# REDUCING THE THREAT OF NUCLEAR THEFT AND SABOTAGE

M. Bunn,[*] G. Bunn[**]

ABSTRACT
The appalling events of September 11, 2001 require a major international intiative to strengthen security for such materials and facilities worldwide, and to put stringent security standards in place. This paper recommends a range of specific steps to upgrade security at individual facilities and strengthen national and international standards, with the goal of building a world in which all weapons-usable nuclear material is secure and accounted for, and all nuclear facilities secured from sabotage, with sufficient transparency that the international community can have confidence that this is the case. These steps will cost money, and accomplishing them will require sustained political leadership and reconsideration of a range of past policies and approaches. But the costs and risks of failing to act are far higher than the costs of acting now.

## *Introduction*

*"The tragic terrorist attacks on the United States were a wake up call to us all. We can not be complacent. We have to and will increase our efforts on all fronts - from combating illicit trafficking to ensuring the protection of nuclear materials - from nuclear installation design to withstand attacks to improving how we respond to nuclear emergencies."*

-- IAEA Director General Mohamed ElBaradei, September 21, 2001

The appalling events of September 11, 2001 require a far-reaching new effort to strengthen security for such materials and facilities worldwide, and to put stringent security standards in place. This is a global problem, requiring a global solution – but the best global solution may be a mosaic including national, bilateral, and multilateral pieces.

The September attacks make clear that the threat of large, well-organized global terrorist groups bent on causing mass destruction is not hypothetical but real. The attackers achieved horrifying destruction with box-cutters. But there can be little doubt that if the attackers had had access to weapons of mass destruction, they would have used them, with even more horrifying results. Indeed, Osama bin Laden has called the acquisition of weapons of mass destruction a "religious duty," and the subsequent anthrax attacks – clearly designed to spread fear and disrupt the U.S. media and government – may ultimately be linked to the September 11 attackers. There is evidence that bin Laden's Al Qaida organization has been seeking nuclear, chemical, and biological weapons, including seeking to purchase stolen nuclear material from the former Soviet Union for use in nuclear explosives.[1]

Ensuring that the technologies and materials of weapons of mass destruction – especially weapons-usable nuclear materials, whose acquisition is the most difficult part of making a nuclear bomb – do not fall into the hands of terrorist groups or hostile states must therefore be a central element of the coming global effort to prevent catastrophic terrorism. At the same time, nuclear facilities and materials – along with a wide range of other especially hazardous facilities and materials – must be protected from mass-consequence sabotage. Securing these

[*] Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University. 79 JFK St, Cambridge MA 02138
[**] Center for International Security and Cooperation, Institute for International Studies, Stanford University. Encina Hall, 2nd floor, Stanford, CA 94305-6165.

materials and facilities must be a top priority on the international agenda – something that must be pursued at every opportunity, at every level of authority, until the job is done.

At the same time, the threats against which we must defend have to be fundamentally reconsidered. On September 11, the threat revealed itself to be bigger, smarter, better organized, and more deadly than the threats most of the world's security systems were designed to defend against. We must ensure that our defensive response is every bit as intelligent and capable as the attackers of September 11. And we may have to rethink some of the approaches to nuclear energy that the world has been pursuing or contemplating.

Fragile modern industrial societies present a wide range of targets for attacks that could cause mass destruction or mass disruption, many of which would be far easier to attack than nuclear weapons, materials, or facilities. The attacks of September 11 make clear that terrorists need not rely on weapons of mass destruction to cause mass destruction. Nevertheless, given the horrifying consequences if a terrorist group did manage to acquire a nuclear explosive or destroy a nuclear power plant – or if nuclear weapons or fissile material to make them were to fall into the hands of a hostile state – it is appropriate to focus on protection of nuclear assets, and every reasonable effort must be made to ensure that these materials and facilities are effectively secured.[2] In the past, many scenarios with enormously high consequences were dismissed as too unlikely to contribute much to overall risk – but after September 11, many of these probability estimates will have to be revised.

*International Arms Control: Now More Than Ever*

This paper focuses on steps to strengthen security for nuclear material and facilities. But the attacks of September 11 also clearly send the message that a broad range of other efforts to reduce the global threats posed by nuclear, chemical, and biological weapons, from nuclear arms reductions to strengthened export controls, must be redoubled. Realistically, to be truly effective, a regime to keep weapons of mass destruction out of the hands of terrorists must be built on a solid structure of arms control and nonproliferation measures binding states to norms and rules of behavior, and to cooperative approaches to security problems. In addition, arms control and nonproliferation agreements bind bureaucracies into implementing good practices, add strength to the arguments of domestic advocates of improved controls, and give governments more authority in regulating facility operators and private enterprises. In the case of nuclear materials, the necessary regime would include a strengthened and adequately funded IAEA safeguards system, a verified cutoff in the production of fissile material for weapons, international verification of the removal of large quantities of fissile material from military stockpiles, and other measures.[3]

Moreover, there is the issue of building political support among the non-nuclear-weapon states on whom most of the burdens and inconveniences of the nonproliferation regime fall. If the United States is not prepared to re-engage on multilateral arms control, including supporting measures that impose some constraints and inconveniences on its own forces and facilities, it is unlikely to be possible to build the needed support for an effective international regime to protect nuclear material and facilities from terrorists. In short, if we are to achieve the security we need, September 11 must bring an end to the period of U.S. unilateralism. As President Bush's father remarked on September 13, the terrorist attacks should "erase the concept that America can somehow go it alone in the fight against terrorism, or in anything else for that matter."[4]

*The Threat of Nuclear Theft*

Limited access to fissile materials—the essential ingredients of nuclear weapons—is the principal technical barrier to nuclear proliferation in the world today. Unfortunately, making at least crude nuclear explosives from such material, while difficult, is not as difficult as is

often assumed: the possibility that a terrorist group as well-organized as the September 11 attackers could make at least a crude nuclear explosive if they acquired enough fissile material cannot be ruled out. As the U.S. Department of Energy has officially warned:

> "Several kilograms of plutonium, or several times that amount of HEU, is enough to make a bomb. With access to sufficient quantities of these materials, most nations and even some sub-national groups would be technically capable of producing a nuclear weapon…"[5]

