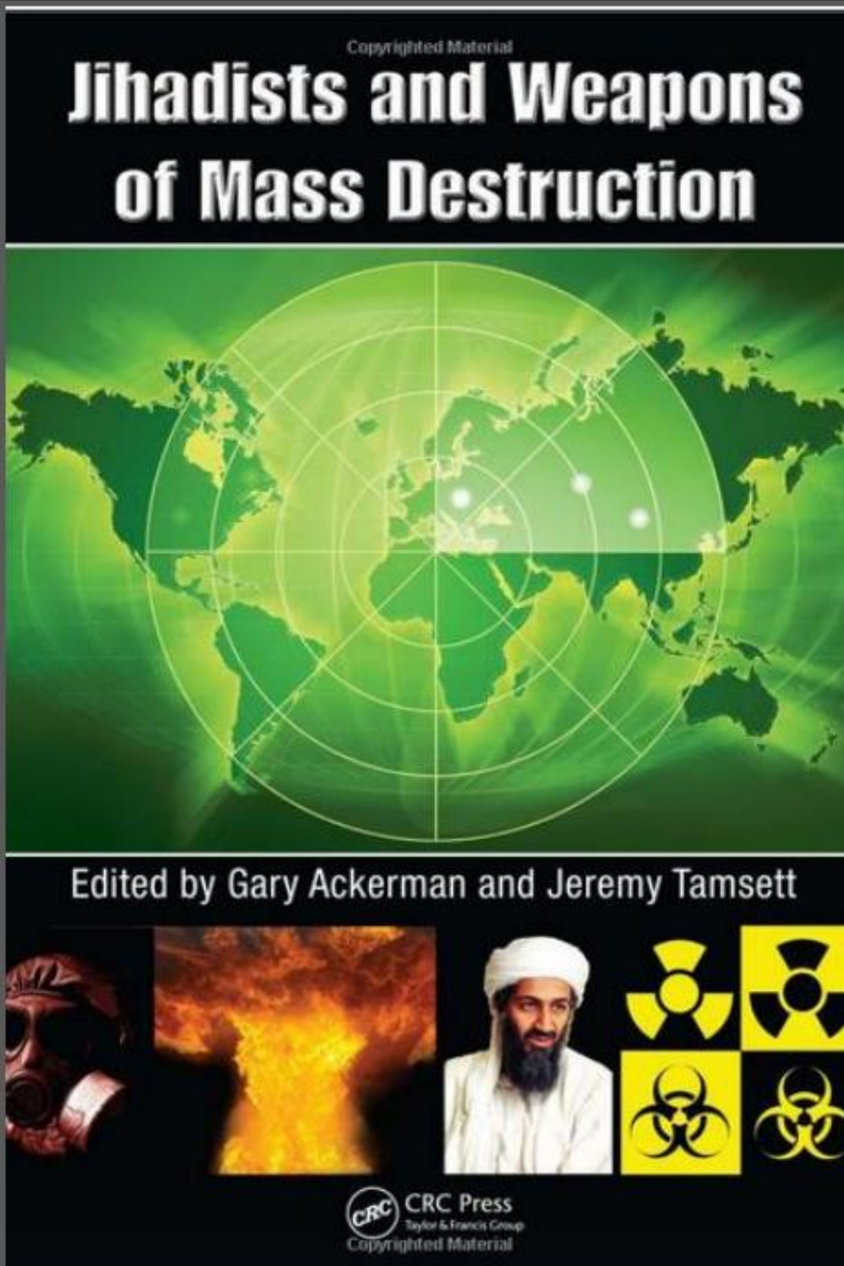

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chapter 8

Jihadists and Nuclear Weapons

Charles P. Blair

CONTENTS

INTRODUCTION

On December 1, 2001, CIA Director George Tenet made a hastily planned, clandestine trip to Pakistan. Tenet arrived in Islamabad deeply shaken by the news that less than three months earlier—just weeks before the attacks of September 11, 2001—al-Qa‘ida and Taliban leaders had met with two former Pakistani nuclear weapon scientists in a joint quest to acquire nuclear weapons. Captured documents the scientists abandoned as they fled Kabul from advancing anti-Taliban forces were evidence, in the minds of top U.S. officials, that a nuclear device was now "within reach" of al-Qa'ida.[1]

As Tenet's motorcade sped to a meeting with President Pervez Musharraf at Pakistan's Presidential Palace, present then were many of the elements that today have come together to form a possible nexus of jihadists and nuclear weapons, a nightmarish merging that, sadly, is more likely today than it was it was in 2001. Tenet's journey was in direct response to the attacks of 9/11; al-Qa'ida long battled the Soviets as well, and the subsequent collapse of that empire has left the world awash in potential sources of nuclear weapons and materials. Tenet's arrival coincided with the beginning of the battle of Tora Bora; Usama bin Ladin would escape, and, today, it is generally understood that al-Qa'ida has established a safe haven in Pakistan. Having "reconstituted its attack capability," al-Qa'ida undoubtedly continues its quest for nuclear weapons.[2] Tenet's convoy passed monuments to Pakistan's "great victory of building a nuclear bomb"; seven years later, its nuclear arsenal would make Pakistan, in the eyes of many experts, "the most dangerous country on earth."[3] Tenet's visit with President Musharraf solidified the seven-part agreement the United States had reached with Pakistan immediately after the attacks of 9/11; left intentionally unmentioned by both countries were the well-known proliferation activities of the A.Q. Kahn Network—deals that could portent nuclear transfers to terrorists.[4]

Thus, while the threat of nuclear terrorism has loomed for over half a century, current— that is, post-9/11—nuclear trepidation is indelibly intertwined with the publicly perceived paragons of terrorism: jihadists.[5] This chapter collectively examines the nexus of jihadists and nuclear weapons in four ways. The first section acquaints the reader with relevant nuclear weapon designs and the source of their explosive power—fissile materials. The second section presents a summary of intact nuclear weapons—specifically where jihadists might acquire them. The third section examines known jihadist activities and interests with regard to nuclear weapons. The fourth section looks at the overall likelihood of jihadists obtaining a nuclear capability. Finally, readers should be aware that the appendix to this chapter gives a brief history of the physics behind nuclear weapons. This section is placed as an appendix because it is not essential that the reader have an understanding of these principles in order to appreciate the potential merging of jihadists with nuclear weapons. However, it does offer the ability to approach the subject with a more nuanced understanding of how, in just fifty years, the field of nuclear physics went from innocuous x-rays to weapons of almost unimaginable fury.

While other chapters in this book deal in great depth with the calculus that determines jihadists' attitudes, proclivities, and strategic calculus toward chemical, biological, radioactive, and nuclear (CBRN) weapons in general, it is useful to consider what jihadists likely would hope to gain from a *nuclear* option. Jihadists' decisions to pursue a nuclear weapon would probably be informed by one or more of the following eight factors:

1. *Tactical concerns*: To achieve a first strike weapon or to forestall enemy action.
2. *Strategic concerns*: To help achieve military symmetry or superiority. Additionally, jihadists might perceive nuclear weapons as an effective political bargaining (blackmail) tool.
3. *Religious "duties"*: Usama bin Ladin has been widely quoted as saying that, "To seek to possess the weapons that could counter those of the infidels is a religious duty…. It would be a sin for Muslims not to seek possession of the weapons that

would prevent the infidels from inflicting harm on Muslims."[6] Some jihadists, moreover, have strong millenarian impulses; consequently, there is a strong psychological link between the kinds of destruction only imaginable with nuclear weapons and, what Robert Jay Lifton has deemed, "the relentless impulse toward world-rejecting purification."[7]

4. *The escalatory nature of some forms of terrorism*: Jihadists, in short, likely seek to outdo the destruction wrought by the attacks of September 11, 2001.
5. *Prestige*: A jihadist group publicly armed with a nuclear weapon (or having successfully detonated one, even one with a "fizzle" yield) would arguably enjoy enormous popularity in the Muslim world and could, consequently, garner greater financial and recruitment opportunities.
6. *Political advantages*: Some jihadists might perceive the acquisition of a nuclear weapon as a step toward formal international recognition and even statehood.[8]
7. *Opportunities*: The decision to attempt to procure intact nuclear devices or fissile materials might simply boil down to opportunity. If nuclear-armed governments collapse, and if general chaos ensues, jihadists might find procurement efforts well-rewarded.
8. *Revenge*: Usama bin Ladin's former official press spokesman, Suleiman Abu Gheith, asserted in 2002 that al-Qa'ida has the "the right to kill four million Americans" in retaliation for, among other things, sanctions and enforcement of UN resolutions against Iraq ("1.2 million dead"), U.S. support of policies "against Palestinians" ("260,000 dead"), U.S. actions in Somalia ("12,000 dead"), and the U.S. war in Afghanistan ("12,000 dead").[9]

Jihadists seeking a nuclear capability have two broad options. First, they can attempt to indigenously build their own device. In this case, however, external procurement options still exist; they could, for example, theoretically fashion all the non-nuclear components of the warhead, turning then to external sources for the weapon's *nuclear* components, that is, fissile material. Second, jihadists could attempt to secure an *entire* nuclear device that has already been fabricated, either from a state or the putative nuclear weapons black market. The following two sections explore these two methods of fabrication and acquisition. [10]

IMPROVISED NUCLEAR DEVICES (INDs)

Nuclear weapons draw their explosive force from fission, fusion, or a combination of these two methods. The latter two of these weapon types are considered far too sophisticated for fabrication by contemporary jihadists, and, thus, this study only considers the production of fission-type nuclear weapons. Such weapons use fissile materials to generate their explosive properties. (See the appendix at the end of this chapter for a full accounting of the physics behind fission.) While over twenty fissionable isotopes exist (Table 8.1), most of them are only found in very minute—gram size or smaller—quantities. Moreover, many of these fissile materials have isotopic properties that make their use in an IND problematic. This chapter, therefore, mainly examines highly enriched uranium (HEU)[11] and plutonium—the most ideal isotopes with which to fuel an IND. Readers should be aware, however, that other isotopes likely pose a significant danger vis-à-vis INDs, most notably uranium-233, neptunium-237, and americium.[12]

TABLe 8.1 Fissioinable Isotopes

Isotope	Availability	Possible Fission Weapon Types	Bare Critical Mass
Uranium-233	LOW: DOE reportedly stores more than one metric ton of U-233.	Gun-type or implosion-type	15 kg
Uranium-235	HIGH: As of 2007, 1700 metric tons of HEU existed globally, in both civilian and military stocks.	Gun-type or implosion-type	50 kg
Plutonium-238	HIGH: A separated global stock, both civilian and military, of over 500 tons. Produced in military and civilian reactor fuels. Typically, reactor-grade plutonium (RGP) consists of roughly 60 percent plutonium-239, 25 percent plutonium-240, 9 percent plutonium-241, 5 percent plutonium-242, and 1 percent plutonium-238 (these percentages are influenced by how long the fuel is irradiated in the reactor). Large quantities found in spent nuclear fuel.	Implosion	10 kg
Plutonium-239		Implosion	10 kg
Plutonium-240		Implosion	40 kg
Plutonium-241		Implosion	10–13 kg
Plutonium-242		Implosion	89–-100 kg
Protactinium-231	VERY LOW: Produced in isotope production reactors. Very small quantities exist for research.	Gun-type or implosion-type	162 kg
Neptunium-236	VERY LOW: Very small amounts found in scientific research (it has no commercial use).	Implosion	7 kg
Neptunium-237	HIGH: An estimated 54 tons globally. Small amounts found in commercial and scientific applications. Large quantities found in spent nuclear fuel.	Gun-type or implosion-type	59–60 kg
Americium-241	HIGH: Total for all americium (241, 242m, 243) estimated to be 87 tons. Small amounts found in commercial and scientific applications. Larger quantities found in spent nuclear fuel.	Implosion-type	57 kg–100 kg
Americium-242m	LOW: Small amounts found in commercial and scientific applications. Large quantities found in spent nuclear fuel.	Implosion-type	9–18 kg
Americium-243	LOW: Small amounts found in commercial and scientific applications. Larger quantities found in spent nuclear fuel.	Implosion-type	50–155kg
Curium-243	VERY LOW: Available in milligram quantities only. Found in spent reactor fuels.	Gun-type or implosion-type	7–10 kg
Curium-244	VERY LOW: Available in milligram quantities only. Found in spent reactor fuels.	Implosion-type	30 kg

