2. The Threat

In January 2001, long before the September 11 attacks occurred, a distinguished bipartisan panel warned that "the most urgent unmet security threat to the United States today is the danger that weapons of mass destruction or weapons-usable material in Russia could be stolen and sold to terrorists or hostile nation states and used against American troops abroad or citizens at home."[1] What the world has learned since then only emphasizes the danger. The attacks of September 11 demonstrated beyond doubt that the threat of terrorists with global reach, bent on inflicting mass destruction, is not hypothetical but real. Since then, information gathered from al Qaeda camps in Afghanistan has highlighted the group's extensive efforts to get weapons of mass destruction, including nuclear weapons, while further examination of the state of nuclear security has made it clear that the problem of insecure nuclear weapons and materials is not limited to Russia, but spread across the globe. The danger that terrorists might acquire a stolen nuclear weapon or the materials to make one is very real – and is likely to grow unless fast and effective action is taken to reduce it.

Mother Nature has been both kind and cruel in setting the laws of physics that frame the nuclear predicament the world faces. Kind, in that the essential ingredients of nuclear weapons, highly enriched uranium (HEU) and plutonium, do not occur in significant quantities in nature, and are quite difficult to produce. Making them is well beyond the plausible capabilities of terrorist groups. Hence, if all of the existing stockpiles could be effectively guarded, nuclear weapons terrorism could be reliably prevented: no material, no bomb. (This makes nuclear weapons quite different from chemical and biological weapons, for which the essential ingredients can be found in nature.) Cruel, in that, while it is not easy to make a nuclear bomb, it is not as difficult as many believe, once the needed materials are in hand. Most states, and even some particularly well-organized terrorist groups, could do it. And cruel, in that HEU and plutonium, while radioactive, are not radioactive enough to make them difficult to steal and carry away, or to make them easy to detect when being smuggled across borders. Therefore the best defense is keeping these items from being stolen in the first place.

Since September 11, many officials have said that while there were warnings, there was no intelligence specific enough to tell the U.S. government what actions to take. Here, that is not the case – the warning signs are undeniable:

- By word and deed, Osama bin Laden and his al Qaeda terrorist network have made it clear that they are seeking nuclear weapons to use against the United States and its allies.[2] Bin Laden has called the acquisition of weapons of mass destruction (WMD) a "religious duty."[3] Intercepted al Qaeda communications reportedly have referred to inflicting a "Hiroshima" on the United States.[4] Al Qaeda operatives have made repeated attempts to buy stolen nuclear material from which to make a nuclear bomb.

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[1] Howard Baker and Lloyd Cutler, co-chairs, *A Report Card on the Department of Energy's Nonproliferation Programs with Russia* (Washington, D.C.: U.S. Department of Energy, Secretary of Energy Advisory Board, January 10, 2001; available at http://www.hr.doe.gov/seab/rusrpt.pdf as of January 13, 2003).

[2] For more on demand for stolen nuclear materials by both terrorist groups and hostile states, see Appendix B.

[3] "Interview with Bin Laden: 'World's Most Wanted Terrorist'," *ABCNews.com* (available at http://more.abcnews.go.com/sections/world/DailyNews/transcript_binladen1_990110.html as of January 31, 2003).

[4] See James Risen and Steven Engelberg, "Signs of Change in Terror Goals Went Unheeded," *New York Times*, October 14, 2001.

They have tried to recruit nuclear weapon scientists to help them. The extensive downloaded materials on nuclear weapons (and crude bomb design drawings) found in al Qaeda camps in Afghanistan make clear the group's continuing desire for a nuclear capability. [5] Detailed analysis of al Qaeda's efforts suggests that, had they not been deprived of their Afghanistan sanctuary, their quest for a nuclear weapon might have succeeded within a few years – and the danger that it could succeed elsewhere still remains.[6]

- If they got the materials, making a bomb is at least potentially within the capability of a large and well-organized terrorist group. With enough HEU, terrorists could potentially make a simple "gun-type" bomb, little more than firing two pieces of HEU into each other to form a critical mass. Making a bomb from plutonium (or from a stock of HEU too small for a gun-type bomb) would be more difficult, because it would have to be an "implosion" bomb, in which explosives are set off all around a nuclear material core, crushing it down to a smaller, denser configuration where the nuclear chain reaction will begin. Getting these explosives right was a tremendous challenge in the Manhattan Project, when such a thing had never been done before. It would still be a significant challenge – but today the relevant explosive technology is in wide use in conventional military and even commercial applications. Detailed examinations by U.S. nuclear weapons experts have concluded again and again that with enough nuclear material in hand, it is plausible that a sophisticated terrorist group could build at least a crude nuclear explosive – including, potentially, an implosion bomb, though that would be substantially more difficult for them than a gun-type bomb.[7] These conclusions were drawn before September 11 demonstrated the sophistication and careful planning and intelligence gathering of which al Qaeda is capable. Indeed, Department of Energy (DOE) internal security regulations envision the possibility of an "improvised nuclear device" – a nuclear bomb the terrorists might be able to put together while they were still inside the facility where they stole the HEU.[8]

