability to point out illicit procurement practices used by some countries and their networks is more robust than their capacity to report on failures by specific UN member states to implement resolutions, due to constraints inherent in the UN system. They are highly circumscribed in their ability to report on lapses in all countries—particularly in Security Council member states since they adopt or reject their reports—and typically only point out lapses by already ostracized countries, such as Syria. China, for example, blocked the adoption and publication of the North Korea Panel of Experts' 2011 report because of its sensitive relationship with the DPRK. Member states also do not report on a systematic basis to the Panels of Experts on instances in which they prevent attempted illicit trade or proliferation financing efforts by Iran and North Korean entities. As a result, the Committees and Panels of Experts only recommend just a few new Iranian and North Korean entities for sanctioning each year.

The United States should work through the Security Council to gain a resolution:

- Granting more independence for the Panels of Experts, including the ability to report freely on member state implementation of resolutions and autonomy to recommend non-compliant entities of any country for designation, as well as broad publicity over lapses leading to member state action, would dramatically improve the effectiveness of these bodies and prevent proliferant states from obtaining more of the goods they seek.

- Amend UNSC sanctions resolutions on Iran and North Korea to require that all interdictions and seizures of goods by nations related to those sanctions are reported to the relevant UN Panel of Experts.

- Strengthen the conditions in UN Security Council sanctions that ban the supply of certain goods usable in Iran's nuclear program. In particular, paragraph 13 of UNSC resolution 1929 on Iran needs strengthening. This paragraph bans the supply of goods on the two control lists established by the Nuclear Suppliers Group (INFCIRC 254 Parts 1 and 2), and "any further items if the State determines that they could contribute to enrichment-related, reprocessing, or heavy water-related activities or to the development of nuclear weapon delivery systems." In practice, the phrase on "further items" has a major loophole that allows certain states to permit the export of dual-use goods that are well known to be used in Iran's sanctioned nuclear programs, especially its gas centrifuge program. In addition, this loophole allows states to weaken the conclusions of the Panel of Experts on whether specific illicit Iranian procurement efforts violate Security Council resolutions. The language should be amended by removing "the State determines that," leaving in an amended resolution "any further items if they could contribute to enrichment-related, reprocessing, or heavy water-related activities or to the development of nuclear weapon delivery systems."[96]

- Strengthen UN Security Council sanctions resolutions on North Korea to have the same conditions as those on Iran, as amended above.

Implementing these measures would send a powerful signal of member states' commitment to enforcing UN Security Council resolutions related to illicit trade. The primary obstacle to gaining a Security Council decision in this regard is admittedly China; a change in China's views about enforcing sanctions and trade controls may well need to come before this recommendation can be fulfilled (more on China's failures and how to encourage a change below).

U.S. unilateral sanctions:

Due to inherent constraints in the United States' ability to deploy strong tools to prevent illicit trade by working internationally, U.S. unilateral sanctions often serve more effectively to pressure other countries or suppliers to implement and enhance controls and sanctions. They are valuable in bringing pressure to bear on other countries where diplomacy has not yielded results and creating international norms that increase pressure on other countries to improve efforts against illicit trade in WMD-related goods.

U.S. unilateral measures include U.S. designations of entities, individuals, and countries, and designations of entire jurisdictions of money laundering concern. The United States regularly adds entities and individuals to its own sanctions lists, which prevents those named from doing business with U.S. companies or financial institutions and augments the reach of UN sanctions. Foreign business is restricted when the United States threatens to sanction those foreign companies or institutions which do business with entities on its sanctions lists.

The United States should:

- Increase the frequency with which it adds to its own sanctions lists.

[96] *United Nations Security Council Resolution 1929 (2010), S/RES/1929 (2010),* Adopted on June 9, 2010, pp. 5-6. http://www.isisnucleariran.org/assets/pdf/UNSCR_1929.pdf

- Work through the UN Security Council to encourage the adoption of its designations by the Security Council through relevant sanctions committees on Iran and North Korea.

Related Measures:

Countries of Diversion Concern:

The United States now has the ability to act against entire countries which fail to enforce trade related sanctions to prevent entities and individuals from diverting goods to proliferant states via their territories. This relatively new tool is a U.S. designation of a country of diversion concern, embodied in Subchapter III of the 2012 Comprehensive Iran Sanctions, Accountability, and Divestment Act (CISADA).[97] Under CISADA, the president is, under specified circumstances, required to designate a country a destination of diversion concern and impose a presumption of denial on the export to that country of sensitive items of a type the President has determined are being diverted through that country to Iran.

Two territories in particular continue to resist enforcing trade controls and sanctions against Iran—China and its special administrative province of Hong Kong. Both should be designated under CISADA.

China needs to improve its implementation of Security Council sanctions and of its trade controls in general. Despite several years of back-door U.S. diplomacy and pressure on the issue, China reportedly remains a key procurement and transshipment point used by Iranian, Pakistani, and North Korean smugglers. In October 2010, the Washington Post reported, "[t]he Obama administration has concluded that Chinese firms are helping Iran to improve its missile technology and develop nuclear weapons, and has asked China to stop such activity..."[98] The Post quoted a senior U.S. official explaining that "China so far has not devoted resources to crack down on violators." Two years later, the problem appeared just as dire. In August 2012, the Washington Post reported that, "[a]lthough Iran has used Chinese go-betweens in the past, U.S. officials said sanctions have forced the isolated and besieged Iranian government to rely increasingly on China for economic help and access to restricted goods."[99]

Hong Kong is also a significant diversion concern. Hong Kong has been an administrative region of China since 1997. It is treated as a separate destination under the U.S. Export Administration Regulations and in some circumstances is subject to more favorable licensing treatment than mainland China. However, there are increasing signs that Hong Kong is failing to effectively police the transshipment and illicit trade practices of the myriad trading and international companies on its territory. Several recent U.S. cases have identified diversion of U.S. nuclear

[97] U.S. Department of State, "Fact Sheet: Comprehensive Iran Sanctions, Accountability, and Divestment Act (CISADA)," May 23, 2011. http://www.state.gov/e/eb/esc/iransanctions/docs/160710.htm
[98] John Pomfret, "Chinese Firms Bypass Sanctions on Iran, U.S. Says," *The Washington Post*, October 18, 2010. http://www.washingtonpost.com/wpdyn/content/article/2010/10/17/AR2010101703723.html
[99] Joby Warrick, "Nuclear Ruse: Posing as Toymaker, Chinese Merchant Allegedly Sought U.S. Technology for Iran," *The Washington Post*, August 11, 2012. http://articles.washingtonpost.com/2012-08-11/world/35490055_1_nuclear-program-civilian-energy-program-chinese-firms

dual-use goods to Iran via Hong Kong.[100] In 2012, a U.S. law enforcement official told The New York Times that this "illustrate[s] an emerging trend of smugglers using Hong Kong as a transshipment hub," in contrast with the past, when "it was more common for smuggling networks to use hubs like Malaysia, Singapore and the United Arab Emirates."[101]

The United States should:

- Announce it will designate China and Hong Kong as destinations of diversion concern unless they make concrete changes within a given grace period. Just the threat of making this designation could inspire action on the parts of China and Hong Kong, as it did with the UAE in 2007. If made official, such designations could reduce the supply to Iran of proliferation-sensitive goods, services, or technologies by: enhancing scrutiny by U.S. government licensing agencies of specific proliferation-sensitive exports from the United States to China and Hong Kong; increasing pressure on the Chinese and Hong Kong authorities to crack down on diversion through their territories to Iranian end-users and Iranian intermediaries; and helping secure support from other countries which likewise face challenges in ensuring that sales to China and Hong Kong do not end up in Iran.