TABLe 8.1 Fissioinable Isotopes (continued)

Isotope	Availability	Possible Fission Weapon Types	Bare Critical Mass
Curium-245	VERY LOW: Available in milligram quantities only. Found in spent reactor fuels.	Implosion-type (possibly a gun-type candidate)	10–13 kg
Curium-246	VERY LOW: Available in milligram quantities only. Found in spent reactor fuels.	Implosion-type	39–84 kg
Curium-247	VERY LOW: Available in milligram quantities only. Found in spent reactor fuels.	Implosion-type (possibly a gun-type candidate)	7 kg
Berkelium-247	Has not yet been fabricated in an elemental form.	Implosion-type (possibly a gun-type candidate)	10 kg
Californium-249	VERY LOW: Very small bulk quantities found in spent reactor fuels.	Implosion-type	6 kg
Californium-251	VERY LOW: Very small bulk quantities found in spent reactor fuels.	Implosion-type (possibly a gun-type candidate)	9 kg

When fissile materials undergo fission, they release both energy and neutrons. These escaping neutrons can cause other nuclei to fission, releasing more energy and neutrons in what is termed a chain reaction. This cycle can repeat itself until either (1) the chain reaction dies out as all the neutrons escape due to a lack of fissile material or density—a subcritical mass, (2) there is a precise balance between neutrons lost and neutrons produced—a critical mass, or (3) the number of fissioning nuclei grows exponentially and ultimately releases an enormous amount of energy—a supercritical mass (a nuclear explosion). The goal for jihadists would be to utilize this last example: a rapidly achieved chain reaction that utilizes very large quantities of atomic nuclei. This objective could be met either by bringing two just-below critical masses rapidly together, or by changing the density of a subcritical mass into a supercritical configuration.

The weapon used on Hiroshima, Japan, in 1945 utilized technologies employing the former method. The mechanics of this kind of weapon, a so-called "gun-type" device, are quite basic; indeed, the first such mechanism was not even tested before it was employed against the Japanese. The design can include very few major components. Because of plutonium's relatively high rate of spontaneous neutron emission, use of it in a gun-type weapon would likely result in the device blowing apart before any substantial nuclear yield could occur; plutonium is therefore generally unsuitable for this type of weapon.[13] Thus, a gun-type device typically uses the barrel of a small artillery piece to fire one slug of just-below critical mass HEU into a mass of stationary just-below critical mass HEU. In addition to the gun's barrel and the HEU, a chemical explosive propellant is required to drive the HEU masses together. The final broad requirement is some kind of firing circuitry. Once the firing mechanism is triggered, the propellant drives one slug of HEU down the gun's barrel and toward the stationary mass of HEU. When the masses get to within 25 centimeters of one another, they become critical and, once they meet, they become supercritical.[14]

Utilizing approximately 60 kilograms (kg) of HEU, the gun-type weapon employed over Hiroshima had a yield of 16 kilotons, or ~~1,600~~ tons of TNT.[15]

The nuclear weapon detonated over Nagasaki, Japan, demonstrates the other type of fission weapon design that jihadists could plausibly use: a so-called "implosion-type" device. Rather than propelling two subcritical fissionable masses together, this weapon type *implodes* a single just-below critical mass of fissionable material, increasing, by a factor of two or more, the density of the mass into a supercritical configuration (i.e., only the *volume* of the plutonium changes, not the total *mass*). Because implosion-type devices compress the fissile mass extremely fast, either HEU or plutonium (or, theoretically, other fissionable isotopes) can be used to fuel the weapon—their relatively high neutron emission rates are not a complicating factor as they are in the gun-type device.

Implosion-type devices are much more complex than gun-type weapons. For example, they require the production of roughly 100 simultaneous explosions spread evenly over a subcritical mass of plutonium or HEU.[16] The arrangements of these explosives are called lenses, and their task is to perfectly compress substances of different size and density uniformly—an extremely challenging mission.[17] Properly employed, explosive lenses cumulatively produce pressures above 10 million pounds per square inch, compressing the subcritical mass into a supercritical nuclear explosion.[18] The implosion bomb used on Nagasaki, which employed 6 kg of weapons-grade plutonium, had a yield of 22 kilotons.[19]

Fissile Materials

With regard to fissionable materials, jihadists seeking to fabricate an IND have two acquisition possibilities. Jihadists might consider fabricating fissionable materials themselves, although, as detailed below, this is a highly unlikely route; they would be far more likely to look to external sources for their nuclear materials.

Indigenous Fissile Material Fabrication

Because of the enormous resources and technical sophistication needed for its production, production of HEU by nonstate actors has been generally dismissed as implausible for even the most sophisticated terrorists. (As noted below, plutonium is produced by irradiating uranium-238 in nuclear reactors; indigenous production of it by jihadists is extremely unlikely—they would obviously seek to develop HEU long before they considered plutonium options.) However, nonstate actors have pursued indigenous uranium enrichment alternatives in the past. Most notable among these groups was Aum Shinrikyo. This millenarian cult, best known for its infamous Tokyo, Japan, sarin gas attack in 1995, went as far as purchasing a sheep farm in Australia thought to be rich in uranium deposits.[20] The cult hoped to produce HEU by mining the uranium, converting it to uranium hexafluoride, and enriching it via laser isotope separation. Al-Qa'ida, during its time of sanctuary in Afghanistan from 1996 to 2001, reportedly looked into enrichment options as well.[21]

While experts do not foresee any changes in enrichment technologies that would allow for quick and easy production of enriched uranium, there exists a slim chance that such know-how could develop some time in this century.[22] Thus, it is conceivable that jihadists could secure uranium deposits and develop enrichment techniques at some point in the future if, as Graham Allison notes, "terrorist groups can rent a state [and secure] assistance from the international nuclear black market."[23] Given the fact that a nexus between state sanctuary and the alleged black market is presently unlikely, it is assumed that jihadists will be unable to plausibly pursue a nuclear weapon with the use of indigenously produced fissile materials for the foreseeable future. Thus, jihadists will have to turn to willing states, theft, seizure, or the putative nuclear black market to secure plutonium or HEU.

External Procurement of Fissile Materials

Current inventories of fissile materials are vast: As much as 2000 metric tons of HEU and 500 metric tons of separated plutonium, virtually all weapon-usable, exist globally.[24] As for the former, over 99 percent of the global HEU stockpile is in the custody of just seven states: Russia and the United States possess the vast majority, with France, the United Kingdom, and China having significant stores.[25] The amount of HEU in Pakistan and India is a fraction of the other nuclear weapon states, yet of all of the countries just mentioned, they are the only states that presently continue to produce HEU. The remaining global stockpile of HEU—less than 1 percent of the world's total—is spread out among 40 countries, in about 100 sites worldwide.[26] The vast majority of this HEU, as discussed below, is found in research reactors.

Two hundred and fifty metric tons of separated plutonium presently exist in military stockpiles with an additional 250 metric tons (separated as well) found in civilian stocks.[27] Over a dozen countries house these inventories, with Russia and the United States possessing the vast majority. France, Germany, and the United Kingdom all hold large stocks. Belgium, China, India, Israel, Japan, North Korea, Pakistan, and Switzerland also have inventories of separated plutonium.[28]

Jihadists could obtain HEU or plutonium in several forms and in a variety of settings. Notable among these are (1) weapons-grade plutonium or uranium, (2) oxide forms of uranium and plutonium, (3) plutonium found in spent nuclear fuels, and (4) HEU found in nonpower reactors, specifically research reactors.

Weapons-grade uranium and Plutonium

Metallic forms of uranium or plutonium would be the most ideal structure of fissionable materials for jihadists seeking to construct an IND. "Weapons-grade" material consists of either metallic uranium enriched to 90 percent or more uranium-235 or metallic plutonium containing 90 percent or more plutonium-239. In comparison to other forms fissionable materials might take, the purity and form of metallic weapons-grade material can substantially enhance the destructiveness, reliability, and deliverability of an IND.

Weapons-grade uranium can be employed in either a gun-type or an implosion-type IND, although more of it is needed when compared to weapons-grade plutonium (the bare critical mass of weapons-grade uranium is just over 50 kg. For weapons-grade plutonium the bare critical mass is around 11 kg).[29] Uranium's appeal is further bolstered by its relatively low signature—when compared to plutonium—vis-à-vis radiation detectors.

Although less weapons-grade plutonium is needed to fuel an IND compared to one utilizing uranium, jihadists would face several challenges with the material. Plutonium is "so unusual as to approach the unbelievable," wrote plutonium pioneer Glenn Seaborg in 1967. "Under some conditions it is as hard and brittle as glass; under others, as soft as plastic or lead. It will burn[30] and crumble quickly to powder when heated in air, or slowly disintegrate when kept at room temperature.… And it is fiendishly toxic, even in small amounts."[31]

In addition to plutonium's challenging physical properties described by Seaborg, jihadists would likely encounter three other difficulties in trying to utilize it in an IND. First, since there is no substitute for plutonium—chemically or in a metallurgical sense—jihadists would be unable to perform critical implosion tests prior to actual acquisition of the material (i.e., determining how best to utilize lenses so as to perfectly implode plutonium). In contrast, natural uranium can be used to simulate many of the properties of enriched uranium. Second, plutonium is usually much more detectable than uranium.[32] Finally, plutonium is extremely deadly and requires somewhat complicated handling capabilities; accidental inhalation, even by jihadists willing to sacrifice their lives in the fabrication of an IND, could lead to incapacitation via acute radiation poisoning.

Weapons-grade uranium and plutonium can be found in nuclear weapons, at nuclear weapons production and assembly/disassembly facilities, at nuclear laboratories, and on specific transportation links. Moreover, weapons-grade plutonium can be found at reprocessing facilities that are specifically designed to produce plutonium for nuclear weapons. The United States, for example, presently has weapons-grade materials spread among twelve Department of Energy (DOE) sites.[33] Security at some of these facilities has often been strongly criticized.[34] Furthermore, every year, two non-DOE sites handle tons of weapons-grade uranium for power reactors (the facilities blend the HEU into low enriched uranium—LEU) and U.S. Navy propulsion reactors. Security at these latter facilities has reportedly been sharply criticized in classified U.S. governmental reports.[35]

Oxide Forms of Uranium and Plutonium

If jihadists were able to acquire oxide forms of HEU and plutonium, they could theoretically use them to fuel an IND in one of two ways. In the first scenario, once jihadists obtained enough of the oxide—for example, from fuel fabrication facilities or civilian reprocessing plants—they would ideally convert it into metal. This would give the jihadists increased confidence that the weapon would successfully detonate with a reasonably high yield while enhancing delivery options by reducing the overall weight and bulk of the IND. While converting oxide to metal is considered by experts to be "within the reach of a dedicated technical team," it is still a complicated and time-consuming chemical operation.[36]

The other option is to use the oxide directly, with no post-acquisition processing. The drawback to this route, notes one nuclear weaponeer, is that it would require quantities "large enough to appear troublesome."[37] Still, if very well compacted, the critical mass of plutonium oxide is reportedly about "one and a half times as large" as that of metallic plutonium.[38] Other reports indicate that as little as 110 kg of uranium oxide and 35 kg of plutonium oxide (both at full crystal density) could function as bare critical masses for an IND.[39]

In addition to the disadvantage of having to grapple with copious amounts of oxide materials, there are two other general drawbacks, from a jihadist's perspective, to utilizing oxides. First, proper implosion of such quantities of oxide would likely require very large quantities of explosives, increasing the weight of the IND considerably.[40] Second, oxide-fueled INDs are likely to produce relatively small yields. With its longer neutron generation time, plutonium oxide, for example, would not likely produce a yield nearly the size of that generated by metallic plutonium.[41]

Plutonium Acquired from Spent Nuclear Fuels

Every year the world's nuclear reactors produce about 10,000 tons of spent nuclear fuel, 75 tons of which is plutonium.[42] Jihadists could theoretically fuel an IND with less than 15 kg of this so-called reactor-grade plutonium (RGP). RGP is fabricated in commercial nuclear reactors around the world. Global stockpiles of separated civil plutonium totaled, at the end of 2005, roughly 250 metric tons (enough for 40,000 nuclear weapons).[43] The process begins when the uranium-235 (contained in rods within the reactor) fissions, or "burns," bathing uranium-238 with neutrons (most fresh-fuel rods consist of 3–5 percent uranium-235 and approximately 95 percent uranium-238). Over time, some of the uranium-238 absorbs neutrons, becoming plutonium-239. The longer the plutonium stays in the reactor, however, the more neutrons it absorbs and, thus, significant amounts of plutonium-240, plutonium-241, and plutonium-242 are also fabricated.[44] Over time the fuel rods are removed and the so-called "spent" fuel can then be chemically separated via a process known as reprocessing. The broken down fuel typically consists of the unfissioned uranium-235 (about 1 percent), reactor-grade plutonium (about 1 percent), uranium-238 (about 93 percent), and fission fragments and other transuranics (totaling about 5 percent).

