Report

Strengthening Nuclear Security Against Terrorists and Theives Through Better Training

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The September 11, 2001, attacks on the World Trade Center and the Pentagon have shown that well-organized global terrorist groups bent on causing mass murder and destruction are no longer hypothetical. There can now be little doubt that if such terrorists could acquire weapons-usable nuclear material from thieves and learn how to make nuclear weapons, they would employ them in their attention-seeking tactics. If they could learn how to disperse highly radioactive materials across a city, they would likely attempt that as well. Under these circumstances, measures to further strengthen the protection of nuclear materials and nuclear installations are urgently needed.

This report first reviews the need to strengthen protection of nuclear materials and nuclear reactors against terrorists and thieves and then examines the need for better training of those charged with protection responsibilities to meet this challenge. Our research suggests that security practices vary significantly from country to country, giving thieves and terrorists opportunities to steal nuclear material or to sabotage nuclear facilities in some countries that they do not have in others.

THE NEED TO PROTECT NUCLEAR MATERIAL AND FACILITIES

National practices for what is called "physical protection" of nuclear material vary widely.[1] Some states have obligated themselves to apply International Atomic Energy Agency (IAEA) recommendations for such protection, but others have only agreed to give consideration to those recommendations or have made no commitment at all. Some have adopted domestic regulations with requirements as high or higher than these recommendations, but others have adopted lower standards or none at all.[2]

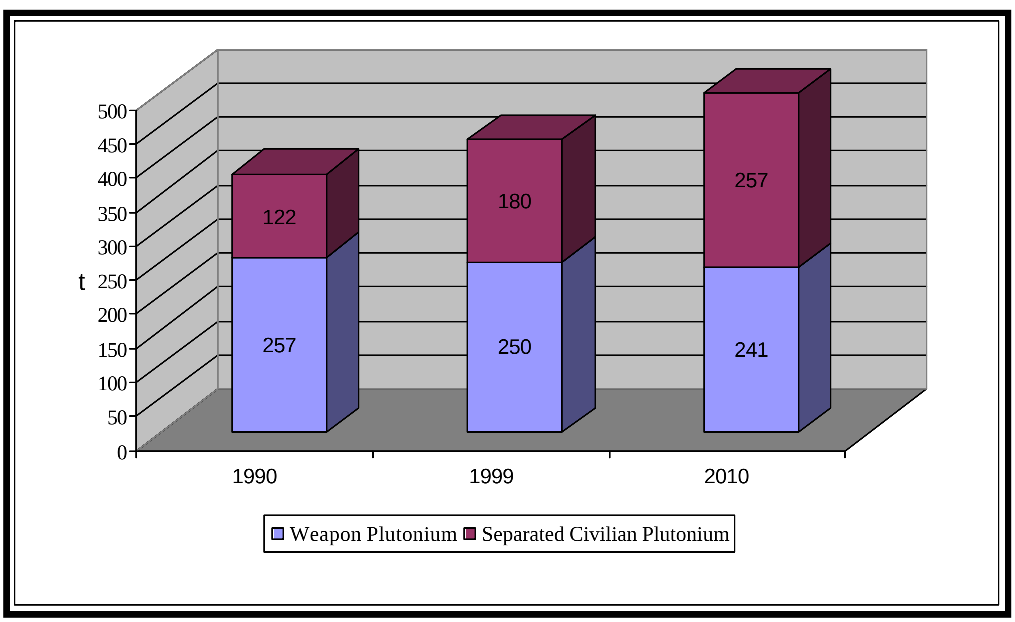
Although the 182 non-nuclear weapon state parties to the NPT must accept IAEA safeguards on their nuclear activities, these material accounting and inspection requirements are designed to prevent diversion of nuclear material from peaceful uses to weapons production by persons working for the country where the material is present. They are not designed to protect it from theft or sabotage by unauthorized persons. Inspectors from the IAEA implementing NPT-mandated inspections check for the disappearance of nuclear material from peaceful nuclear activities. It is not their job, however, to inspect the fences, walls, locks, intruder sensors, alarm systems, or guard arrangements that an operator has provided to prevent theft or sabotage by terrorists.[3]

The urgent need for improved security for nuclear material and facilities has been recognized for Russia and some other former Soviet republics and former Soviet allies. Over the last decade, strengthening this security has been the focus of major programs to improve material protection, control, and accounting (MPC&A) in these countries, programs underwritten with financial assistance from the United States, Western Europe, and Japan. These efforts have been well studied but they have not been the focus of attention in other settings around the world.[4] This report describes the global problem. It reflects our conclusions from our research that financial and technical assistance are needed in more countries than those that have received it to date, that global standards for physical protection are needed, and that, in particular, better training is needed in many countries for those responsible for nuclear material security.

It is worth reiterating the basic reason for the concern about "loose nukes" in Russia and elsewhere. First, obtaining enough weapons-usable nuclear material to make an explosive nuclear device is the greatest obstacle to manufacturing these weapons. The designs of unsophisticated weapons (such as the Hiroshima bomb) are fairly well known. Given the requisite weapons-usable material, bomb building is within the capability of many countries and even some well-organized terrorist groups – conceivably including Osama bin Laden's al Qaeda, which has already attempted to acquire weapons-usable material.[5] Accordingly, the U.S. Department of Energy has concluded that, "controls on access to these materials is the primary technical barrier to nuclear proliferation in the world today."[6]

Second, weapons-usable materials are present in many countries. The common weapons-usable nuclear materials are plutonium or highly enriched uranium (HEU, that is, uranium enriched to 20 percent or more in the isotope U-235).[7] According to the standards used by the IAEA, 8 kilograms (kg) of plutonium or 25 kg of HEU are sufficient to manufacture a nuclear explosive. (A kilogram is 2.2 pounds.) At least twelve countries possess among them 180,000 kg of separated, civilian, weapons-usable plutonium (Belgium, China, France, Germany, India, Italy, Japan, the Netherlands, Russia, Switzerland, the United Kingdom and the United States). The amount of this civilian plutonium is growing and, at the current rate of increase, in a few years, these stocks will surpass the estimated 250,000 kg of plutonium in weapons or weapons reserves held by the five NPT nuclear-weapon states (China, France, Russia, the United Kingdom, and the United States), plus India, Israel and Pakistan.[8] According to more recent data, the amount of separated commercial plutonium owned by just eight countries (Belgium,

Table 1:Past, Current, and Projected Stockpiles of Weapon and Civilian Plutonium (in Metric Tons)



France, India, Japan, Germany, Russia, the United Kingdom, and the United States) has already reached 210,000 kg.[9]