It should be acknowledged that China tends to retaliate against U.S. executive branch actions, and the U.S. executive branch is particularly vulnerable to such retaliation (for example because its diplomats regularly seek meetings, and engage in negotiations, with Chinese officials on a variety of issues). Trade and economic related retaliation – sometimes involving deals worth millions of dollars to significant parts of the U.S. economy – has often been front and center in Chinese retaliation efforts and thus the U.S. executive branch is under constant pressure from the U.S. private sector to avoid angering China. Therefore, if designating China a destination of diversion concern is untenable, the United States should:

- Make diplomatic overtures to China over specific cases and the U.S. executive branch should make selective cases and problems with Chinese private companies public and make clear the desired remedy. Non-governmental organizations also can have an impact by drawing attention to Chinese non-compliance without the retaliatory complications engendered by U.S. executive branch naming and shaming.

- As part of a diplomatic effort, press China to step up border checks on its border with North Korea for controlled and watch list goods for nuclear and missile programs. There are few border crossings, and North Korea has few civilian industries that use these goods. Therefore, North Korea has limited imports of these types of goods, and Chinese border authorities should be suspicious if any of these goods are detected in a border search.

[100] See for example: Charlie Savage, "U.S. Charges Men in Plot to Violate Iran Embargo," *The New York Times*, July 13, 2012. http://www.nytimes.com/2012/07/14/world/middleeast/two-men-charged-with-violating-iran-embargo.html; Andrea Stricker, "United States Prosecutes U.S.-Based Smuggler Working for Iran," ISIS, October 26, 2012. http://isis-online.org/isis-reports/detail/united-states-prosecutes-u.s.-based-smuggler-working-for-iran/

[101] "U.S. Charges Men in Plot to Violate Iran Embargo," op cit, July 13, 2012.

Another diversion concern is Turkey.[102] The United States should:

- Consider designating Turkey as a destination of diversion concern if Turkey's record does not improve, and if there is sufficient evidence that U.S.-origin goods are being diverted.

- Use its relationship with Turkey to urge it to take additional steps to improve its compliance with UN sanctions resolutions and limit in particular Iran's ability to shop illicitly for goods using Turkish territory. It should, if necessary, provide Turkey with additional assistance for this effort.

A More Comprehensive Law on Diversion:

CISADA concerns only Iran. A broad-based law against diversion by any country would demonstrate U.S. credibility to preventing diversion. It would augment the United States' ability to encourage action on the parts of other countries lagging or refusing to fulfill their obligations under UN sanctions resolutions and Resolution 1540. A broader law would also prepare for other developing countries emerging in the future whose domestic industrial capabilities could rival China's in their attractiveness to proliferant states seeking needed nuclear-related goods and materials. The Executive Branch should:

- Propose a law allowing the president to designate as destinations of diversion concern countries allowing substantial diversion to countries other than Iran, such as diversion to North Korea, Syria, Pakistan, and any future proliferant states.

- Encourage its European and other allies to consider creating similar laws or regulations targeting exports to China, Hong Kong, and other countries over their failure to prevent diversion to Iran, North Korea, and other proliferant states.

Enhancing Regional Partnerships on Sanctions:

Reaching out to the European Union or other coalitions of willing countries internationally to coordinate with U.S. sanctions and impose additional unilateral and regional sanctions will remain an important tool. Unfortunately, sanctions implementation and coordination between EU Member States is uneven.

The United States should:

- Work with the EU to better coordinate U.S. and EU sanctions lists. There will inevitably be times when the United States, for important policy reasons, will choose to have broader nonproliferation sanctions than the European Union, and vice versa. However, non-substantive discrepancies should be minimized, as coordination can contribute to stronger and more effective sanctions regimes. When the United States enacts sanctions against

[102] For examples of Turkish companies involved in diversion, see: *U.S. Nonproliferation Strategy for the Changing Middle East*, op cit, pp. 51-52.

new entities and persons identified as engaging in proliferation, the European Union should strive if possible to sanction the same entities and persons, and vice versa.[103]

4) Improving Controls over Sensitive Nuclear Information and Assets

Proliferant states and terrorists are expected to continue seeking classified and sensitive information related to the production of nuclear weapons and fissile materials. A priority is stopping additional proliferant countries and smuggling networks from succeeding in obtaining sensitive nuclear and nuclear-related information and assets related to nuclear enrichment, reprocessing, weaponization, and delivery processes, and reducing the risk of countries leaking it. This problem is becoming worse as information continues to spread. New methods, lists, and safeguards should be developed now for future threats including the likely development of new dangerous technologies and the increased spread of information.

The U.S. government should take the following steps:

- Continue to protect older information about nuclear weapons and the nuclear fuel cycle. Older information about nuclear weapons or gas centrifuges should not be further declassified, even if some of it is already in the public domain.

- Initiate an international effort to improve and standardize security and classification rules among responsible nations. Nations make different, sometimes conflicting, decisions about which information is sensitive and how much to protect it. After it was revealed in the mid-2000s that India was incidentally leaking centrifuge component design drawings, through its free-for-all tender bidding process in support of its unsafeguarded uranium enrichment program, the Indian government responded that it did not consider these designs to be classified.[104] Yet, equivalent gas centrifuge design drawings in Europe and the United States are indeed classified. Developing and enforcing uniform international standards over sensitive nuclear information is therefore long overdue.

- Encourage all governments to create government-wide processes to evaluate newer or "rediscovered" technologies and to designate information or objects as classified.

- Continue efforts to find and retrieve sensitive or classified information. Recovering stolen or missing classified information has proven critical and should be a priority for all responsible nations.

- Dramatically strengthen government efforts to defend private and government U.S. intellectual property and information from foreign cyber attacks and espionage.

[103] *U.S. Nonproliferation Strategy for the Changing Middle East*, op cit, pp. 136.
[104] David Albright and Paul Brannan, "Surprising Admission by India's Department of Atomic Energy (DAE)," ISIS, September 19, 2008. http://isis-online.org/uploads/isis-reports/documents/India_DAE_19September2008.pdf

- Carefully monitor and discourage when necessary joint ventures by U.S. high technology companies with companies or entities in emerging countries known to seek or in some cases steal advanced technologies from supplier states.

- Encourage all nations to expand export controls on sensitive information relevant to nuclear or nuclear-related technology. One priority concerns the sharing of sensitive information domestically with students, scientists, or technicians from sanctioned countries or countries of proliferation concern. Throughout the nuclear age, states have learned critical information about nuclear weapons or fuel cycle activities by sending representatives to consult with foreign scientists and engineers, ostensibly in an open, unclassified setting.

- Encourage experts in key nuclear fuel cycle and nuclear weapons areas to be vigilant about approaches by proliferant states and smuggling networks. They seek specialized training and know-how with the aim of aiding covert nuclear weapons or sanctioned nuclear efforts. The United States should work with allies to ensure that such efforts are instituted and maintained. In less friendly countries, the U.S. government should seek contacts with key institutions and experts to inform them about the need to avoid and report on attempts by proliferant states to approach them for information.

- Broaden cooperation among allies to screen students from proliferant states who may seek training on high technology applications and equipment in order to bypass controls on exports of these technologies to their home countries. By sending one or two students or trainees to each country, proliferant states hope that these students will not be noticed by national authorities. In some cases, countries send dozens of students to a sole country. There is a need for targeted efforts by governments of supplier states to collect and share more relevant data on this issue.

5) Stopping the Money Flows Related to Illicit Trade

Governments led by the United States must better leverage the financial industry as one of the last lines of defense against illicit nuclear trade and proliferation. International smugglers, like any other vendor, need to make and receive payments for goods acquired for their proliferant state clients. They have become adept at using the global financial system to facilitate transactions for goods purchased in contravention of national laws and international sanctions.

