ISIS
Institute for Science and International Security

The Nuclear Terrorist Threat

by Kevin O'Neill
Institute for Science and International Security

August 1997

Introduction

The proliferation of nuclear weapons or radiological dispersal devices to terrorist groups is perhaps one of the most frightening threats to U.S. security. Nuclear materials, technologies and know-how are more widely available today than ever before. Small quantities of both fissile materials and highly radioactive materials, sufficient to manufacture a radiological dispersal device, are actively traded on the black market. Although terrorist groups are not suspected of actually acquiring such materials in large quantities, it is difficult to know for sure.

A nuclear detonation by a terrorist group would likely result in an unprecedented number of casualties. In contrast, a radiological dispersal attack would probably be less violent, but could significantly contaminate an urban center, causing economic and social disruption. Both types of attacks would have significant psychological impacts on the entire population.

Whether terrorists could make nuclear weapons has been addressed by many governmental and nongovernmental groups. This report, which draws upon a several year effort at ISIS in the mid-1990s to better understand nuclear terrorism, contains much information and many references on this subject. The fundamental conclusion is that terrorists would find obtaining the wherewithal to make nuclear weapons a difficult task. Nonetheless, terrorist organizations could over time develop such a capability, if they can obtain sufficient fissile material, likely through theft.

This report also reviews information about the threat of a terrorist attack using radiological weapons. The report concludes that the acquisition or use of radiological weapons involves fewer barriers than the acquisition or use of nuclear weapons. The effects of such use could include widespread panic and disruption that is disproportionate to the actual damage or risk posed by the dispersion of radioactive materials.

Nuclear Explosive Devices

Experts and governments officials have long acknowledged that a sub-national terrorist group could gather the technical skills and information needed to manufacture a nuclear weapon, given access to the necessary materials. In the mid-1970s, the Congressional Office of Technology Assessment (OTA) concluded that “a small group of people, none of whom have ever had access to the classified literature, could possibly design and build a crude nuclear device."[1] In the mid-1980s, J. Carson Mark, Theodore Taylor and other former nuclear weapons designers estimated that the "the number of specialists required [to build a crude nuclear weapon] would depend upon the background of those enlisted, but their number could scarcely be fewer than three of four and might as well have to be more."[2] Information about the Iraqi and South African nuclear weapons programs suggests that considerably more individuals are needed to design and assemble a reliable nuclear weapon that is deliverable as a gravity bomb or missile warhead. However, the estimate by Mark, Taylor et. al. serves as a lower bound of what is needed to assemble a far less sophisticated and reliable device that those pursued by these or other countries. In contrast, Mark and Taylor suggest, a crude terrorist device would likely weigh a tonne or more, have a nominal yield in the range of tens of kilotons, and be delivered by a truck, airplane or a ship.[3]

In order to manufacture a crude nuclear weapon, a terrorist organization needs to possess specialized expertise in areas such as high explosives, propellants, electronics, nuclear physics, chemistry and engineering. Knowledge of the physical and chemical properties of plutonium or highly enriched uranium (HEU) is essential. The terrorist group also must obtain detailed design drawings of weapons components and of the final assembled device.

In the past, such information was difficult to come by in the open literature. Today, according to Defense Department and Energy Department officials, important and useful information about the design and assembly of nuclear weapons or weapons components can be found on internet sites and World Wide Web pages. Unlike other resources, the internet provides a comfortable anonymity to those posting or seeking sensitive information. Egocentric individuals can post information anonymously or under pseudonyms and comfortably brag about their technical prowess. Serious browsers can wander through huge technical databases without the unpleasant task of confronting a human librarian. Given this anonymity, the internet can function as an instantaneous, global clearinghouse of information and provide a useful first source for terrorist groups, which otherwise would have to search the public literature in more conspicuous ways. Indeed, perhaps the best defense against information transferred over the internet is the sheer size of the internet itself and the large quantity of erroneous, incomplete or misleading information that is being posted.

Terrorists bent on assembling a nuclear explosive must acquire sufficient quantities of plutonium or HEU that is in a weapons-usable form. Depending on the quantity and form of material that it initially acquires, a subnational terrorist group may need to convert fissile materials from one form to another, requiring expertise in chemistry and access to necessary chemicals and equipment. Much of the world's less-protected stocks of fissile material cannot be used directly in nuclear weapons. By one recent estimate, over 700 tonnes of plutonium is contained in highly radioactive spent nuclear reactor fuel that has been discharged from commercial nuclear power reactors.[4] Before this plutonium could be used in nuclear weapons, it would have to be separated from the remaining uranium, cladding and fission products in a laboratory or reprocessing facility. It is highly unlikely that a subnational terrorist group would be able to gain access to such facilities or carry out such activities without being detected.