It is important to understand what exactly comprises the separated plutonium. Typically, RGP consists of roughly 60 percent plutonium-239, 25 percent plutonium-240, 6 percent plutonium-241, 5 percent plutonium-242, 1 percent plutonium-238,[45] and 3 percent americium-241 (these percentages are influenced by how long the fuel is irradiated in the reactor).[46]

All of these isotopes are fissionable. Indeed, nuclear weaponeer J. Carson Mark has noted, "that a bare critical assembly could be made with plutonium metal *no matter what its isotopic composition might be*."[47] Yet for decades the public was under the impression that, due to the properties of plutonium isotopes that were not plutonium-239 (e.g., isotopes with very high spontaneous neutron emission rates), a nuclear warhead could not be plausibly fueled with RGP. As Manhattan Project veteran Leona Marshall Libby explained, this erroneous belief began with the Los Alamos scientists themselves and their initial hope that RGP "might be spiked with so much plutonium-240 as to make stolen plutonium useless for clandestine bombs…."[48] However, in 1972 U.S. officials publicly acknowledged that by employing relatively simply design modifications, RGP could be used to successfully fuel a sizable nuclear yield.[49] "Clever bomb design," Libby noted a few years later, "has improved to the point that plutonium-240 can be made into an effective bomb. […]What once was hoped to be a safeguard against clandestine terrorism is now little defense at all."[50]

HEU Acquired from Research Reactors

HEU is employed in over 130 research reactors around the world.[51] While most typical commercial power reactors are in the 3,000 megawatt (MW) range, research reactors vary in size from 1 MW to 250 MW.[52] Yet, despite their size, research reactors can possess significant quantities of HEU: As recently as 2004, 128 research reactors and their associated facilities possessed 20 kg of HEU or more.[53]

In addition to potentially possessing large amounts of HEU, research reactors have four other unique qualities that could make them of great interest to HEU-seeking jihadists. First, as noted in this book's radiological section (Chapter 7), research reactor fuels are often man-portable—the fuel rods are "often less than a meter long, several centimeters across, and weighing a few kilograms."[54] Second, separating HEU from other elements in the reactor fuel, while complex, is not an overwhelming task for a resourceful terrorist group.[55] Experts have noted that "the chemistry involved in converting opium poppies to heroin…is probably roughly as complex as the chemistry required to separate uranium from research reactor fuel...."[56] Third, irradiated research reactor fuels are very highly enriched. Indeed, whereas commercial nuclear power plants routinely have spent fuels that are 3 to 5 percent enriched, experts note with apprehension that "many fresh research reactor fuels are 90 percent enriched and are still more than 80 percent enriched after irradiation."[57]

Finally, jihadists might have a particular interest in research reactors because they are generally perceived to have lower security levels when compared to other potential sources of HEU and plutonium. Many countries have little to no security around their research reactors and "simply rely on the cavalry coming" in the event of some kind of terrorist incursion.[58] In Russia, for example, which has more HEU-fueled research reactors than any other country in the world, most civilian research reactor sites do not have the security to withstand a sophisticated assault by terrorists, nor are they likely immune to subterfuge by multiple insiders acting in unison.[59]

More Advanced Fission Weapon Designs: Initiators and Reflectors

Jihadists seeking to bolster the reliability and efficiency of the gun- and implosion-type INDs outlined above could attempt to enhance their weapons in two ways. First, they could employ a device that emits a burst of neutrons, at just the right time, to assist in triggering the chain reaction—a so-called "initiator." If a neutron initiator is not used, the IND must utilize background neutrons to trigger the chain reaction or the jihadists would risk a "fizzle yield." Yet, in order for a gun-type IND to work with only these background neutrons (i.e., without an initiator), the device's assembly must be crafted to "hold the bullet in place after it has been fired, for tens of millionths of seconds"—a significant engineering challenge.[60] Alternatively, jihadists could simply fit the IND with a "source that continually emitted neutrons"; however, this would dramatically decrease the yield of the device and might likely result in predetonation.[61]

The other enhancement jihadists might consider is a reflector: a device located around the bomb's fissile material that returns neutrons back into the fissioning mass during criticality.[62] As early as 1943 it was understood by physicists at Los Alamos that a reflector could serve, "not only to retard the escape of neutrons but also by its inertia to retard the expansion of the active material […] thus giving the opportunity of the reaction to proceed further before it is stopped by the expansion."[63] Thus, the term *reflector* is a bit misleading; experts often use the expression *tamper* as well to describe this latter role of weakening or interfering with the expansion of the fissile core.[64] While the use of a reflector reduced the critical mass needed for the Nagasaki implosion weapon by 15 percent, far greater reductions of critical masses are presently possible with proper use of a reflector[65] (see Table 8.2).

TABLE 8.2 Effect of Reflector on Critical Mass[a]

Percentage of Uranium-235	Reflector Thickness (Utilizing Beryllium)		
	None	5 cm	15 cm
15%	1351.0 kg	758.3 kg	253.8 kg
30%	367.4 kg	171.2 kg	68.7 kg
45%	184.7 kg	80.5 kg	35.6 kg
70%	87.2 kg	36.5 kg	18.2 kg
93%	53.3 kg	22.3 kg	11.7 kg

[a] Alexander Glaser, "On the Proliferation Potential of Uranium Fuel for Research Reactors at Various Enrichment Levels," *Science & Global Security*, 14(1): 18, (2006), http://www.princeton.edu/~aglaser/2006aglaser_sgsvol14.pdf (accessed 03/01/08).

LIKELY IND CONSTRUCTION

The proceeding discussion implies that jihadists would have several options with which to design and fuel an IND. The reality, however, is that jihadists will likely have to design an IND based on whatever materials they are able to secure. Thus, one can look at an *ideal* weapon (if all of the above materials were available) and a *likely* weapon choice (if only the most probable fissile materials were available).

Initially, one might suppose that an implosion device might be ideal for jihadists. Such a device, especially one equipped with an initiator and a reflector, could be relatively light (adding to its deployability), reliable, and destructive (a yield of 10–20 kilotons).[66] It could theoretically utilize all of the fissile materials outlined above and in far fewer quantities than those needed for a gun-type device. However, there are several disadvantages to the implosion-type device. Most obviously, the required levels of technological sophistication necessary for its fabrication pose one engineering challenge after another, and, even after the device was completed, it would be less rugged and, thus, potentially more prone to malfunctions that a gun-type device. If jihadists wanted to enhance the reliability of their implosion weapon, the device would have to go through a series of tests, some of which would require plutonium. Moreover, use of impure fissile materials—reactor-grade plutonium, for example—could lead to a "fizzle yield." (Such a predetonation could still result in a yield as high as 2 kilotons.[67]) The North Korean nuclear test of 2006 is revealing in this regard. While some experts attribute the blast's relatively small yield—between 0.5 and 2 kilotons[68]—to the use of plutonium that was high in plutonium-240, it seems more probable that the yield was a likely result of an imperfect implosion design. "I don't think that it was a problem of the isotopics," observed former Los Alamos National Laboratory (LANL) director Dr. Siegfried Hecker. "The [North Korean] rudimentary design just didn't work; in the end it is difficult to get a perfectly spherical implosion."[69]

Because of easier fabrication requirements and a greater theoretical availability of HEU (which is also harder to detect than plutonium), a gun-type device would be a much more practical and likely design route for jihadists to take. (Although experts frequently assert that plutonium could not be used in a gun-type device, the reality is that use of plutonium could result in a "fizzle yield" resulting in widespread physical damage and enormous psychological harm over a wide target area.[70])

As already noted, the reliability and yield of a gun-type device could be augmented with the use of an initiator and/or a reflector. Fabrication of the former, while requiring technical sophistication, is not viewed by some experts as particularly difficult to design and manufacture.[71] Crude nuclear weapons have typically employed neutron initiators that utilized the neutrons produced when beryllium, or some other light element, is bombarded by alpha particles.[72] Thus, the acquisition of a suitable alpha emitter appears to be the biggest obstacle jihadists would likely face in fabricating and utilizing a neutron initiator.[73] The alternative, to forego a neutron initiator entirely, risks a fizzle yield or requires an IND engineered to extremely precise specifications.

Natural and depleted uranium can be used as a reflector for implosion weapons; however, these materials emit too many neutrons for use in a gun-type weapon.[74] Alternative reflector materials, suitable for both types of fission weapons, include beryllium, tungsten, and, possibly, iron.[75] As with an initiator, the greatest challenge jihadists likely face as they seek to employ a reflector is obtaining such materials.[76]

In sum, while ultimately the design of an IND would likely be determined by the fissile materials that jihadists are able to acquire, a gun-type device that utilizes uranium is the most plausible. Use of an initiator and/or reflector would dramatically enhance the reliability of the weapon while reducing the amount of fissile materials needed. However, the fabrication of an initiator and/or reflector would, in itself, add additional technical and resource hurdles that would likely be insurmountable to all but the most resourceful jihadists. Many observers have concluded, consequently, that any IND fabricated by terrorists would utilize a gun-type design that forgoes both an initiator and a reflector.[77] Such a device would be prone to predetonation and might likely “fizzle” when employed.

EXTERNAL PROCUREMENT OF INTACT NUCLEAR WEAPONS

For over fifteen years, there have been reports of jihadist groups attempting to procure intact nuclear devices. To date, these efforts are believed to have been unsuccessful, yet by all indications it appears that the quest continues. This section examines two sources from which jihadists might plausibly acquire an intact nuclear weapon: a state with an existing nuclear stockpile or the putative nuclear black market.

State Acquisition of an Intact Nuclear Weapon

Safety from Unauthorized Use

Nine states presently possess nuclear weapons: the United States, Russia, the United Kingdom, France, China, Israel, India, Pakistan, and North Korea. Experts generally foresee two to five new nations joining the nuclear club in the next ten years—most notably Iran.[78] While this section argues that willing state transfer of a nuclear weapon to jihadists is highly unlikely with all nuclear arsenals, there are deep and generally legitimate security concerns with regard to the Russian, North Korean, and Pakistani arsenals.

