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The Many Threats of Terror

AS NO COMMISSION report could ever do, the terrorist acts of September 11, 2001, have galvanized the United States. More than six thousand people died in New York—one of every thousand workers in the city.[1] Taking over a commercial aircraft to use it as a piloted cruise missile evidently exploited a terrible vulnerability of modern society. No commercial pilot could be induced by threats to do this, but the imagination of public officials did not encompass those willing and even wishing to die to kill hundreds or thousands of others.

This instrument of kilo-terrorism is fragile; it can be defeated by not much more than a sturdy locked cockpit. The terrorist planners knew this and went to the trouble, and risked the vulnerability, of planning at least four such hijackings within minutes of one another—too little time to spread the word effectively throughout the aviation system.

My purpose here is to discuss threats and not primarily solutions, although the two are interlinked. If hijacking a passenger aircraft will no longer work, motivated terrorists will doubtless choose something else. I have heard from at least six of my colleagues proposals, for example, to modify the aircraft flight control system so that the pilots can irrevocably switch control to the ground. Or to program the

1. As of year's end 2001, the official figure has declined to about 3,000.

aircraft to automatically land at the nearest suitable airport. Such remedies are unnecessary and distracting. It is enough to lock a strengthened cockpit door and to make all understand that it would not be opened even if hijackers kill the passengers and cabin crew. Clearly, once the aircraft radar transponder is switched to emergency or hijack mode, it should not be possible to switch it back until the aircraft has landed. There is a case to be made for improved 1990s-era crash-proof recorders that will capture video and audio from the cabin as well as the cockpit.

Both smaller and bigger terror weapons exist, and their use may be expected. But even if we have seen the end of hijacked passenger jets as cruise missiles, that is not the end of their equivalent—the use of rented or stolen cargo jets as piloted cruise missiles. Opportunities range from large fleets such as those of UPS or Federal Express to the hundreds of 707s and even 747s available for lease at airports in the United States and elsewhere. More skill but less violence would be involved in stealing such an aircraft. It might be used against buildings or against operating nuclear reactors, which are not designed to withstand the impact of a jumbo jet at high speed. It is relatively simple to have an automatic radar that shuts down a nuclear reactor if a high-speed aircraft is detected within a few seconds of collision; but even in that condition a reactor might suffer a core meltdown because of interference with the emergency core cooling system and other engineered safeguards.

Thomas Friedman in his *New York Times* column of September 25 characterizes the new type of terrorist as evil, educated, and suicidal. Of course, the terrorists don't characterize themselves as "evil" or even "suicidal." A brief anecdote. After a few years of being involved in building and testing nuclear weapons (from 1950 on, at Los Alamos), I began to work on North American air defense, and in the mid-1950s joined several panels of the President's Science Advisory Committee (PSAC)—among them the Strategic Military Panel. This panel met two days each month until the demise of PSAC in 1973.

I had already spent a month in Korea and Japan during the Korean War. I never understood why it was a source of comfort for some US strategists that the Soviet Union had not mastered in-flight aerial refueling of bombers; most people seemed to feel more secure in the knowledge that Soviet bombers armed with nuclear weapons would not have fuel to return home after a nuclear attack on the United States. I argued that I, for one, would be quite willing to participate in a one-way retaliatory nuclear strike on the Soviet Union, and I regard myself as rational—not suicidal.

Just as I struggled for years in Washington to bring cruise missiles into the US force rather than unmanned bombers (because of the relative simplicity and increased payload of the one-way mission), so have committed terrorists found a way to exchange commitment for complexity. It is a powerful tool. During the 1960s I recall discussions with experts on terrorism in the PSAC and intelligence community who judged at the time that terrorists did not really want to kill people but to gain sympathy for their cause. Hence, it was said, they wanted to show their power to explode bombs at places and times of their choice, with a propensity to warn so as to reduce the damage.