The financial institutions of developing and underdeveloped countries are highly at risk for being used as turntables by illicit procurement networks to route payments from proliferant states to suppliers. Getting basic enforcement mechanisms in place, including creating agencies and laws, training government bureaucrats to enforce proliferation financing laws and UN sanctions resolutions, and informing employees of financial institutions what is required of them are necessary steps for countries to move toward better prevention of illicit trade. Nations must also increase their efforts to coordinate transnationally and share more information about money flows related to illicit trade.

Internationally-focused measures:

The United States should:

- Convince lagging UN member states to better implement the provisions of UN resolution 1540 which requires states to develop modern financial controls to prevent proliferation financing, ideally using the guidance of the 2012 anti-money laundering, terrorist and proliferation financing recommendations of the FATF.[105]

- Help countries create and globally deploy screening systems against proliferation financing to help close financial loopholes exploited by illicit procurement networks. In developed countries, major financial institutions employ sophisticated screening systems that flag suspicious transactions by looking for information included in transactions against a list of suspicious names, entities, and related information, allowing them to freeze or refuse transactions attempted by proliferators. Banks in developed countries are also subject to strict reporting requirements which oblige them to report any potential illegal activity that they detect to the relevant authorities. In less developed countries, however, such systems are often not yet in place, and for this reason their banks are targeted by proliferation networks.

- Work with its partners in other developed nations to strengthen assistance efforts and the FATF's mandate and resources to assist developing countries in fulfilling obligations under Resolution 1540 to create financial tracking and screening systems as well as reporting requirements.

- Pressure alongside partners holdout countries to better implement UN sanctions resolutions provisions on preventing proliferation financing by Iran and North Korea. Member state implementation of the financial sanctions embodied in Iran and North Korea resolutions varies widely. The Iran Panel of Experts reported in 2012 that member states continue to have practical problems with implementation but that their efforts are more rigorous than in the past.[106] The North Korea Panel of Experts in 2012 also noted similar problems with the enforcement of the financial sanctions relevant to North Korea.[107]

- Amend UNSC sanctions resolutions to require that all financial transaction freezes or denials by nations related to those sanctions are reported to the relevant UN Panel of Experts. They should encourage thorough reporting on Iranian and North Korean violations to the relevant UN Panels of Experts. The Iran Panel of Experts has noted that few member states actually share information with it about specific instances in which financial institutions had blocked Iranian transactions or froze assets.[108]

---

[105] Financial Action Task Force, *International Standards on Combating Money Laundering and the Financing of Terrorism & Proliferation – The FATF Recommendations,* February 16, 2012. http://www.fatf-gafi.org/documents/documents/internationalstandardsoncombatingmoneylaunderingandthefinancingofterrorismproliferation-thefatfrecommendations.html

[106] *Report to the Security Council from the Panel of Experts on Iran established pursuant to resolution 1929 (2010),* S/2012/395, June 12, 2012, pp. 41.

[107] *Report to the Security Council from the Panel of Experts on North Korea established pursuant to resolution 1874 (2009),* S/2012/422, June 14, 2012, pp. 39.

[108] *Iran Panel of Experts report,* op cit, June 12, 2012, pp. 41.

- Work with other nations to share and track more information about money flows related to illicit trade. Following a suspicious money flow from a possible smuggler can unravel the members and *modus operandi* of an entire smuggling network as well as the schemes they use to send money—in some cases across many countries using multiple formal or informal channels. Tracking money flows can reveal goods sought and information about nuclear programs. It also reveals which financial institutions are not complying with UN sanctions resolutions or national sanctions which ban proliferation related or other financial transactions with Iran or North Korea. States must work more closely with financial institutions both domestically and internationally through other governments to follow these money flows and learn more about smuggling networks and penalize or prosecute law-breakers. The FATF's guidance on information sharing can serve as a useful guide to national authorities on setting up sharing of proliferation financing relevant information.[109]

Unilaterally- and Regionally-focused measures:

Unilateral U.S. financial sanctions have supplemented the weaknesses of UN-mandated financial sanctions and controls, proving very powerful in the case of Iran by reducing Iran's access to the international financial system. The United States has spearheaded the enactment of significant barriers against Iran transacting internationally—which is having a serious impact on its currency, ability to trade and do business, and overall economy, especially when combined with oil and shipping sanctions. They also cut off identified and sanctioned smugglers from being able to pay for goods in dollars, an important restriction which reduces their ability to transact through New York banking institutions. The Iran Panel of Experts reported in 2011, "Iranian individuals and entities find themselves increasingly cut-off from international financial markets, making it increasingly difficult to find ways to pay in U.S. dollars or euros for the equipment they need to procure overseas for their prohibited programmes."[110]

The United States, cooperating with its European partners, should:

- Continue to expand unilateral and regional financial sanctions against Iran, as well as North Korea and future proliferant states.

- Coordinate more closely to ensure that mutual trade in controlled and watch list goods is not exploited by smugglers. In particular, the United States and the EU should create legal and regulatory mechanisms to provide assurance that the declared end use is legitimate and that retransfers within each are subject to end use verification by the other.

---

[109] Financial Action Task Force, *Best Practices Paper: Sharing Among Domestic Competent Authorities Information Related to the Financing of Proliferation,* June 2012. http://www.fatf-gafi.org/media/fatf/documents/recommendations/BPP%20on%20Recommendation%202%20Sharing%20among%20domestic%20competent%20authorities%20re%20financing%20of%20proliferation.pdf

[110] U.N. Panel of Experts on Iran: *Report to the Security Council from the Panel of Experts on Iran established pursuant to resolution 1929 (2010),* May 8, 2011, unpublished, circulated in 2011, pp. 54-56.

- Urge additional countries to emulate the practice of going after foreign banks that allow Iran transactions in their major international financial hubs. The United States is setting major precedents by going after these foreign banks that allow Iran transactions and demanding fines to continue doing business in the United States. It has commanded fines into the multimillions of dollars and publicly embarrassed major financial institutions for these violations.[111]

- Indict and seek to extradite key smugglers who violate its financial sanctions on Iran, as it did with Limmt's owner, Li Fang-Wei of China, who laundered millions of dollars through New York banks on behalf of Iran's illicit procurement needs.[112] Increased prosecution of financial violations in the United States and around the world would send a message to traffickers that their activities may pose legal risks.

[111] Douwe Miedema and Edward Taylor, "Years of U.S. Fines over Iran Loom for Foreign Banks," Reuters. September 2, 2012.
[112] "Chinese Executive is Indicted for Using U.S. Banks in Sales to Iran," *The Washington Post*, April 8, 2009.

Chapter 8. Detection/Interdiction/Enforcement Measures

6) Better Coordinating Prosecutions and More Rigorously Prosecuting Smugglers

Increased arrests and prosecutions of nuclear smugglers would delay or interrupt illicit procurement operations and actively shut down more networks. The United States has spearheaded arrests and indictments against Iranian smugglers, for example, who are caught operating or passing through U.S. territory.[113] It has also extradited them from allied countries. Other countries should model these efforts. But to overcome many current problems with prosecuting smugglers and preventing future illicit trade, domestic legal processes in many countries must be improved to more effectively try and punish trafficking. Many problems currently exist which impede successful prosecutions, such as:

- barriers to the sharing of evidence and witnesses among countries;
- lack of bilateral extradition treaties or laws in both countries that cover these crimes; particularly against illicit nuclear dual-use trade;
- lack of specific laws altogether against smuggling in some countries;
- an absence of strong uniform penalties against these crimes; and
- lack of international coordination and rules for prosecuting this trade.

The U.S. government, led by the Department of Justice, must therefore create or support efforts to increase cooperation among nations to overcome legal impediments to prosecuting smugglers and sanctions violators to better deter and prevent illicit trade.

Internationally-focused measures:

The United States should:

- Support the revision by other countries of their rules governing witness testimony and evidence sharing to allow access between countries to nuclear trafficking suspects, case witnesses, and needed information.

- Urge partner countries to revise or create extradition treaties including crimes of illicit nuclear trade to allow the extradition of suspects.