If jihadists were able to obtain an intact nuclear weapon, its detonation could be prevented by various technological barriers that have been employed by some nuclear-armed states. Most notable among these are so-called permissive action links (PALs):

a sophisticated combination of coded locks that block unauthorized detonation of the weapon.[79] "Bypassing a PAL," it has been noted, "should be about as complex as performing a tonsillectomy while entering the patient from the wrong end."[80] However, despite the technological security provided by PALs, "they are only effective if the codes for the locks are also kept secure," notes Zia Mian. "If anyone can have access to [or guess] the codes then PALs offer little if any restraint as command and control devices," Mian warns.[81] Moreover, if jihadists simply settled on accessing the nuclear materials within a PAL safeguarded weapon, they could eventually take the warhead apart. However, any warhead safeguarded with a PAL would not likely possess the *quantity* of nuclear material necessary to fuel an IND; jihadists would have to acquire and dismantle several such weapons.

States can also outfit their nuclear weapons with so-called safing, arming, fuzing, and firing (SAFF) features to prevent a weapon from detonating unless very specific requirements have been met.[82] These systems can be extremely complex, often employing barometric, temperature, and radar altimeter sensitive arming mechanisms; such arrangements can also be rather primitive, for example, the insertion of "mechanical devices into the pit (e.g., chains, coils of wire, bearing balls) to prevent complete implosion."[83] As opposed to PALs, it is highly unlikely that senior military and/or governmental officials could be of much assistance in defeating most complex SAFF procedures.[84] Again, jihadists might consequently be forced to abandon their quest to detonate the weapon and might simply settle on accessing the SAFF secured weapon's fissile materials.

United States

All U.S.-deployed nuclear weapons—3,575 strategic and 500 tactical warheads—are thought to utilize PALs and SAFF features.[85] Despite security mishaps, some of them quite serious, all U.S. nuclear weapons are generally viewed by experts as being "highly secure in all phases of their life cycle" and virtually immune to seizure by jihadists.[86] There are concerns that U.S. tactical nuclear weapons may not be as secure as their strategic counterparts, and some nuclear weapons experts have warned that tactical nuclear weapons "represent a particular concern from the standpoint of nuclear terrorism because of a combination of their physical properties and basing modes. Their relatively small size; portability; and….their forward deployment, make tactical nuclear weapons the likely weapon of choice for a nuclear terrorist organization."[87] Other experts note that U.S. tactical nuclear weapons are presently "as secure as strategic nuclear weapons."[88] It should be noted that the United States presently deploys several hundred tactical nuclear warheads in six different NATO countries, including Turkey.[89]

Russia

Even before the demise of the Soviet Union there were concerns over the security of nuclear materials and weapons in its Republics. In 1991 the United States began working with its allies to ensure that Soviet stocks of fissile materials and nuclear warheads were repatriated to the Russian Republic.[90] Even before these transfers were completed in 1994, however, it was evident that nuclear security within the newly independent state of Russia was deeply flawed.[91] Consequently, the United States made frantic efforts to assist Russia in securing and dismantling its nuclear infrastructure.[92] Presently, more than half of Russia's nuclear warhead sites have been cooperatively upgraded,[93] with one expert recently noting that "the difference between the security in place today and the security in place in 1994 is like night and day."[94]

As of early 2008, deployed Russian nuclear forces consist of approximately 3,113 strategic and 2,079 tactical warheads.[95] All of the former likely have PALs and employ SAFF features; however, there is debate over whether or not all of Russia's tactical nuclear weapons possess PALs.[96] Notwithstanding these technological safety features and ongoing physical security enhancements, profound concerns still exist over the security of Russian nuclear forces.

In large part these nuclear anxieties stem from widespread state corruption in Russia and a nuclear security culture perceived as lax. Moreover, fraud and nuclear negligence concerns are exacerbated profoundly with the existence of Russia's active and sophisticated jihadist networks.[97] Russia's Chechen jihadists, for example, have undertaken some of this decade's most audacious and tactically successful terrorist attacks.[98] The 2002 Dubrovka theatre incident and the 2004 Moscow subway and Beslan school attacks all reveal, notes one expert on Russian terrorists, that Chechen jihadists may have the operational capability to "take possession of … Russian nuclear weapons and fuel sites."[99] The relative success of these and other terrorist operations reveals as well that Russia's nuclear security apparatus is frequently insufficient, careless, corrupt, and quite possibly willing to provide forms of insider assistance.[100]

As demonstrated in this book's radiological chapter, Russian jihadists have shown that they are intent on acquiring nuclear materials and weapons.[101] Russia is the only known nuclear weapon state to admit to having had its nuclear weapon storage facilities targeted and reconnoitered by terrorists.[102] Such potential nuclear insecurities, however, should not obscure the fact that all of Russia's nuclear weapons are presently under control and that, by all open-source accounts, no Russian nuclear device—strategic or tactical—has ever "made its way into the world's illegal arms bazaars," let alone into the hands of jihadists.[103]

United Kingdom, France, and China

On the one hand, the prevalence of terrorist groups in the United Kingdom—virtually every major jihadist group has had, at one time or another, a network operating within England—naturally leads to concerns over its nuclear arsenal. On the other hand, because of its size and deployment characteristics, the United Kingdom's nuclear arsenal is arguably the world's most secure: Its entire arsenal of active nuclear weapons, estimated to be about 185 warheads, is deployed on a fleet of nuclear-powered ballistic missile submarines (SSBNs).[104] Furthermore, all of the United Kingdom's operational warheads are believed to be equipped with PALs and possess SAFF features.[105]

French nuclear forces—estimated, in 2005, to be comprised of 348 active warheads[106] —are also widely seen as very secure despite the existence of several jihadist networks within that country. With the possible exception of France's submarine-launched ballistic missiles (SLBMs), all active warheads are thought to utilize PALs and SAFF features. [107]

China's nuclear arsenal is believed to possess about 200 warheads, 130 of which were thought to have been deployed in 2006.[108] There is no consensus on how many, if any, of these warheads are tactical. Experts agree that if China does have tactical nuclear weapons, they number less than twenty-five.[109] Various reports indicate that China likely has not yet incorporated PALs or critical SAFF features, or, according to one expert, "any other safety feature into its warheads."[110]

Little is known about potential jihadist threats to Chinese nuclear forces. Uighur separatists, active in Xinjiang Province, reportedly may have stolen radioactive sources from a Chinese nuclear facility in 1993.[111] In April 2008, the East Turkistan Islamic Movement (ETIM) allegedly plotted suicide attacks and kidnappings to disrupt the Beijing Olympics, perhaps portending an increase in sophisticated jihadist-related terrorist activity in China.[112] Nevertheless, even with restive native populations in Xinjiang, Tibet, and Inner Mongolia, and an arsenal that likely incorporates very few modern safety features, the domineering role of the Chinese Communist Party and the restrictive nature of Chinese society makes it highly improbable that jihadists could secure an intact Chinese nuclear weapon in the foreseeable future.

Israel

Despite its proximity to numerous jihadist groups and notwithstanding frequent terrorist attacks against it, the threat of jihadists seizing any of Israel's nuclear weapons is likely to be low. Little is known about Israel's undeclared arsenal—estimated to consist of between 75 and 200 warheads.[113] Many of these weapons are thought to be tactical.[114] The types and status of technological safeguards on Israeli nuclear weapons is unknown. A dated account suggests that, up until at least the early 1990s, some warheads were kept in a preassembled state in "special secure boxes that could be opened only with three keys, to be supplied by the top civilian and military leadership."[115] Recently, experts have advanced the idea that rather than relying strictly on PALs, Israel likely relies "on procedures and codes."[116]

India

India's nuclear arsenal is rapidly increasing. Its growth is constrained, according to a retired Indian vice admiral, "more by production capabilities than by international restraints."[117] While presently believed to have approximately "50–60 assembled warheads," India has announced plans to enhance this number many-fold—some Indian officials have given numbers as high as "300–400 fission and thermonuclear weapons" by 2010.[118] It is widely believed that India does not possess PALs technology.[119]

Several well-organized and resourceful jihadist groups are active in and around India.[120] Jaysh-e Muhammad (JEM), for example, conducted sophisticated attacks against the Kashmir State Assembly and the Indian Parliament in 2001 that again demonstrated JEM's very high operational capabilities.[121] Additionally, Lashkar-e-Taiba (LeT) has targeted Indian nuclear facilities in the recent past.[122] Arguably assuaging concerns over jihadist activities and India's potential lack of nuclear technological safeguards is the fact that India is unique among nuclear states in that its military does not have possession of India's nuclear arms.[123] In practice, this means that the physical authority of nuclear warhead cores resides with civilian authorities, while the military maintains possession only of the delivery vehicles for the warheads—a so-called "de-mated" posture.[124] Consequently it would be extraordinarily difficult for jihadists to secure an intact Indian nuclear warhead.

Pakistan

Pakistan is believed to have enough fissile material for 60 to 130 nuclear weapons.[125] The existence of jihadist groups on its soil (including a reconstituted al-Qa'ida in South Waziristan[126] and the Pakistani Taliban), internal political turbulence, jihadist influences in its military and intelligence services, and a disturbing history of nuclear technology and material transfers has led some observers to conclude that Pakistan's nuclear arsenal is profoundly insecure.[127] Indeed, since at least 1999, there have been calls for the United States and other countries to develop contingency plans to seize and "exfiltrate"

Pakistan's nuclear weapons to prevent them from falling into the hands of extremists in the event of widespread civil unrest or a governmental coup by Islamist forces.[128] In a thinly veiled recent reference to Pakistan, the U.S. Department of Defense (DoD) noted that, "although not necessarily hostile to the United States," certain states lack "effective governance" presenting opportunities for terrorists "to acquire or harbor WMD."[129] In contrast to these concerns, however, Pakistan consistently maintains that its arsenal is under "ironclad" control.[130] In addressing these seemingly contrary threat perceptions, four points can be made.

First, Pakistan's nuclear arsenal is widely believed to be stored in a "trifurcated" manner, that is, the nuclear core of the weapon, the non-nuclear components of the device, and the delivery vehicle are all kept separate.[131] Moreover, the nuclear components are said to be guarded by upwards of "10,000 troops."[132] Even during its extremely tense military standoff with India in 2001 to 2002, Pakistan is not believed to have mated its nuclear weapon components.[133] Consequently, it would appear to be virtually impossible for jihadists to overtly seize or steal an intact Pakistani nuclear device without considerable insider help. The greater threat, therefore, is of jihadists somehow acquiring weapons-grade fissile materials from a Pakistani source and subsequently employing them in an IND.

Second, while it is not clear whether or not Pakistan's warheads utilize PALs, the head of the Pakistani body that runs nuclear weapons operations has stated that the military utilizes both "enabling and authenticating codes" to safeguard its nuclear weapons.[134] Moreover, commentators frequently point to Pakistan's "two-man" or "three-man" rules and very tight selection process for vetting personnel involved with nuclear weapons—mirroring in many ways, some believe, the U.S. Personnel Reliability Program—as evidence that insider nuclear subterfuge, vis-à-vis an intact device, is a near impossibility.[135] Again it seems very likely that the extant threat lies in Pakistan's fissile materials.