HEU is more widely spread around the world than plutonium and often less well guarded. If it has not been irradiated in a research reactor so long that its radioactivity makes it too hot to handle even for terrorists, it can be made into an explosive nuclear device. According to IAEA estimates of August 2000, more than 2,772 kg of HEU exist in 170 operating research reactors in 43 countries, sometimes in quantities at least the size of the critical mass needed to make a nuclear explosive device. In addition, there are 258 shut-down research reactors, many of which have HEU that has not been returned to its supplier as originally intended and some of which did not operate long enough to make their HEU too hot to handle. The IAEA estimates that 28 developing countries have research reactors that use HEU and some of these probably have not-yet-irradiated HEU awaiting future use.[10]

Security at many research reactors appears poorer than that at nuclear power plants or weapons-complex facilities.[11] And that is true not only of the former Soviet Union and Eastern Europe. For example, in 1998, members of a smuggling ring were arrested in Italy in possession of non-weapons-usable uranium enriched to 19.9 percent that was stolen some years earlier from a research reactor in the Congo, where security conditions were described as appalling.[12] Security at some U.S. and European Union research reactors has been criticized as lax.[13] For example, after the September 11 attacks, two individuals with false identities were allowed access to the research reactor facility in Petten, the Netherlands, and were not apprehended until they had gotten inside.[14]

Third, protection is needed not just for weapons-usable material, but also for spent fuel from reactors and for the reactors themselves. The danger of a major dispersion of radioactivity from a truck bomb detonated near spent nuclear reactor fuel has been much less analyzed than possible terrorist use of a nuclear weapon. The total amount of spent fuel accumulated worldwide at the end of 1997 was about 200,000 metric tons (MT) and projections indicate that the cumulative amount generated by the year 2010 may surpass 340,000 MT. About 130,000 MT of spent fuel is presently being stored in interim storage facilities awaiting either reprocessing (chemical treatment to separate uranium and plutonium from other constituents of spent fuel) or final disposal. The quantity of accumulated spent fuel is more than twenty times greater than the present total annual reprocessing capacity. Assuming that some of the spent fuel to be generated in the future will be reprocessed, the amount to be stored by the year 2010 is projected to be about 230,000 MT. Since the first large-scale repositories for final disposal of spent fuel are not expected to be in operation before then, the indications are that on-site storage will be the primary option for a long time, each site making a potential target for terrorist attack.[15]

The IAEA recommends that, in addition to guarding nuclear material from theft, physical protection should be designed to prevent sabotage of nuclear facilities, such as spent fuel storage pools and reactors.[16] Current major terrorist threats to physical protection are probably first, the use of stolen nuclear explosive materials against a variety of targets and, second, the attack by a truck bomb or a terrorist-piloted jumbo jetliner against a nuclear reactor or spent fuel.

The devastating consequences of nuclear-explosion terrorism can be visualized from the case of the "conventional" terrorist bombing carried out at the World Trade Center in New York City in 1993. The easiest way to deliver the nuclear bomb would probably be with a truck, the way the 1993 bomb was delivered, not by aircraft – though the September 11, 2001, commercial airliners with full fuel tanks destroyed all 110 stories of the twin buildings. In 1993, the conventional high-explosive truck bomb inside the World Trade Center garage blew a large cavity through several floors above and below the bomb; the ceiling collapsed in the train-station located on the 4th level below grade; and the power plant for the entire complex was knocked out. Six people were killed and over a thousand injured.[17]

Assuming that instead of the jetliners or high explosives, terrorists had used a truck bomb containing a nuclear device made from, say, 40 kg of HEU, the result would have been a nuclear blast equivalent to approximately 15,000 tons of conventional TNT. This blast would have destroyed or severely damaged all buildings in an area of almost three square miles in Lower Manhattan. In addition, large areas of Manhattan would have been contaminated by radioactive fallout, depending on the prevailing meteorological conditions. If such an attack occurred during business hours, the number of immediate casualties would probably exceed 20,000 deaths among the occupants of the building and cause perhaps 120,000 additional immediate deaths among others present in the neighborhood. Delayed health effects would increase this number further over the next several decades. These estimates are extrapolated from estimates of Hiroshima casualties and damage.[18] The number killed would be much higher than the estimate of about 5,000 people killed in the September 11, 2001 terrorist attack on the World Trade Center.

Terrorist attacks with conventional explosives against nuclear power plants, spent fuel in transport, or spent fuel storage ponds are another source of major concern. Given the major increase in truck bomb attacks over the last decade, protection against them should be provided for nuclear reactors and spent fuel storage pools. Conventional high-explosive bombs in a truck, car, or boat were used in several terrorist attacks on U.S. facilities prior to September 11, 2001: the U.S. Marine Barracks in Lebanon (1983), the World Trade Center in New York City (1993), the Federal building in Oklahoma City (1995), the U.S. military housing complex in Dhahran, Saudi Arabia (1996), two American embassies in Africa (1998), and a U.S. naval vessel in a port in Yemen (2000).

In 1984, shortly after the truck-bombings directed against U.S. installations in Lebanon, a study on the truck bomb threat to nuclear power plants was commissioned by the U.S. Nuclear Regulatory Commission (NRC). One conclusion: "Unacceptable damage to vital reactor systems could occur from a relatively small charge at close setback distances, and from larger but still reasonable-sized charges at larger setback distances, greater than the protected area for most plants."[19] This means that a large conventional bomb detonated *outside* the fence barriers surrounding a reactor, under the regulatory standards of that time, might have caused enough damage to lead to a release of radioactivity unless the fence was a considerable distance from the reactor.[20]

In 1993, a depressed man drove his station wagon into the guarded entrance of the Three Mile Island (TMI) Nuclear Generating Station. The station wagon crashed through both a fence and a roll-up door and proceeded 63 feet into a turbine building of the plant.[21] Luckily, the man had no explosives in his station wagon. This incident showed that, given inadequate protection at perimeter barriers including the entrance, the truck-bomb method that has proved so successful in terrorists' practices could also be used to blow up vulnerable parts of a nuclear facility. The lack of strong vehicle barriers and the absence of blast deflection shields at the TMI plant might have resulted in a catastrophe, if the station wagon had carried an "Oklahoma-sized" conventional-explosive bomb.