- Support efforts and advise partners on improving their laws against nuclear dual-use smuggling. A few recent extradition cases of the United States against smugglers arrested

[113] David Albright, Paul Brannan, and Andrea Stricker, "Getting to the Core of Iran's Smuggling Networks for Nuclear, Missile, and Conventional Military Goods," ISIS, February 16, 2010. http://isis-online.org/isis-reports/detail/busting-the-members-at-the-core-of-irans-smuggling-networks/

in Europe have shown there is a need to do so.[114] These cases failed due to a lack of European recognition of U.S. export laws, underlining a need for more consensus and reform of this transnational issue.

- Support and assist through consultation and training efforts in other nations to create appropriate laws to prosecute nuclear smuggling.

- Encourage and assist other countries in instituting stronger sentences against smugglers in order to better deter and disrupt illicit procurement operations internationally. Many of these difficulties were on display during onerous, multiyear efforts to try and punish Khan network operatives.[115] Prosecutors in other countries found it difficult to try many of these operatives for specific proliferation crimes; they were unable to obtain access to witnesses and needed evidence located abroad; and when they were successful, the few smugglers convicted of a crime generally served only months to a few years in jail and few received fines large enough to deter other traffickers.

- Encourage and assist countries through investigative and prosecutorial training and through the creation of a regional network of national WMD law enforcement coordinators to more effectively prevent, detect, and interdict illicit trade in proliferation-sensitive items.

- Support the creation of an informal international consortium among prosecutors of illicit nuclear trade and related matters. Members should include prosecutors from the United States, the European Union, Switzerland, China, Malaysia, and Singapore.

- Create an obstruction of justice condition in UN Security Council sanctions resolutions on Iran and North Korea. If there is evidence of obstruction of justice by a state that prevents the enforcement of UN Security Council sanctions, then the resolution should impose sanctions on that state. Developed legal systems have long realized that obstruction of justice provisions and penalties are essential for combating those who would terrorize and threaten witnesses and their victims from participating in legal actions and from cooperating with enforcement or investigative efforts. When bad actors seek to coerce witnesses and victims and thereby defeat the rule of law – whether that law is in the form of international sanctions, international legal cooperation through Mutual Legal Assistance Treaties (MLATs) or extradition treaties, or domestic law – the law begins to crumble and enforcement is made materially more difficult and problematic.

- Spearhead an effort by states to agree to implement universal prosecution guidelines for prosecuting illicit nuclear trade that include commitments to aid other countries' prosecutions.

---

[114] For example, "Update: U.S. Extradition Request Denied in France for Alleged Iranian Military Parts Smuggler," ISIS, May 12, 2010. http://isis-online.org/isis-reports/detail/update-u.s.-extradition-request-denied-in-france-for-alleged-iranian-milita/

[115] David Albright, Paul Brannan, and Andrea Stricker, "Detecting and Disrupting Illicit Nuclear Trade after A.Q. Khan," *The Washington Quarterly*, vol. 33, no. 2, April 2010, pp. 95-97.

- Work in the long term to gain passage at the UN Security Council of a new resolution authorizing the development of an international organization or office responsible for coordinating transnational prosecutions of significant nuclear traffickers.

- Seek passage, as a long term goal, of a UN Security Council resolution to grant universal jurisdiction to major cases of nuclear trafficking which would allow a state to prosecute non-citizens for crimes committed elsewhere, treating significant nuclear trafficking as a crime which any state is authorized to punish.

Domestic-focused measures:

The United States should:

- Revise its own rules and governing witness testimony and evidence sharing to allow access between countries to nuclear trafficking suspects, case witnesses, and needed information.

- Improve existing U.S. extradition treaties and seek the creation of new treaties with other nations that include crimes of illicit nuclear trade and allow the extradition of suspects.

- Work to institute stronger U.S. sentences against smugglers in order to better deter and disrupt illicit procurement operations domestically. The U.S. Sentencing Commission has been reticent to recommend the imposition of mandatory minimum sentences for nuclear-related export control violations, and therefore, sentences for these violations range from no jail time and small fines to several years in prison and large fines.[116] Standardizing the guidance for judges on sentencing for nuclear-related export crimes would be highly beneficial to creating a stronger deterrent to breaking U.S. export control laws.

- Carefully review any proposed revisions to US export control laws or regulations to ensure that any changes do not inadvertently complicate prosecutions of violators. The Department of Justice should be given a statutory responsibility to review such proposed changes with regard to their enforceability and the difficulty of launching a successful prosecution.

Special Method to Support Better Prosecutions – Sting Operations:

A promising effort today and in the future is U.S. sting operations against illicit nuclear and nuclear-related trade. Arrests and prosecutions of smugglers resulting from U.S. sting operations have helped roll up smuggling networks, stymied their efforts, and established deterrence against future violators. The United States is the only country of the major supplier states that runs

[116] *Report from Patti B. Saris, Chair, U.S. Sentencing Commission, to U.S. Senate and House leaders, regarding the Comprehensive Iran Sanctions Accountability and Divestment Act of 2010,* December 14, 2011; *Letter from Lisa O. Monaco, Assistant Attorney General for National Security, U.S. Department of Justice, to Judge Patti B. Saris, Chair, U.S. Sentencing Commission,* September 9, 2011.

nuclear dual-use equipment sting operations.[117] One advantage of U.S. sting operations is that they make it harder for smugglers to operate in countries that do not necessarily cooperate effectively with the United States. Another benefit is they can identify in countries that do not effectively implement trade controls or sanctions smugglers or other sanctions violators. Violators of U.S. law are vulnerable to arrest in countries where there is a mutual extradition treaty. Moreover, the violators can be sanctioned by the United States. Better government/industry cooperation in the United States would only improve the ability of the U.S. government to more frequently and effectively use sting operations.

The United States should:

- Continue and increase its use of sting operations against illicit nuclear procurement.
- Encourage other major supplier countries to use sting operations and provide training to them as needed.
- Work with partners transnationally on conducting and carrying out sting operations against foreign smugglers.

7) Enhancing Early Detection Methods

The single, most significant shortcoming of current counter illicit nuclear trade efforts is the lack of systematic, universal methods to detect nuclear trafficking. Early detection is key to preventing illicit nuclear trade. The first step is to improve the chance of detecting secret nuclear facilities and activities in states conducting illicit nuclear trade.

Universal Ratification of the Additional Protocol

One of the IAEA's central inspection tools is the Additional Protocol, developed in the mid-1990s to expand the IAEA's ability to pursue its inspection rights and make it much easier to detect when a country is attempting to conceal secret nuclear materials, facilities, or activities. The protocol in practice makes a country's nuclear program far more transparent than what is provided by older, comprehensive safeguards agreements. Under the protocol, the inspectors can more easily investigate questionable imports and exports to determine whether a state is in compliance with its safeguards or NPT obligations. If the IAEA learns of suspicious purchases, it can more easily press the country for more information.

Many key countries have not brought the Additional Protocol into force. Iran, Syria, and prior to its leaving the NPT, North Korea, have all refused to implement the Additional Protocol. The IAEA and its key member states have not insisted that countries that have signed the NPT also implement this protocol. This mistake should be reversed. Any country refusing to accept the Additional Protocol should not receive nuclear assistance. As a result, the U.S. government should:

[117] *U.S. Nonproliferation Strategy for the Changing Middle East*, op cit, pp. 55-56.

- Draw attention to the failure by a small minority of states to implement the IAEA's Additional Protocol and seek to gain hold out countries' implementation.

- Launch country-by-country campaigns to pressure individual hold out states to implement the Additional Protocol. Any country refusing to accept the Additional Protocol should not receive nuclear assistance from NSG members or another coalition of willing countries.