Third, it can be argued that the threat of coup by extremists in Pakistan is very low. While those Islamic political parties that are most often linked to an Islamist political takeover (for example, Jama`at-i-Islami, Jami'at-i-Ulema-i-Islam, and Jami'at-i-Ulema-i-Pakistan) are the *loudest* groups that oppose Pakistani leadership, their political base is small, and they enjoy little backing from the key military and political coteries necessary to successfully take power.[136] Summing up this argument against the notion of an Islamist seizure of power, South Asian expert Frédéric Grare has noted that, "No Islamic organization has ever been in a position to politically or militarily challenge the role of the one and only center of power in Pakistan: the army."[137]

As for the Pakistani military, there are widespread concerns that significant elements of its ranks are linked to jihadist groups.[138] Consequently there is trepidation by some that radicalized elements of the military could collectively conspire to transfer an intact nuclear device to jihadists or, if they successfully seized power, directly assume control of Pakistan's nuclear assets.[139] Such scenarios are unlikely to transpire any time in the near future. President Musharraf and his regime are known to have mercilessly weeded out extremists from the Pakistani nuclear weapons complex.[140] Others argue that even if Islamists *did* occupy the upper echelons of military power, it is extremely unlikely that they would undertake or support nuclear transfers.[141] While acknowledging the military's loyalty and stability, however, there are still concerns among experts that growing civil unrest in Pakistan could distract the military "from its guard duties," rendering some of Pakistan's fissile materials more vulnerable to theft or direct seizure by jihadists.[142] In short, there is a strong sense by many informed analysts that the nexus between the Pakistani military and Islam is less political and more ideological and inspirational, and that Pakistan's army officers are "extremely sensitive to the corporate interests of the military."Moreover, it is still generally accepted that Pakistan's military sees its interests as being well-served by "enduring political, economic, technical, and military links with the United States," a perspective that would occlude any nuclear involvement with jihadists.[143]

Finally, there are acute concerns that transfers of nuclear technologies, materials, and know-how by Pakistan's top nuclear scientist, Dr. Abdul Qadeer Khan (commonly referred to as "A. Q. Khan"), pressage similar transfers to jihadists. Yet, despite claims that Pakistan has become the, "Wal-Mart for nuclear weapons shoppers," it is important to note what Pakistan has *not* stood accused of in the proliferation scandal that was publically revealed in 2004.[144] Most importantly from the perspective of jihadists, the Khan Network transfers were to state entities (as opposed to nonstate actors), they did not involve intact nuclear warheads, and the nuclear material that was transferred was in the form of uranium hexafluoride—suitable for weapons use only *after* enrichment.[145] The bulk of what was apparently transferred—centrifuge technologies—would be of no present value to jihadists determined to acquire nuclear capability. Moreover, a nuclear weapon design, like the Chinese one that Dr. Khan allegedly gave to Libya, is not considered terribly difficult to come by, nor would jihadists need such a sophisticated blueprint.[146] In short, there is no evidence of a nexus between nuclear networks and terrorists, and the Khan Network, even as it existed at its apogee, would likely have been of little use to jihadists.

In sum, Pakistan is unique among all nuclear states with regard to the theoretical ability of jihadists to obtain nuclear weapons and materials. Its geographical proximity to, and, indeed, inclusion of jihadist groups is unparalleled. Additionally, Pakistan's nascent nuclear armory is unlikely to employ the same level of technical security sophistication that other arsenals possess. Amid a turbulent domestic venue that is punctuated by ongoing civil turbulence, including an insurrection in its federally administered tribal areas (FATA), coups, and assassinations, Pakistan's nuclear custodianship credibility is further tarnished by probable high-level state collusion with the A. Q. Khan nuclear network. While these factors have led some to speculate that Pakistan is the ultimate "nuclear nightmare," a more nuanced appraisal reveals a nuclear state with robust nuclear security arrangements collectively make it unlikely that intact nuclear weapons could end up in the hands of jihadists.[147] "Only if there's a complete breakdown in society, would there be an issue," notes Pakistani nuclear expert Leonard Spector, adding that, "Even then, I think you'll find a cadre, a very loyal military, who protect the assets because it's the patrimony of the country."[148]

North Korea

Having detonated its first nuclear weapon in October 2006, North Korea is the latest state to enter the nuclear club. Presently, North Korea is believed to have the nuclear materials to fabricate five to twelve warheads.[149] Three plausible scenarios exist linking North Korea's nuclear capability to jihadist acquisition of nuclear weapons. First, it is possible that should the present regime of Kim Jong-Il fall from power—from internal strife, military invasion, or a combination of the two—nuclear warheads might go missing in the ensuing disorder and could, presumably, end up in the hands of jihadists.[150] Second is the possibility that North Korea, already well experienced in missile sales to other countries, will begin to trade and sell its nuclear know-how with other states who, in turn, may supply warheads to jihadists.[151]

Third, and of greatest concern, North Korea could willingly provide nuclear weapons directly to jihadists. According to the U.S. State Department, North Korea maintains relations with various terrorist organizations, has supplied weapons to several terrorist groups including the Moro Islamic Liberation Front (a Sunni Islamist group), and allegedly provides "safe haven" to terrorists.[152] Moreover, coupled with missile sales to "states of concern," North Korea's involvement with drug smuggling and money counterfeiting are seen by some as proof positive "that Kim Jong-Il would be equally open to selling nuclear materials, technology, or weapons to terrorist groups."[153] A 2006 U.S. intelligence report to Congress—a "721 Report"—stated that in April 2005 Pyongyang warned that it "could transfer nuclear weapons to terrorists if driven into a corner."[154] As recently as December 5, 2006, a spokesperson for the National Nuclear Security Agency (NNSA) stated that the United States now has to consider "the possibility that the North Koreans…would be willing to either sell materials or sell a warhead to the highest bidder."[155]

Knowledgeable and responsible experts perceive the risk of North Korean nuclear transfers to terrorists as low.[156] Mindful that past behavior is often a key indicator of future actions, they stress that "no one has produced evidence to suggest that Pyongyang has ever attempted to sell nuclear materials to terrorist groups."[157] This fact would fall into line with the belief that North Korea views its nuclear arsenal not as a commodity to sell to terrorists but rather as a bargaining chip and a deterrent. During a visit to North Korea in 2006 by U.S. nuclear weapons experts, North Korean officials told Siegfried S. Hecker that North Korea "needs the deterrent; otherwise it can't defend its sovereignty," adding that North Korea would "not use nuclear weapons first, nor give them to terrorists like al Qaeda." The North Korean official went on tell Hecker that, "We make these expensive weapons to defend our right to survive."[158]

Significantly, at the time of this writing, it appears that North Korea is serious about dismantling its nuclear infrastructure.[159] The Six-Party talks, reenergized in February 2007, might ultimately lead to a completely de-nuclearized Korean Peninsula. In contrast, there are dramatic new allegations that North Korea helped Syria in building a nuclear reactor that was attacked by Israel in September 2007.[160] If true, such actions by North Korea will only fuel the erroneous argument that they would show no compunction in selling nuclear arms and materials to terrorists.

Iran

Because of its well-known support of groups that are on the U.S. State Department's list of foreign terrorist organizations and its ongoing nuclear program, Iran is perceived by some as a likely future source for jihadist acquisition of intact nuclear weapons. In a direct reference to Iran, for example, President Bush has warned of "outlaw regimes" supplying WMD to "their terrorist allies who would use them without hesitation."[161]

Despite "high confidence" assertions of the 2007 National Intelligence Estimate (NIE) that Iran likely halted nuclear weapons *development* in 2003 (and "moderate confidence Tehran had not restarted its nuclear weapons program as of mid-2007"), Iran undoubtedly continues to develop the technological *capability* to build nuclear weapons.[162] In doing so Iran will likely emulate the Japanese model of being a "virtual nuclear weapon state"—a technically *non*-nuclear weapon state with a robust civilian nuclear infrastructure that can be quickly modified with relative ease for nuclear weapons fabrication.[163] Accordingly, while certain geopolitical developments short of a foreign military occupation could convince Tehran to abandon its efforts,[164] it seems likely that within the next three to seven years Iran will have fully developed the ability to weaponize a nuclear device within months of a final decision to do so.[165]

Iran could produce a nuclear weapon using either plutonium or HEU. The former could theoretically be extracted from spent nuclear fuel rods taken from Iran's Bushehr reactor (or its Arak research reactor, due to be completed in 2009); the latter could be fabricated at Iran's Natanz facilities. Because all of Iran's declared nuclear facilities are presently under IAEA safeguards, the use of Bushehr or Natanz (or, in the future, Arak) to procure or produce fissile materials would instantly expose Iran's noncivil nuclear intentions to the international community. Consequently, some analysts postulate that Iran may be developing clandestine uranium enrichment facilities that could complement its efforts at Natanz. Conceivably, such a scenario would involve Iran fabricating LEU at Natanz and then "breaking out" by quickly enriching the uranium to HEU, ostensibly at a secret facility that, even if discovered, would not be as vulnerable as Natanz.[166] Such a route would seriously tax Iran's centrifuge capabilities and, if successful, would likely only initially yield a few nuclear devices annually.[167]

Iran is linked to several jihadist groups. Consequently there are deep, yet unfounded, concerns that, should Iran weaponize a nuclear capability, it would pass these weapons along to jihadists.[168] Created and largely funded by the Iranian Revolutionary Guard, Hizballah is the most frequently mentioned candidate as a potential Iranian nuclear proxy. Palestinian Islamic Jihad, although a Sunni group, is unique in its pro-Khomeini ideology and also enjoys backing from the Iranians. Hamas is also linked to Iran, yet it would be far less likely to be considered as a nuclear surrogate due to critical ideological incompatibilities between it and Tehran.[169] Finally, despite a widespread perception that Iran supports al-Qa'ida,[170] experts have recently reiterated that there are no indications that "Iran is supporting al-Qa'ida activities or harboring its members."[171]

Thus, of all potential jihadist groups, Hizballah and Palestinian Islamic Jihad are Iran's only plausible nuclear surrogates. Yet, despite their relationship with Iran, neither could usefully serve any purpose to Iran vis-à-vis nuclear weapons. Should Iran wish to attack, retaliate, or deter regional nuclear-backed threats, it could do so on its own with a nascent nuclear arsenal and ballistic missile capability. "Covert" use of a nuclear weapon against a nuclear region power (i.e., Israel) or U.S. forces would be suicidal for Iranian leadership. Iranian culpability of a nuclear strike using a proxy would almost certainly be established immediately,[172] and it is likely that Iran would suffer immediate and unimaginably destructive nuclear retaliation.[173] Contrary to popular perceptions, Iran's leadership is highly rational and, while it has made tactical and strategic miscalculations in the past, there is no evidence to suggest that the regime is suicidal or grossly delusional.[174]

In sum, Iran is moving toward a nuclear weapons capability. However, to go beyond being a "virtual nuclear weapon state"—to actually possess a weaponized nuclear arsenal—is a commitment that Iran would likely undertake only if it believed that it needed an immediate deterrent to some kind of massive military attack. Indeed, Iranian expert Trita Parsi has noted that, absent such dire circumstances, "The Iranians are well aware that a decision to weaponize would likely weaken rather than advance Iran's strategic position."[175] Subsequent transfers of nuclear warheads to jihadists are extremely unlikely and could only plausibly occur if Iran thought that its national existence was in jeopardy via a military invasion—a concern that would likely be obviated by the actual possession of nuclear weapons by Iran.

NUCLEAR BLACK MARKET

A 2005 survey of eighty-three experts in the field of CBRN security overwhelmingly concluded "black market purchase to be the most likely means through which terrorists would acquire nuclear weapons or weapons grade material."[176] While no one denies that nuclear trafficking and organized crime exist simultaneously in several regions of the world, no definitive proof has yet emerged linking the two. More importantly, "there is no compelling evidence of a solid nexus" among nuclear trafficking, organized crime, and terrorism.[177] In part, these uncertainties result from a lack of data collection and information sharing by various law enforcement agencies around the world and, obviously, by the fact that only known plots and incidents can be evaluated. In short, while there may be a robust nonstate nuclear black market in operation, one that ostensibly could supply jihadists with intact nuclear weapons, no known empirical evidence yet exists to support this fear.

Incidents of known nuclear trafficking are relatively widespread, but only a few of them involve fissile materials. The IAEA's Illicit Trafficking Database, for example, recorded only sixteen incidents from 1993 through 2006 that involved HEU or plutonium.[178] Only a few of these cases had "proliferation significant quantities" of materials (kilogram-level quantities of plutonium-239 or HEU) and none such cases have occurred since the 1990s.[179] Moreover, since at least 2001, only three cases are *potentially* linked to terrorists, and, according to one of the world's foremost nuclear trafficking experts, their actual connection to terrorism "really doesn't exist at this point."[180] Thus, the overwhelming motivation in all known cases of nuclear theft and smuggling appears to be profit and the market appears to be entirely supply-driven; there is almost no data to support any connections to terrorists or organized crime.