A 1977 report by Sandia National Laboratories emphasized the need for "stringent access controls and intrusion detection for those areas which contain vital equipment" as the "most efficient and effective means of prevention of sabotage acts which could lead to significant release of radioactive materials."[22] According to a later NRC site-specific environmental impact assessment, if a large truck-bomb explosion had occurred next to the San Onofre nuclear power plant near Los Angeles before new NRC barrier rules were put into effect in 1994, it could have produced up to 130,000 acute fatalities.[23]

The September 11, 2001 attacks have caused great interest in protecting nuclear reactors from targeted hits by aircraft hijacked by terrorists. U.S. power reactors are supposed to be strong enough to prevent dispersion of radioactivity from accidental crashes of aircraft much smaller than the fuel-loaded jetliners that crashed into the Pentagon and World Trade Center.[24] Indeed, after the September 11, 2001 crashes, an IAEA spokesperson said most nuclear power plants were not strong enough to withstand attack by "a large jumbo jet full of fuel" without dispersion of radioactive material.[25] Later, the NRC announced a new review of nuclear power plant security and a spokesperson said: "Nobody conceived of this kind of assault."[26] According to an NRC spokesperson, in the worst-case scenario, such an attack could result in an extended release of deadly radiation, similar to that caused by the 1986 Chernobyl accident.[27] Even so, assuming much better jetliner and airport safeguards in the future, the often-used truck bomb seems more likely to be a future threat to reactors and spent fuel than a jumbo jet full of fuel. Controlling all trucks, vans, sport-utility vehicles, and station wagons to prevent their use by terrorists to bomb nuclear facilities seems much more difficult than preventing jetliner attacks like those of September 11, 2001.

How to protect spent fuel from terrorist attack is also being reconsidered. Spent fuel is usually kept in cooling ponds for a long time after its removal from a reactor. Cooling is essential to prevent it from overheating and possibly dispersing radioactivity to the surrounding area. The 1977 Sandia study suggested effective barriers, such as strong fencing, for the cooling pond because, so long as the pond was not damaged sufficiently to permit its cooling water to escape, the spent fuel would likely withstand attack by saboteurs.[28] An NRC study in 2000 outlined an aircraft crash on a spent fuel pond as a scenario that could damage the pool sufficiently to drain the cooling water and release radioactivity.[29] A recent Russian study suggested consequences from the destruction of a spent fuel pond that would be similar to the explosion of a reactor.[30] A French study of the large spent fuel storage ponds at the La Hague reprocessing plant estimated huge possible releases of radioactive material if terrorists using conventional explosives were able to fracture the cooling-pond walls sufficiently to drain water from a large spent fuel pond.[31] Similar descriptions of possible releases from the British Sellafield reprocessing plant's high-level waste tanks were reported if a hijacked airliner plunged into them.[32]

Threats to blow up nuclear reactors have been voiced in Europe and Russia, as well as the in the United States.[33] Attempts to penetrate nuclear power plants were reported to have taken place in South Korea, South Africa, and Argentina.[34] Recent international recognition of this threat appears in IAEA Information Circular 225, Revision 4 (INFCIRC/225/Rev.4), the IAEA recommendations for physical protection in the absence of any treaty requirement. This 1999 revision added a new chapter on "sabotage of nuclear facilities during use and storage." It begins: "An act of sabotage involving nuclear material or against a nuclear facility could create a radiological hazard to the personnel, and a potential radioactive release to the public and the environment."[35]

At their "Nuclear Summit" in Moscow in 1996, the G-8 countries affirmed,

> the fundamental responsibility of nations to ensure the security of all nuclear materials in their possession and the need to ensure that they are subject to effective systems of nuclear material accounting and control and physical protection.…We recognize the importance of continually improving systems and technologies for controlling and protecting nuclear material.[36]

Such improvements are still needed. This point was recognized again by the September 2001 IAEA General Conference, the meeting of the more than 130 countries that are IAEA members. Meeting after the September 11, 2001 attacks, the Conference welcomed a report of experts drawn from IAEA-member states who recommended that the Convention on Physical Protection be amended to apply to nuclear materials in *domestic* use, storage and transport—*i.e.,* that its application should be expanded beyond its present coverage of materials in *international* transport. The Conference participants then unanimously requested the IAEA to strengthen its "training, guidance and technical assistance" to improve physical protection around the world and urged that it increase its efforts to prevent "acts of terrorism involving nuclear materials and other radioactive materials."[37]

PHYSICAL PROTECTION TRAINING

In 1978, when few courses on physical protection were given besides the nuclear-weapon-state courses for their own nuclear-agency employees, the U.S. Congress called for an International Training Course.[38] What became the leading training course in this area was developed by Sandia National Laboratories. It has been given since 1978 in Albuquerque, New Mexico, with IAEA support and American funding. Fifteen biannual courses have now been given for some 550 participants from around the world. During the last few years, seven regional training courses, serving at least 200 participants, have also been organized by the IAEA. During the same period, the IAEA has also provided six specialized workshops in various countries for some 80 participants. Training manuals have been developed for the International Training Course and these are also used for regional courses. New manuals have been prepared to deal with the changes in IAEA physical protection recommendations contained in INFCIRC/225/Rev.4.[39]

Typically, existing training courses for physical protection emphasize the hardware components (*e.g.,* barriers, sensors, individual-identification and alarm mechanisms, communication- and data-analysis systems). However, equally important for training are recognition and analysis of the dangers of proliferation and the threats to nuclear materials, some of which are described above, but which are rarely covered in these training sessions. Current courses also fail to include analysis of how security improvements can be sustained over multi-year periods or how human factors, such as motivation and the effects of stress, can effect the performance of guard forces in crisis situations.

In addition to recommending amendment of the Convention on Physical Protection, the group of experts that reported to the 2001 IAEA General Conference provided recommendations on training for physical protection, a subject that the group had studied for the previous two years. They pointed out the absence of national training courses in most countries, the need to initiate training to address the threat of sabotage of nuclear facilities, and the growing danger of theft of weapons-usable material. In addition, they urged training programs be implemented to address the risk of sabotage to nuclear land transportation of both unirradiated nuclear material and spent nuclear fuel. They also argued that existing courses needed to be taught more frequently and in more locations and that a curriculum for "graduate security training" should be developed. Finally, they urged the IAEA to provide "physical protection familiarization for policy makers (managers)."[40]

During their 1999-2001 meetings, some experts from developing countries had privately described the difficulties they had had in gaining budget appropriations from their governments for strengthened protection of nuclear facilities for which they had responsibility. Without any international requirements for such protection, they said, they could not gain approval of national statutes or regulations requiring stronger protection.[41] The experts' suggestion for a short course to familiarize policy makers with the need for protection against sabotage and theft clearly stemmed from such concerns.