Table 1 **Forms of Fissile Material and Associated Activity to Convert Materials to a Weapons-Usable Form**			
Form (separated from spent fuel)	**Nuclear Weapon Activity**		
	Weapon Design	**Conversion to Metal***	**Foundry and Machining**
Pure Metal	Yes	No	yes
Oxide	Yes	yes	yes
Scrap or Residue	Yes	yes	yes
Intermediate Forms	Yes	yes	yes
** includes dissolution, purification, precipitation, calcination and metal reduction*			

Other less-protected materials pose a greater risk of diversion, but would still require purification and chemical processing to make them usable for nuclear weapons (see table 1). The manufacture of tens of thousands of nuclear weapons by the United States, Russia, Great Britain, France and China has generated large quantities of scraps, residues and other forms containing plutonium and HEU. For example, declared plutonium inventories at the Rocky Flats Plant, where the U.S. manufactured plutonium pits for nuclear weapons, include 6.6 tonnes of metal, 3.2 tonnes of oxide and 2.9 tonnes of scraps and residue, and 98 kilograms of plutonium in solution (see table 2).[5] Additional quantities of plutonium or HEU are also contained in waste, which were shipped off site and are even less well characterized and protected.

Table 2 **Plutonium Forms at Rocky Flats**		
Form	**Quantity (kg)**	**Typical Forms**
Metal	6,600	pits, buttons ingots, metal scrap
Oxides	3,200	Casting skulls, peroxide cake, non-specific forms
Scrap and Residues	2,900	pyrochemical salts, filters, graphites/carbides, impure oxide, fluorides, wet combustibles, dissolver heels, sand, slag and crucible scraps, glass, chlorides
Solutions	98	Acidic nitrates and chlorides

Many of the chemicals and equipment needed to convert all but the most highly irradiated forms of plutonium or HEU can be purchased commercially. But the conversion of material from one form to another adds complications and time to the terrorist group's efforts to obtain nuclear weapons, which increases the risk of detection by the authorities. Unlike a country that produces its own fissile materials, a terrorist group is constrained by its ability to obtain whatever type of material it can find.

The breakup of the Soviet Union has made nuclear weapons, materials and technologies more accessible to proliferant nations and terrorist groups, alike. In March 1996, Director of Central Intelligence John Deutch warned that the Soviet collapse has brought about "the chilling reality ... that nuclear materials and technologies are more accessible now than at any other time in history."[6] According to U.S. intelligence, the deteriorating economic situation, low pay and poor morale among Russian military personnel "could undermine the [nuclear weapons] stockpile's security, making theft of warheads or subcomponents possible."[7]

While the quantities of fissile materials that may be vulnerable to theft are measured in tonnes, the amount of such materials that a terrorist group would need to assemble a nuclear explosive device is measured in tens of kilograms. Former U.S. nuclear weapons designers Carson Mark and Theodore Taylor note that terrorists would require "something like a critical mass" of fissile material for an implosion device.[8] Bare, unreflected critical masses are given in table 3 for comparison purposes.

Table 3 -- Bare-sphere critical masses of uranium- 235, plutonium, and other fissionable materials

Material	Bare critical sphere
Uranium-235 metal*	50 kg
Plutonium-239 metal	
Weapon Grade (94 % Pu-239; alpha phase)*	10 kg
Weapon Grade (delta phase)**	17 kg
Reactor Grade (65 % Pu-239; delta phase)**	20 kg
Other Fissionable Materials	
Uranium-233***	15 kg
Neptunium-237+++	60 kg
Americium-241+++	100 kg

* Source: "Nuclear Weapons Concepts," Seminar on Nuclear non-Proliferation, sponsored by the Office of Export Controls and International Safeguards, Office of Arms Control and Non-Proliferation, U.S. Department of Energy, December 1993.
**Source: Paxton, 1975
*** Source: Mark, Taylor, et. al. p. 56.
+++ Source: "Utility and Availability of Reactor Grade Plutonium for Weapons," William Sutcliffe, Lawrence Livermore National Laboratory, Briefing Slides delivered at PRIF workshop on "The Cutoff Convention, Interests, Scope, Verification, Problems," Bonn, December 12, 1996. Sutcliffe attributes the data to an unclassified briefing by R.W. Selden.