Acquisition of such material could shorten a proliferator's bomb program from years to months or even weeks (if substantial prior preparations had been made). The international community could be faced with a new threat with virtually no warning—and virtually no time to dissuade the proliferator from building a bomb. Reactor-grade plutonium poses nearly as great a proliferation threat as weapons-grade plutonium, as crude nuclear explosives can be made from reactor-grade material with no greater technology or sophistication than would be required for making explosives from weapon-grade material, and sophisticated states can also make reliable, high-yield, light-weight nuclear weapons from reactor-grade material.[6] Unirradiated mixed materials such as uranium-plutonium mixed oxide (MOX) fuel pose only a modestly smaller threat, as any group capable of making a nuclear weapon from plutonium metal would likely be capable of accomplishing the less difficult task of separating plutonium from fresh MOX and reducing it to metal.[7]

Those seeking to acquire nuclear material will go wherever it is easiest to steal, and buy it from anyone willing to sell – and the terrorists of September 11 have demonstrated global reach. Hence, vulnerable weapons-usable nuclear material anywhere is a threat to everyone everywhere. While security for nuclear material has traditionally been seen as a solely national responsibility, the international community has an overwhelming interest in seeing that all such material is secure and accounted for.

Global stockpiles of such material are large and widespread. A decade after the end of the Cold War, there are still some 30,000 nuclear weapons in the world (more than 95% of them in the U.S. and Russian arsenals). The world's stockpiles of separated plutonium and highly enriched uranium (HEU), the essential ingredients of nuclear weapons, are estimated to include some 450 tons of military and civilian separated plutonium, and over 1700 tons of HEU.[8] These stockpiles, both military and civilian, are overwhelmingly concentrated in the five nuclear weapon states acknowledged by the Nonproliferation Treaty (NPT), but enough plutonium for many nuclear weapons also exists in India, Israel, Belgium, Germany, Japan, and Switzerland.[9] In addition, as of estimates made in 2000, a total of more than 2,772 kilograms of civilian HEU existed in research reactors in 43 countries, sometimes in quantities large enough to make a bomb.[10]

Most of these weapons and materials are reasonably well secured and accounted for. But this is by no means universally the case. Levels of security and accounting for both the military and civilian material vary widely, with no binding international standards in place. Some weapons-usable material is dangerously insecure and so poorly accounted for that if it were stolen, no one might ever know.

Today, the problem is most acute in the former Soviet Union, where the collapse of the Soviet state left a security system designed for a closed society with closed borders, well-paid nuclear workers, and everyone under close surveillance by the KGB facing a new world it was never designed to address.[11] Nuclear weapons, which are large and readily accountable objects, remain under high levels of security – though even there, scarce resources for maintaining security systems and paying nuclear guards raise grounds for concern. For nuclear material, the problem is more urgent. Many nuclear facilities in Russia have no detector at the door that would set off an alarm if some one were carrying plutonium out in a

briefcase, and no security cameras where the plutonium is stored. Nuclear workers and guards protecting material worth millions of dollars are paid $200 a month. As a result, there have been a number of confirmed cases of theft of kilogram quantities of weapons-usable material in the former Soviet Union. Russian officials have confirmed that as recently as 1998, there was an insider conspiracy at one of Russia's largest nuclear weapons facilities to steal 18.5 kilograms of HEU – one that was stopped before the material actually left the gates.[12] These are the conditions that led a distinguished U.S. bipartisan panel to warn, earlier this year, that "the most urgent unmet 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 and sold to terrorists or hostile nation states."[13]

The problem of insecure nuclear material, however, is by no means limited to the former Soviet Union. Many analysts have expressed concern that the current anti-terrorist campaign could create instabilities in South Asia that could put nuclear stockpiles and facilities at risk. In the United States itself, which has among the toughest physical protection regulations in the world, there have been repeated scandals going back decades over inadequate security for weapons-usable nuclear material.[14] In countries around the world, there are research facilities with fresh HEU fuel that simply do not have the resources to sustain effective security for this material over the long haul. The problem was highlighted by the 19.9% enriched uranium seized in 1998 from criminals trying to sell it in Italy, which appears to have been stolen from a research reactor in the Congo.[15] Theft of insecure HEU and plutonium, in short, is not a hypothetical worry: it is an ongoing reality, not only from the former Soviet Union but from other states as well.

At the same time, tens of thousands of people worldwide have critical knowledge related to the manufacture of nuclear weapons and their essential ingredients, which must be controlled, and many thousands of these are seriously underemployed and underpaid, creating serious proliferation risks. In 1998, for example, a weapons expert from one of Russia's premier nuclear weapons laboratories was arrested on charges of spying for Iraq and Afghanistan – in this case on advanced conventional weapons.[16] In October, 2000, an official of Russia's Security Council confirmed that Russia had blocked a Taliban effort to recruit a former Soviet nuclear expert from a Central Asian state.[17] A knowledgeable expert from a major state weapons of mass destruction program could substantially accelerate a proliferator's weapons of mass destruction program, or make it possible for a terrorist group to achieve a nuclear, chemical, or biological capability that would otherwise be beyond their reach.

*The Threat of Nuclear Sabotage or Radiological Dispersal*

A range of means is available by which terrorists might seek to disperse radioactive contamination – with the goal either of causing mass fatalities or simply provoking fear and economic disruption. The recent anthrax incidents in the United States demonstrate graphically the fear and consternation that unconventional terrorism can cause even if few people are killed or injured.

By far the most potentially devastating radiological attack (but also the most difficult to accomplish) would be to sabotage a nuclear power plant or spent fuel pond – both of which have huge concentrations of intensely radioactive material, and for both of which scenarios exist for generating the nuclear or chemical energy needed for dispersing it widely.[18] Studies sponsored by the U.S. Nuclear Regulatory Commission (NRC) have projected, in a worst case, over a hundred thousand deaths from a beyond design-basis accident, as might be caused by successful sabotage.[19] Unlike many other hazardous industrial facilities, nuclear power plants in most countries are protected by containment vessels several feet thick, are equipped with redundant safety systems, and are protected by armed guards and other security systems. To cause a core meltdown and disperse a substantial fraction of the radioactive

material into the atmosphere would require defeating the plant's security systems and destroying or disabling multiple safety systems simultaneously.