The IAEA Secretariat's report to the September 2001 General Conference responded to the experts' recommendations by urging expanded training activities, and, in particular, the development of a course entitled: "An Introduction to Physical Protection for Policy Makers and Facility Managers."[42]

Training in the former Soviet Union

Since the mid-1990s, the Russian Ministry of Atomic Energy (Minatom) has taught specialized courses concerning MPC&A at the Russian Methodological Training Center at the Institute of Physics and Power Engineering (IPPE, Obninsk) and the Minatom Institute for Professional Education (MIPE Atomenergo, Moscow). In addition, in 1999, the Moscow State Engineering and Physics Institute (MEPhI) initiated an academic training program in MPC&A. The first graduate degrees have been awarded within this program. Kazakhstan and Ukraine have also begun courses that deal in part with physical protection:

- Unlike the IAEA International Training Course, the courses offered by the Russian institutions, IPPE, MIPE or MEPhI, are not focused exclusively on physical protection, but include it in the framework of a larger training program on MPC&A. This situation is understandable because, as a Nuclear Weapon State under the NPT, Russia has no obligation to accept IAEA safeguards, which rely on material control and accounting—the "control and accounting" (or C&A) of MPC&A. In Russia, physical protection lectures are given as a sub-unit of the MPC&A course given by IPPE. An MPC&A course recently begun in the Ukraine is also focused more on control and accounting than physical protection. The threats discussed are usually theft of material, not terrorist attacks on nuclear reactors or spent fuel.
- All the Russian and Ukrainian institutions are in considerable part dependent on external financial assistance for equipment and operational costs for physical protection training (*e.g.*, funding from the United States, the IAEA, or the European Union). Although there is interest and need for training more students in physical protection (*e.g.*, MEPhI is seeking to double its current number of 12-15 students per year), lack of adequate finances severely limits any significant expansion of the current physical protection related training programs.
- All teaching institutions rely—in varying degrees—on external professional assistance from foreign physical protection experts for training instructors and conducting lectures and exercises (*e.g.*, by using lecturers from Sandia National Laboratories; the Center for International Trade and Security (CITS) of the University of Georgia, USA; and the Center for Nonproliferation Studies (CNS) of the Monterey Institute of International Studies.) Typically, these outside lecturers are funded by the United States and they try to show what the proliferation of nuclear weapons to additional countries might mean to Russia, Kazakhstan, or Ukraine; which countries or terrorists might be seeking weapon-usable material and why; and what the motivations of thieves and terrorists might be. These are subjects often not taught by scientists or engineers in standard physical protection courses.[43]
- The technological standard of the hardware used at these training courses is very heterogeneous and does not necessarily reflect state-of-the-art in physical protection technology.
- The outreach of the Russian institutions to other republics of the former Soviet Union is limited, *i.e.*, the need to create relatively quickly a cadre of physical protection experts for other republics is not assured, because the graduates from other republics tend to stay in Russia.
- Due to the high demand for well-trained security specialists in non-nuclear industries with a high level of operational security (e.g. financial institutions, energy production, information technology industries) a significant number of trainees find employment at these non-

nuclear facilities upon completion of their training on physical protection.[44]

We believe that physical protection training in Russia, Kazakhstan, and Ukraine requires increased funding to pay for more courses and more students. In the past, the United States and European Union countries have provided such financial assistance, mostly to Russia. If more funds are provided, the donors could be persuasive in urging course improvements, one of which should be increased emphasis on terrorist threats to nuclear facilities, not just the dangers of theft for nuclear material.

Training is also essential to ensure the sustainability of improvements in physical protection in Russia, Kazakhstan, and Ukraine. If the personnel who provide physical protection are not trained in the potential threats to their nuclear material and on how to maintain and operate the new protection equipment and barriers to deal with those threats, the millions of dollars invested in improved MPC&A in Russia may not result in long-term improvement.

This conclusion is supported by two experts on Russian physical protection at CNS, William C. Potter and Fred L. Wehling. They have taught material security in Russian courses or workshops, and been responsible for research on this subject related to Russia. They argue that the "most difficult and important component" of "sustainability" for nuclear material security in Russia is

> [t]he transformation of the attitudes and "mind-sets" of nuclear workers, guards, and administrators. The history of the U.S. material safeguards [meaning physical protection as well as accounting and control] shows that this had been a difficult challenge in the United States. The task of building a safeguards culture [including physical protection] in Russia will be at least as difficult. Although much of this work force has acquired excellent technical skills…, only a small percentage has more than a vague understanding of why safeguards [including physical protection] and nonproliferation are vital to Russian and international security.[45]

As these two see it, expanded and continued education on nuclear proliferation and the reasons for effective physical protection and safeguards are essential to sustainability.[46] Financial assistance to this end should be continued and expanded.

A poll of Russian experts taken by researchers from the CITS of the University of Georgia, who have taught in Russian MPC&A courses, came to similar conclusions. The participants in the poll were ninety high-level and mid-level managers with MPC&A responsibilities. The poll asked these Russians to weigh the relative importance in building a security culture of six factors relating to MPC&A personnel: systematic training, well articulated regulations/instructions, skills and knowledge, sense of personal responsibility, effective personnel-equipment interface, and guards. The poll showed that the participants believed that skilled personnel, the provision of regular training, and clear security regulations were the most important of the six factors for developing a better security culture.[47] Regular training is clearly important to that end.

Training in the United States: The International Training Course

The most important objective of the Sandia International Training Course (ITC) supported by the IAEA and funded by the United States is to teach professionals how to design and evaluate a physical protection system. It now focuses on the relationship between the design of a system and the likely threats it will face. When it is taught again, it will cover threats of sabotage to nuclear reactors as well as threats of theft to nuclear material. The course describes typical system objectives based on the expected threats, the system characteristics to meet these threats, and the quantifiable or other methods for assessing the effectiveness of such a system.[48] The course takes three weeks and includes lectures, subgroup exercises, field trips to inspect equipment and security installations, and a final exercise in which small working groups design a system and evaluate its ability to meet the threats it was designed to address.[49] The strength of this course is the systematic treatment of physical protection of nuclear material, covering the whole range of topics from threat perception to technical countermeasures.[50]

Acknowledging the pioneering character of this course, it could continue to serve as a model for state-of-the-art didactics and training in the future by making the following changes:

Evaluation of student achievement. Due to the wide range of technical background, experience and ability to understand English, it is not considered essential that all of the course material be mastered by all participants. This approach implicitly prohibits any objective assessment of the effectiveness of the know-how acquired by the trainee during the course. Although students are given several exercises and tasks to fulfill during the course, the evaluation of the level of expertise acquired by the trainee is given a relatively low priority. The introduction of modern integrated achievement evaluation procedures could provide a valuable record for both the trainee and the trainer on the individual achievement and potentially remaining gaps. This would also upgrade the value of attending the ITC course for trainees upon return to their home institutions by being upgraded from a mere "certificate of attendance" to a "certificate of graduation," including a score sheet. It is essential that such an evaluation should take into account both the theoretical and practical problem-solving skills obtained during the course.