Additional Role of IAEA

An underutilized tool is the IAEA's experienced and technically sophisticated inspectorate aimed increasingly at detecting secret nuclear programs in states of proliferation concern. The IAEA has a unique ability to collect and assess information as a gatherer of its own information and a recipient of intelligence related information from member states and private companies. Even intelligence agencies rarely have the technical depth of the IAEA and a sustained commitment to maintaining that level of expertise. Because of its experiences uncovering the nuclear smuggling activities of Iran, Libya, Syria, and the A.Q. Khan network, the IAEA established a special program to detect trafficking networks. The United States should:

- Seek to increase the funding of such IAEA efforts.

- Encourage member states to share more information about illicit procurement schemes and attempts with the IAEA, including export denials, illegal or suspicious procurement attempts, and trafficking schemes.

- Encourage U.S. companies to provide relevant information to the IAEA via a U.S. government entity. It is important for the IAEA to collect suspicious enquiry data from high-technology manufacturers that contain key information about the goods sought and the people seeking them. The IAEA must typically obtain the support of the government of the country where high-technology manufacturers reside before it contacts individual companies to acquire data. It now has an outreach program to many countries, but the United States should do more in this regard.

Voluntary Government/Industry Cooperation

One of the biggest chances for preventing proliferant states from obtaining the goods they seek is improving cooperation on detecting and preventing illicit trade between governments and industries that supply sensitive and dual-use equipment. Currently it is not done extensively on a global basis and is only known to be practiced in a systematic way by Britain, Germany, and the United States. Occasional cooperation between U.S. companies and the Immigrations and Customs Enforcement agency, for example, has led directly to successful sting operations against foreign and domestic nuclear traffickers. This cooperation is not part of an export licensing system; typically it plays out well before an order is placed.

Under a robust government/industry cooperation program, the following elements are required in order for the system to function effectively:

- Industry provides government routinely with suspicious requests for equipment that could originate in a sanctioned or covert nuclear program. This information is typically in the form of enquiries asking for the price of goods.
- Governments inform companies about the latest procurement schemes or equipment needs of proliferant states or other suspect entities.
- Companies and government consult on a confidential basis about suspicious activities.
- Companies need an unclassified but confidential method to provide information free of any civil liability.
- Governments must have authority to selectively or in single instances declassify information collected by the government that could warn or help a company avoid making a sale to a proliferant state.

Major advantages of this system for governments include:

- Early detection of illicit trade;
- Successful disruption of smuggling networks; and
- Gaining strategic intelligence on secret nuclear efforts.

Major advantages of this system for companies include:

- By consulting with government about potentially suspicious requests, and drawing on the resources governments have that companies do not—namely intelligence—companies avoid making accidental bad sales to nuclear programs.
- Companies feel more confident that the sales they make will not lead to public embarrassment, reputational damage, criminal charges, or fines.
- Companies avoid the problem of waiting on the government to update formal guidance and sanctions lists with up-to-the-minute intelligence on new entities and individuals to avoid.

Britain and Germany provide useful models of voluntary government/industry cooperation. These programs have a proven history in strengthening national export control and sanctions efforts. In these countries, domestic and sometimes foreign intelligence agencies are responsible for facilitating cooperation. One unique feature of these systems is if a company which cooperates regularly inadvertently makes a bad export, the company is unlikely to be prosecuted. The government would expect cooperation aimed at tracking down what happened and developing remedies. The British and German systems both acknowledge that intelligence is required for companies to prevent sophisticated procurement networks from acquiring goods and factor in leniency for companies that regularly volunteer suspicious information but make a regulatory mistake. Their relationship with the company and its past record of cooperation serve as mitigating factors in any decision to pursue penalties and calculate a penalty.

Key elements that make these systems function include:

- In both countries, companies regularly provide information to authorities, while the governments tip off companies about illicit procurement networks targeting their products in order to prevent an inadvertent sale.

- British authorities maintain contact with more than 2,000 domestic companies, trade associations, and academic institutions through phone calls, e-mails, and personal visits. From them, the British government receives technical advice, enquiries and orders from entities of concern, and suspicious enquiries from unknown entities.
- German authorities provide companies with confidential information that includes names of suspicious entities and strategies used by proliferant states. Companies forward suspicious enquiries to authorities on a voluntary basis for guidance. In the nuclear area, intelligence officials meet periodically with key company officials to provide tips to watch for illicit procurement attempts involving specific trading companies, technical specifications, and end-users. In turn, they receive important information from the companies.

The United States, perhaps surprisingly given its focus on stopping Iran's, North Korea's, and other countries' nuclear smuggling, has significant room for improvement on implementing this type of cooperative system. There are legal and classification issues that inhibit full cooperation. Intelligence agencies are hesitant and question their authority to reveal or share relevant information that could be part of ongoing intelligence efforts with companies. U.S. companies are concerned about their exposure to civil liability if they fully cooperate and must consult lawyers about any cooperation with the government.

The U.S. government should:

- Create an institutionalized, voluntary system that leads to government providing industry with more systematic tips about smuggling efforts and the goods that are sought. One entity that can serve as a point of contact for industry is the interagency Export Enforcement Coordination Center . This entity already includes intelligence agencies and could serve to deliver single instance, declassified or unclassified, albeit confidential, information to industry. Single instance declassifications may require companies to sign a statement indicating they will not divulge the information to anyone or be subject to criminal penalties. Through this mechanism, industry could provide information on a confidential basis, and E2C2 could ensure that the intelligence and enforcement community received it.

- Grant civil immunity to companies voluntarily providing information to the government aimed at detecting and preventing illicit trade. Useful precedents for this immunity are included in the Bank Secrecy Act and Title III of the Patriot Act called the International Money Laundering Abatement and Anti-Terrorist Financing Act of 2001. These laws provide civil immunity to financial institutions from being sued by the customers named in a disclosure. Such laws build cooperative relationships between U.S. government and private sector entities and would facilitate the type of cooperation needed with companies to prevent illicit nuclear trade.

- Undertake additional outreach to industry that includes encouraging industry to view the prevention of nuclear proliferation as a fundamental company principle. Proliferators and their smuggling agents need to deceive responsible suppliers into providing goods for

banned or sanctioned nuclear programs. Companies should be encouraged to integrate nonproliferation into corporate ethics infrastructures.[118]

- Undertake outreach globally in cooperation with Britain and Germany to promote the institutionalization of government/industry worldwide. As part of this outreach, they should emphasize that in order to implement effective government/industry cooperation, countries will require having several key elements in place, such as:

    - Effective trade controls and companies that are generally compliant with those controls;
    - Enforcement of trade control laws and regulations, including adequate fines or sentences to provide deterrence; and
    - Domestic intelligence agencies, or their national equivalent, involved in investigating and analyzing illicit trade. These conditions are currently missing in China and India, for example—key emerging markets which conduct or allow illicit trade—but as these countries implement their controls more effectively, they can also strengthen government/industry cooperation. Even if a state does not implement effective trade controls, another government with good cooperation with its own companies can still obtain important information about illicit trade in that non-compliant state via its companies' subsidiaries located there. However, this cooperation necessarily needs to be handled carefully.

Intelligence Methods

Intelligence methods will remain both in the near and long term critical to detecting and disrupting smuggling networks and discovering covert nuclear programs. The U.S. government should:

- Encourage U.S. intelligence and law enforcement agencies to actively cooperate in surveying and disrupting the operations of overseas smuggling networks.

Effective operations require intelligence agencies to coordinate with allies across national boundaries in order to find out what major procurement networks are seeking, detect how they operate, and eventually shut them down through intelligence operations or arrests and prosecutions.

Internationally, the U.S. intelligence community should:

- Increase its coordination and information sharing transnationally with other governments.

- Advise other countries in establishing domestic intelligence agencies and programs aimed at investigating and analyzing illicit trade and export control violations.