- The amounts needed to build a bomb are small. With an efficient implosion design, a baseball-sized lump of plutonium weighing 4 kilograms (about 10 pounds), or a softball-sized lump of HEU weighing perhaps three times as much, is enough.[9] For a less-efficient gun-type design, four to five times more HEU would be needed. Unless proper security and accounting systems are in place, a worker at a nuclear facility could put

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[5] For the best available summary of al Qaeda's nuclear efforts, see David Albright, "Al Qaeda's Nuclear Program: Through the Window of Seized Documents," *Special Forum* 47 (Berkeley, Cal.: Nautilus Institute, November 6, 2002; available at http://www.nautilus.org/fora/Special-Policy-Forum/47_Albright.html as of January 27, 2003). See also David Albright, Kathryn Buehler, and Holly Higgins, "Bin Laden and the Bomb," *Bulletin of Atomic Scientists* 58, no. 1 (January/February 2002; available at http://www.thebulletin.org/issues/2002/jf02/jf02albright.html as of January 31, 2003); Mike Boetcher and Ingrid Arnesen, "Al Qaeda Documents Outline Serious Weapons Program," *CNN*, January 25, 2002 (available at http://www.isis-online.org/publications/terrorism/cnnstory.html as of January 31, 2003); Gavin Cameron, "Multi-Track Microproliferation: Lessons from Aum Shinrikyo and Al Qaeda," *Studies in Conflict and Terrorism* 22, no. 4 (1999); and Kimberly Mclound and Matthew Osborne, "WMD Terrorism and Usama bin Laden," (Monterey, Cal: Monterey Institute for International Studies, Center for Nonproliferation Studies; available at http://cns.miis.edu/pubs/ reports/binladen.htm as of January 31, 2003).

[6] Albright, "Al Qaeda's Nuclear Program," op. cit. Albright has likely examined more of the al Qaeda nuclear documents than any other analyst – certainly any other analyst outside the government.

[7] See J. Carson Mark et al., "Can Terrorists Build Nuclear Weapons?" in Paul Leventhal, and Yonah Alexander, *Preventing Nuclear Terrorism* (Lexington, Mass.: Lexington Books, 1987; available at http://www.nci.org/k-m/makeab.htm as of January 31, 2003). This remains the most authoritative unclassified treatment of the subject – in part because it represents something of a negotiated statement by experts with a range of views on the matter. See also John P. Holdren and Matthew Bunn, "Technical Background," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/overview/technical.asp as of March 12, 2003).

[8] U.S. Department of Energy (DOE), Office of Security Affairs, Office of Safeguards and Security, *Manual for Protection and Control of Safeguards and Security Interests, Chapter I, Protection and Control Planning* (Washington, D.C.: DOE, July 15, 1994; available at http://www.fas.org/irp/doddir/doe/m5632_1c-1/m5632_1c-1_c1.htm as of January 31, 2003).

enough material for a bomb in a briefcase or under an overcoat and walk out.

- By contrast, the world stockpiles of nuclear warheads, plutonium, and HEU are immense. More than a decade after the end of the Cold War, the world's arsenals still contain some 30,000 assembled nuclear weapons. Enough separated plutonium and HEU exists in the world to make nearly a *quarter million* nuclear weapons – all of it intentionally produced by human beings during the five decades of the nuclear age.[10]

- These stockpiles are not only immense, but are widely dispersed. Nuclear weapons are owned by at least eight countries, and exist on the territories of several others as well, in many hundreds of individual bunkers and weapon deployment sites. Weapons-usable nuclear materials exist in many hundreds of buildings in scores of countries around the world. For example, there are over 130 operating research reactors fueled with HEU, in more than 40 countries around the world, ranging from the United States to Ghana.[11] Most of these research reactors have only small amounts of HEU – but some, including a significant number outside the nuclear-weapon states, have enough fresh HEU for a bomb. Even more have enough HEU for a bomb if "spent" HEU that is not radioactive enough to deter suicidal terrorists from taking it and using it in a bomb is included, as it should be.[12]

- The world's stockpiles are not only immense and widely dispersed, but some of them are very poorly secured. No binding international standards for securing nuclear weapons and materials exist, and the security now in place varies from excellent to appalling.

- Security for nuclear weapons and weapons-usable nuclear materials in the former Soviet Union poses a particular challenge. The collapse of the former Soviet Union, an empire armed with tens of thousands of nuclear weapons and enough nuclear material for tens of thousands more, created a unique security crisis, for much of the Soviet system for securing warheads and materials fell apart when the Soviet Union crumbled. The Soviet nuclear security system was based on a closed society with closed borders, pampered nuclear workers, and everyone under close surveillance by the KGB – a world that no longer exists. At most facilities, when the Soviet Union collapsed, there was no detector at the door to set off an alarm if some one walked out with plutonium or HEU; few security cameras in the areas where the plutonium and HEU were

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[9] The Department of Energy has officially declassified the fact that four kilograms of plutonium is in principle sufficient to make a nuclear weapon. See DOE, *Drawing Back the Curtain of Secrecy: Restricted Data Declassification Decisions 1946 to the Present,* RDD-5 (Washington, D.C.: DOE, January 1, 1999; available at http://www.osti.gov/opennet/rdd-5.html as of January 31, 2003).