Unfortunately, a variety of terrorist attack and insider sabotage scenarios raise at least the possibility of overcoming these redundant safety features and causing a catastrophic release. And nuclear plants have been the subject of some terrorist interest: threats or attempts to blow up or penetrate nuclear reactors have been reported already in Argentina, Russia, Lithuania, Western Europe, South Africa, and South Korea.[20] In the United States, the NRC requires that nuclear power plants have armed guard forces and a variety of barriers capable of protecting the plants from a small group of well-armed and well-trained terrorists, possibly working with one insider at the plant; since 1994, the plants have also been required to be protected against truck bombs (though there is ongoing debate as to whether currently required protections are sufficient, as a 1984 Sandia National Laboratory study concluded that large truck bombs could potentially cause unacceptable damage to critical safety systems even if detonated outside the protected area of most plants).[21]

Roughly half the U.S. commercial nuclear power plants have failed tests involving a threat of the kind specified in the regulations (typically involving only a few attackers, and an insider involved only in providing information) – where failure means that the test attackers would have been able to destroy critical safety systems.[22] After such tests, security upgrades are undertaken to correct identified deficiencies.

As with security for nuclear material, there appear to be wide variations in national practices with respect to security for nuclear facilities. A survey of information on physical protection provided at a Stanford and an IAEA conference in 1997 showed great variation in practices from country to country: some countries did not even explicitly identify terrorism or sabotage among the threats their systems were designed to defend against.[23] In Japan and several other countries, for example, there are no armed guard forces at nuclear facilities – even facilities with enough plutonium for scores of nuclear weapons. Reliance is placed instead on technological barriers to delay potential intruders, and armed police 10-15 minutes away. (Security is particularly crucial for early-generation Soviet-designed reactors, which do not have Western-style containment vessels or the same level of redundant safety systems, and are hence particularly vulnerable to catastrophic sabotage. High priority should be placed on ensuring effective and sustainable security for all of these plants against both insider and outsider threats.) Overall, internationally required standards, accompanied by an effective and well-financed effort to assist countries in meeting them, could do much to reduce the differences in practices and improve national standards.

In addition to power plants, spent fuel storage and processing facilities are another target whose destruction could conceivably lead to catastrophic releases. A recent NRC study concluded that an accident at a spent fuel pool that led to a loss of the cooling water could, if the fuel temperature reached over 900$^{o}$ C, lead to a zirconium fire that could disperse a large fraction of the cesium and other potentially volatile radionuclides into the surrounding atmosphere.[24] The large spent fuel pools at reprocessing plants pose a particular concern in this regard.[25] In the case of dry cask stores, while it is certainly possible to imagine scenarios in which one or more casks might be destroyed, the prospects for mobilizing large quantities of radionuclides into the atmosphere seem much more limited. Spent fuel transports are another potential target for sabotage, which must be well-secured – including against anti-tank weapons, which are widely distributed throughout the world, and surely available to groups such as the September 11 attackers.[26]

Military facilities are another potential target – though often one equipped with even higher security. An attack on a warhead facility that succeeded in setting off the conventional explosives of a weapon and scattering plutonium, or an attack on a facility with large numbers

of plutonium metal components that succeeded in setting some of them afire, could have serious consequences.

Other forms of nuclear terrorism have the potential to cause enormous fear and disruption, given the public fear of anything "radioactive," and could result in large economic and cleanup costs, but would not be likely to result in large numbers of fatalities. Sabotage of most research reactors or uranium processing facilities, for example, would lead to few if any fatalities, because of their relatively modest inventories of toxic radionuclides, and the lack of plausible accident sequences for mobilizing those materials into the atmosphere. Similarly, although there are many lurid press accounts of the possibility of radiological "dirty bombs," there are few detailed analyses of this issue in the unclassified literature. From the information that is available, it seems clear that it would be very difficult for terrorists to cause large numbers of fatalities by this means.[27] Dispersal of material from radiation sources from hospitals or industry would not be sufficient to cause hundreds or thousands of deaths. Such weapons have already been the subject of active interest by terrorists – most notably when Chechen terrorists planted radioactive cesium in a popular Moscow park as a warning of what they could do in the future.[28] More analysis of the likely impact of terrorist use of different types of radiological materials, and of the accessibility of these materials and means to reduce it, is clearly needed. In the remainder of this paper, we will refer to those nuclear facilities whose successful sabotage could lead to catastrophic consequences as "high-consequence" nuclear facilities.

*Current International Cooperative Efforts to Improve Security, Strengthen Standards*

In recent years, there have been substantial international cooperative efforts both to upgrade the security of specific facilities around the world and to put more effective security recommendations and standards in place. The United States has spent hundreds of millions of dollars on cooperative efforts with the states of the former Soviet Union to modernize material protection, control, and accounting (MPC&A) systems at dozens of sites throughout the former Soviet states, and expects to spend more than a billion and a half more by the time the program is completed. Other states have contributed to this effort as well. Substantial international cooperation has also focused on improving capabilities to monitor, analyze, and interdict nuclear smuggling. The IAEA has established a physical protection advisory service, which offers international expert peer reviews and coordinates donor state assistance for upgrading physical protection, at the request of member states. Through that mechanism and others, significant physical protection upgrades have been accomplished in several states outside the former Soviet Union as well. In the area of nuclear material accounting and control, every non-nuclear weapon-state under the NPT must submit its nuclear material and accounts to international inspection; civilian material in Britain and France is under similar inspection from EURATOM. This creates a multilateral discipline that is absent in the other nuclear weapon states.

In the area of standards and recommendations, a substantial revision of the IAEA's recommendations on physical protection was completed in 1999 (INFCIRC 225/Rev. 4). New initiatives have been undertaken to provide assistance to states in developing design-basis threats for their physical protection systems, and to expand international physical protection training. In the wake of the September 11 attacks, the IAEA General Conference unanimously endorsed 12 physical protection principles developed by an experts' group.