Integration of "human" into the material-facility approach. Of the approximately 30 lectures given in this course, about 23 focus on design/characterization and operation of a physical protection system. It is thus primarily a technical training course at present. As some of the Russian courses described above have already begun to do, the International course should add lectures on the international security issues underlying threats to nuclear material, on the potential consequences of proliferation may be, on stress management in crisis situations, and on ergonomics. On the last point, the course should enlarge the current integrative approach to physical protection from "material-facility" to "man-material-facility." This addition would require extending the course for several more days.[51]

Pedagogy and Didactics. The course is taught in a conventional manner in English, using a proven system of mostly up-front tutorial presentations, supplemented by scripts, hands-on experiences, and field trips. The introduction of innovative pedagogy and modern didactics could provide an added value to the effectiveness, with which expert know-how is transmitted to the trainees who have a diverse educational and cultural background and varying knowledge of the English language. Such a new approach should include *inter alia:* the additional provision of self-paced tutorials on selected topics on CD-ROM in several of the major languages spoken by trainees; the development of a web-based distance learning program with optional video-conferencing; the provision of educational resource databases; the increased use of computer-based interactive simulation training games.

Specialization. The course is based on a training curriculum developed by technical physical protection experts from the Sandia National Labs. Its training is intended primarily for individuals engaged in the design of new physical protection systems, and the evaluation or management of existing systems. Additional specialized course curricula could be tailored to meet the specific requirements of other target groups, such as operators, security guards, response forces or policymakers/managers. As a matter of fact, in some countries the policymakers/managers decide who should come to ITC, and they sometimes choose to come themselves rather than to send personnel who actually design physical protection systems. Perhaps if new short courses were provided for policymakers/managers, more designers would come to the ITC.

Accreditation. The value of the course is fully acknowledged by the U.S. Department of Energy and the IAEA. Nevertheless, its international recognition would be further strengthened if it were accredited by a recognized "international physical protection advisory board" or similar institution, consisting of international experts from academia, research, industry, and regulatory agencies. The experts from many countries convened by the IAEA from 1999 to 2001 to consider whether to amend the Physical Protection Convention recommended the creation of an IAEA expert advisory committee for all IAEA work on physical protection.[52] Such a committee has not yet been created, but, if it is, its review of training courses could be useful.[53]

Internationalization. The international dimension of physical protection training is reflected in the course by the use of foreign experts and by dedicating one session to non-U.S. approaches to physical protection. The course discusses and demonstrates equipment from Germany, Israel, Japan, and the United States, among others. Upon return to their home institutions, some international trainees may help design or revise physical protection systems using Russian or other hardware not demonstrated during the course. The presence and use of equipment reflecting the products of the national industries of the trainees would obviously be helpful when they returned home, but adding more equipment would increase costs unless the equipment manufacturers were prepared to provide the equipment without cost.

Maintenance and sustainability. Maintenance of equipment and sustainability of practices are not taught at the International course. Some such training is covered when courses are taught at the sites where the actual hardware and software are put into practice.[54]

At present there is no other teaching to follow-up on the initial training provided during the course; for example, continuing education on new developments. If a "material security" culture is to be developed in order to sustain effective protection over a long period of time, short refresher courses that deal with new developments should be added.[55] A way of doing that will be available soon between Russia and the U.S. in interactive software and distance learning via the Internet.[56] Refresher and "new developments" courses, and perhaps, one day, the course itself could be provided in several Russian cities, and eventually elsewhere.

Adoption of our recommendations would cost money. The U.S. has provided the largest share of the money spent on training for the IAEA for the ITC, for regional courses and for some of the other training courses. On the whole, this has been money well spent. Contributions to sustainability of physical protection practices and therefore to preventing nuclear proliferation and nuclear terrorism would seem to make the expenditures clearly worthwhile.

Current IAEA training

As discussed above, training was an important subject for many country experts convened by the IAEA from 1999 to 2001 to consider amending the Convention on Physical Protection. These experts asked the IAEA for a report on the training it sponsored, and they recommended adding subjects such as sabotage to the current training, providing training to more areas of the world, and establishing new specialized courses including a new short course for policymakers/managers.[57]

Besides its involvement in the ITC, the IAEA has also offered regional courses for countries in three regions. The first, for Eastern Europe, the Caucasus and Central Asia, has been given four times in Russian and English in the Czech Republic. The second, for Latin America, has been given once in Argentina and is in Spanish and English. The third, for Southeast Asia, the Far East, and the Pacific, has been given in China twice and is in Chinese and English. Like the International Training Course, these courses are intended primarily for the designers of physical protection systems. In the last few years, the IAEA also organized a one-time national training course in China, and a number of workshops on specific physical protection problems in Ukraine and Kazakhstan for their nationals, and in Cyprus for nationals of Middle Eastern and North African countries. The IAEA recognizes the need for more courses in more regions, but additional funds and additional teachers must be found.[58]

RECOMMENDATIONS

This report has referred to research showing major differences from country to country in the levels of physical protection they provide. It has set forth reasons why stronger physical protection is needed around the world. It has described the important courses now provided for physical protection and argued that such training is essential to the effectiveness and sustainability of physical protection.

To focus on what should be done in the future to improve physical protection training internationally, a workshop was organized at Stanford on March 30, 2001, by the Stanford University Center for International Security and Cooperation. Representatives took part from the IAEA, from two of the U.S. national laboratories responsible for aspects of physical protection (Lawrence Livermore and Sandia National Laboratories), and from two of the U.S. academic institutions that have been involved in physical protection training in Russia (CITS of the University of Georgia, and CNS of the Monterey Institute of International Studies). At the meeting it was emphasized again by the IAEA representative that the physical protection training program of the IAEA has two main objectives: to establish a "trained cadre of expert personnel with an understanding of the need to protect nuclear materials from theft, and nuclear materials and facilities from sabotage;" and to teach "how to implement the necessary measures" to achieve improved physical protection.[59]

We acknowledge the importance of the IAEA goals and its past efforts. Based on the discussions at the our meeting, the following plan is proposed:

- Establish an *International Advisory Board* to the IAEA to review the existing physical protection curricula, to advise on possible improvements, and to identify future training needs. This board could provide the service of indirect international "accreditation" of physical protection training courses by defining course criteria (see below). The Experts' meeting at the IAEA has already recommended that a physical protection advisory board be established for other purposes.[60]
- Increase the number of institutions providing physical protection training by establishing IAEA *Regional Physical Protection Training Centers.* Such centers would have to fulfill certain criteria in terms of the cur-

ricula, equipment, staff expertise, and on-site logistics as prescribed by the International Advisory Board.