[10] The total world stockpile of HEU is estimated to be some 1,600 tons (potentially enough to fabricate 130,000 nuclear weapons), while the world stockpile of plutonium separated from spent fuel is estimated to be over 480 tons (enough to fabricate an additional 110,000 nuclear weapons). See David Albright and Mark Gorwicz, "Tracking Civil Plutonium Inventories: End of 1999," *ISIS Plutonium Watch* (October 2000; available at http://www.isis-online.org/publications/puwatch/puwatch2000.html as of January 31, 2003); the figures presented there have been updated to reflect continuing blend-down of HEU and continuing accumulation of civil separated plutonium. The weapons equivalent calculation assumes four kilograms of weapon-grade plutonium per weapon, five kilograms for reactor-grade plutonium, and three times the weapon-grade plutonium figure for HEU.

[11] In last year's report, relying on numbers from DOE's budget justifications, we referred to 345 HEU-fueled reactors (both operational and shutdown) in 58 countries. Unfortunately, these DOE figures were incorrect, including a significant number of reactors whose fuel is just below the internationally defined line of 20% enriched for HEU. In addition, a large number of the reactors listed in the IAEA's database as shut down but not yet decommissioned (and included in the DOE figure we used) have in fact been decommissioned, and the HEU removed, but have not yet communicated that information to the experts who maintain the database at the IAEA. Thus, we are now relying on figures for operational research reactors fueled with HEU; including facilities that are shut down but still have HEU on-site would probably increase the figure in the text by several dozen, but not by hundreds. Data from International Atomic Energy Agency, *Nuclear Research Reactors of the World* (Vienna, Austria: IAEA, September 2000), supplemented with personal communications with James Matos, Argonne National Laboratory, and Iain Ritchie, International Atomic Energy Agency, 2002.

AL QAEDA AND CHECHEN TERRORIST ATTEMPTS TO ACQUIRE NUCLEAR WEAPONS AND MATERIALS

In late October 2002, a force of some 40 Chechen terrorists armed with automatic weapons and explosives seized more than 700 hostages at a Moscow theater. The official Russian government newspaper reported that the terrorists had previously considered seizing a reactor at the Kurchatov Institute in Moscow, where hundreds of kilograms of highly enriched uranium (HEU) are located.[1]

- In October 2001, the commander of the force that guards Russia's nuclear weapons reported that during that year, terrorist groups had twice carried out reconnaissance at Russian nuclear warhead storage sites – whose very locations are a state secret.[2] The Russian official government newspaper later confirmed these incidents and reported two more in which terrorists were monitoring nuclear warhead transport trains, possibly in preparation for an attempt to seize one.[3]
- In 1998, senior al Qaeda deputy Mamdouh Mahmud Salim was arrested in Germany, and charged with attempting to obtain HEU in the mid-1990s. Salim is still in prison.[4]
- In 1993, senior al Qaeda deputies instructed Jamal Ahmad al-Fadl, an al Qaeda operative, to attempt to purchase HEU for a nuclear bomb in the Sudan. Al-Fadl has described this attempted purchase in detail in court testimony. It appears that al Qaeda was scammed, and that the material on offer was not actually HEU.[5]There are multiple credible but unconfirmed reports of al Qaeda attempts to purchase nuclear materials in the former Soviet Union, particularly Kazakhstan and Ukraine, in the 1990s. In 1998, Israeli intelligence reportedly learned that Osama bin Laden had paid millions to a middleman in Kazakhstan who had claimed to be able to deliver a nuclear bomb. Israel reportedly sent a Cabinet minister to Kazakhstan to encourage the government to take action to block any such transfers.[6]
- There are a large number of reports of low credibility that al Qaeda has already acquired tactical nuclear weapons from the Russian nuclear arsenal. Bin Laden himself, when asked if he had nuclear or chemical weapons, replied: "We have the weapons as a deterrent."[7]

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[1] Vladimir Bogdanov, "Propusk K Beogolovkam Nashli U Terrorista (A Pass To Warheads Found on a Terrorist)," *Rossiiskaya Gazeta*, November 1, 2002.

[2] Pavel Koryashkin, "Russian Nuclear Ammunition Depots Well Protected – Official," *ITAR-TASS*, October 25, 2001; "Russia: Terror Groups Scoped Nuke Site," *Associated Press*, October 26, 2001.

[3] Bogdanov, "A Pass To Warheads," op. cit.

[4] Benjamin Weiser, "U.S. Says Bin Laden Aide Tried to Get Nuclear Weapons," *New York Times*, September 26, 1998.

[5] For a discussion and a full transcript of al-Fadl's testimony, see Mclound and Osborne, "WMD Terrorism and Usama bin Laden," op. cit.

[6] Marie Colvin, "Holy Warrior with US in His Sights," *Times* (London), August 16, 1998.