Today, there is no treaty requiring countries using weapons-usable material to protect it from being stolen, or requiring that high-consequence nuclear facilities be protected from sabotage. The only treaty in this area is the Convention on the Physical Protection of Nuclear Material of 1980, which calls for physical protection measures only for material in international transport (or storage incidental to such transport); its requirements do not apply to material in

*domestic* use, storage and transport. Furthermore, its protection requirements are against theft of nuclear material; there are no added requirements to deal with sabotage attacks on nuclear facilities. Moreover, the Convention's protection requirements are very general and non-specific.[29] It includes no mechanisms for verification, or even voluntary reports on, or peer review of, physical protection practices. Such measures could build international confidence that states were adequately protecting their nuclear material and facilities. In 1998, the United States proposed that the Convention be amended to (a) extend its coverage to civilian nuclear material in domestic storage, use, and transport; (b) require that at a minimum, states provide levels of protection comparable to those recommended in INFCIRC 225; and (c) require that states provide reports on their physical protection arrangements every five years, to be discussed at international conferences that would also take place every five years.[30] IAEA staff outlined additional possibilities, including provisions for protecting against sabotage of facilities as well as theft of materials, and extending the convention's coverage to protection of military as well as civilian nuclear material.

The IAEA Director General then convened an experts' meeting, which, after some initial disagreement, recommended drafting an amendment to the Convention extending its coverage to civilian nuclear material in domestic use, storage, and transport; adding a requirement to protect against sabotage of nuclear facilities as well as theft of nuclear material; stating 12 fundamental principles for physical protection that parties should follow; and including some additional issues related to confidentiality and national responsibility. The experts' report and the Director-General's decision to convene a group of experts to draft a proposed amendment to the Convention were welcomed by the September 2001 IAEA Board of Governors and General Conference meetings, and the Board endorsed the fundamental principles for physical protection recommended by the experts. The draft amendment, when completed, will be reviewed by the Convention parties, a majority of whom must agree to convene an amendment conference; then, two-third of the parties must approve the amendment before it can enter into force. [31]

The experts' group, however, opposed including any requirement that states prepare any form of reports on their physical protection arrangements and regulations; any mechanism for international peer review of such arrangements; any reference to the much more detailed IAEA physical protection recommendations, even a requirement to give them "due consideration" or take them "into account"; and any extension of the convention to material in military use. In our view, in the aftermath of September 11, the experts' pre-September 11 caution in these areas – perhaps reflecting in significant part a desire to minimize the costs and inconvenience of any new security measures – should be fundamentally reconsidered. Where there are legitimate concerns in these areas, means can be found to address them.

*The Vision: A World of Secure Materials and Facilities*

In the aftermath of September 11, our vision must be of a world in which:

- Every nuclear weapon and all weapons-usable nuclear material worldwide is secure and accounted for, to stringent standards;
- All high-consequence nuclear facilities (and high-consequence material transports) are secure from both insider and outsider sabotage and attack;
- Effective measures are put in place to interdict nuclear smuggling;
- There is sufficient transparency to give the international community confidence these steps have been undertaken.

Of course, it is not possible to defend every facility against every imaginable threat. Society has other things to secure besides nuclear material and facilities, and other things to expend its resources on besides security. The debate over "how much is enough?" is crucial, and has only just begun. While there are clearly a wide range of aspects of security for nuclear

materials and facilities that must be kept secret, it is our belief that this is a debate that must be as open and transparent as is possible, allowing a well-informed public to make judgments as to how much it believes should be spent to reduce the risks, and what remaining risks are acceptable. In the United States, for example, while some have complained that the NRC's physical protection regulations are not strong enough, they are published in some detail, making them available for public discussion and debate[32] – which is not the case in many other countries.

In our judgment, the stakes justify a significant investment in improving security worldwide. Given that proliferating states have been willing to spend billions of dollars on their efforts to produce fissile material—and given that a single bomb could threaten tens of thousands of lives—the level of effort devoted to securing and accounting for stocks of even a few kilograms of fissile material should be even higher than that devoted to protecting stores of millions of dollars worth of cash, gold, or diamonds. This is manifestly not the case at many facilities in many countries today. Indeed, a strong case can be made that the essential ingredients of nuclear weapons should be protected roughly as rigorously as nuclear weapons themselves are, as a committee of the U.S. National Academy of Sciences recommended in 1994.[33] As the DOE regulations on physical protection put it, "use of weapons of mass destruction by a terrorist(s) could have consequences so grave as to demand the highest reasonably attainable standard of security."[34] Similarly, for nuclear facilities where successful sabotage could threaten tens of thousands of lives, very high levels of security are called for. Ultimately, the levels of security provided should be such that even large and highly capable terrorist groups bent on causing mass destruction could more easily cause comparable numbers of casualties by other means.

While every threat cannot be defended against, substantial security improvements could be made for costs that would be quite small when judged against what societies routinely spend for military security, or when judged as a percentage of the cost of nuclear-generated electricity. Safeguards and security today are a very small contribution to nuclear costs: to take one example, even at the THORP reprocessing plant, one of the most sensitive civilian nuclear facilities in the world, capital cost was over $5 billion in current dollars, annual operating costs are nearly $500 million – but security costs for all the plutonium operations for THORP and other facilities at the Sellafield site are estimated by BNFL at $15 million per year.[35]

*Priority One: Implementing Security Upgrades*

Below, we provide a range of specific suggestions for action in the wake of the September 11 attacks, grouped into two main categories – direct steps to implement security upgrades at specific facilities and to interdict nuclear smuggling, and steps to strengthen national and international security standards.