Now that almost three times as many Americans have been killed in one day as died at Pearl Harbor, and twice as many as died in the entire history of the "troubles" in Northern Ireland, and without a demand being made, that old judgment must be definitively retired. And it doesn't take years of preparation for a person to gain access to an aircraft and to detonate a few-pound bomb disguised as a book or a computer, thus killing a few hundred people and further disrupting the modern economy.

It is doubtful that the terrorists had confidence that the World Trade Center towers would collapse—which they did, not from the impact but from the softening of the steel from the intense fire fed by the aircraft fuel. In fact, the amount of fuel in the form of paper in filing cabinets on a given floor is comparable with that delivered by

the plane, but it is more difficult to ignite and easier to put out. It is entirely feasible to build into tall buildings features that would be adequate for fighting such fires and furthermore to equip buildings with means for rapidly bringing firefighters to any floor. This latter might be done on a World Trade Center–like structure by having a number of pulleys of twenty-ton capacity projecting from the roof, with a lead line down near ground level. Firefighters could snag the line and with a ground-based winch pull up a heavy cable which, in turn, could be used to carry platforms, hoses, and pumps to the floors involved. But it would be preferable to have dispersed foam nozzles in a hardened sprinkler system.

Terrorists have other means of turning the strength and assets of American society against itself. These include targeted attacks on chemical plants, but even more important, on shipments of industrial chemicals such as chlorine, which are transported in tank cars or trucks. The terrorist driver might apply for a job with the intent of fitting the tank truck with detonators and exploding it in a community; or such a truck might be ambushed and the material dispersed by a rocket-propelled grenade. While the use of nerve gas or other material would give a far higher number of casualties per ton of material, the vast amounts of dangerous chemicals that move in commerce make this a significant problem.

Some failures to protect particular vulnerable points would cause tremendous damage and inconvenience to modern society—at the major bridges and tunnels, for instance. Not only destruction but radiological contamination of tunnels could be very disturbing, even if it killed few people.

Detonating thousands of tons of ammonium nitrate loaded on a ship in a harbor would have the impact of a small nuclear explosion. Three hundred tons (0.3 kilotons) of ammonium nitrate apparently exploded in France on September 24, killing twenty-nine people and injuring more than 2,500.

Terrorist acts are possible that would be less significant in damage but highly significant in causing terror and weakening perceptions of American strength. Attacks on spectators in a sports stadium seem a particular hazard, especially in the case of events shown on TV. Such an attack could combine explosives and chemical agents; it could even be made by diving a small aircraft loaded with fuel into the stands. The attractiveness of such tactics to terrorists might be reduced by a several-second delay in TV transmission, so that there would be no broadcast, even if thousands of people were killed and several times that number injured.

Concerning nuclear and biological terrorism, the largest amount of damage would be caused either by a nuclear explosion in a city or by a biological warfare attack. It is abundantly clear that the same nineteen terrorists who hijacked the aircraft and destroyed buildings and thousands of lives in what seemed an instant would not have hesitated to detonate a nuclear explosive if they had acquired one. A first-generation (10-kiloton) nuclear explosive would kill at least 100,000 people in a typical urban environment. The theft and detonation of one of the 500-kiloton strategic weapons would probably kill a million people in an instant and flatten 100 square kilometers of buildings. Fifty-five years of development of technology and spread of knowledge make it relatively simple to build a 20-kiloton nuclear weapon if sufficient highly enriched uranium were available, of which there is a thousand-ton surplus in Russia. Much excess plutonium that was developed for making weapons is available as well, although it is somewhat more difficult to use. We must give the security of such materials the attention it deserves.

As for biological warfare, many tons of anthrax may still exist in Russia. Infection can be prevented by prior vaccination; but it is extremely durable as a spore and kills 30 percent or more of the people who have been infected, if there is no adequate prolonged treatment with antibiotics. Even more potentially dangerous are biological warfare

agents that are contagious, by contrast with those, such as anthrax, that are simply infectious. High among the contagious agents is smallpox. Although legitimate stocks of smallpox have existed only in two places—in the US and in Russia—it is not precluded that other stocks may have survived the smallpox eradication campaign.