[118] For one approach to doing so, see: Andrew Kurzrok and Gretchen Hund, "Beyond Compliance: Integrating Nonproliferation into Corporate Sustainability," *Bulletin of the Atomic Scientists*, vol. 69, no. 3, May/June 2013, pp. 31-42. http://bos.sagepub.com/content/69/3/31.full.pdf+html

More broadly, the U.S. intelligence community should continue and expand its work against illicit nuclear trade via:

- Transnational surveillance and disruption;
- Data gathering;
- Covert actions such as infiltration of procurement networks leading to tracking or sabotage of goods so as to render them useless or able to cause damage to other parts of a system; and
- Cyber infiltration.

8) Emphasizing Interdictions

Increased U.S. and partner efforts to interdict goods heading to proliferant states or transit points would render proliferant states less able to obtain the goods they require and provide intelligence-usable information about their needs and activities.

The U.S. government should:

- Encourage other governments to increase and improve border operations and interagency government coordination for conducting national operations.

- Work to expand the use of transnational operations among allies and partners, necessitating better government-government coordination and sharing of intelligence information that can catch illicit shipments.

- Offer and encourage other countries that have made progress in this area to offer training and cooperation programs to other nations.

- Expand the Proliferation Security Initiative as part of these efforts. The PSI, through which participating states agree to stop proliferation cargos crossing their air, terrain, or maritime boundaries, has proven effective on numerous occasions and expanded participation would lead to more interdictions.

9) Creating a Universal Standard against Illicit Nuclear Trade

As the United States continues to seek internationally to strengthen export controls and efforts to thwart illicit nuclear trade, it should create a "Universal Standard against Illicit Nuclear Trade" for improved compliance by other states. It should also develop sets of benefits for states that improve their records and enact consequences for those that refuse to do so. Laying out clear criteria that indicates what a country must do to be considered as having come into compliance with globally-recognized counter illicit trade efforts is important to reducing confusion on this issue and incentivizing action. This standard draws upon and extends the criteria in U.N. Security Council Resolution 1540. It also seeks to establish that implementing this standard warrants tangible benefits, particularly in developing countries.

The following is a draft list of such standards. A state should have:

- appropriate laws and penal codes criminalizing nuclear smuggling and domestic laws implementing the sanctioning of UN-sanctioned entities or individuals
- lists of controlled or licensable goods
- lists of sanctioned entities or individuals
- a justice system in place to enforce laws and regulations and to seek appropriate penalties for violators. A domestic investigation agency, prosecutors and courts committed to preventing illicit nuclear trade are examples of components of this system
- export control agencies, financial crimes units, and intelligence agencies to investigate cases and oversee implementation by the private sector, with a goal of protecting the country from domestic and foreign violators
- outreach programs to companies for information sharing, training, and enforcement
- guidance on best practices and internal compliance for supplier or manufacturing companies targeted by illicit networks
- guidance on best practices and internal compliance for shipping companies
- guidance on best practices and internal compliance for financial institutions
- efforts by relevant agencies to check end uses of controlled or sensitive goods

Once a country decides to start making the prevention of illicit trade on their territories a national priority, it could take several beneficial steps. For example, it could make public governmental declarations about an intention to come into compliance with counter illicit trade efforts and subsequently announce concrete plans to do so. It could seek assistance of the UN Security Council resolution 1540 Committee and relevant UN sanctions committees. It could accept offers of aid on implementing robust export controls from the U.S. government and the European Union.

Coming into compliance with the Universal Standard could be judged by a set of indicators, such as:

- generally compliant companies and financial institutions;
- periodic, successful enforcement cases;
- consistent reduction of transshipment through that country;
- reduction of illicit trade by domestic trading or other companies; and
- reduction in use of country for or facilitation by that country's financial institutions of proliferation financing.

Countries which come into compliance with clearly specified preventive measures and norms against illicit trade should receive tangible economic and political benefits. Today, the benefits of coming into compliance with these measures have not always been so apparent to many developing countries. Many are more afraid of hurting their burgeoning foreign trade and simply have not yet created domestic governance structures to manage the problem.

Toward encouraging a Universal Standard worldwide, the U.S. government should:

- Publish a list of the criteria on a Universal Standard against Illicit Nuclear Trade, including effective export controls, adequate enforcement, and government/industry cooperation on detecting and preventing illicit trade, et cetera (see above candidate list).

- Work in specific high priority regions toward establishing regional Universal Standard codes of conduct with regard to stopping illicit trade and transshipment.

- Develop, consistent with U.S. laws and regulations, a series of benefits to newly compliant countries with the Universal Standard, including lucrative trade agreements, fast-tracked export license approvals, fewer obstacles for cargo and customs processes at ports, and increased foreign aid and investment.

- Continue working at the NSG to gain consensus on rules to prevent the supply of nuclear facilities to countries without an Additional Protocol in force.

State as a matter of policy that those countries which refuse or consistently lag in implementing counter illicit trade efforts will be subject to having their entities added to sanctions lists. It could also warn that it will impose additional export licensing requirements on entire sets of sensitive and dual-use goods sought from the United States by states that do not meet their obligations in order to ensure that the goods are not transshipped to proliferant states. (See additional explanation under recommendation 3 on diversion concern.)

Chapter 9: Other Measures Aimed at Developed and Developing States

10) Preventing Additional Developed/Industrialized Market Nations from Developing Nuclear Weapons

If developed or newly industrialized countries decide to pursue nuclear weapons or build sensitive nuclear facilities, they pose a particular challenge. These nations already possess the industrial base, technological know-how, and domestic scientific capacity to build nuclear weapons within a relatively short period of time. They may also possess domestic nuclear energy and research programs and regularly import or produce nuclear and nuclear dual-use goods. They would not rely heavily on illicit nuclear trade to obtain needed materials and equipment because they supply these high technology goods or regularly and easily procure them for their industries without attracting suspicion by supplier companies and governments. Nevertheless, gathering certain goods on the open market for a covert nuclear weapons effort may be detectable, particularly if suspicions of such activity existed and the attempts involved distinctive "watch list" types or large quantities of dual-use goods. Most attempts may turn out to be legitimate and not part of a covert nuclear weapons program, but intensified surveillance and awareness may reveal illicit trade.

Therefore, the U.S. government should:

- Deploy new and existing measures including closer government and U.S. corporate vigilance to detect suspicious activities in these countries.

- Actively discourage any such country from developing centrifuge or other enrichment plants or plutonium separation plants.

- Work to dissuade any supplier from providing parts or goods to sensitive facilities in that country. In the case of foreign suppliers, a direct approach could be made to that government where the supplier is located. For domestic suppliers, the U.S. government could impose sanctions on any supplier providing goods to the sensitive program.

- Provide strong diplomatic pressure and as appropriate, security guarantees, to the developed country as further incentives to remain within the nonproliferation regime. U.S. security guarantees or nuclear umbrellas can also apply to developed nations.

11) Reinvigorating a U.S. Policy to Discourage Uranium Enrichment and Plutonium Separation Capabilities in Regions of Tension

In the next five to ten years, additional states in regions of proliferation concern may seek advanced, civilian nuclear technology including uranium enrichment and plutonium reprocessing capabilities. Some countries that have announced or implied intentions to do so are developing nations or emerging markets that are of particular concern for proliferation or are at risk as diversion and illicit trade hubs. At least one, South Korea, is a developed country that has earlier forsaken the development of these capabilities.

Additional enrichment plants and reprocessing facilities are the most proliferation-sensitive parts of the fuel cycle, and more of them are unnecessary during the next decade for creating robust civilian nuclear power capabilities. The United States should as a matter of policy:

- Actively discourage additional countries from building enrichment or plutonium separation plants in regions of tension, whether the country is a developing or advanced industrialized country. The United States should increase outreach efforts by the Department of Energy to facilitate this policy's implementation.