• Establish new *specialized physical protection training courses*, such as a course focusing on "design-basis threat"[61] and a course specializing in protection against sabotage to nuclear reactors and spent fuel, as well as theft or sabotage of nuclear material.[62]

• Inaugurate national *graduate-degree programs* in physical protection to produce the necessary expertise to design and maintain a high quality national physical protection system. At least one such initiative has begun at MEPhI in Russia and several others have been proposed at universities in South Africa, the Ukraine and the United States.

• Explore the possibilities of using distance learning via the Internet for teaching—starting with refresher and new-developments courses.

• Prepare the curriculum for an *Introductory Course On Physical Protection for Policy Makers*. The need for such a course was identified by the group of country experts convened by the IAEA from 1999 to 2001; some details about what it might include are provided next.

Proposed course for policymakers

The objective of this course would be to create an intrinsic understanding of the need for adequate physical protection. The course should provide participants with an understanding of a state's obligations under existing international standards for physical protection, as well as the basic requirements for establishing and maintaining a suitable national physical protection program. The course should be directed primarily towards three target groups:

• Representatives of national government agencies responsible for, or participating in, national decisions regarding budgetary allocations and regulations or statutes for physical protection. At the course, representatives of developing countries would hear arguments as to why national efforts in strengthening physical protection are warranted; representatives of industrialized countries would be provided with information related to the threats pertinent to their own countries, including threats originating from inadequate physical protection in other countries;

• Individuals deciding on the selection of future trainees among the national operators and designers of physical protection systems for attending future physical protection training courses; and

• Representatives of the media responsible for informing the public about the need to provide an adequate national physical protection program. In this manner policy-makers would receive an opportunity to convey the reasoning for increased efforts in physical protection to their political constituencies.

The one-day course should address the following subject areas:

(1) A brief description of the recent history of threats around the world to nuclear material and facilities, including current information on the possible threats from terrorists, not just to weapons-usable material but also to reactors and spent fuel.

(2) An exchange of views as to whether these threats are applicable in the countries or regions from which the course participants come. For example, for years there did not appear to be any significant threat that insiders in the Soviet Union would steal weapons-usable material or assist outsiders in doing so. But, two years ago, a Russian report on the thefts from Russian civil nuclear facilities over a five-year period in the early 1990s suggested that all thefts known to the Russian regulatory agency, Gosatomnadzor, had been the work, at least in part, of insiders.[63] The changes from Soviet times including reduced fear of authority and inadequate payment of salaries, among other things, had produced dramatic changes in the kinds of threats faced by Russian nuclear facilities.

(3) A general description of physical protection systems and how they relate to material accounting and control systems. This should describe what each kind of system attempts to contribute to preventing theft of nuclear material.

(4) A demonstration of a terrorist attack on a generic nuclear facility such as a nuclear reactor and an insider theft of nuclear material from a generic storage facility, both illustrated by a "virtual walk-through" computer model. Some national labs now use computer models to help demonstrate physical protection. But the models are much more complex than we have in mind, because their most important purpose is to evaluate existing physical protection systems, not to teach students.

(5) Estimates of the costs of improving these facilities if they prove unable to prevent the attack or theft in the demonstration. This estimate should include a discussion of the international assistance program run by the IAEA that can recommend improvements which can be paid for by the United States and a few other coun-

tries. This program is the International Physical Protection Advisory Service (IPPAS), which has not received as many requests for advice by experts and financial assistance in remedial efforts as were expected when it was set up.[64] A training course for policymakers might change that.

(6) A description of the international norms for physical protection of facilities such as the generic facilities shown in the demonstration. Included would be a discussion of some of applicable standards from, and the design basis threat approach in INFCIRC/225/Rev.4. Also included should be a brief reference to the Physical Protection Convention referring to the negotiations to revise it to be applicable domestically, not just for international transport of nuclear materials.

(7) A discussion of typical legislation and/or regulations adopted to meet the recommendations of Revision 4, providing time for participants to discuss how these compare with that on the books in their countries.

To be accepted around the world, such a course should take place under the auspices of a dedicated international organization, such as the IAEA.

CONCLUSION

Many multilateral efforts have been useful in improving controls over nuclear materials in the past, ranging from IAEA physical protection recommendations and IAEA NPT-safeguards requirements to a collaborative program on illicit trafficking between IAEA, INTERPOL and the World Customs Organization. Yet stronger physical protection practices are badly needed all over the world. Improved training is a key part of the efforts to strengthen physical protection described in the unanimous recommendations of the IAEA General Conference following the September 11 attacks. Training is essential to an understanding of what kinds of threats nuclear materials may face, how protection systems should be designed to meet these threats, and how these systems should be operated and maintained if costly improvements are to be sustained into the future. Just as important is training on how reactors and spent fuel should be protected from terrorist attack. Though such an attack would have less serious consequences than a nuclear explosion, it may be more likely to happen and it could produce a Chernobyl-like dispersion of radioactive materials over areas with major populations.

[1] Kevin J. Harrington, *Physical Protection of Civilian Fissile Material: National Comparisons* (Albuquerque, NM: Sandia National Laboratories, 1999), pp.4, 64-66; George Bunn, "Raising International Standards for Protecting Nuclear Materials from Theft and Sabotage," *Nonproliferation Review* 7 (Summer 2000), p. l46; George Bunn, Fritz Steinhausler and Lyudmila Zaitseva, "Strengthening Global Practices for Protecting Nuclear Material from Theft and Sabotage," Proceedings of 42nd Annual Meeting of the Institute for Nuclear Materials Management, Indian Wells, CA, July 15-19, 2001.

[2] See Bonnie D. Jenkins, "Establishing International Standards for Physical Protection of Nuclear Material," *Nonproliferation Review* 5 (Spring-Summer 1998), pp. 98,102; Bunn, "Raising International Standards," p. 149.

[3] See, for example, George Bunn and Fritz Steinhausler, "Guarding Nuclear Reactors and Material from Terrorists and Thieves," *Arms Control Today* 31 (October 2001), pp. 8-9.