Even though some of these threats are ill-defined and it may be hard to prevent their being carried out, some nonspecific solutions are eminently practical. None will give 100 percent protection, but 99 percent protection could be the difference between a million deaths and ten thousand deaths. In a war, that is a great difference. To the 99 percent, it is the difference between life and death. And some of the solutions can be implemented by individual families, corporations, or localities.

The first and most practical defense against biological warfare attack is to maintain "positive" pressure of filtered air within buildings. It takes a very small capital expenditure and a very small expenditure in power to provide a positive pressure so that normal winds will not infiltrate a building, and the anthrax spores or other microbes will be kept out. To do this the air intake to a normal building—whether an office building, an apartment building, or a private house—should be provided with a small blower that delivers air through a High Efficiency Particulate Air filter (HEPA) at a rate that exceeds the leakage of air in or out of the building. Such "makeup" air will then produce excess pressure in the building so that air flows out through any cracks or apertures, blocking any inflow of unfiltered air. If no form of air intake exists, a window or a portion of a window can be removed to make one. It is interesting to note that any normal building, no matter how tightly closed, will have the same exposure to a biological warfare agent as it would if the windows were wide open—it takes longer for the agent to enter, but it stays there a much longer time. Positive-pressure filtered air largely eliminates this problem.

Other approaches that should be implemented contribute not only to the reduction of threats but to lowering the cost of reducing

the threats. Such measures would include sealing at the point of departure trucks, ships, or cargo containers, so that auto parts entering Detroit from Canada, if they were inspected at the factory, would not have to be inspected individually. Electronic manifests and bills of lading could be required in advance, and shipments that comply with these efficiency- and security-based rules would incur less delay and less cost than those shipped the old way.

Similarly, people willing to carry biometric-based identification (a thumbprint plus photo, for instance) could be given "EZ-Pass" treatment. These people would have had a suitable interview and would have provided data to be kept in an electronically accessible file. Those without the EZ-Pass would be delayed longer in driving their trucks into a city or in boarding aircraft.

Thus far, I have discussed a few of the threats that might be expected from terrorists; some of these are greatly increased by the willingness to die for the cause. On the assumption that there are dozens or even hundreds of similar agents already in place, it is unlikely that their motivation can be annulled; hence the critical importance of ensuring that such attempts in the near term will not succeed. Here are some near-term measures:

- To prevent a hijacked passenger aircraft being used as a manned cruise missile, strengthen and lock the cockpit door. Assign air marshals to many flights. Ensure that the radar transponder, once switched to emergency mode by a pilot who is being attacked, cannot be switched back.
- To counter the use of rented or stolen large aircraft, ensure that each aircraft landing gear is blocked by heavy concrete barriers or other means that would sound an alarm and disable the gear if moved without authorization.
- Foreign aircraft entering US air space must be subject to the same standards as US aircraft.
- To counter biological warfare, individuals, firms, government, and other organizations should consider installing a unit to provide

positive-pressure HEPA-filtered makeup air to their buildings. For most establishments, these units should not be used to guard against biological warfare agents liberated within the building but against those from outside. Because of the far smaller hazard from chemical warfare or industrial chemical attack, HEPA filters should filter only particles from the air. These are typically not individual virus particles, but bacteria or viruses that are attached to some inert material in the range of diameters from about one to five microns.

• To facilitate travel and access to sensitive areas, a first-generation biometric identification pass should be made available. Those who have had an adequate interview and have information on file could rapidly be provided with a picture ID augmented by a thumbprint. This would be analogous to the EZ-Pass now widely used at tolls.

• To facilitate the movement of cargo, more use should be made of sealing at the departure point containers, ships, aircraft, or trucks, so that inspection would occur there with adequate time and space, rather than on the fly at bridges or other choke points. Electronic manifests could be sent ahead and would also accompany the vehicle. Lower customs charges for inspection and accelerated processing would be given to those vehicles and containers packed so as to facilitate high-energy X-ray or neutron scanning. Such vehicles would be processed more rapidly and at a lower cost than those without such helpful features.