[7] Hamid Mir, "Osama Claims He Has Nukes: If U.S. Uses N-Arms It Will Get Same Response," *Dawn* (Pakistan), November 10, 2001 (available at http://www.dawn.com/2001/11/10/top1.htm as of January 30, 2003).

stored; accounting systems that were never designed to detect theft of bomb quantities of nuclear material; and wax seals on containers holding plutonium or HEU, which could be easily faked by any worker with an authorized stamp. At many of these facilities, for much of the 1990s, scientists, workers, and guards were receiving pay of less than $100 per month – and that pay was sometimes delayed for months at a time. During the Russian financial crisis of 1998, guards at some nuclear facilities were leaving their posts to forage for food, and alarm systems were shutting down when facilities' electricity was cut off for non-payment of bills.[13] Even at nuclear weapon storage facilities, which are generally more secure, security equipment is often outdated or broken, and guards are potentially exposed to hostile fire.[14] While many of

these problems have since been addressed through the former Soviet states' own efforts and through international cooperative programs, much more remains to be done.

- Inadequate security for nuclear materials is a global problem as well. Many of the more than 130 HEU-fueled research reactors around the world have little more security on-site than a night watchman and a chain-link fence. At some facilities where the essential ingredients of nuclear weapons reside, there are literally no armed guards on duty; at some, there is no security camera in the area where the material is stored, and no detector at the door to sound an alarm if someone was carrying out nuclear material in their briefcase; a few of these facilities are so impoverished that they have dead rats floating in the spent fuel pool.[15]

- While little is known about the details of security arrangements for nuclear weapons in other countries, there appear to be substantial grounds for concern, particularly where the potential threats are very high. In Pakistan, for example, there is widespread sympathy for the Taliban and for extreme Islamic causes within the nuclear weapons establishment – as evidenced by the case of the two nuclear weapon scientists who traveled to Afghanistan and met with bin Laden, to whom – according to Pakistani intelligence sources – they then provided classified nuclear weapons information.[16] At the same time, there are large armed remnants of al Qaeda operating in Pakistan. The possibility of a large terrorist attack on a Pakistani nuclear weapons site, possibly with help from insiders, cannot be ruled out.

- As a result of such conditions in countries around the world, there have been multiple documented cases of real theft of kilogram quantities of real weapons-usable nuclear material. The International Atomic Energy Agency has a database that includes 18 incidents involving seizure of stolen HEU or plutonium that have been confirmed by the relevant states. To cite just one example, in 1998 there was a conspiracy by

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[12] Research reactors pose terrorist threats resulting from possible theft of HEU for a nuclear bomb, from possible theft of irradiated fuel of any type for use in a radiological "dirty bomb," and from possible sabotage, given the location of many of these facilities in major urban areas. For an excellent discussion, see G. Bunn, C. Braun, A. Glaser, E. Lyman, and F. Steinhausler, "Research Reactor Vulnerability to Terrorists: An Unrecognized Peril in Need of Urgent Attention," *Science and Global Security*, forthcoming. For a useful discussion of the proliferation hazards of spent HEU fuel, and the lack of requirements that such material be protected from theft even in the United States, see Edwin Lyman and Alan Kuperman, "A Re-Evaluation of Physical Protection Standards for Irradiated HEU Fuel" (paper presented at the 24th International Meeting on Reduced Enrichment for Research and Test Reactors, Bariloche, Argentina, November 5, 2002). Assessing which facilities have enough fresh HEU on-site to pose a serious proliferation risk is difficult, as information about stocks of fresh and spent HEU fuel at individual facilities is not typically made publicly available. The U.S. State Department has publicly estimated that there are 24 research facilities outside the United States and Russia that pose proliferation risks serious enough to justify urgent removal of the HEU. See Robert Schlesinger, "24 Sites Eyed for Uranium Seizure," *Boston Globe*, August 24, 2002.

[13] For an unclassified summary of the situation in Russia from 2002, well after the passing of the 1998 financial crisis, see National Intelligence Council, *Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces* (Langley, Virginia: Central Intelligence Agency, February 2002; available at http://www.cia.gov/nic/pubs/other_products/icarussiansecurity.htm as of January 31, 2003); for earlier accounts of the state of security and accounting for nuclear weapons and materials in the former Soviet Union, see Matthew Bunn, *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Washington, D.C.: Carnegie Endowment for International Peace and the Project on Managing the Atom, Harvard University, April 2000; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/FullNextWave.pdf as of January 31, 2003), and sources cited therein.

[14] Personal communications with Russian and American participants in cooperative efforts to upgrade nuclear warhead security, 2002.

[15] For a discussion of the global threat outside the former Soviet Union, see Matthew Bunn, John P. Holdren, and Anthony Wier, *Securing Nuclear Warheads and Materials: Seven Steps for Immediate Action* (Washington, D.C.: Nuclear Threat Initiative and Project on Managing the Atom, Harvard University, May 2002; available at http://www.nti.org/e_research/securing_nuclear_weapons_and_materials_May2002.pdf as of February 25, 2003).

insiders at one of Russia's largest nuclear weapons facilities to steal 18.5 kilograms of HEU – potentially enough for a nuclear bomb at a single stroke. Fortunately, Russian officials report that the conspirators were caught before the material left the facility.[17] Theft of the essential ingredients of nuclear weapons is not a hypothetical worry – it is an ongoing reality. What we do not know is how many of these thefts have not been detected – how many horses have already left the barn.