Still, such trafficking data generate more questions than they answer. Is the lack of recent cases involving fissile materials an indication that improved security measures in Russia and elsewhere are increasingly effective, or do they indicate that traffickers are simply more adept at not getting caught? Does the recent trend of cases involving small, as opposed to proliferation significant, quantities of fissile materials imply that smugglers are being forced to traffic less material due to enhanced security measures or less supply, or are the smaller quantities indicative of *samples* of larger quantities of materials that flow freely?[181] Finally, do these data simply represent underreporting? For example, one study has shown that only one-third of the smuggling incidents reported in the Russian media from 1993 to 2005 were "confirmed to the IAEA by the Russian Federation."[182] "This makes it difficult," the study concludes, "to rely for a comprehensive global assessment on nuclear trafficking on state-supplied information only."[183]

Complicating any analysis of the nuclear black market is the existence of proliferation networks that have supplied states with nuclear know-how and materials, specifically the aforementioned A. Q. Khan Network. The discovery of this network raised speculation that a similar subrosa system might exist, linking terrorists to nuclear materials. To date, however, there have been no credible reports linking the Khan Network to jihadist attempts to acquire a nuclear capability. This is not surprising given the nature of the Khan Network: profit-motivated operatives, dealing exclusively with states in enrichment technologies, typically engaging in transactions of several million dollars.

INCIDENTS OF JIHADIST INTEREST IN NUCLEAR WEAPONS AND WEAPONS-GRADE NUCLEAR MATERIALS

Despite no conclusive evidence of a nuclear black market servicing nonstate actors, jihadists have, since at least 1993, made serious attempts to acquire fissile materials and nuclear weapons. Several individuals linked to jihadist groups have been arrested or detained for plotting or attempting to acquire nuclear weapons or materials, yet to date there have been no confirmed incidents of a jihadist-linked individual or a jihadist group successfully obtaining fissile materials suitable for a nuclear weapon or an intact nuclear warhead.[184] In terms of technological know-how, this book (see Chapter 4) has already detailed how, to date, jihadists are thought to have secured mostly basic, often grossly inaccurate, information about nuclear weapons.[185]

Al-Qa'ida

Most active among jihadist groups seeking to acquire nuclear weapons and weapons-grade nuclear materials has been al-Qa'ida; according to the U.S. government, their determined efforts to acquire nuclear materials began "at least as early as 1992."[186] Jamal Ahmad al-Fadl, a Sudanese national and former Ibn Ladin associate, has testified that in late 1993 or early 1994 he observed the preliminary phases of a transaction between al-Qaida and various operatives for the purchase of uranium in Khartoum, Sudan.[187] It is not known if the actual transaction (reportedly for $1.5 million) ever took place, yet al-Fadl's testimony is generally considered to be credible. Throughout the 1990s there were numerous subsequent reports of al-Qa'ida unsuccessfully attempting to acquire uranium and nuclear warheads.[188]

Al-Qa'ida's efforts took a significant turn in 2000 and 2001, when Bin Ladin and Mullah Omar (Taliban's leader and Afghanistan's de facto head of state from 1996 to 2001) met with two former Pakistani nuclear scientists. One of them, Sultan Bashir-ud-din Mahmood, was a former chairman of the Pakistan Atomic Energy Commission (PAEC) and an expert in uranium enrichment and plutonium production.[189] Considered by Pakistan's Inter Services Intelligence (ISI) to be too politically and religiously radicalized for continued work as head of Pakistan's Khosab nuclear reactor complex, Mahmood was forced out of office in 1999 and subsequently founded the aid organization Ummah Tameer-e-Nau (UTN). Under the cover of UTN, Mahmood, along with Abdul Majid, another PAEC scientist, allegedly met with al-Qa'ida operatives and various Taliban state officials with the hopes of assisting them in the fabrication of nuclear weapons (documents seized in Kabul detail UTN's desire to undertake uranium mining in Afghanistan). Over a period of a few days, three weeks prior to the 9/11 attacks, Mahmood and Majid reportedly met with Bin Ladin and Ayman al-Zawahiri, around a "campfire in Kandahar," to discuss al-Qa'ida's quest for nuclear and radiological weapons.[190]

David Albright has written that Mahmood and Majid likely provided al-Qa'ida with "a blueprint for making nuclear weapons," while also providing al-Qa'ida or the Taliban with "classified information about producing nuclear weapons…or of facilitating access to others in the Pakistani nuclear program who had that knowledge."[191] With their vast experience in the Pakistani nuclear program, Mahmood and Majid, Albright adds, "could have provided important tips or direct assistance on managing and running a complex nuclear project."[192]

Following the demise of the Taliban in 2001, materials recovered by coalition military forces and the media shed more light on al-Qa'ida's nuclear enterprises while in Afghanistan.[193] While most of the documents revealed a relatively low level of understanding vis-à-vis nuclear weapons, some were reported to be of "higher quality," including, according to nuclear expert Matthew Bunn, "one fact about initiating a nuclear chain reaction that remains classified and could not simply have been downloaded from the internet."[194] Since 2002 there have been perennial reports of al-Qa'ida attempting to procure nuclear weapons and weapons-grade materials—none of which are believed to have been successful.[195] There are reports as well that al-Qa'ida has "at least one Central Asian nuclear weapons expert" presently working within its ranks.[196] Not surprisingly, there are reports that al-Qa'ida continues to maintain a strong desire to employ nuclear weapons against the United States and its allies.[197]

Altogether the documents recovered in Afghanistan, along with other reports of al-Qa'ida's nuclear activities, reveal a group that is serious about acquiring a nuclear capability. Al-Qa'ida has made several efforts to secure intact nuclear devices and fissile materials and has reportedly been prepared to pay many millions of dollars to do so.[198] While al-Qa'ida's technical grasp of nuclear weapons is thought to be nascent and occasionally bordering on the absurd, a caveat is in order. "History is replete with cautionary tales warning against basing threat assessments on static analyses of an opponent's motivations and capabilities," notes terrorism expert Gary Ackerman. "After all," he continues, "if their actions over the past decade have taught us anything, it is that terrorists are audaciously nimble operators who can adapt through reinvention and are prepared to persevere to attain their goals."[199] In this sense, al-Qa'ida and Taliban contact with nuclear scientists may may be a harbinger of substantial substantial jihadist nuclear expertise should they ever acquire enough fissile materials to fuel a nuclear weapon.

russia's Chechen-Led Jihadists

Russia's Chechen jihadists, already noted as having a very high operational capability, have long been associated with nuclear materials acquisition and have made clear their intention to acquire nuclear weapons.[200] (Chechen militants have also been linked to attempts to *sell* fissile materials and entire nuclear warheads that they supposedly possessed.[201]) "Suspicious persons," allegedly linked to Chechen militants, scouted Russian nuclear warhead facilities in 2001.[202] In 2002 and 2003, suspected Chechen militants likely linked to jihadists attempted to break into one of Russia's facilities housing nuclear warheads.[203] Additionally, Chechen militants are suspected of conducting reconnaissance on Russian transport trains carrying nuclear weapons,[204] and they have been known to have obtained identification passes allowing them access to closed Russian nuclear facilities.[205] Warning that Chechens have insider knowledge of the location and security of Russia's nuclear weapons, Viktor Ilyukhin, a Russian Member of Parliament and deputy chairman of the Russian Parliament's security committee, has noted that "many Chechens served in the armed forces, in the interior ministry troops, and many have experience of guarding crucial [nuclear] facilities…. Their location is not in any way a secret for the Chechens."[206]

Nuclear-related Threats and Attacks in India and Pakistan

Jihadists are publically known to have plotted against India's civil nuclear infrastructure. In December 2005, Lashkar-e-Taiba (LeT)—a Sunni Islamist group—reportedly targeted an Indian nuclear power plant for attack. [207] In 2006 there were several security breaches at other nuclear power plants,[208] leading India's prime minister, Manmohan Singh, to conclude that terrorist targeting now includes "nuclear installations."[209] It is likely that such attacks would seek to disrupt the operations of the plant or cause them to malfunction. Such plots may herald future attacks on India's military nuclear infrastructure by jihadists seeking to acquire a nuclear capability.

In 2007, jihadists plotted, and in some cases actualized, attacks that targeted Pakistani military nuclear installations. While it appears that these strikes were tactically designed to inflict loss of life and generate mayhem, such attacks may by strategically intended to "erode the military's capacity to defend nuclear installations if the Taliban and al Qaeda can mount a raid to seize nuclear weapons."[210] Sargodha Air Force Base, which serves as the headquarters of the Central Air Command of the Pakistan Air Force (PAF) and likely houses "partially assembled air-deliverable nuclear devices," has been targeted by jihadists—allegedly linked to al-Qa'ida and the Taliban—on several occasions. [211] In November 2007, a suicide bomber killed eight and wounded twenty-seven in an attack at the air base.[212] Pakistan's Kamra Air Weapon Complex (AWC) has also been stuck by jihadist suicide bombers.[213] The facilities at Kamra are reportedly coupled with the "weaponization of Pakistan's nuclear devices."[214]

OVERALL LIKELIHOOD OF JIHADISTS OBTAINING NUCLEAR CAPABILITY

To date jihadists have been unsuccessful in all publically known attempts to acquire fissile materials or intact nuclear weapons. These failures might be explained by tighter and more reliable security than is commonly presupposed at Russian and other nuclear facilities, a weak or nonexistent nuclear black market, or they could be attributable to a lack of resources by jihadists or, in the case of al-Qa'ida, "too many projects running simultaneously."[215]

Despite this unsuccessful history, however, there are no indications that serious interests by jihadists in acquiring a nuclear capability will abate in the near future. Whether or not they will succeed is one of the modern era's most daunting questions. Four broad factors will have a direct effect on any probable outcome. First is the quantity of global fissile materials, and the security associated with these stocks. As outlined above, present inventories are daunting: As much as 2,000 metric tons of HEU and 500 metric tons of separated plutonium, virtually all weapon-usable, exist globally. While the overall global stockpile of HEU is shrinking, production continues in Pakistan and India. Meanwhile, civilian stockpiles of separated plutonium are growing—they now likely exceed military stocks.[216] Global warming and concomitant dwindling oil reserves will likely be accelerating this trend, as states seek to secure carbon-free electricity.[217] While security over plutonium and HEU stocks continues to generally improve, Russia will remain as a source of great anxiety for many years to come, as well as fissile material stocks in other states.[218]

Second, global stockpiles of intact nuclear weapons and their security have an obvious bearing on the odds of jihadists successfully obtaining a nuclear capability. Inventories are declining in many states, yet they are growing in India, Pakistan, and China (and, perhaps, Israel). While overall security is arguably improving, concerns remain over the

Russian and Pakistani arsenals. Moreover, the nuclear weapons inventories of all other nuclear weapon states are not immune to all forms of nuclear subterfuge, with tactical nuclear weapons posing an especially acute threat.

Third, the spread of nuclear know-how and weapons to other states could dramatically alter any calculus used to determine the odds of jihadists being successful in their nuclear endeavors. A group of luminaries in the field of nuclear security recently concluded that, "the greatest danger to United States and indeed global security stems from the weakening or even collapse of the international consensus to prevent proliferation."[219] Foreseeable nuclear proliferation will likely occur in the world's least stable area—the Middle East.[220]

Finally, the number and sophistication of jihadist groups will likely have an enormous bearing on future developments. If their numbers remain the same or grow, it is very likely that their odds of eventual success will increase. If the conflict in Iraq significantly subsides, an exodus of jihadists is probable. They would likely take with them not only a fully militarized anti-Western ideology but also an increasingly sophisticated understanding of explosives and improvised explosive devices (IEDs). U.S. Director of National Intelligence, J. Michael McConnell, has addressed this possibility, noting that he is "increasingly concerned that as we inflict significant damage on al-Qa'ida in Iraq, it may shift resources to mounting more attacks outside of Iraq."[221] Such eventualities have already begun to transpire: The June 2007 London and Glasgow car-bomb attacks had alleged links to al-Qa'ida in Iraq and utilized a "technique previously employed in Iraq."[222]

In sum, the future will likely see the growth of fissile materials stockpiles and nuclear weapon arsenals in some of the world's least stable regions. It is very plausible that this dynamic will be bolstered by *new* nuclear states amid a post–Iraq exodus of increasingly well-trained jihadists. In December 2001, George Tenet believed that al-Qa'ida was on the verge of a nuclear capability; seven years later, jihadists are closer than ever.