There are many more potential terrorists than there are terrorists. In moving against terrorist organizations and states and others supporting terrorism, we need hardly fear that those who are implacable enemies of society will become more deeply implacable. But it would be easy enough to swell the ranks of terrorists with those who up to now have been largely passive. Accordingly, if the United States were, for example, to undertake military action against the Taliban, it should be accompanied by an effective and sincerely concerned program to relieve the plight of the people of Afghanistan.

In taking action against terrorists and their co-conspirators, it would be useful to recall that in the United States conspiracy to commit a crime is in itself an offense. While aiding and abetting the actual crime has the same penalties as the crime itself, conspiracy has a lesser penalty. But one can be imprisoned for conspiracy even if the crime is never committed. Such doctrines could be drawn on to lay the basis for the legitimacy of US action in protecting against and responding to terrorism.

I have neither tried nor succeeded in providing here a complete evaluation of terrorist threats to modern society—let alone a reasoned evaluation of the effectiveness and cost of countermeasures. For instance, cyberterrorism is a serious potential problem, and individual hackers have already caused billions of dollars' worth of damage. It is clear, however, that acting as individuals and as a society as a whole, we will need to make considerable investments in reducing our vulnerability. If we do this wisely and make use of market incentives wherever possible, the cost in efficiency and diversion of resources should be tolerable.

—October 2, 2001

EPILOGUE

Since my article was published in early October, several people have died from inhalation anthrax, and others have become ill with the cutaneous form of the disease.

Some of the illness arises from anthrax spores that emerge from envelopes being handled in post offices—especially by automated equipment. An envelope normally has some air in it. If one bends or compresses the envelope, the air comes out—either through apertures or perhaps through the paper; and anthrax spores are small enough to penetrate a standard envelope. An envelope containing a couple of

grams of anthrax spores can contaminate an entire post office. Many spores are deposited on other envelopes and taken to their destinations, transferring their spores to other envelopes on the way.

The health hazard involved is not easy to estimate. It is a misconception that there is a threshold dose of anthrax consisting of thousands of spores. I believe it is more accurate to say that a single inhaled anthrax spore has about one chance in 8,000 of initiating the infection. The limited number of experiments done decades ago with monkeys to determine the infectiousness of anthrax spores did not distinguish between the two cases. It is much more likely, in principle, that the spores act individually, so that as long as one or more spores are present, there is no "threshold" below which one is safe from infection. In addition, some people will be more susceptible to infection than others.

If there were a threshold of 8,000 spores, then simply diluting the contamination would reduce the overall hazard. An envelope that had picked up 10,000 spores from a neighboring envelope might cause infection; but on the assumption of a threshold of 8,000 spores, and if the envelope transferred half of its spores to several others, no one would become ill. By contrast, if the single-spore hypothesis were valid, the number of people infected would only increase with greater dilution.

Thus if a million spores were delivered to one person, that person would very likely contract inhalation anthrax. If the million spores were divided among 100 people (whether a single-spore or an 8,000-spore dose was valid) there would be about 100 cases. But if the million spores were delivered to ten million people, so that each person received no more than one spore, there would be still, according to the single-spore hypothesis, about 120 cases of anthrax.

This may be the explanation for the death of a sixty-one-year-old hospital worker in New York, who had no occupational contact with anthrax, and little contact with the post office. And the same might be said for a ninety-four-year-old woman in Connecticut who died from inhalation anthrax in November.