- Require that countries without reprocessing or enrichment facilities commit not to enrich or separate plutonium domestically in new or renegotiated peaceful nuclear cooperation agreements with the United States, known as Section 123 Agreements under the Atomic Energy Act. Exceptions could be made for internationally controlled, safeguarded enrichment or reprocessing plants used for the production of energy.

- Seek in other nuclear security related agreements, such as those involving North Korea or Iran, the specification that the Middle East and the Korean Peninsula are regions that should be free of uranium enrichment and plutonium separation facilities. A key aspect of this goal in the Middle East is achieving an agreement that verifiably cuts off the production of fissile materials for nuclear weapons.

- Continue working through the NSG to gain new restrictions against members sharing enrichment and reprocessing technology with additional states. The new guidelines on enrichment and reprocessing in NSG Guidelines for Nuclear Transfers are a significant accomplishment but represent the lowest common denominator of the members of the NSG.[119] In the interim, the United States should work with like-minded states in the NSG or those outside it to set up a coalition of states that voluntarily commit to no further exports of enrichment and reprocessing technologies to countries in regions of tension, such as the Middle East and North Asia.

- Support, with respect to preventing the spread of laser uranium enrichment capabilities, amendments to Annexes and 1 and 2 of the Additional Protocol (which is based on revision 2 of the Part 1 list of INFCIRC/254 in 1995, reflecting laser systems used then). These annexes define what is contained in a state's declaration and is subject to state export and import reporting. The manufacturing of key lasers should also be included in Annex 1 either by modifying Annex 2 or adding this condition directly into Annex 1.[120]

- Provide fuel supply assurances for new and existing nuclear power and research reactors so countries have no incentive to seek enrichment and reprocessing capabilities.

---

[119] Nuclear Suppliers Group, *Nuclear Suppliers Group Guidelines*, http://www.nuclearsuppliersgroup.org/A_test/01-eng/09-guide.php?%20button=9

[120] Under Article 16 of the Additional Protocol, the list of activities specified in Annex I, and the list of equipment and material specified in Annex II, may be amended by the Board upon the advice of an open-ended working group of experts established by the Board. Any such amendment shall take effect four months after its adoption by the Board.

- Block, and encourage allies to block, acquisitions by any enrichment or reactor program in a non-nuclear weapon state that contributes to the development or production of nuclear fuel or reactors for a naval nuclear program. Naval nuclear programs in non-nuclear weapons states are unjustified and are inherently concerning because of their potential for proliferation.

Chapter 10. International Cooperative Measures

12) Gaining and Verifying Pledges to Renounce Illicit Nuclear Trade

No matter the progress that is made on preventing the emergence of future illicit trade and transshipment outposts, the demand-side of the problem must be addressed. Most illicit nuclear trade is driven by a handful of states. Their efforts are highly resilient; network theory reinforces that smuggling hubs in proliferant states are very difficult to uproot. In essence, the smuggling state protects its own domestic operatives and does not criminalize such activities. In many cases, the state encourages and rewards such criminal behavior. As a result, the U.S. government should:

- Make it a policy to gain verifiable commitments from states that they will renounce illicit trade practices. The United States should use its full diplomatic weight to gain these pledges and actively verify them.

- Pressure partners such as India and Pakistan to stop breaking U.S. and other nations' laws to equip their nuclear weapons or unsafeguarded nuclear programs. Under U.S. pressure in the 1980s and early 1990s, Israel which formerly rivaled Pakistan in the extent of its illicit nuclear procurement, decided to largely stop its illicit procurement for its nuclear weapons program. Today, there is evidence that Israel may still make occasional illicit procurements—U.S. sting operations and legal cases show this. This fact only underlines the need for continued verification and pressure to ensure that states abide by non-trafficking commitments.

- Include in all major nuclear agreements with Iran and North Korea a condition that they will halt any engagement in illicit trafficking for their nuclear programs. Verifiable commitments against these countries conducting illicit nuclear trade would be invaluable as a way to limit their ability to build secret nuclear sites, and more importantly, ease the task of verifying that these countries do not have undeclared nuclear facilities. A stronger and more inclusive agreement that includes a **verifiable non-trafficking pledge** only builds more confidence among interested parties in the reliability of a long term agreement.

Verification Approaches to ensure non-trafficking pledges:

Under a pledge to stop conducting illicit trade, countries would in essence agree not to outfit their own banned, undeclared nuclear facilities or programs. But verifying non-trafficking pledges is difficult to do and relatively unexplored. It was done in the case of Iraq after the 1991 Persian Gulf War. However, the relevant UN Security Council resolutions granted extraordinary powers to the inspection organizations to take actions in Iraq, required detailed Iraqi declarations, and mandated stringent requirements on member states to cooperate with the inspectors on the issue of procurement. Two limited approaches that can be used to verify non-trafficking pledges include:

- **UN Security Council imposed mandate:** Resolutions can contain a set of clauses that provide appropriate prohibitions against illicit trade, requirements on member states to implement these prohibitions, and a Committee appointed by the Security Council to review the resolutions' implementation, establish additional banned items, and take action in case of violations. In addition, these resolutions can include provisions for reporting by states, interdicting cargo, and seizing financial assets in cases of banned activity.
- **Identification of banned goods on lists as part of negotiated agreements:** Negotiated agreements to limit nuclear programs can include comprehensive lists and characterizations of what states are prohibited to acquire for their nuclear programs. There would need to be some exceptions for permitted civil nuclear activities, but overall, this approach would lead to a comprehensive, relatively well-defined understanding of what is prohibited for import.

Regardless of which verification approach is taken, it will be important for UN member states to report any suspicious procurements they detect to a central authority—whether the IAEA, a UN Committee, or a member state that is tasked with verifying the non-trafficking pledge. States which commit to non-trafficking pledges must also implement and enforce trade controls to regulate the flow of commerce on their territories and prove that domestic entities have ceased engaging in such activity.

13) Obtaining Additional State Commitments Not to Proliferate

A special concern is posed by North Korea's history of nuclear proliferation, as evidenced by its provision of a nuclear reactor to Syria, and allegations of transferring nuclear-capable missiles to Iran. Moreover, there are growing concerns that Iran over the next decade will proliferate its nuclear capabilities. As a result, additional state commitments not to proliferate are important to establish and verify. In particular, there is a need to ensure that Iran, North Korea, and Syria agree not to transfer nuclear materials, reactors, centrifuges, other nuclear facilities or equipment, or the means to make such equipment or facilities to any state, company, or other entity.

Such a commitment has some parallels in the NPT, which bans any nuclear weapon state from supplying to any non-nuclear state nuclear weapons or nuclear technology and/or assistance to manufacture nuclear weapons. Moreover, each state party to the NPT commits not to provide plutonium, enriched uranium, or the wherewithal to make them unless accompanied by IAEA safeguards. In addition, UN Security Council resolution on Iran and North Korea also provide some precedents to ban the provision of the capabilities to enrich uranium or separate plutonium.

Based on these precedents, the U.S government should seek as a part of any negotiated agreement with Iran and North Korea affecting their nuclear programs the following model condition:

- The state of concern agrees not to transfer to any state or entity whatsoever, or in any way help a state or entity obtain, nuclear weapons or explosive devices, or components of such weapons; nuclear material; nuclear know-how or technology; or equipment, material,

goods, technology designed for, prepared for, or that can contribute to the processing, use, or production of nuclear materials for nuclear weapons or in sanctioned nuclear programs.

This language would complement other international agreements and provide a measurable standard against the proliferation of dangerous nuclear technologies while banning nuclear cooperation among Iran, North Korea, and Syria.