Actual quantities of material needed to assemble a nuclear weapon depend on the type, form and density of the material involved, and on the characteristics of the weapon design, such as whether or not a reflector was employed. Around two critical masses of HEU, either metal or oxide, would be required for a gun-type device. Depending on the amount of chemical conversion and machining needed to produce finished metal components, additional amounts of material would be required to cover inevitable process losses. In some cases, the terrorist group may need to start with twice the amount of material used in the finished weapon to cover these losses.

The type of nuclear explosive device that a terrorist group might assemble depends primarily upon the type and quantity of fissile material that it can obtain. Each type of device has its advantages and disadvantages. A gun-assembly device can only be manufactured using HEU, which poses less of a radiological threat than plutonium to the terrorists assembling the device. Global stocks of HEU are larger than stocks of separated plutonium, and may be less well protected.

Implosion devices can be manufactured from either plutonium or HEU, and require less of either type of material than a gun-assembly device. But implosion devices are far more complex than gun assembly devices and are popularly regarded as more difficult to manufacture. Consequently, the predictability and reliability of an implosion device is less certain than a gun assembly device.

In addition to sufficient fissile materials, a nuclear explosive device requires the assembly of several non-nuclear components. For an implosion system, these include high explosive lenses and high-speed switches; some form of a neutron generator; an iron or depleted uranium tamper; and perhaps natural uranium reflector. Assembling these components requires specialized knowledge and the ability to operate specialized machine tools. Access to these and other necessary items is generally restricted, although most have civil applications.

Effects of a nuclear terrorist attack

The detonation of a crude nuclear device by a terrorist group would be devastating. Although the actual yield of such a device is highly variable, the OTA concluded that "a clever and competent group could design and construct a device which would produce a significant nuclear yield (ie., a yield *much* greater than the yield of an equal mass of high explosive)" (emphasis in original).[9] Even a device with a yield of 1-10 tonnes, small by military standards, could topple large buildings and devastate urban centers. A one tonne nuclear explosion, for example, would theoretically produce an overpressure of 3 pounds per square inch (psi), sufficient to knock down wooden structures at a radius of 65 meters from the center of the blast.[10]

A nuclear explosion would also create considerable fallout, potentially contaminating large areas. A one tonne surface detonation would theoretically result in fallout with gamma radiation levels in excess of 500 rad to a distance of 30-100 meters from the point of the explosion, with lesser amounts settling over a wider area.[11] Larger explosions would be expected to result in greater and more widespread contamination. Table 4 lists some of the expected effects of a nuclear weapons explosion as a function of yield.

Beyond the immediate physical damage caused by a nuclear terrorist attack, the psychological, economic and sociological impacts of such an attack would be devastating. Unlike natural disasters, a nuclear attack may occur without warning, leaving little chance for preparation. An attack in an urban area would not only kill large numbers of people, it also could render the area virtually uninhabitable for a long period of time. Survivors may have to be relocated; hospitals and shelters would quickly become filled with displaced persons, many of them injured or suffering from radiation exposure. The trauma of such an attack would leave lasting psychological and emotional scars on the survivors. The clean up task would no doubt rival even the largest efforts undertaken following comparable natural disasters, such as hurricanes, and would require long-term commitments from local, state and federal relief programs.

Table 4 -- Effects of Nuclear Explosions as a Function of Yield*

	Radius for Indicated Effect (meters)			
Yield (HE Equivalent)	**500 RAD Prompt Gamma Radiation**	**Fallout (500 RAD total dose)**	**Severe Blast Damage (10 psi)**	**Moderate Blast Damage (3 psi)**
1 ton	45	30-100	33	65
10 tons	100	100-300	71	140
100 tons	300	300-1,000	150	300
1 kiloton	680	1,000-3,000	330	650

* Source: Adapted from Mason Willrich and Theodore Taylor, *Nuclear Theft: Risks and Safeguards* (Cambridge, MA; Ballinger Publishing Company, 1974), table 2-1 p. 23. Fallout of 500 RAD assumes a one-hour exposure to fallout region.