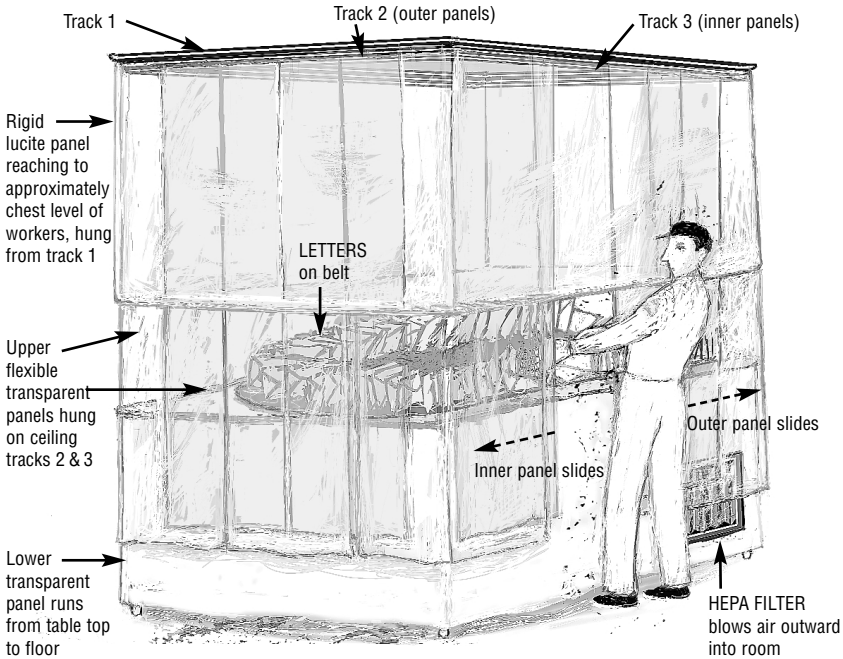
The source of these contaminated letters is of great interest. I believe that if al-Qaeda were responsible for the letters, there would be not three or four but perhaps 10,000 mailed within a few days of one another. That this was not the case argues strongly against al-Qaeda as a source. A small number of letters has disrupted mail service and caused widespread fear, but these presumed goals of a terrorist organization could have been accomplished much more effectively with 10,000 letters than with a few. And al-Qaeda's other proclaimed goal of killing would also have been achieved. Instead, we now have been put on guard by a brief encounter with anthrax.

What can be done to minimize infection from spores still in existence from these few letters, and in the future? Transparent, flexible plastic curtains could be hung over mail-handling machines, so that the machines are accessible as needed from the sides at waist level for maintenance and the transfer of mail. The interior of the enclosure, in which the machines are located, should have a slightly lower pressure than the rest of the room. The pressure would be maintained by a blower that continuously draws air from the semi-enclosed region between the hanging plastic and the barriers that might extend to the floor, and returns the air to the room through a High Efficiency Particulate Air filter (HEPA). (See illustration on page 248.)

This is analogous to the fume hoods in chemistry labs, with which we have much experience, except that for the fume hoods a blower expels the noxious fumes that might be generated within the hood directly to the outside. In the case of anthrax spores or other biological warfare agents, HEPA filters, which typically collect 99.97 percent of particles that are 0.3 microns in size or larger, would reduce the likelihood of infection by a very large factor—probably 1,000 or more.

As I wrote in my original article, both homes and office buildings can benefit from the installations of small blowers that deliver air through a HEPA filter at a rate that exceeds the leakage of air in and out of a building, and thus prevents biological warfare agents from

leaking in from outside. Maintaining such pressure is a simple matter in a home or in an office suite with its own heating, ventilation, and air conditioning. Where it is not implemented, some benefit can still be obtained from devices that circulate HEPA-filtered air and will thus reduce the concentration of biological warfare agents in a room. The effectiveness of such circulators is limited by the amounts of air



Postal workers may be substantially protected from contamination caused by the squeezing and jostling of letters containing anthrax in postal machinery. The sketch shows a machine largely enclosed by curtain panels which can be slid back and forth along tracks to give access to the mail. A blower within the enclosure exhausts air into the workroom through a HEPA (High Efficiency Particulate Air) filter and ensures that air moving through any gaps or apertures in the curtains will flow into the enclosure and that bacteria such as anthrax will be removed from the air as it is being returned to the room. If tests show that spores are discharged at certain locations in the machinery that processes mail, only those particular places need to be partially enclosed and equipped with directed, filtered airflow. (Illustration by Judy Glasser.)

infiltrating the building; the result might be to reduce the concentration of the agent only by a factor of ten rather than the hundredfold or thousandfold reduction that can be achieved when positive pressure is employed to prevent infiltration of unfiltered air.