14) Preventing Non-State Actors from Obtaining Nuclear Weapons via Illicit Trade

Implementing the above described measures dealing with developing and developed countries will go far in preventing non-state actors from acquiring nuclear weapons. Two other measures pertain to non-state actors, including terrorist groups and rogue private or government sector suppliers who provide significant assistance to a nuclear weapons program. An example of the latter is A.Q. Khan or some of his top accomplices, such as Gotthard Lerch. These actors can have significant determination to develop nuclear weapons or in the latter case sell major capabilities to others that threaten the United States. Countermeasures developed against them today to combat future threats should involve: 1) better security over nuclear explosive material and other nuclear assets; and 2) designating major involvement in illicit nuclear trafficking as an international crime against humanity.

Preventing Terrorists from Obtaining Fissile Material and Nuclear Weapons

An imperative global priority must be to prevent terrorists from obtaining nuclear weapons. Countries must continue working to better protect nuclear explosive materials such as highly enriched uranium, plutonium, neptunium, and americium from being stolen or diverted from poorly secured facilities to non-state actors such as terrorist groups or sold on the black market by rogue private sector suppliers. Universal export controls and better control over sensitive nuclear assets and information will remain critical to preventing non-state actors' procurement of additional needed nuclear assets, in addition to detecting and preventing such efforts via intelligence methods.

U.S. and international programs to better protect stocks of highly enriched uranium, plutonium, and other fissile materials at sensitive nuclear sites remain decisive prevention measures. Given the sheer amount of such materials in the world and the inadequate security controls over them in some countries' facilities, action must be continue to receive a high priority.

Illicit nuclear trade networks provide to proliferant states or non-state actors a shortcut on the path to nuclear weapons if they can obtain the needed nuclear explosive materials through theft or diversion. So far, it is unknown if networks have traded in these materials in any substantial manner, but they could do so in the future, greatly magnifying the threat.

For terrorist groups, their main constraint is expected to remain for many years not having access to enough nuclear explosive material for a crude nuclear explosive. They likely will over time overcome the challenge of learning to make a rudimentary nuclear explosive. They will still need to accumulate via illicit procurement the capability to make one.

The U.S. government should:

- Continue working diligently and cooperatively to ensure that all fissile materials are well protected and under rigorous material accounting, surveillance, and control. These efforts should also include irradiated fuel containing plutonium and highly enriched uranium, since in the next decade a terrorist group may seek to build a low-tech plutonium or highly enriched uranium separation plant. Moreover, personnel with access to fissile materials should follow procedures that ensure that fissile material cannot be stolen or otherwise diverted. In his April 2009 speech on nuclear disarmament in Prague, President Obama called for securing all vulnerable nuclear material within four years. This goal has not yet been met.

- Fully fund and expand DOD/NNSA's Global Threat Reduction Initiative (GTRI), which works to secure, protect, and in some cases remove vulnerable nuclear and radiological materials at civilian facilities around the world, in order to remove U.S.-origin fissile material from vulnerable overseas facilities and facilitate the removal of non-U.S-origin fissile material, contribute to upgrading security at overseas facilities, and aid in the conversion of research reactors from the use of highly enriched uranium to low enriched uranium fuel and targets.

In order to fashion a nuclear explosive, a terrorist group would need additional nuclear assets in the form of technology, equipment, materials, and information. A concern with smuggling networks and rogue suppliers is that terrorists could buy from them such detailed information as nuclear weapon designs—which may exist on the black market—easing their task of building improvised nuclear explosive devices. Armed with a design, a terrorist group would need to acquire equipment and materials to convert the fissile material into bomb components and construct or acquire a range of other equipment. This effort to weaponize would likely require the procurement of a range of dual-use goods, making early detection of such efforts and intelligence methods to stop them vital. Several of the recommendations above will assist this effort.

Preventing terrorist groups from setting up havens in failed or quasi-failed states, where they could import the equipment and materials to cobble together their own crude nuclear weapons, is fundamentally important. A terrorist group would need a safe location to assemble the components and expertise to build the nuclear explosive.

The U.S. government should:

- Continue monitoring lawless regions of the globe, such as some parts of Africa or Asia, for efforts that may seek to secretly take root and pursue covert nuclear programs.

Prosecuting Major Rogue Suppliers under an International Crime against Humanity Law

The transfer of the capability to develop, produce, or trade nuclear weapons deserves international censure, because acquisition of nuclear weapons severely threatens international security and the detonation of a single nuclear weapon can kill tens or even hundreds of thousands of innocent people. International censure would further help deter non-state actors from transferring nuclear weapons or significant capabilities and know-how to make them via illicit trade.

Over the long term, the United States should:

- Work to develop the legal methods and institutions to prosecute as an international crime against humanity individuals who transfer major and critical assistance to nuclear weapons efforts of terrorists or countries in violation of the Nuclear Non-Proliferation Treaty.

- In the interim, seek to prosecute or sanction under U.S. laws those who transfer the capability to develop, produce, or trade nuclear weapons.

15) Implementing Relevant Arms Control Agreements and Extending Security Assurances

Legally-binding arms control treaties limiting or banning the creation of nuclear weapons will remain bedrocks of nonproliferation efforts. Through caps on fissile material production and bans on tests of nuclear weapons, international security can be more adequately safeguarded and concrete steps taken toward global nuclear reductions or disarmament. In particular, as ultimate goals, the United States should increase its efforts to obtain:

- The global implementation of a Comprehensive Test Ban Treaty (CTBT).

- The successful conclusion to negotiations and global adherence to a universal, verifiable Fissile Material Cutoff Treaty (FMCT).

- Negotiations toward tension reduction and caps on fissile material and nuclear weapons production between India and Pakistan.

Over the longer term, weapons of mass destruction free zones in regions of tension are important in creating fundamental constraints against illicit nuclear trade. The United States should:

- Identify, seek agreement on, and support a set of non-binding practical nonproliferation measures that regional countries could undertake individually, in support of weapons of mass destruction free zone (WMDFZ) aspirations. For example, parties in the Middle East and Northeast Asia could commit to reporting regularly, to each other, or to a mutually acceptable third party, on their national nonproliferation activities, including legislative measures and hosting of conferences and training activities.[121]

- Encourage and assist the creation of Track Two experts groups that would investigate and make recommendations for, the technical dimensions of a regional verification system in support of Middle East and Northeast Asia WMDFZs.

- Encourage Israel and Arab states to engage in verification and confidence building efforts as a preliminary step toward an eventual Middle East WMDFZ.

[121] *U.S. Nonproliferation Strategy for the Changing Middle East*, op cit, pp. 129-130.

The security calculations of developing states in regions of proliferation concern such as the Middle East and Northeast Asia should be influenced through discreet diplomatic pressure and potentially security guarantees. Where possible and where security and other major interests align, the United States should:

- Maintain and extend the guarantee of a nuclear umbrella to additional allied nations which might otherwise seek nuclear weapons if their security situations deteriorated. For example, Turkey is a developing nation covered by the U.S./NATO nuclear umbrella which in the future may be restrained to remain a non-nuclear weapon state in the event that one of its closest neighbors of concern, Iran, develops nuclear bombs. Although Turkey would require many years to develop a nuclear infrastructure of its own capable of producing nuclear weapons, security guarantees could prevent it from doing so.

- Extend U.S. security guarantees and use strong diplomatic pressure to prevent allies from developing nuclear weapons or the capabilities to make them. U.S. pressure succeeded in convincing Taiwan to stop its covert plutonium separation activities on two occasions in the 1970s and 1980s.

- Extend U.S. negative security assurances (NSAs) to additional regions and partners that are in compliance with nonproliferation obligations as non-nuclear weapon states under the NPT. NSAs entail a legally-binding agreement that the United States will not use nuclear weapons in a particular region or against a particular country.

Final Note

The future world does not inevitably need to become dominated by illicit efforts to smuggle and acquire nuclear and nuclear-related technologies and goods. Proliferation by additional countries is also not inevitable. It can be stopped through measures taken today so long as the political will is there to foresee and address future threats. Preventing the future world of illicit trade is imperative to U.S. and international security and to the creation of a world safer from the spread and use of nuclear weapons.