- Every state with weapons-usable nuclear materials or high-consequence nuclear facilities should urgently assess its security arrangements and regulations in light of the magnitude of the threat demonstrated on September 11, and upgrade them where necessary. Every such state should also review its organizational arrangements, to ensure that lines of authority and approaches to coordination for the different aspects of nuclear security are clear, and those in charge have adequate authority and resources. If technical assistance is needed to perform security reviews, the state should request that the IAEA help organize such help – and if the state does not have adequate resources to carry out needed upgrades, it should request that the IAEA organize assistance. Where nuclear material cannot be effectively and sustainably secured in place, it should be consolidated at secure facilities.
- Working with Russia, the United States should launch a new initiative to control and secure weapons of mass destruction in both their countries and worldwide. The September 11 attacks have created a security moment as unique as the collapse of the

Soviet Union, justifying a new initiative on the scale of the Nunn-Lugar initiative launched at that time. As recommended in the Baker-Cutler report of January 2001, the United States should (a) work with Russia to develop a strategic plan "to secure and/or neutralize in the next eight to ten years all nuclear weapons-usable material located in Russia, and to prevent the outflow from Russia of scientific expertise that could be used for nuclear or other weapons of mass destruction"; (b) appoint a senior official to manage the many programs involved; and (c) appropriate approximately $1 billion to implement the plan. This could come from the $40 billion authorized by Congress for responding to the September 11 attacks to this accelerated WMD control effort.

- In particular, as part of such an initiative, the United States and Russia should drastically accelerate their joint cooperation to improve material protection, control, and accounting (MPC&A). Other states should substantially increase their contributions to this effort as well. This would include: (a) substantially increased funding (to a U.S. budget in the range of $250 million for fiscal year 2002, for example); (b) joint U.S.-Russian development of a strategic plan to complete the needed upgrades as rapidly as the job can be accomplished, but certainly in no more than 8-10 years; (c) high-level Russian commitment to sustain effective security and accounting after U.S. and international assistance phases out in the future, with a working group established to work out specific measures and commitments for sustainability; (d) agreement on a drastically expanded and accelerated effort to consolidate nuclear material in fewer buildings and facilities, including providing comprehensive incentives to facility managers to give up their material; (e) agreement on a "rapid accounting" initiative, in which all nuclear weapons and weapons-usable materials would be identified, tagged, and sealed very rapidly, with the more laborious process of actual measurement of the nuclear material (likely to take years) following behind;[36] (f) rapid agreement on measures to sweep aside the disputes over access and assurances to ensure that U.S.-funded upgrades at sensitive facilities are implemented appropriately, which have delayed progress; and (g) a greatly increased focus on achieving security that can be and will be sustained after initial upgrades are complete, including strengthened MPC&A regulation and a wide range of other measures related to resources, organizations, and incentives to sustain MPC&A.[37] The scope of these efforts should be expanded to include physical protection assistance needed to prevent catastrophic sabotage, as well as theft of nuclear material.
- As additional elements of such an initiative, the United States and Russia should also accelerate their other cooperative programs designed to secure, monitor, and reduce stockpiles of nuclear weapons, plutonium, and HEU; downsize nuclear complexes and re-employ nuclear weapons and materials experts; interdict nuclear smuggling; and control sensitive nuclear exports. Here, too, other states should substantially expand their contributions. This would include, for example, measures to accelerate the blend-down of highly enriched uranium, and to place excess weapons plutonium under international verification (ideally designed to allow real-time monitoring of the material's status) and transform this plutonium into forms no more usable in nuclear weapons than commercial spent fuel.[38] Where such efforts have run into substantial obstacles from lack of funding, political leadership, or cooperation (as in the case of disposition of excess plutonium, for example) intensive efforts should be made to overcome these obstacles.
- The United States and other major nuclear states should also provide substantial funding – at least several tens of millions of dollars for the coming year – to finance MPC&A upgrades and assistance for sustaining high levels of security in other countries around the world – focused both on securing nuclear material and on preventing sabotage. These could be carried out both through bilateral arrangements

and through the IAEA, but in any case should be coordinated with the IAEA serving as a central clearinghouse for information.

- States that have so far had no armed guards at their nuclear facilities (such as Japan) should reconsider, and develop culturally appropriate approaches to deploying armed security personnel at each nuclear facility with weapons-usable nuclear material or whose sabotage could cause a major catastrophe. (Japan is already actively debating whether its Self Defense Forces should be given a role, along with the police, in defending nuclear power plants.)[39]
- The United States and other major nuclear states should finance a drastic increase in physical protection training around the world, as recommended in the final report of the IAEA-convened experts group. This training should include not only technical training, but discussion of the crucial role of such security in preventing the spread of nuclear weapons and stopping nuclear terrorism. Effective training is crucial to improving security and assuring that improvements are sustained over time.[40]
- The budget and personnel available to the IAEA's physical protection programs should be drastically increased, making it possible to carry out a much larger number of missions to help member states improve security measures, and to provide more effective follow-up to such missions. At a minimum, the available resources should be increased two to three times.
- International cooperative efforts to reduce the number of sites around the world where HEU and separated plutonium are stored should be drastically expanded. The budgets available for converting HEU-fueled research reactors to low-enriched uranium (LEU), taking back fresh and spent research reactor fuel to the country of origin, and developing new higher-density fuels should be substantially increased, so that these efforts can be accelerated – including particularly Russian take-back of Soviet-supplied HEU from vulnerable sites around the world. Efforts to reduce the size of these stockpiles – including bringing plutonium supply and demand into balance and reducing the existing stocks of civilian separated plutonium – should also be increased.
- Every state with weapons-usable nuclear materials should review, and strengthen as necessary, the accuracy and effectiveness of its state system of accounting and control – as control and accounting systems are an important part of preventing and detecting insider theft. Non-nuclear-weapon states party to the NPT already have state control and accounting systems reviewed by the IAEA, as it implements safeguards. The nuclear weapon states should each undertake a "self-audit," identifying the quantities and locations of all of its weapons-usable nuclear material, and matching these to historical production and use (comparable to the audit the United States undertook as part of its Openness Initiative).[41]
- Firms in the nuclear industry should drop their opposition to more stringent security standards; this opposition is "penny wise and pound foolish." While increased security measures will cost money, successful theft of nuclear material for a nuclear weapons program, or successful catastrophic sabotage of a nuclear power plant, would be a gigantic disaster for the nuclear industry in all countries, wherever it occurred. For the same reason, the nuclear industry would be well-advised to add their voices and lobbying muscle to efforts to convince governments to allocate funds to upgrading security wherever that is needed.
- The nuclear industry should establish a cooperative industry organization focused on improving security standards worldwide through peer review and assistance, comparable to the role the World Association of Nuclear Operators (WANO) has played in improving nuclear safety.
- All relevant states should undertake dramatically increased efforts to interdict nuclear smuggling and control sensitive nuclear exports, including: (a) far-reaching sharing of intelligence and law-enforcement information; (b) ensuring that every relevant state has at least a small unit of the national police trained and equipped to deal with