Radiological Dispersal Devices

An alternate type of nuclear terrorism involves the use of a radiological dispersal device. A radiological weapon involves the dispersal of highly radioactive materials over a target area to make the area uninhabitable or to produce casualties. With few exceptions, governments have not deployed radiological weapons, in part because the standards set for such weapons by the military are often too difficult to sustain. To deny territory during a military campaign, for example, the Defense Department requires that a radiological weapon produce a dose rate of 1,000 rad per hour over an area of 10 square kilometers. Isotopes best suited to produce such levels of radiation typically have relatively short half-lives, and therefore must constantly be replenished.

Iraq considered a radiological weapon during its war with Iran, but found it costly and militarily ineffective. But as a terrorist weapon, the performance of the radiological weapon is less important than the disruption and panic that the dispersal of even small quantities of radioactive materials would cause. In contrast to the exotic, short-lived isotopes that countries would seek to use for military objectives, terrorists might be able to use isotopes commonly found in commercial use. Many such isotopes are sufficiently radioactive to contaminate an unprotected urban area, even when dispersed in small quantities. Such an attack would have a devastating psychological impact on those exposed to the dispersed materials, who would fear increased risks of cancer or genetic defects. A radiological dispersal would also necessitate an expensive environmental cleanup, and would likely leave large areas unusable even if the level of radiation was small. As the former Director of Central Intelligence John Deutch has pointed out, a terrorist radiological dispersal attack "could cause damage to property and the environment, and cause societal and political disruption."[12]

The manufacture of a radiological weapon is vastly less complicated than the assembly of a nuclear explosive device, and may be well within a terrorist groups capability, although the handling and dispersion of highly radioactive materials poses health and safety challenges that a terrorist group might not wish to risk for fear of incapacitation or discovery. The quantity of radioactive materials needed for a dispersal device is substantially less than the amount of plutonium needed to build an explosive device. Nor would the terrorist group be limited to plutonium or HEU for source materials; any highly radioactive substance could cause contamination and necessitate an expensive clean up if dispersed effectively.

The accidental contamination of a village in Brazil with an industrial radiation source exemplifies the potential for a terrorist group to traumatize an unsuspecting population. In September 1987 a 20 gram mass of cesium-137 chloride broke open in Goiana, Brazil, a city of about one million inhabitants. The 1,371 curie (Ci), lead-shielded source was initially found by scavengers at an abandoned cancer clinic and taken to a junkyard for sale as scrap. Workers broke open the shielding and discovered the shiny, white cesium chloride capsule inside.

The cesium capsule was broken up and pieces were taken home by workers and dispersed as curiosities to friends. Soon after, thirteen people exposed to the cesium fell ill. Thirteen people checked into hospitals, and four eventually died. By the time authorities in Rio de Janeiro realized what had happened, 249 people were affected by radiation, some receiving doses as high as 1,000 rem, with thousands more rushing to emergency rooms fearing contamination. To decontaminate the area, 6,000 tonnes of clothing, furniture, dirt and other materials, filling, 3,460 cubic meters, were packed into steel drums and removed to away to an abandoned quarry.

Isotopes that could be used in a radiological dispersal device have widespread commercial application in industry, medicine and research. These sources are virtually unprotected as compared to fissile materials and are generally more accessible to terrorists than fissile materials. Isotopes used for industrial purposes may be particularly at risk of loss or theft, given the need to transport these materials to and from sites in the field. Owners sometimes lack adequate control over their radioactive sources, which may place these sources at risk of being lost or stolen. For example, an assistant radiographer for a petrochemical company disappeared for almost two weeks with a 41.5 Ci iridium-192 source; he was later arrested for drunk driving while driving the company vehicle containing the source.[13] In another instance, the driver of a truck transporting medical isotopes was apprehended under gunfire by federal officials on charges of kidnapping.[14]

As the Goiana contamination shows, sources that are improperly disposed of can be easily mistaken for harmless materials. The motivations of individuals who acquire lost or discarded materials are suspect until the sources are discovered. For example, in early 1996, two cobalt-60 sources, each more than 1,000 curies, were stolen from an abandoned industrial facility in Texas. The sources were encased in heavy depleted uranium, and the thieves intended to sell the materials for scrap. According to Energy Department officials, who were called out by Texas authorities in response to a possible terrorist incident, the thieves were apparently unaware that the materials they had stolen were radioactive.