NOTES

1. Ron Suskind, *The One Percent Doctrine* (New York: Simon and Shuster, 2006), 67.
2. "Combating Terrorism: The United States Lacks Comprehensive Plan to Destroy the Terrorist Threat and Close the Safe Haven in Pakistan's Federally Administered Tribal Areas," *Government Accountability Office (GAO), US Congress*, GAO-08-622, 2008, 9.
3. Joseph Cirincione, "Pakistanis under Musharraf and the Bush Doctrine," KGNU, Boulder, Colorado, April 8, 2008.
4. For the seven-part agreement, see Dan Balz, Bob Woodward, and Jeff Himmelman, "Afghan Campaign's Blueprint Emerges," *Washington Post*, January 29, 2002, available at http://www.washingtonpost.com/wp-dyn/content/article/2006/07/18/AR2006071800687_pf.html (accessed 03/21/08).
5. For a history of concerns around nuclear terrorism, see, for example, Micah Zenko, "Intelligence Estimates of Nuclear Terrorism," *The Annals of the American Academy of Political and Social Science* 2006; 607; 87, 93, available at http://ann.sagepub.com/cgi/reprint/607/1/87.pdf; and Central Intelligence Agency, National Intelligence Estimate (NIE) 31, "Soviet Capabilities for Clandestine Attack against the US with Weapons of Mass Destruction and the Vulnerability of the US to Such Attack," September 4, 1951, 3–6, available at http://www.fas.org/irp/threat/nieca1951.pdf (accessed 03/25/08).

6. As quoted in Michael Scheuer, *Through Our Enemies' Eyes: Usama bin Ladin, Radical Islam, and the Future of America* (Washington, DC: Potomac Books, Inc., 2002), 72.
7. Robert Jay Lifton, *Destroying the World to Save It*: *Aum Shinrikyo, Apocalyptic Violence, and the New Global Terrorism* (New York: Metropolitan Books, 1999), 204.
8. This would more likely be the goal of jihadists not wedded to the idea of the "restoration of the Caliphate"; for example, Hizballah and Hamas have a national goal, and "They have no global agenda or aspirations; they do not want to reestablish the Caliphate." Sammy Salama, "Islamist Organization in the 20th Century," *Monterey Institute of International Studies*, Monterey, CA, January 19, 2006.
9. " 'Why we fight America': Al-Qa'ida Spokesman Explains September 11 and Declares Intentions to Kill 4 Million Americans with Weapons of Mass Destruction," *Middle East Media Research Institute*, Special Dispatch Series, no. 388, June 12, 2002, available at http://memri.org/bin/articles.cgi?Page=archives&Area=sd&ID=SP38802 (accessed 08/03/07).
10. This study explores the acquisition of a single nuclear weapon by jihadists. It seems likely, however, that jihadists who have one nuclear weapon will have others as well. See, for example, Roger C. Molander, "Perspectives on Nuclear Terrorism," Testimony presented before the Senate Committee on Homeland Security and Governmental Affairs on April 15, 2008, available at http://hsgac.senate.gov/public/_files/041508Molander.pdf (accessed 04/18/08).
11. HEU is uranium with a content of 20 percent or more of the isotope uranium-235. Unless otherwise indicated, in this chapter it refers to uranium with an enrichment level above 80 percent uranium-235. See U.S. Congress, Office of Technology Assessment, *Technical Aspects of Nuclear Proliferation* (Washington, DC: Government Printing Office, 1993), 121.
12. See David Albright and Lauren Barbour, "Troubles Tomorrow? Separated Neptunium 237 and Americium," in David Albright and Kevin O'Neill, eds., *The Challenges of Fissile Material Control*, (Washington, DC: Institute for Science and International Security Press, 1999), 85–96, available at http://www.isis-online.org/publications/fmct/book/New%20chapter%205.pdf, and "US Nuclear Weapons Complex: Homeland Security Opportunities," *Project on Government Oversight*, May 2005, available at http://www.pogo.org/p/homeland/ho-050301-consolidation.html (accessed 04/02/08). See also "Evaluation of Nuclear Criticality Safety Data and Limits for Actinides in Transport," *Institut de Radioprotection et de Sûreté Nucléaire (IRSN)*, Département de Prévention et d'étude des Accidents, Service d'Études de Criticité, République Française, 2003, available at http://ec.europa.eu/energy/nuclear/transport/doc/irsn_sect03_146.pdf.
13. See Lillian Hoddeson, Paul W. Henriksen, Roger A. Meade, and Catherine Westfall, *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943–1945* (New York: Cambridge University Press, 1993), 228–248; and Michael Levi, *On Nuclear Terrorism* (Cambridge, MA: Harvard University Press, 2007), 73.
14. See Jeremy Bernstein, *Plutonium: A History of the World's Most Dangerous Element*, (Washington, DC: Joseph Henry PRess, 2007), 112.
15. Robert W. Young and Geroge D. Kerr, eds. *Re-assesment of the Atomic Bomb Radiation Documentary in Hiroshima and Nagasaki* (Hiroshima, Japan: The Radiation Effects Foundation, 2005), 53.

16. Mason Willrich and Theodore B. Taylor, *Nuclear Theft: Risks and Safeguards: A Report to the Energy Policy Project of the Ford Foundation* (Cambridge, MA: Ballinger Publishing Company, 1974), 8.
17. One can imagine a drop of water hitting a pool of water. The shock waves go *out* uniformly. The idea of an implosion device is to have the water go *in* uniformly. No part of the inward-moving shock wave in an implosion device can reach the center before all the others. Author's personal communication with Dr. James A. McNeil, Professor, Colorado School of Mines Physics Department, March 22, 2008. For an excellent description of how lenses worked on the first two implosion devices, see Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986), 575–578.
18. Willrich and Taylor, *Nuclear Theft*, 10.
19. Glasston and Dolan, *The Effects of Nuclear Weapons*, 36.
20. See Robert Jay Lifton, *Destroying the World to Save It: Aum Shinrikyo, Apocalyptic Violence, and the New Global Terrorism*; and Richard A. Falkenrath, Robert D. Newman, and Bradley A. Thayer, *American's Achilles' Heel: Nuclear, Biological, and Chemical Terrorism and Covert Attack* (Cambridge, MA: The MIT Press, 1998).
21. David Albright, "Al Qaeda's Nuclear Program: Through the Window of Seized Documents," *The Nautilus Institute Policy Forum On Line*, Special Forum 47, November 6, 2002, available at http://www.nautilus.org/archives/fora/Special-Policy-Forum/47_Albright.html (accessed 01/21/08).
22. For current trends in enrichment technologies, see M. D. Zentner, G. L. Coles, and R. J. Talbert, *Nuclear Proliferation Technology Trends Analysis*, PNNL-14480, *Pacific Northwest National Laboratory*, September 2005.
23. Graham Allison, *Nuclear Terrorism* (New York: Times Books, 2004), 98–99.
24. "Global Fissile Material Report," *International Panel on Fissile Materials*, 2007, 10.
25. See, ibid., 10–12.
26. Ibid., 12.
27. Ibid., 13.
28. Ibid., 17, 20.
29. A critical mass that does not utilize a reflector (explored below) is often called "the bare critical mass." Use of a reflector with a critical mass is often called "a reflected critical mass."
30. Plutonium can spontaneously ignite (it is pyrophoric) if not stored and handled correctly. For an excellent account of how plutonium's pyrophoric properties frequently wreaked havoc on U.S. military efforts to weaponize plutonium, see Len Ackland, *Making a Real Killing: Rocky Flats and the Nuclear West* (Albuquerque: University of New Mexico Press, 1999).
31. "The First Weighing of Plutonium," *Atomic Energy Commission Division of Technical Information*, Oak Ridge, TN, 1967, 4, available at http://www.osti.gov/accomplishments/documents/fullText/ACC0071.pdf (accessed 02/13/08).
32. Levi, *On Nuclear Terrorism*, 79–81.
33. "Global Fissile Material Report 2007," 21.
34. See, for example, "DOE Needs to Resolve Significant Issues Before It Fully Meets the New Design Basis Threat," *US General Accounting Office*, April 2004; and "US Nuclear Weapons Complex: Security At Risk," *Project on Government Oversight Report*, October 2001, available at http://www.pogo.org/p/environment/eo-011003-nuclear.html (accessed 04/02/08).
35. "Global Fissile Material Report 2007," 47, 54.

36. Paul Leventhal, Sharon Tanzer, and Steven Dolley, *Nuclear Power and the Spread of Nuclear Weapons* (London and New York: Brasseys, 2002), 236. See also Willrich and Taylor, *Nuclear Theft*, 14.
37. John McPhee, *The Curve of Binding Energy* (New York: Farrar, Straus and Giroux, 1973), 131.
38. Willrich and Taylor, *Nuclear Theft*, 14.
39. Mark, Taylor, et al., "Can Terrorists Build Nuclear Weapons?" 56–74
40. Michael Levi has estimated that the device's explosives, in such circumstances, might likely weigh more than the oxide itself. Levi, *On Nuclear Terrorism*, 83.
41. Willrich and Taylor, *Nuclear Theft*, 14.
42. "Global Fissile Material Report 2007," 13.
43. Ibid., 3
44. See, Bernstein, *Plutonium*, 159–160, and Garwin and Charpak, *Megawatts and Megaton*, 136–137.
45. Plutonium-238 is created when uranium-238 absorbs a neutron, becoming uranium-239, and then emits two neutrons. The resultant uranium-237 beta-decays into neptunium-237, which can become neptunium-238 after absorbing another neutron. This, in turn, can beta-decay into plutonium-238. Such circumstances occur if the plutonium is extracted from the rector after a relatively long period of time. See Bernstein, *Plutonium*, 159–160.
46. Richard L. Garwin and George Charpak, *Megawatts and Megaton*: *The Future of Nuclear Power and Nuclear Weapons* (Chicago: University of Chicago Press, 2001), 136–137; and, J. Carson Mark, "Reactor-Grade Plutonium's Explosive Properties," NPT/95, *Nuclear Control Institute*, August 1990, available at http://www.nci.org/NEW/NT/rgpu-mark-90.pdf (accessed 02/03/06). "Global Fissile Material Report 2007," 34.
47. Mark, "Reactor-Grade Plutonium's Explosive Properties" (emphasis added).
48. Leona Marshall Libby, *The Uranium People* (New York: Charles Scribner's Sons, 1979), 210.
49. Richard L. Garwin, "Reactor-Grade Plutonium Can be Used to Make Powerful and Reliable Nuclear Weapons," *Council on Foreign Relations*, August 26, 1998, available at http://www.fas.org/rlg/980826-pu.htm (accessed 05/25/05). It has been argued too that the relatively intense heat of reactor-grade plutonium, compared to that of WGP, would overheat "the thick high-explosive that surrounds the plutonium and any additional metal shells in a simple implosion weapon." However, it is now generally acknowledged that this development could be avoided by simply inserting the plutonium into the device just prior to detonation. Ibid.
50. Libby, *The Uranium People*, 210.
51. Matthew Bunn and Anthony Wier, *Securing the Bomb: 2007* (Cambridge, MA, and Washington, DC: Project on Managing the Atom, Harvard University/Nuclear Threat Initiative, 2007), vi.
52. The HEU that the Iraqis planned on using for their first few nuclear weapons—during the "crash program" of 1990—utilized the HEU from 5 megawatt and 40 megawatt research reactors. See Bukharin, Ficek, and Roston, "US-Russian Reduced Enrichment for Research and Test Reactors (RERTR) Cooperation."
53. "Nuclear Nonproliferation: DOE Needs to Take Action to Further Reduce the Use of Weapons-Usable Uranium in Civilian Research Reactors," *Government Accountability Office*, US Congress, GAO- 04-807, 2004, 28.