nuclear smuggling, and other law-enforcement and border-control units are trained to contact them as appropriate; (c) ensuring that every relevant country has a unit of its national intelligence service focused on, trained to deal with, and cooperating with other states on, the nuclear smuggling and illicit export threats; (d) providing equipment and training for detection at key border crossings, airports, ports, and at potential key nodes within countries as well (e.g., major highways near nuclear facilities, train stations in Moscow); and (e) substantially improving international nuclear forensics capabilities to examine seized samples and determine their origin.

- The United States, the countries of the European Union, Japan, and other states should increase their assistance for measures to assist the states of the former Soviet Union in re-employing weapons of mass destruction experts, downsizing the WMD complexes, and strengthening controls on exports and transfers of sensitive technologies.

*Priority Two: Strengthening National and International Standards*

In addition to immediate upgrades, strengthened standards are needed if security is to be improved consistently worldwide and sustained over the long haul. *National* standards and regulations need to be strengthened in many cases to ensure that facilities have security in place that will meet current threats; *international* recommendations and agreements should be strengthened, to help ensure that states around the world provide effective security for their materials and facilities, and to give advocates of increased security within individual states the arguments they need; and, within the limits of necessary secrecy, *transparency* needs to be increased, to give the international community confidence that needed security measures are being taken, to identify the facilities most in need of further improvement, and to support informed public debate on what next steps are needed.

*National Standards and Regulations*

- Every state with weapons-usable nuclear material or high-consequence nuclear facilities should move urgently to put in place effective national security standards and regulation (including clear regulations, strong and independent regulators, appropriate inspection programs, and effective enforcement) reflecting the threat as perceived *after* September 11 – at a minimum offering a level of security comparable to that recommended in INFCIRC 225/Rev. 4, and with the physical protection principles adopted at the September, 2001 IAEA General Conference.
- Every state with weapons-usable nuclear material or high-consequence nuclear facilities should incorporate design basis threats into its regulations (while maintaining confidentiality as necessary). These threats should take into account the global reach of terrorist organizations such as that which struck on Sept. 11 (see discussion below). At a minimum, it is difficult to argue that there is *any* country with major nuclear facilities where an attack by a small group of well-armed, well-trained terrorists, making use of a vehicle and explosives, and possibly with the assistance of one insider, is not a plausible threat against which security systems should be prepared to defend.
- These national standards and regulations should include regular, realistic, independent testing of the performance of security systems in defeating intelligent, well-trained insider and outsider efforts to overcome them. The IAEA's physical protection advisory service should be expanded to include helping countries to carry out such tests and establish such domestic testing programs. In the United States, which already has regular performance-testing programs in place, the performance-testing program run by the Nuclear Regulatory Commission should not be transferred to industry to manage, as this could reduce the testers' incentives to identify weaknesses requiring correction.

- Every relevant country should put in place strong legal and regulatory frameworks to deal with the problem of theft and illicit trafficking in nuclear material. In particular, given the immense potential consequences, states should modify their laws to make the penalties for theft or unauthorized possession or transfer of plutonium or HEU, or major sabotage of a high-consequence nuclear facility, comparable to those for murder or treason.

*International Recommendations and Agreements*

- Every state with weapons-usable nuclear material or high-consequence nuclear facilities that has not already done so should sign and ratify the Convention on the Physical Protection of Nuclear Material.
- Every state with weapons-usable nuclear material or high-consequence nuclear facilities should voluntarily commit to provide security for its facilities comparable to or better than that recommended in INFCIRC 225/Rev. 4. Major wealthy nuclear states such as the United States, France, the United Kingdom, Japan, and Germany should join in making a politically binding commitment that they will provide the levels of security recommended in INFCIRC 225/Rev. 4 for all their nuclear material and facilities, military and civilian; that they will report to the IAEA on their regulations and procedures; that they will allow managed peer review of physical protection at selected facilities; and that they will encourage other states to make comparable commitments (including requiring that foreign facilities that they supply or contract with demonstrate that they are meeting the INFCIRC 225/Rev. 4 recommendations). The United States, in particular, should extract itself from the embarrassing position of opposing its own previous proposal to create an obligation to meet INFCIRC 225 standards by investing the resources necessary to bring its own facilities up to these standards and working to convince other states to do likewise.[42]
- A new review of INFCIRC 225 should be initiated, to make whatever modifications are necessary given the new understanding of the threat in the aftermath of September 11.[43]
- The Convention on Physical Protection of Nuclear Material should be amended as rapidly as practicable, to expand its coverage to domestic material and make the other improvements recommended by the experts' group.
- At the same time, in the aftermath of September 11, some of the experts' group's conclusions should be reversed. Parties to the convention should work to build support for an amendment that *would* include: (a) an obligation to provide levels of security comparable to those recommended in INFCIRC 225 (with an option to provide reports explaining how measures that differed in some respects from the recommendations offered a comparable level of security); (b) coverage of materials in military as well as civilian stockpiles (which should not, in principle, be a problem since the convention calls for no inspections); and (c) an obligation to report to the IAEA on the national legislation and regulations put in place to meet the amendment's requirements (as the convention already requires for its requirements to pass legislation relating to legal jurisdiction over nuclear theft), and to report to the IAEA every few years on overall physical protection arrangements within that state. Means can readily be found to address states' legitimate concerns over committing themselves to abide by recommendations that may change in the future (such as the initial U.S. proposal that no state would be required to abide by any changes from the initial requirements until that state itself had accepted the changes).
- The effort to negotiate a nuclear terrorism convention should be revived. In the aftermath of September 11, this convention is not the forum for the non-nuclear-weapon states to insist on the desirable goal of a legally binding no-first-use commitment from the weapon states (the issue that had previously blocked agreement). The previously drafted text should be reviewed and modified to ensure

that it includes all the provisions that now seem most important to contribute to the international struggle to prevent nuclear terrorism.