- Nuclear materials, or even nuclear weapons, could readily be smuggled across U.S. borders, or other nations' borders. If stolen or built abroad, a nuclear bomb might be delivered to the United States, intact or in pieces, by ship or aircraft or truck, or the materials could be smuggled in and the bomb constructed at the site of its intended use. The length of the border, the diversity of means of transport, and the ease of shielding the radiation from plutonium or highly enriched uranium all operate in favor of the terrorists. Today, none of the major ports that ship cargo to the United States are equipped to inspect that cargo for nuclear weapons or weapons material, and few of the points of entry into the United States have an effective ability to carry out routine searches for nuclear materials either. In an experiment in September 2002, *ABC News* shipped depleted uranium (enough for a nuclear bomb had it been HEU) to the United States in a cargo container – and although that container happened to be among the small percentage that are inspected, the uranium was not detected.[18] Building the overall system of legal infrastructure, intelligence, law

AL QAEDA AND TALIBAN ATTEMPTS TO RECRUIT NUCLEAR EXPERTISE

- Two Pakistani nuclear weapon scientists, Sultan Bashiruddin Mahmood and Chaudiri Abdul Majeed, have admitted that in August 2001, they had extensive discussions with Osama bin Laden and other al Qaeda officials concerning nuclear, chemical, and biological weapons. Both have extreme Islamic views and were involved in a charity founded to support the Taliban. Mahmood had been a leading participant in Pakistan's nuclear weapons program for decades, at one time heading Pakistan's production of weapons plutonium. Pakistani intelligence sources told the *Washington Post* that the two had provided classified information on nuclear weapons to al Qaeda.[1]
- In October 2000, an official of Russia's Security Council reported that Taliban envoys had attempted to recruit at least one Russian nuclear expert. While the recruiting target did not agree to work for the Taliban, three of his colleagues had left his institute for foreign countries and Russian officials did not know where they had gone.[2]
- In 1998, an employee at Russia's premier nuclear weapons laboratory in Sarov (formerly Arzamas-16) was arrested for attempting to sell weapons documents – on advanced conventional weapons, in this case – to the Taliban and Iraq. The regional head of the Federal Security Service (FSB) reported that there had been other similar cases at Sarov, and said that such spying was the result of the "very difficult financial position" of workers at such defense enterprises.[3]

[1] See discussion in Albright, "Al Qaeda's Nuclear Program," op. cit, and sources cited therein.

[2] *Radio Free Europe/Radio Liberty Daily Report,* Oct. 9, 2000.

[3] "Nuclear Center Worker Caught Selling Secrets," *Russian NTV*, Moscow, 16:00 Greenwich Mean Time, December 18, 1998, translated in *BBC Summary of World Broadcasts,* December 21, 1998.

[16] See, for example, Kamran Khan and Molly Moore, "2 Nuclear Experts Briefed Bin Laden, Pakistanis Say," *Washington Post*, December 12, 2001; and Kamran Khan, "Pakistan Releases Nuclear Scientists for Ramadan's End," *Washington Post*, December 16, 2001; and Peter Baker, "Pakistani Scientist Who Met Bin Laden Failed Polygraphs, Renewing Suspicions," *Washington Post,* March 3, 2002.

[17] For discussions, with references, of many of the major theft cases, including this one, see Bunn, *The Next Wave*, op. cit.

enforcement, border and customs forces, and nuclear detectors needed to find and recover stolen nuclear weapons or materials, or to interdict these as they cross national borders, is an extraordinarily difficult challenge. In short, once terrorists get or make a nuclear bomb, there is little to stop them delivering it to a U.S. city – where the destruction it could wreak, as described below, would be almost unimaginable.

These facts lead immediately to an inescapable conclusion: the United States and its partners must do everything in their power to ensure that every nuclear weapon, and every kilogram of HEU and plutonium, wherever it may be in the world, is secure and accounted for, to stringent standards. The terrorists who have sworn to destroy us have demonstrated global reach, and – with attacks such as those on the U.S. embassies in Africa in 1998 or the USS *Cole* in 2000 – an ability to identify weak points and strike at them on a global basis. The procurement agents for hostile states such as Iraq, Iran, and North Korea have demonstrated similar capabilities. Those seeking material for a nuclear bomb will go wherever it is easiest to steal, or buy it from anyone willing to sell. Thus insecure nuclear bomb material anywhere is a threat to everyone, everywhere. The world has the warning it needs to know what needs to be done. Failing to act on this clear warning would simply be irresponsible.