[4] See U.S. General Accounting Office, *Nuclear Proliferation: Security of Russia's Nuclear Material Improving: Further Enhancements Needed*, GAO-01-312, February 2001; Secretary of Energy Advisory Board, U.S. Department of Energy, *A Report Card on the Department of Energy's Non-Proliferation Programs with Russia,* January 10, 2001, < http://www.hr.doe.gov/SEAB/>; "Special Report: Assessing U.S. Nonproliferation Assistance to the NIS," *Nonproliferation Review* 7 (Spring 2000), pp.55-125; Oleg Bukharin, Matthew Bunn, and Kenneth Luongo, *Reviewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Princeton, NJ: Russian American Nuclear Security Advisory Council, 2000); IAEA Secretariat, "Bilateral Physical Protection Support," Secretariat Paper No. 15 for Working Group of Expert Meeting on Whether to Revise the Convention on Physical Protection of Nuclear Material, Vienna, Austria, November 2000.

[5] See, e.g., J. Carson Mark, Theodore Taylor, Eugene Eyster, William Maraman, and Jacob Wechsler, "Can Terrorists Build Nuclear Weapons?" in Paul Levanthal and Yonah Alexander, eds., *Preventing Nuclear Terrorism* (Lantham, MD: Lexington Books, 1987), pp 55-65; U.S. Department of Energy, *Nonproliferation and Arms Control Assessment of Weapons-Usable Material Storage and Excess Plutonium Alternatives* (Washington, DC: U.S. Department of Energy, 1997), pp. 35-39; "U.S. Indictment: 'Detonated an Explosive Device,'" *New York Times*, November 5, 1998, p. A-9; Benjamin Weiser, "U.S. Says Bin Laden Aide Tried to Get Nuclear Weapons," *New York Times,* September 26, 1998, p. A3; "Responsibility for the Terrorist Atrocities in the United States, 11 September 2001," *New York Times* October 5, 2001, p. B-4.

[6] U.S. Department of Energy, *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material,* p. vii. Critical-mass estimates for weapons-useable plutonium and HEU given in the text, based on IAEA conclusions, are much higher than the "several" kilograms of plutonium and the "several" times that for HEU specified for weapons-grade materials given by the U.S. Department of Energy in the publication just cited. Uranium 80 percent enriched in the isotope U-235 is sometimes classified as weapons-grade uranium. A bomb made from 20 percent enriched uranium would be heavier than one made from 80 percent enriched uranium. See the discussion later in the text of possible terrorist use of a nuclear weapon against the World Trade Center. See also, e.g., Gavin Cameron, *Nuclear Research*, *Nuclear Terrorism: A Threat Assessment for the 21st Century* (New York: St. Martin's Press, 1999), p. 131-32; Jessica Stern, *The Ultimate Terrorists* (Cambridge, MA: Harvard University Press, 1999), pp. 28-29.

[7] See C.W. Forsberg, C.M. Hopper, J.L. Richter, and H.C. Vantine, "Definition of Weapons-Usable Uranium-233," Oak Ridge National Laboratory, 1998, p. 7. While focused on U-233, this paper states that uranium that is 20% or more enriched in U-235 is weapons-usable.

[8] David Albright and Lauren Barbour, "Separated Inventories of Civil Plutonium Continue to Grow," *ISIS Plutonium Watch* (Washington: Institute for Science and International Security, 1999), pp. 2-3.

[9] Arjun Makhijani, "A Global Truth Commission on Health and Environmental Damage from Nuclear Weapons Production," *Science for Democratic Action* (Institute for Energy and Environmental Research Newsletter), February 9, 2001.

[10] IAEA, *Nuclear Research Reactors in the World,* IAEA-RDS-3 (Vienna: IAEA, 1997); Iain G. Ritchie, "Growing Dimensions: Spent Fuel Management at Research Reactors," *IAEA Bulletin* 40 (March 1998), <http://www.iaea.or.at/

worldatom/Periodicals/Bulletin/Bull401/article7.html>. These figures do not include much of the HEU in Russian reactors, because much of it is not reported to the IAEA. Specifically, they do not include stored HEU, *i.e.*, HEU not in research reactors. From personal experience, one of the authors believes this quantity of HEU to be significant, especially for a research reactor in regular use.

[11] Many research reactors are at universities and similar research facilities that are not accustomed to worrying about saboteurs and thieves. Their security has traditionally seemed weaker than that of government facilities. Although, according to a study by a nongovernmental watchdog group, security at U.S. nuclear weapons research and production facilities also leaves something to be desired. About half of recent security drills carried out at 10 U.S. weapons complex facilities failed, allowing mock terrorists to penetrate the facilities and, in several cases, to escape with enough weapons-usable material to make weapons. See Stephen J. Hedges and Jeff Zeleny, "Mock Terrorists Breached Security at Weapons Plants," *Chicago Tribune*, October 5, 2001.

[12] "More Wreck Than Reactor," *Financial Times*, August 21, 1999, p. 8.

[13] This assessment is based on personal observations of the authors.

[14] Eric van Staten, "Two Strangers Were Caught with False Identities," *De Telegraaf* (Amsterdam), September 28, 2001.

[15] Peter Dyck and Martin J. Crijns, "Management of Spent Fuel at Nuclear Power Plants," *IAEA Bulletin.* 40 (March 1998), <http://www.iaea.org/worldatom/Periodicals/Bulletin/Bull401/article6.html>.

[16] INFCIRC/225/Rev.4, <http://www.iaea.org/worldatom/program/protection/inf225rev4/rev4_content.html>.

[17] Port Authority of New York and New Jersey, <http://members.aol.com/fd347/wtc.html>.

[18] See Samuel Glasstone and Philip Dolan, *The Effects of Nuclear Weapons* (Washington, DC: U.S. Department of Defense, 1977); J. Carson Mark, "Nuclear Weapons: Characteristics and Capabilities," in Ruth Adams and Susan Cullen, eds., *The Final Epidemic: Physicians and Scientists on Nuclear War*, (Chicago: University of Chicago Press, 1981).

[19] Nuclear Regulatory Commission (NRC) Staff report to NRC on the results of a 1984 Sandia National Laboratories study. See NRC Weekly Information Report to NRC Commissioners, April 20, 1984, enclosure E, p. 3.

[20] Sandia National Laboratories, "Investigation of Truck Bombs Threats at Nuclear Facilities," unpublished report, 1984. See also Sandia National Laboratories, *Summary Report of Workshop on Sabotage Protection in Nuclear Power Plant Design,* SAND76-0637, UNREG-0144 (1977).

[21] For details of this incident, see the website of the Three Mile Island Alert Security Committee, <http://www.tmia.com/intrude.html>.

[22] See Sandia National Laboratories, *Summary Report of Workshop on Sabotage Protection*, pp. 18, 28.