54. Matthew Bunn and Anthony Wier, "Terrorist Nuclear Weapon Construction: How Difficult?" *Annals of the American Academy of Political and Social Science* 607 (September 2006), 137.
55. Extracting HEU from research reactor fuel, noted James C. Warf, a nuclear specialist who headed the chemical processing program during the Manhattan project, "are not difficult procedures, particularly for someone intent on acquiring an atomic explosive; one might say, in fact, that they are not beyond the ability of most students in introductory chemistry classes at the college level." As quoted in Matthew Bunn and Anthony Wier, *Securing the Bomb: 2007*, 6.
56. Ibid., 138.
57. Ibid., 37.
58. Author's interview with Dr. Edwin Lyman, Senior Staff Scientist, Global Security Program, Union of Concerned Scientists, 02/27/08.
59. Bunn and Wier, *Securing the Bomb: 2007*, 78. Bunn and Wier conclude that Russian HEU-fueled civilian research reactor sites would "have great difficulty defending against a Beslan-scale attack (more than 30 well-trained attackers with automatic weapons, rocket-propelled grenades, and explosives, striking without warning)." Ibid.
60. Levi, *On Nuclear Terrorism*, 43.
61. Ibid.
62. For a detailed description of the technical parameters of reflectors, see "Military Critical Technologies List (MCTL) Part II: Weapons of Mass Destruction Technologies, Nuclear Systems Technology," *US Department of Defense*, 1998, Section 5, 58, available at http://www.fas.org/irp/threat/mctl98-2/p2sec05.pdf (accessed 02/02/08).
63. Robert Serber, *The Los Alamos Primer: The First LEctures on How to Build An Atomic Bomb*, (Berkeley, University of California Press: 1992), 43–44.
64. Jeremy Bernstein, *Nuclear Weapons: What You Need to Know* (New York: Cambridge University Press, 2007), 132.
65. Ibid, 133. See also Alexander Glaser, "On the Proliferation Potential of Uranium Fuel for Research Reactors at Various Enrichment Levels," *Science & Global Security*, vol. 14, no. 1 (2006), available at http://www.princeton.edu/~aglaser/2006aglaser_sgs-vol14.pdf (accessed 02/01/08).
66. For potential weapons' yield, see Ferguson and Potter, *The Four Faces of Nuclear Terrorism* (New York: Routledge, 2005), 112.
67. Mark, "Reactor-Grade Plutonium's Explosive Properties." See also Garwin and Charpak, *Megawatts and Megaton*, 315.
68. Richard L. Garwin and Frank N von Hippel, "A Technical Analysis of North Korea's Oct. 9 Nuclear Test, *Arms Control Today*, November 2006, available at http://www.armscontrol.org/act/2006_11/NKTestAnalysis.asp (accessed 05/06/07). The test reportedly utilized 6 kg of plutonium. See "North Korea Claims 30 Kilograms of Plutonium," *Global Security Newswire*, April 21, 2008, available at http://www.nti.org/d_newswire/issues/2008_4_21.html#30E487A0 (accessed 04/21/08).
69. Author's interview with Dr. Siegfried S. Hecker, co-director, Center for International Security and Cooperation, 03/10/08.
70. Author's interview, Dr. Louis Rosen, former Manhattan Project weaponeer and Los Alamos National Laboratory Fellow, 11/30/07.
71. See Richard. R. Paternoster, *Nuclear Weapon Proliferation: Indicators and Observables* (Los Alamos, NM: Los Alamos National Laboratory, 1992), 15, available at http://www.fas.org/sgp/othergov/doe/lanl/la-12430-ms.pdf (accessed 03/04/08).

72. U.S. Department of Defense, "Military Critical Technologies List (MCTL)," 60.
73. See Paternoster, *Nuclear Weapon Proliferation*, 14–15; and Levi, *On Nuclear Terrorism*, 43–44.
74. Bernstein, *Nuclear Weapons*, 132–133.
75. U.S. Department of Defense, "Military Critical Technologies List (MCTL)", 62; and Levi, *On Nuclear Terrorism*, 45–46.
76. Ibid.
77. See, for example, Robin Frost, "Nuclear Terrorism After 9/11," *Adelphi Papers*, December 2005, 45:378.
78. Richard Lugar, "The Lugar Survey on Proliferation Threats and Responses," June 2005, available at http://lugar.senate.gov/reports/NPSurvey.pdf (accessed 01/18/08).
79. See Peter Stein and Peter Feaver, *Assuring Control of Nuclear Weapons: The Evolution of Permissive Action Links* (Lanham, MD: University Press of America, 1987); Dan Caldwell and Peter D. Zimmerman, "Reducing the Risk of Nuclear War with Permissive Action Links," in Barry M. Blechman, ed., *Technology and the Limitation of International Conflict* (Washington, DC: SAIC, 1989), 149; and "Military Critical Technologies List (MCTL) Part II: Weapons of Mass Destruction Technologies, Nuclear Systems Technology," U.S. Department of Defense, 1998, Section 5, 68, available at http://www.fas.org/irp/threat/mctl98-2/p2sec05.pdf (accessed 02/02/08).
80. As quoted in Caldwell and Zimmerman, "Reducing the Risk of Nuclear War with Permissive Action Links," 159.
81. Zia Mian, "A Nuclear Tiger By the Tail: Problems of Command and Control in South Asia," in M. V. Ramana and C. Rammanohar Reddy, eds., *Prisoners of the Nuclear Dream* (New Delhi: Orient Longman, 2003), 107; see also Bruce Blair, "Keeping Presidents in the Nuclear Dark (Episode #1: The Case of the Missing Permissive Action Links)," Center For Defense Information, Bruce Blair's Nuclear Column, February 11, 2004, available at http://www.cdi.org/blair/permissive-action-links.cfm (accessed 03/21/2008).
82. See Gerald W. Johhnson, "Safety, Security, and Control of Nuclear Weapons," in Blechman, ed., *Technology and the Limitation of International Conflict*, 149.
83. "Nuclear Weapon Design," *Federation of American Scientists*, October 1998, available at http://www.fas.org/nuke/intro/nuke/design.htm.
84. For a study concluding that some modern SAFF systems can be overcome with "limited imagination," see Allison, *Nuclear Terrorism*, 90.
85. See, for example, Ferguson and Potter, *Four Faces of Nuclear Terrorism*, 66–67. For a discussion outlining the differences between strategic and tactical nuclear weapons, see Brian Alexander and Alistair Millar, eds., *Tactical Nuclear Weapons* (Washington, DC: Brassey's Inc., 2003), 6. For U.S. arsenal numbers, see, Robert S. Norris and Hans M. Kristensen, "US Nuclear Forces 2008," *Bulletin of the Atomic Scientists* (March/April 2008), 50–53, 58, available at http://thebulletin.metapress.com/content/pr53n270241156n6/fulltext.pdf (accessed 03/20/08).
86. Ferguson and Potter, *The Four Faces of Nuclear Terrorism*, 66–67. See also Michael Hoffman, "Nuclear Safety Slipped for Years Before Minot," *Air Force Times*, February, 26, 2008, available at http://www.airforcetimes.com/news/2008/02/airforce_250208_nukesafety/ (accessed 03/03/08). See also Scott D. Sagan, *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons* (Princeton, NJ: Princeton University Press, 1993).

87. William C. Potter, "Book Review: Using Murphy's Law Against Nuclear Terrorist," *Arms Control Today*, April 2008, available at http://www.armscontrol.org/act/2008_04/BookReview.asp (accessed 04/20/08).
88. Joshua Handler, "The 1991–1992 PNIs and the Elimination, Storage and Security or Tactical Nuclear Weapons," in Brian Alexander and Alistair Millar, eds., *Tactical Nuclear Weapons*, 32.
89. See Robert S. Norris and Hans M. Kristensen, "US Nuclear Forces 2008," *Bulletin of the Atomic Scientists* (January/February 2008), 81, available at http://thebulletin.metapress.com/content/91n36687821608un/fulltext.pdf (accessed 03/20/08).
90. See Charles P. Blair and Jean P. du Preez, "Visions of Fission: The Demise of Negative Security Assurances on the Bush Administration's Pentomic Battlefield," *Nonproliferation Review*, March 2005, 41–42.
91. See, for example, John M. Shields and William C. Potter, eds., *Dismantling the Cold War* (Cambridge, MA: Harvard University Press, 1997).
92. For an overview of recent efforts, see Jennifer Lackie, Reported Accomplishments of Selected Threat Reduction and Nonproliferation Programs, By Agency, for Fiscal Year 2006, Partnership for Global Security, July 2007, available at http://www.ransac.org/Publications/Reports%20and%20Publications/Reports/index.asp (accessed 12/13/07).
93. See Bunn and Weir, *Securing the Bomb: 2007*.
94. Mathew Bunn Testimony, United States Senate Committee on Homeland Security and Governmental Affairs Hearing on "Nuclear Terrorism: Assessing the Threat to the Homeland," April 2, 2008, 7, available at http://hsgac.senate.gov/public/_files/040208Bunn.pdf (accessed 4/5/08).
95. Robert S. Norris and Hans M. Kristensen, "Russian Nuclear Forces, 2008," *Bulletin of the Atomic Scientists* (May/June 2008), 54–57, available at http://thebulletin.metapress.com/content/t2j78437407v3qv1/fulltext.pdf (accessed 04/29/08).
96. Russian nuclear weapon experts have reported an "absence" of PALS on older generation Russian tactical nuclear weapons. William Potter and Nickolai Sokov, "Tactical Nuclear Weapons: The Nature of the Problem," CNS Report, James Martin Center for Nonproliferation Studies, January 4, 2001, available at http://cns.miis.edu/pubs/reports/tnw_nat.htm (accessed 07/21/07). See also Ferguson and Potter, *Four Faces of Nuclear Terrorism*, 62.
97. Russia is considered one of the most corrupt countries in the world. See Transparency International, "Corruption Perceptions Index," 2007, available at http://www.transparency.org/policy_research/surveys_indices/cpi/2007 (accessed 04/01/08).
98. See Gordon M. Hahn, *Russia's Islamic Threat* (New Haven, CT: Yale University Press, 2007); Gordon M. Hahn, "The Jihadi Insurgency and the Russian Counterinsurgency in the North Caucuses," *Post-Soviet Affairs*, 2008, 24, 1; and, Gordon M. Hahn, "The New Caucasus Emirate?" *Russia Profile*, November 29, 2007, available at http://www.russiaprofile.org/ (accessed 03/12/08).
99. Hahn, *Russia's Islamic Threat*, 229.
100. See ibid.; Bunn and Weir, *Securing the Bomb: 2007*; and Simon Saradzhyan, "Russia: Grasping Reality of Nuclear Terror," International Security Program, Belfer Center for Science and International Affairs, 2003, 28, available at http://belfercenter.ksg.harvard.edu/files/saradzhyan_2003_02.pdf (accessed 03/24/08).
101. See, for example, Hahn, *Russia's Islamic Threat*, 229–230.
102. See Steve Gutterman, "Russia: Intruders Targeted Nuclear Site," AP June 22, 2005; "Terrorists Make Two Attempts on Russia Nuke Facilities," *Itar-Tass*, June 22, 2005; Andrew Osborn, "Chechen Militants Have Tried to Steal Nuclear Weapons

Twice, Says Russian Security Chief," *The Independent* June 24, 2005; National Intelligence Council, Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces, December 2004, 6, available at http://www.dni.gov/nic/PDF_GIF_otherprod/russiannuke04.pdf (accessed 01/30/07). See also Bunn and Weir, *Securing the Bomb: 2007*, vi.

103. Robin M. Frost, "Nuclear Terrorism After 9/11," 8.
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