An Appalling Scenario

In October 2001, U.S. intelligence received a report that terrorists had acquired a 10-kiloton nuclear bomb, and were planning to smuggle it into Manhattan. After a few tense weeks, the report turned out to be false.[19] But the chilling fact is that at the time, no one could dismiss the possibility that the report might be true. Given the threat just described – the weaknesses in security for nuclear material around the world, the lack of insuperable technical barriers to making a nuclear bomb with sufficient material in hand, the desire of al Qaeda and potentially other extreme terrorist groups to inflict nuclear violence on the United States, and the virtually nonexistent ability to stop nuclear contraband coming into the United States – the scenario was all too credible.

The probability of a terrorist attack with an actual nuclear weapon cannot be reliably estimated, and is surely lower, given the difficulties of getting nuclear material and building a nuclear bomb, than the probability of virtually any other type of terrorist attack. But the devastation from such an attack would be so overwhelming that, when threat is considered to be the probability multiplied by the consequences, this must be considered one of the greatest dangers America faces.

Let us imagine that the report had been true, and that the terrorists set off their 10-kiloton nuclear bomb at Grand Central Station on an average workday. Some 550,000 people work within a half-mile (805 meter) radius of the station.[20] This figure does not include the tourists and visitors present on an average day, and hence is quite conservative. Within this radius, the blast overpressure would be over five pounds per square inch (psi), enough to destroy wood, brick, and cinderblock buildings. The heat from the blast would be enough to ignite paper and other combustibles throughout the area, and to give everyone not protected by a building second degree burns over much of their body. The possibility of a firestorm – a coalescence of the many fires that would be set by the blast into a raging storm of fire consuming everything and everyone within it, as occurred at

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[18] See Christopher Paine, "Preventing Nuclear Terrorism," testimony to the House Committee on Government Reform, Subcommittee on National Security, Veterans Affairs, and International Relations, 107th Congress, 2nd Session, September 24, 2002 (available at http://www.house.gov/reform/ns/schedule_107th_2nd_session/paine_sept_24.htm as of January 21, 2003).

[19] Massimo Calabresi and Romesh Ratnesar, "Can We Stop the Next Attack?" *Time*, March 11, 2002.

[20] See Federal Transit Administration, *Annual Report on New Starts: Proposed Allocations of Funds for Fiscal Year 2003* (Washington, D.C.: U.S. Department of Transportation, 2002), Appendix A, "Long Island Rail Road East Side Access" (available at http://www.fta.dot.gov/library/policy/ns/ns2003/pelirr.html as of January 20, 2003). This translates to a density, on an average workday, of 300,000 people per square kilometer. The authors are grateful to Steve Fetter of the University of Maryland for providing this reference.

Hiroshima, Dresden, and Tokyo in World War II – would be very real. The prompt radiation from the blast would be enough to sicken everyone in this zone, and kill most of those not protected by buildings. If the skyscrapers fell, those inside would virtually all be killed. Falling would be a near certainty for all the buildings within roughly 500 meters of the blast (where the blast wave pressure would be over 15 psi, with winds of 400 miles per hour), and a serious possibility for every building in this half-mile zone, given the combination of blast overpressure and fire. From the combination of these effects, the vast majority of the people in this zone would die, as would a substantial number of the people beyond. More than half a million people would likely be killed by the immediate effects of the explosion, from the combination of blast, heat, radiation, and building collapse.[21] This zone of almost total destruction would extend from the Hudson to the East River, from just north of Battery Park up almost to Grand Street.

In addition to those killed, there would be hundreds of thousands of people injured – burned, battered, irradiated, hit by flying glass and debris. Every bed in every hospital for a hundred miles would not be remotely sufficient to handle the casualties.[22] Tens of thousands, or perhaps hundreds of thousands, of injured people would likely go without treatment for days, and many would die.

Such a blast would also draw thousands of tons of rock and debris into the fireball, to be distributed as a cloud of lethal radioactive fallout extending miles downwind from the blast. If the blast occurred in late afternoon, with the wind headed north, all of Manhattan that remained would have to be evacuated. Depending on factors such as wind, weather, the effectiveness of the evacuation, and the degree to which people were able to take shelter from the radioactive fallout, tens to hundreds of thousands more people downwind from the blast might suffer a lingering death from radiation exposure.