- Every nuclear supplier state should undertake steps to examine whether security in its recipient states is adequate, and if not, work with the recipient states to ensure that effective and sustainable security measures and regulations are put in place, including providing assistance where needed. The Nuclear Suppliers' Group should adopt more stringent requirements prohibiting exports to countries that do not provide levels of security comparable to those called for in INFCIRC 225/Rev. 4. Either peer reviews by the supplier state or international peer reviews organized by the IAEA could be used to confirm that such requirements were being met.
- Major nuclear states should adopt a policy that their governments and firms will not enter into contracts with nuclear facilities that fail to provide effective security and accounting for their nuclear material – making this part of the "price of admission" for doing business in the major nuclear markets.
- Major nuclear states should place the issue of adequate security for nuclear materials and facilities high on the diplomatic agenda, giving it a prominence comparable to enforcing effective export controls and accepting safeguards on all civilian facilities.

*Transparency*

- Every state with weapons-usable nuclear material or high-consequence nuclear facilities should take care to keep confidential details of its physical protection arrangements that would be useful to terrorists seeking to overcome them.
- At the same time, sufficient information should be made available to enable informed public debate and build public and international confidence that sufficient steps are being taken.
- Every state with weapons-usable nuclear material or high-consequence nuclear facilities should voluntarily report to the IAEA on the steps it has taken to strengthen security and put in place effective national regulations. Major nuclear states should take the lead in taking particularly stringent measures and being among the first to report them to the IAEA.
- Voluntary peer reviews of physical protection arrangements, such as have been organized in recent years by the IAEA's International Physical Protection Advisory Service, should become, over time, a regular, normal part of doing business in major nuclear facilities – just as safety peer reviews have become. Toward that end, major nuclear states such as the United States, France, Japan, Britain, and Germany should not only provide greater funding for such peer reviews but should invite peer reviews at selected facilities of their own. As noted earlier, a new industry-led organization comparable to WANO could potentially also provide such peer reviews.
- New cooperation should be established between the IAEA's safeguards inspectors and its physical protection experts. The IAEA's safeguards inspectors should be instructed to provide relevant information observed during their inspections to the physical protection office (while keeping the information safeguards-confidential). The IAEA's inspectors should be provided limited physical protection awareness training to facilitate this.
- Using information from all available sources, the IAEA physical protection office should work to establish a confidential data base on the state of physical protection for nuclear materials and high-consequence nuclear facilities around the world, with a view toward identifying the facilities most in need of security upgrades.

*Rethinking the Design Basis Threat*

The September 11 attacks require a fundamental rethinking of the threats that nuclear security systems must be designed to address. The September 11 threat consisted of 19 well-trained attackers operating in four independent but coordinated teams; who were both suicidal and

bent on causing mass destruction; who came from an organization with access to automatic weapons, explosives, and heavy weapons, and extensive combat training and experience; who attacked without warning; and who appear to have planned, trained, and collected intelligence for the attack for more than a year. Even without the addition of the use of large civilian aircraft fully loaded with jet fuel, this is a threat far larger and more capable than most nuclear security systems (at least for civilian facilities) were ever designed to cope with. (As noted earlier, for example, U.S. regulations for power plants are focused on a design-basis threat of only a few people in a single team.)

Countries around the world will now have to ask fundamental questions about what threats their nuclear facilities should be required to defend against – including how much they are willing to spend to provide security against large threats, and how much military force they are willing to put in place around civilian energy facilities. Security at U.S. nuclear weapons facilities and nuclear power plants has been beefed up, and the chairman of the U.S. NRC has indicated that the NRC and the U.S. government are undertaking a major review of nuclear security arrangements. [44] Nuclear authorities in other countries around the world are doing the same. Questions that must be answered include:

- Is this a threat only the United States must defend against, given the particular hatred of America expressed by Al Qaida? Or is it more likely (as we think) that all of the states supporting the current anti-terror coalition (which includes nearly all of the largest users of nuclear energy and holders of fissile material) are also at risk, and that Al Qaida will not be the last group with global reach bent on mass destruction?
- What, if anything, should be done to protect nuclear facilities from attack by aircraft? An IAEA spokesman has acknowledged that current nuclear power plants were never designed to withstand attack by "a large jumbo jet full of fuel,"[45] and the U.S. NRC has indicated that the likelihood of such a crash was never considered high enough to be included in safety regulations. Regulatory authorities in France, the United Kingdom and several other countries have said the same. Can it now be assumed that large civilian airliners will become sufficiently difficult to hijack that the threat of a September 11-type attack on a power plant can be safely ignored? Or should we consider deploying anti-aircraft defenses at such facilities, as two U.S. watchdog groups have recommended? [46] What about small planes, operating from unregulated airports, which might be packed with explosives?
- How many people, with what level of training and weaponry, should design basis threats now include? What would be the cost of providing effective protection against threats of the scale of that of September 11?
- Should facilities be protected against attackers arriving and departing by unconventional means designed to overcome delays at the perimeter, such as helicopters?

While this reconsideration has only just begun, a few things do seem clear already. First, high-consequence nuclear facilities *should* be designed to survive truck bomb attacks. Second, it is unsafe to rely on the assumption that there will be prior warning before an attack.