[23] U.S. Nuclear Regulatory Commission, *Supplement to Draft Environmental Statement, San Onofre Units 2 and 3,* NUREG-0490 (1981), explained in Sandia National Laboratories, "Analysis of Truck Bombs Threats."

[24] See Sandia National Laboratories, *Summary Report of Workshop on Sabotage Protection,* p.5.

[25] See William J. Cole, "Global Atomic Agency Confesses Little Can Be Done to Fix Nuclear Plants," Associated Press, September 19, 2001.

[26] Peter Behr, "Security of Nuclear Power Plants under Review," *Washington Post*, Sept. 26, 3001, p. A8.

[27] See Marc Schogol, "Security at Nuclear Plants Gets Another Look," *Philadelphia Inquirer*, October 9, 2001.

[28] Sandia National Laboratories, *Summary Report of Workshop on Sabotage Protection,* pp.29, 31.

[29] See Paul Choinere, "Officials Taking a Second Look at Vulnerability of Nuke Plants," *The Day* (New London, Connecticut), September 19, 2001.

[30] Lyudmila Zaitseva, "Reaction of Nuclear Regulatory Authorities to Airborne Terrorist Attacks: An International Overview," Stanford Center for International Security and Cooperation, unpublished working paper summarizing foreign press reports, October 1, 2001, p.7.

[31] Xavier Coeytaux, Yacine Faid, Yves Marignac and Mycle Schneider, "La Hague Particularly Exposed to Plane Crash Risk," Wise Paris, September 26, 2001, p.5, <http://www.wise-paris.org/english/ournews/news2.html>.

[32] Rob Edwards, "This Week: The Nightmare Scenario," *New Scientist*, October 13, 2001, p. 10.

[33] Oleg Bukaharin, "Problems of Nuclear Terrorism," *The Monitor: Nonproliferation, Demilitarization and Arms Control* (Spring 1997), p.8 (summary of a longer report for the Congressional Research Service). See also Oleg Bukharin, "Upgrading Security at Nuclear Power Plants in the Newly Independent States", *Nonproliferation Review* 4 (Winter 1997), p. 28.

[34] Three Mile Island Alert Security Committee, <http://www.tmia.com/sabter.html>.

[35] INFCIRC/225/Rev.4, par. 7.1.1., <http://www.iaea.org/worldatom/program/protection/inf225rev4/rev4_content.html>.

[36] Moscow Nuclear Summit of April 1996, INFCIRC/509, <http://www.iaea.org/worldatom/Documents/Infcircs/1996/inf509.shtml>.

[37] See IAEA General Conference, September 20 2001, Resolution GC(45)/L.8, <http://www.iaea.org/worldatom/Press/Statements/2001/html>.

[38] Nuclear Non-Proliferation Act of 1978, Section 202.

[39] IAEA, Secretariat Paper No. 9 for Working Group, *IAEA Physical Protection Training Programme* (2000).

[40] *Final Report of the Working Group*, par. II.2.4 and Attachment 5.

[41] *Final Report of the Working Group,* par. II.4.1 and interviews with some of the Experts.

[42] Security of Material Programme, Plan of Activities, p.3, Attachment to Gov/2001/37-GC(45)/20,
<http://www.iaea.org/worldatom/About/Policy/GC/GC46/Documents/gc45-28.htm>.

[43]See William C. Potter and Fred L. Wehling, "Sustainability: A Vital Component of Nuclear Material Security in Russia," *Nonproliferation Review* 7 (Spring 2000), pp.180, 184-85.

[44] Except for the preceding endnote, the information in these paragraphs was obtained from interviews by the authors with instructors at the Russian institutes.

[45] Potter and Wehling, "Sustainability," pp. 180, 184-85.

[46] Ibid.

[47] Igor Khripunov, Masha Katsva, and Terrell Austin, "Working Towards a Security Culture in Russia: The Human Factor in MPC&A," *The Monitor*: *International Perspectives on Nonproliferation* 7 (Spring 2001), pp. 10, 12.

[48] James Blankenship, *Center of Excellence for Physical* P*rotection Systems*, (Albuquerque: Sandia National Laboratories, 2001), p. 3.

[49] Sandia National Laboratories, *Physical Protection System Design* (Albuquerque: Sandia National Laboratories, n.d.).

[50] A new textbook has just been published for the International Training Course (ITC) and similar courses based upon Sandia National Laboratories' experience in running the ITC. Sandia National Laboratories, *The Design and Evaluation of Physical Protection Systems* (Wohburn, MA: Butterworth-Heinemann, 2001).

[51] Arian Pregenzer, Interview by authors, Sandia National Laboratories, Albuquerque, NM, May 23, 2001.

[52] *Final Report of the Working Group,* par.III.D.

[53] The Director General of the IAEA has taken this recommendation under advisement and the 2001 General Conference simply noted that he had done so. See IAEA General Conference resolution GC(45)/L.8.

[54] Arian Pregenzer, Interview by authors, Sandia National Laboratories, Albuquerque, NM, May 23, 2001.

[55] Potter and Wehling, "Sustainability," pp. 184-87.

[56] Ibid., p.185.

[57] *Final Report of the Working Group,* par.II.2.4 and Attachment 5.

[58] See IAEA Secretariat, Paper No. 9, "*IAEA Physical Protection Training Programme*," pp. 5-6.

[59] Mark Soo Hoo, "Presentation to Meeting at Stanford University, March 2001," quoted in George Bunn, "Summary of Coordination Meeting: Training in Physical Protection of Nuclear Material," Stanford University Center for International Security and Cooperation, Stanford, CA, March 2001, pp. 5-7.

[60] *Final Report of the Working Group,* par. II.2.3.

[61] INFCIRC/225/Rev.4 emphasizes designing and evaluating physical protection systems based upon the current threat that is possible to a given system (performance-based), instead of evaluating a system based upon meeting prescribed regulations or recommendations (compliance-based).

[62] Earlier versions of INFCIRC/225 had focused on protecting weapon-usable material from theft. New concerns about terrorists using conventional explo-

sives to attack reactors or spent fuel storage facilities produced new attention to sabotage in INFCIRC/225/Rev.4.

[63] Irina Koupriyanova, "Russian Perspectives on Insider Threats," Proceedings of the 40th Annual Meeting, Institute of Nuclear Materials Management, Phoenix, Arizona, July 25-29, 1999.

[64] For a discussion of IPPAS, see "Guidelines for IAEA International Physical Protection Advisory Service (IPPAS)," IAEA Service Series No. 3, February 1999, <http://www.iaea.org/worldatom/program/protection/guideline.html>.