Of course, anthrax is not the only biological warfare agent that should cause concern. In a 1970 report of the World Health Organization, "Health Aspects of Chemical and Biological Weapons," we find an estimate that the release of fifty kilograms of anthrax along a two-kilometer line upwind of a population center of 500,000 would kill 95,000 people and incapacitate 125,000; with the release of fifty kilograms of Q fever germs, only 150 would die, while 125,000 would be incapacitated.

As for smallpox, I believe that every practical measure must be taken to ensure that we have enough vaccine for the entire country (and ultimately the world). For this, not only is new production desirable but also other means for increasing the current US stock of some 15 million doses. Efforts are under way, for example, to demonstrate the effectiveness of vaccination with one fifth or one tenth of the usual concentration of vaccine virus. Furthermore, during the smallpox eradication campaign, extensive experience demonstrated that less vaccine is required with the bifurcated needle than with a simple needle. The bifurcated needle holds a drop of vaccine between two tines, and thus one gets about four times as many doses from a vial of vaccine as one does by using a single needle to make the superficial skin punctures called scarification. The bifurcated needles cost four dollars per thousand, and should be produced in quantity so that enough are available. They can be sterilized and reused but, at this price, new production would be desirable. (By the end of November 2001, the US government had contracted for 155 million normal doses of smallpox vaccine and bifurcated needles were being produced in large quantities.)

Other lethal biological warfare materials are not germs at all, but toxins produced from bacteria, such as botulinum toxin. In the US there are several hundred cases each year of illness from botulinus

bacteria growing in food and secreting the toxin. The lethal dose orally is about seventy micrograms, whereas by inhalation it is on the order of one microgram.

The United States had an enormous offensive biological weapons program before 1969. It explored and produced materials to be used in offensive war both against humans and crops. In particular, the United States incorporated anthrax and several other biological warfare agents in weapons. Executive orders in 1969 and 1970, under President Richard M. Nixon, banned offensive biological warfare research and were soon followed by the 1972 Biological Weapons Convention.

Unfortunately, the Soviet Union and Iraq (and several other nations) did not cease their biological warfare activities once they signed the Biological Weapons Convention. In particular, after the 1991 war in the Persian Gulf, the UN inspection team in Iraq discovered, and Iraq admitted, that Iraq had adapted botulinum toxin, anthrax, and aflatoxin for military use. As noted, toxins are bacterial products—produced by living material, but not in themselves alive.

According to the UN, Iraq had produced nineteen tons of concentrated botulinum toxin and loaded about ten tons of it into missiles and bombs. Thirteen 600-kilometer-range missiles were loaded with botulinum toxin; ten with aflatoxin; and two with anthrax spores.[2]

Although a single anthrax spore weighs about one trillionth of a gram, the 8,000 or so spores needed to provide death by inhalation with high reliability weigh about 0.01 microgram—considerably more effective than botulinum toxin. And botulinum toxin degrades rapidly in air. Despite its small size, it is likely to be readily filtered by HEPA filters or by a mask appropriate to protect against other biological warfare agents, since it is difficult to disseminate in particles below 0.2 microns in size.

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2. S. S. Arnon et al., for the Working Group on Civilian Biodefense, "Botulinum Toxin as a Biological Weapon," *JAMA*, Vol. 285, No. 8 (February 28, 2001).

Such agents, whether in the form of bacteria or toxins, are a credible threat. We should provide positive-pressure filtration to protect against them. Meanwhile, we should make it more difficult to put biological warfare agents into the air intakes of buildings, which in many cases are accessible from ground level. The nations of the world should pursue the initiatives calling for control of biological materials advanced by Under Secretary of State John R. Bolton in Geneva, on November 19, 2001. Among these initiatives is one relating to Article IV of the Biological Weapons Convention, according to which:

> "National Implementation": to go from the suggestion to the mandatory commitment that each nation criminalize and set penalties for individual behavior in violation of that nation's adherence to the BWC.