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[21] A common approach for roughly approximating likely deaths from medium-sized nuclear blasts is to assume that the number of people who would die outside the ring where the blast overpressure would be five pounds per square inch (psi) will be about the same as the number of people who would survive within this ring – so that the total number killed would be roughly the total number within the five psi ring. The five-psi ring in this case would extend 1,000 meters in every direction from the blast. This model is not entirely appropriate in this case, as beyond 1,000 meters in several directions the destructive energy would be expended over the rivers, where the population goes to zero. The five-psi ring encloses an area of 3.1 square kilometers, so if such a "cookie cutter" model were used, with a daytime population density of 300,000 people per square kilometer, the estimate would be that over 900,000 people would die, nearly twice our half-million estimate. The rough half-million deaths estimate is partly confirmed by two recent studies of possible nuclear attacks in Manhattan. The daytime population density in lower Manhattan is more than 10 times the residential population (residential population of 50,900 in a half-mile radius around Grand Central Station, reported in FTA, *Annual Report on New Starts: Proposed Allocations of Funds for Fiscal Year 2003*, op. cit.). Each of these recent nuclear attack studies considered only the residential population, and so an approximation to a daytime attack estimate can be reached by multiplying their fatality estimates 10-fold. An estimate in the *British Medical Journal*, based on the use of software developed by the Federal Emergency Management Agency and the Defense Threat Reduction Agency, concluded that 62,000 people (620,000 with a 10-fold higher daytime population density) would die from the immediate blast, heat, and prompt radiation effects of a 12.5 kiloton bomb; while this is slightly larger than the weapon assumed here, they assumed a detonation point at the World Trade Center, so that the bomb wasted a large fraction of its destructive power over the river. They estimated an additional 200,000 deaths from radioactive fallout (a figure that should *not* be increased for higher daytime population density, since these exposures occur over a period of days and weeks). See Ira Helfand, Lachlan Forrow, and Jaya Tiwari, "Nuclear Terrorism," *British Medical Journal* 324, February 9, 2002 (available at http://www.psr.org/bmjarticle.pdf as of January 20, 2003). Analysts at the Natural Resources Defense Council (NRDC), who have developed very detailed software for estimating nuclear weapons effects, estimated that some 66,000 people would die from all effects if a 10-kiloton bomb were detonated while still in its cargo container at a pier in Brooklyn, if it is assumed that all the people in affected areas were protected by buildings and none of the buildings collapsed. This estimate included fallout fatalities (which were hence far lower than those estimated in the previous study), but having been detonated in Brooklyn, the bomb's lethal effects covered only a modest portion of lower Manhattan, and the study considered only the residential population, not the much higher daytime population. See Thomas B. Cochran, Matthew B. McKinzie, and Christopher E. Paine, "Appendix: The ABC News Nuclear Smuggling Experiment," in Christopher E. Paine, "Preventing Nuclear Terrorism," testimony to the Subcommittee on National Security, Veterans Affairs, and International Relations, Committee on Government Reform, U.S. House of Representatives, September 24, 2002 (excerpt available at http://nrdc.org/nuclear/furanium.asp as of January 31, 2003).

"DIRTY BOMBS" VS. NUCLEAR BOMBS

Both U.S. and British intelligence have reportedly concluded that al Qaeda has succeeded in making a radiological "dirty bomb."[1] Fortunately, such a dirty bomb is a far cry from an actual nuclear explosive.

Rather than producing a nuclear blast like those that destroyed Hiroshima and Nagasaki, a "dirty bomb" is designed simply to spread radioactive material over an area. A dirty bomb would be more a weapon of mass disruption than a weapon of mass destruction, designed to sow panic and chaos. By forcing the evacuation of many blocks of a city, it could potentially cause billions of dollars in economic disruption, and billions more in cleanup costs, but it would not kill tens of thousands of people in a flash or obliterate a major section of a city as an actual nuclear bomb could.[2]

As suggested by the conclusion that al Qaeda may have already acquired such a device, a dirty bomb would be far easier for terrorists to acquire than would a nuclear bomb. Millions of radioactive sources are in use for a wide range of beneficial medical, industrial, and agricultural purposes around the world, ranging from tiny bits of material in smoke detectors, whose dispersal would probably not even be noticed, up to sources containing thousands of curies of radioactivity, whose use in a dirty bomb could require the evacuation of tens or hundreds of city blocks. All but the largest radioactive sources have traditionally had very little security. Hence, the material for at least a modest dirty bomb would not be difficult to get – and making at least a crude means of dispersing the material would be a far less difficult task than making a nuclear bomb.

In short, the probability of a dirty bomb attack is much higher than the probability of a nuclear attack, but the consequences would be much lower. A dirty bomb attack would be likely to create an annoying and expensive mess, and profound public fear – but it would not take the lives of thousands of innocent people.

To reduce the threat of a dirty bomb attack, actions should be taken to:[3]

- Find and secure lost and "orphan" radioactive sources, and develop secure means for their disposal;
- Impose strengthened controls on radiological sources and other radioactive materials around the world (including shifting where practicable to non-radioactive means – such as accelerators – for accomplishing similar objectives);
- Improve the U.S. and international ability to detect and stop radioactive materials before they are delivered;
- Educate the public on the likely health effects of a dirty bomb attack, and the actions they can take to protect themselves (including preparation of a public communication plan to provide accurate and timely information in the event of such an attack, to minimize resulting panic); and
- Develop and deploy improved capabilities to decontaminate urban areas should such an attack occur.

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[1] Josh Meyer, "Al Qaeda Feared to Have `Dirty Bombs'," *Los Angeles Times*, February 8, 2003, and Frank Gardner, "Al-Qaeda 'Was Making Dirty Bomb,'" *BBC News*, January 31, 2003.

[2] In some scenarios, a particularly potent dirty bomb might cause low radiation doses to a large enough number of people that one would expect that several hundred to several thousand cancer deaths would result over the following 20-30 years – but these would be a tiny fraction of the cancer deaths that would be expected to occur naturally among the exposed population, and it would therefore be very difficult to detect any increased cancer rate resulting from the dirty bomb. For a discussion of the potential effects of a dirty bomb attack in several specific scenarios, see Henry Kelly and Michael Levi, "Weapons of Mass Disruption," *Scientific American*, November 2002 (available at http://www.fas.org/ssp/docs/ 021000-sciam.pdf as of February 24, 2003).