*Impact on the Future of Nuclear Energy*

Ultimately, a world that includes highly capable terrorist organizations with global reach, bent on causing mass destruction, is a world that is less favorable to technologies that concentrate immense quantities of value and potential vulnerability in one place – including nuclear energy. This is not by any means to say that nuclear energy should be abandoned. But the need to consider, and defend against, the possibility of large-scale terrorist attack on nuclear facilities – and the quasi-militarization of civilian energy facilities that could be the result – will clearly be one concern in the minds of utilities, governments, and publics weighing nuclear energy against the other available energy options. Henceforth, security will have to

be a much more central part of the safety debate than it has been heretofore. The demonstration of this very challenging threat does have some implications for specific nuclear energy choices:

- The desirability of reactors with "inherent safety" features, designed so that no plausible set of circumstances can lead to a core melt and large-scale dispersal of radioactivity, appears even higher than before.
- However, proposals that such reactors can be built with no containment vessels – a key part of the projected favorable economics of the ESKOM pebble bed system, for example – are likely to be as dead as the race to build ever-taller office buildings.
- The concept of underground nuclear reactors should be explored again, to see if such systems can provide energy at reasonable cost.
- Most controversially, perhaps, we believe that there should be a phased-in moratorium on current approaches to reprocessing and recycling plutonium. Whatever safeguards and security measures are put in place, a world in which tens of tons of plutonium are being separated, processed, fabricated, and shipped to dozens of locations around the world every year is a world that poses significant increased risk compared to a world in which that is not occurring. Nuclear power's future will be best assured by making it as cheap, as safe, as secure, as proliferation-resistant, as simple, and as uncontroversial as possible – and current reprocessing and recycling technologies point in the wrong direction on every count.

*Conclusions: Preparing for a New World*

The events of September 11 created a new world – a world in which we know for certain there are highly capable terrorist groups with global reach, bent on mass destruction. At the same time, the aftermath of September 11 is demonstrating that we are living in a world where far-reaching international cooperation toward common objectives can be a reality.

This new world calls for new approaches for securing much of the fragile infrastructure of modern industrial societies – including nuclear materials and facilities. A major new international initiative – composed of national, bilateral, and multilateral pieces – is needed, to achieve, as rapidly as possible, a world in which all weapons-usable nuclear material is secure and accounted for, and all nuclear facilities secured from sabotage, with sufficient transparency that the international community can have confidence that this is the case. Obviously, not everything described above can be done with equal speed. The first priority must be to upgrade security for the least secure nuclear material and high-consequence nuclear facilities, in the former Soviet Union and worldwide; strengthened international standards will likely take longer to achieve (though the momentum from September 11 should not be lost). Over the long term, the goal should be to attempt to come as close as possible to protecting and accounting for weapons-usable nuclear materials as rigorously as the nuclear weapon states protect and account for nuclear weapons themselves. The road to that objective is a long one, however.

These steps will cost money. Many of them have been blocked or slowed in recent years because of lack of political priority, bureaucratic obstacles, penny-pinching budgets, reluctance to make commitments that would cost money, and the like. In the aftermath of September 11, governments and industry should work together to sweep these obstacles aside and take the steps needed to ensure that nuclear materials and facilities do not become the tools of terrorists. For the United States, sustained Presidential engagement will be needed, working in difficult and sensitive partnerships with Russia and countries around the world – along with a new willingness to re-engage in multilateral arms control in a serious way. But the costs and risks of failing to act are far higher than the costs of acting now.

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[3] For outlines of such an international regime to improve controls over nuclear weapons and materials worldwide, see, for example, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (Washington, DC: National Academy Press, 1994), esp. pp. 101-102 and 123-139; David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (Oxford, UK: Oxford University Press for the Stockholm International Peace Research Institute, 1997), esp. Chapter 15; and William Walker and Frans Berkhout, *Fissile Material Stocks: Characteristics, Measures, and Policy Options* (Geneva, Switzerland: United Nations Institute for Disarmament Research, 1999).

[4] Steven Mufson, "For Bush's Veteran Team, What Lessons to Apply? War Doctrines Tough To Call On in Fight Against Terrorism," *Washington Post,* September 15, 2001.

[5] U.S. Department of Energy, Office of Arms Control and Nonproliferation, *Final Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives,* DOE/NN-0007 (Washington, DC: DOE, January 1997), p. vii. For the most authoritative and detailed unclassified discussion of whether terrorist groups could plausibly build nuclear explosives, see the chapter by a group of U.S. nuclear weapons designers representing a range of views on the subject: J. Carson Mark et al., "Can Terrorists Build Nuclear Weapons?" in Leventhal, and Alexander, *Preventing Nuclear Terrorism,* op. cit. Unfortunately, the authors of that chapter conclude that the answer to their title question, in some cases, may be "yes." In addition, it must be remembered that subnational thieves may provide stolen fissile material to states, which can then use the state's resources to transform it into nuclear weapons.

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[7] As a result, U.S. Department of Energy regulations and U.S.-Russian Material Protection, Control, and Accounting guidelines that assign such material to a low-attractiveness category requiring little protection should be changed. For discussion, see Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Washington, DC: Russian-American Nuclear Security Advisory Council, August 2000, available at http://ksgnotes1.harvard.edu/BCSIA/Library.nsf/pubs/ransacreport), pp. 24-25.

[8] For a detailed review of these stockpiles, see Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium 1996,* op. cit.; civilian plutonium figures (increasing by many tons every year) have been updated for these totals on the basis of declarations to the IAEA since then.

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[10] International Atomic Energy Agency, *Nuclear Research Reactors in the World*, IAEA-RDS-3, September 2000.

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[12] See discussion and references in Bunn, *The Next Wave,* op. cit.

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[16] "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.
[17] "Security Council Official Says Afghan Taliban Tries to Access Nuclear Technologies," *Interfax,* October 7, 2000.
[18] For a useful (though dated) overview of this issue, see Bennett Ramberg, *Nuclear Power Plants as Weapons for the Enemy: An Unrecognized Military Peril* (Berkeley, CA: University of California Press, 1984).
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[29] For example, even for the material classified by the Convention as most attractive for weapons use, it has only general requirements such as requiring location in a "protected area" which has guards and not-too-distant response forces, and which limits access to "persons whose trustworthiness has been determined."
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[31] Convention on the Physical Protection of Nuclear Material, Art. 20.
[32] The text of these regulations is in *10 Code of Federal Regulations Part 73.* Until the U.S. Nuclear Regulatory Commission website was taken down to check for sensitive information after September 11, the full text of these regulations could be found at http://www.nrc.gov/NRC/CFR/PART073/index.html; they can still be found in any major U.S. public library. Some U.S. Department of Energy and Department of Defense rules for protecting their nuclear materials are public, but key provisions specifying specific protection standards are not.
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