The United States, in turn, should support the use of challenge inspections under the Biological Weapons Convention. It should refine, not kill, the protocol which has long been under negotiation.

NUCLEAR MEGATERRORISM

Osama bin Laden has declared that acquiring nuclear weapons is a "religious duty." And the Justice Department indictment for the bombing of the US embassies in Kenya and Tanzania in 1998 includes the ominous statement, "At various times from at least as early as 1993, Osama Bin Laden and others, known and unknown, made efforts to obtain the components of nuclear weapons."

To make a nuclear weapon requires highly enriched uranium, or weapon-grade plutonium, or plutonium metal obtained from commercial reprocessing of fuel from power reactors. In Russia there are more than 1,000 tons of highly enriched uranium; in fact, the

United States has already acquired more than 130 tons of such uranium from Russia and diluted it—in the process called "blending down"—in order to make power-reactor fuel. The US also has a contractual agreement by which Russia will deliver to the US another 370 tons of enriched uranium by 2014—enough to make about 6,000 Hiroshima-type bombs. The US has agreed to pay $12 billion for the uranium, primarily to compensate Russia for its costs of enrichment in originally increasing the U-235 content from 0.7 percent in natural uranium to 90 percent or thereabouts for weapon uranium. (In fact the US will pay only for the enrichment costs required to achieve a U-235 content of 4.4 percent.)

In contrast, blending down is cheap. It would only take some tens of millions of dollars for Russia to blend down the material from the range in which it is usable in weapons to the point where it would have a U-235 content of 19.9 percent. The result would be low-enrichment uranium, which is not usable in bombs. Such preliminary blending down would ensure that any such material stolen or diverted could not be directly used in nuclear explosives. It is urgent that this dilution of Russia's weapon-grade uranium soon take place; and there is no reason why Russia would not be willing to perform this work if the Russian government were given financial incentives.

In addition, Russia probably has enough excess weapon-grade plutonium to make 10,000 nuclear weapons of the type that destroyed Nagasaki. And enough plutonium has been separated from the spent fuel from French, Japanese, and German power reactors to make more than 10,000 plutonium weapons.

It is also urgent for us to understand that making a nuclear weapon from so-called civil plutonium—which has been produced in the course of making electrical power, rather than in a plutonium production reactor—is not much more difficult in degree and very similar in nature to making a weapon with weapon-grade plutonium.

In January 2001, the Bush administration was advised by the report

of a bipartisan task force, co-chaired by former Senate Majority Leader Howard Baker and former White House Counsel Lloyd Cutler, that

> The most urgent un-met national security threat to the United States today is the danger that weapons of mass destruction or weapons-usable material in Russia could be stolen, sold to terrorists or hostile nation states, and used against American troops abroad or citizens at home.

The United States has been spending some $700 million a year on Cooperative Threat Reduction; but the task force advised increasing that expenditure to between $3 and $4 billion per year.

Unfortunately, rather than meet the needs for improved security, and instead of following up on the campaign commitment by President Bush to solve this urgent problem, the Bush administration cut its budget request for such reduction by about $100 million. Appearing November 18, 2001, on NBC's *Meet the Press*, National Security Advisor Condoleezza Rice denied that the funding had been cut. But she was mistaken.[3] The administration proposed to reduce the scale not only of efforts to secure nuclear materials but also of efforts to provide security for nuclear weapons in Russia. Fortunately, the final appropriations bill passed at year-end 2001 adds $120 million and contains virtually all the funds proponents had sought for improving security of Russian nuclear materials. Furthermore, Secretary of Energy Spencer Abraham appears now to appreciate the importance of this program, and President Bush himself seems engaged.

A terror nuclear weapon need not be a weapon designed to fit on a ballistic missile or be carried by an aircraft and dropped toward its

3. See the analysis by the Russian-American Nuclear Security Advisory Council (RANSAC) at http://www.ransac.org.

target. The weapon can be stored in an airplane, the hold of a ship, or in a shipping container or truck. Since we do not know with any confidence that material for making nuclear weapons, or even entire weapons, has not been diverted to al-Qaeda, heightened vigilance is necessary in order to prevent what could be the loss of an entire city, in comparison with the three thousand lives tragically lost in New York on September 11.