[3] See Charles D. Ferguson, Tahseen Kazi, and Judith Perera, *Commercial Radioactive Sources: Surveying the Security Risks* (Monterey, Cal.: Center for Nonproliferation Studies, Monterey Institute of International Studies, January 2003; available at http://cns.miis.edu/pubs/opapers/op11/index.htm as of February 24, 2003), and Kelly and Levi, "Weapons of Mass Disruption," op. cit. See also the annotated web-based resources on dirty bombs at "Nuclear Terrorism," Project on Managing the Atom, Harvard University (available at http://ksg-notes1.harvard.edu/BCSIA/MTA.nsf/www/N-Terror as of February 24, 2003).

Beyond the unprecedented human tragedy and terror of such an event, the sheer economic cost would be staggering. The New York City Comptroller has estimated that the direct cost of the September 11 attacks to the city of New York alone was approximately $93 billion – measured only by the income those killed would have received in the remainder of their lives, the value of the property destroyed, and the first three years of the reduction in economic output resulting from the destruction in the city.[23]

The Comptroller estimated that the workers killed in those attacks had an average of 25 years remaining before retirement, and that the average salary of workers in Manhattan is $70,000 per year. Applying these figures to our estimate of lives lost in a nuclear blast at Grand Central Station results in a total lost future income of $875 billion.[24]

The cost of treating the wounded, and the lost income resulting from their injuries, is difficult to estimate, but is surely also in the hundreds of billions of dollars. The Comptroller estimated the cost to replace or repair the buildings, property, and infrastructure damaged or destroyed in the September 11 attacks at value of the buildings and infrastructure at $21.8 billion. Obviously the World Trade Center towers were uniquely valuable real estate, so one cannot simply extrapolate to the much larger area that would be destroyed in a nuclear blast. Nonetheless, it appears very likely that the value of destroyed property and infrastructure in the immediate area of the blast would be well over $100 billion.[25]

Lost economic output would be a critical factor. The Comptroller estimated that the weekly output of lower Manhattan was $2.1 billion per week, while that of the rest of New York combined was $6.3 billion per week. In the wake of a blast such as that envisioned here, a large portion of lower Manhattan would be permanently destroyed, and the whole of lower Manhattan would certainly be evacuated for some period. If we assume, conservatively, that the output of lower Manhattan would be reduced to zero for two weeks and permanently reduced by one-third, and that the remainder of the city's output was only reduced by 5% over the next several years, the lost economic output over 3.3 years after the attack (the period covered in the Comptroller's report) would be $180 billion. This is surely a conservative estimate, since the Comptroller estimated the lost output from the far smaller September 11 attacks at $52–$64 billion. To these figures must be added the immense cost of cleaning up the contamination from the radioactive fallout, which would certainly run into tens or hundreds of billions of dollars. In short, it seems certain that the direct costs of a nuclear attack such as this would be well over $1 trillion.[26]

As was the case for the September 11 attacks, the indirect costs – from loss of value in the stock market, to preparations for war that might result, to all the myriad changes in American life that would follow such a catastrophe – would inevitably be several times the direct costs, amounting to several trillion dollars. One can easily imagine the panic and horrifying economic chaos that would result if the terrorists, after setting off such a bomb, claimed to have another that would soon go off in another major U.S. city: with the cities emptying out, the U.S. economy would effectively grind to a halt, and

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[22] See, for example, Joseph A. Barbera, Anthony G. Macintyre, and Craig A. DeAtley, *Ambulances to Nowhere: America's Critical Shortfall in Medical Preparedness for Catastrophic Terrorism* (Cambridge, Mass.: Executive Session on Domestic Preparedness, Harvard University, October 2001).

[23] William C. Thompson, Jr., Comptroller, City of New York, *One Year Later: The Fiscal Impact of 9/11 on New York City,* September 4, 2002 (available at http://www.comptroller.nyc.gov/bureaus/bud/reports/impact-9-11-year-later.pdf as of January 20, 2003).

[24] Here, we follow the Comptroller's approach in not discounting these future incomes to the present, because these people's salaries would likely have increased over time at a rate comparable to a reasonable discount rate.

[25] That figure is only five times higher, for an area of destruction many times as large as that of September 11.

[26] The lives lost represent a much higher fraction of this estimated cost than was the case for the Comptroller's estimate of September 11 costs, for the simple reason that on September 11, most of the people inside the buildings that were destroyed survived, whereas in the case of nuclear bomb, very few would have time to flee, so that the number of people killed per unit of property destroyed would be much higher.

the problems of supporting millions of panicked people outside the cities would be immense.

Such a catastrophe would transform America and its way of life forever – and not for the better. The history of the world would be indelibly changed. The chance of such a disaster may not be high – but it is high enough to justify doing everything in our power to reduce it. For the safety of ourselves and our children, we cannot afford to wait.