The collapse of the former Soviet Union has led to a lively black market in radioactive isotopes, including long-lived materials that would make effective sources for crude radiological weapons. According to International Atomic Energy Agency (IAEA) officials, a significant percentage of the confirmed nuclear trafficking incidents reported to the IAEA since 1993 involved some type of radioactive material other than uranium (of any enrichment) or plutonium. While many of these illicit transactions appear to be fraudulent, with the seller trying to convince an unwitting buyer that nuclear explosive materials are being exchanged, the unregulated trafficking of radioactive sources from the former Soviet Union provides new opportunities for terrorists to obtain the materials they need.

Effects of radiological dispersion

The effects of a radiological weapon are more difficult to predict than the effects of a nuclear explosion. Environmental conditions, such as temperature, time of day, relative humidity and wind conditions all affect the size of the affected area. The type of material and method of dispersion also affects the size of the contaminated area and the level of dispersed radioactivity.

Even low levels of contamination could have a severe impact on an urban population. The federal government and many states have adopted guidelines to protect citizens against the effects of radiation in the case of the accidental dispersal of radioactive materials. The threshold concentrations of dispersed radioactive materials set by many of these guidelines that would trigger evacuation, relocation or affect land use are often set far below levels that would cause immediate harm. As a result, these guidelines amplify the disruption and fear that even low levels of dispersed radioactive materials would cause on the affected population.

Conclusions

The proliferation of nuclear weapons or radiological dispersal devices to terrorist groups is perhaps one of the most frightening threats to U.S. security. Nuclear materials, technologies and know-how are more widely available today than ever before. Small quantities of both fissile materials and highly radioactive materials, sufficient to manufacture a radiological dispersal device, are actively traded on the black market. Although terrorist groups are not known to have actually acquired such materials, it is difficult to know for sure.

A nuclear detonation by a terrorist group would likely result in an unprecedented number of casualties. In contrast, a radiological dispersal attack would probably be less violent, but could significantly contaminate an urban center, causing economic and social disruption. Both types of attacks would have significant psychological impacts on the affected population.

Opinions on terrorism are changing. In the past, analysts have regarded nuclear terrorism as unlikely, given the international backlash against such an attack. Today, a new breed of terrorists, motivated by religious rather than political goals, seem less concerned with creating large numbers of casualties. Such groups might use nuclear weapons if given the chance.

---

[1]Office of Technology Assessment, *Nuclear Proliferation and Safeguards*, (New York, Praeger Press, 1977); p. 141.

[2]Mark, J. Carson, Theodore Taylor, et al., "Can Terrorists Build Nuclear Weapons?" in Leventhal and Alexander, *Preventing Nuclear Terrorism*, (Lexington, MA, Lexington Books, 1987), pp. 58.

[3]Ibid., p.55.

[4]David Albright, Frams Berkhout and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies*. (London, Stockholm International Peace Research Institute and Oxford University Press, 1997); p.398 table 14.2.

[5]Ibid, table 3.5, p. 45.

[6]"The Threat of Nuclear Diversion," Statement for the Record by Director of Central Intelligence John Deutch, *Global Proliferation of Weapons of Mass Destruction Part II*, hearings before the Governmental Affairs Committee, Permanent Subcommittee on Investigations, U.S. Senate, 104th Congress, 2nd Sess., S. Hrg. 104-422 part 2; p.304.

[7] "Prepared Statement of William Studeman, Acting Director, Central Intelligence Agency, *International Terrorism: Threats and Responses*, hearing before the House Committee on the Judiciary, House of Representatives, 104th Cong., 1st sess., serial no. 24, April 6, June 12 and June 13, 1995; p. 23.

[8]Mark, Taylor, et. al. p. 56.

[9]Office of Technology Assessment, p. 141

[10]Mason Willrich and Theodore Taylor, *Nuclear Theft: Risks and Safeguards,* (Cambridge, MA; Ballinger Publishing Company, 1974), table 2-1 p. 23.

[11] Actual areas of damage and contamination subject to the geometry and prevailing environmental conditions at the time and location of the explosion. Adapted from Willrich and Taylor, table 2-1 p. 23.

[12] Deutch, p.309.

[13] Letter from Lloyd Gray, Corporate Radiation Safety Director, Longview Inspection to Charles Hosey, Chief, Radioactive Materials Branch, U.S. Nuclear Regulatory Commission, April 22, 1996.

[14] Nuclear Regulatory Commission, Preliminary Notification of Event or Unusual Occurrence, PNO-IV-84-2, October 5, 1984.