RADIOACTIVE CONTAMINATION AS A TERROR WEAPON

A separate danger could arise not from the direct effects of a nuclear explosion but from the spread of radioactive contamination, for example by attaching radioactive materials to an ordinary explosive and thus producing a "dirty bomb." The US and other countries have experience with radioactive contamination (which is described in my recent book[4]). In Brazil in 1987, a source of radioactive cesium for radiotherapy was dismantled by junk dealers. The townspeople were attracted by the glowing cesium and used it to paint luminous patterns on their skin. Heavy internal exposures resulted when people's hands were contaminated with cesium and then used for eating. Fifty-four persons were hospitalized and four died. Some four thousand tons of soil had to be removed in the cleanup.

In 1966, US aircraft collided above the Mediterranean coast of Spain. Two nuclear weapons struck the ground at high speed and their explosives detonated, but without a nuclear explosion. According to a 1993 UN report, 2.26 square kilometers of uncultivated farmland and urban land were contaminated. There were no casualties.

4. Richard L. Garwin and Georges Charpak, *Megawatts and Megatons: A Turning Point in the Nuclear Age?* (Knopf, 2001). See Chapter 12, "Current Nuclear Threats to Security" including nuclear explosives, nuclear contamination, and BW threats.

In fact, according to the most conservative estimates by the International Committee for Radiation Protection, there is a 4 percent chance of a single lethal cancer among people living on the contaminated land exposed during the accident.

In my book I describe the estimated consequences of a hypothetical explosion of a kilogram of plutonium in Munich, Germany. The average population density of Munich is about 4,300 people per square kilometer. The study estimated that twelve cancers would occur per milligram of inhaled plutonium. Under the pessimistic assumption that very still air would cause the radioactive cloud to hover over the city for twelve hours, about 120 deaths from cancer would eventually be anticipated. (This would be in addition to the 400,000 people in the city who would likely die of cancer from natural causes.)

The 103 US nuclear power reactors are refueled every year or eighteen months, and the "spent fuel elements," each about fifteen feet long, are stored vertically for years in a deep pool adjacent to the reactor building. Conventional explosives detonated in the pool might be thought to rupture the wall. Loss of the water would prevent proper cooling of the fuel; that most recently removed from the reactor might melt and release radioactive materials created during the four years the fuel had remained in the reactor. Such risks would be countered by preventing the placement of explosives in the pool, and by provision for expedient cooling (water sprayed by a fire-engine pump) to make up for the thirty gallons of water per minute evaporated by the hot nuclear fuel.

Although there are vast amounts of radioactive material available in pools of spent fuel near reactors, transporting such radioactive material and dispersing it by means of an explosion would be difficult; and even if such a venture succeeded it would not be very hazardous. Radioactive materials are very readily detected, and local authorities should be equipped with radiation detection devices. If such an incident took place, the area should be quarantined and

decontaminated by being washed down. Residual contamination might prevent people from living or lingering in the area. In 1983 the Sandia National Laboratory in Livermore, California, published the results of a hypothetical explosive attack on a shipping cask containing spent nuclear fuel. The US Nuclear Regulatory Commission then indicated that for the most densely populated area studied (up to 200,000 persons per square mile) at evening rush hour on a business day, there would be no immediate fatalities and fewer than three fatalities from latent cancer. This would result from a hole that was some six inches in diameter; but the radioactive fuel released as aerosol—fine particles wafted in the air—would be only three grams. As with the hypothetical example for Munich, more harmful consequences could be achieved by using conventional explosives in a sports stadium.

We can hope that the recent attacks will create the sense of urgency that has been lacking both in public policy toward weapons of terror and in public awareness of them. They have too long been dismissed as unreal, with the result that entirely practical means of prevention have been neglected.

—December 22, 2001