Appendix 10D. Efforts to improve nuclear material and facility security

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I. Introduction

International efforts to strengthen the physical protection of nuclear materials and facilities from theft and sabotage have been intensified in the aftermath of the attacks carried out in the United States on 11 September 2001. However, the magnitude of the changes that are needed to protect against terrorist attacks of that nature has not yet been widely appreciated, perhaps in part because of beliefs in some states that what happened in the USA 'can't happen here'. This appendix provides evidence that, in other countries, terrorists and thieves have already threatened or attacked nuclear facilities and tried to purchase or steal nuclear and other radioactive material. Section II of this appendix summarizes the relevant features of the 11 September attacks and the measures taken prior to that date to protect nuclear facilities against sabotage, as far as is known publicly. Section III discusses the illicit traffic in the nuclear and other radioactive materials that might be used by terrorists. Section IV addresses international efforts to improve the physical protection of such materials in both military and non-military contexts.

II. The attacks of 11 September and threats to nuclear facilities

The attacks of 11 September suggest that the threat to nuclear facilities is more complex than many states contemplated when they were built. Data published by the International Atomic Energy Agency (IAEA) show that there are at least 284 research reactors in 55 countries and 472 power reactors (operating or under construction) in 31 countries.[1] Since there is no multilateral treaty requiring physical protection of these facilities or the nuclear material used or stored for use by them, variations from state to state on how they are protected are to be expected.[2] Even in wealthy industrial countries, such as the USA, with many nuclear facilities and well-established regulatory systems, non-governmental organizations have long complained that civilian nuclear reactors are not adequately protected against truck bombs, much less against

[1] International Atomic Energy Agency (IAEA), *Nuclear Power Reactors in the World,* Reference Data Series no. 2 (1999), table 1; and IAEA, *Nuclear Research Reactors in the World*, Reference Data Series no. 3 (2000), table 1. Much of these data are available at URL <http://www.iaea.org/worldatom/rrdb/shtml>.

[2] The only multilateral treaty providing any standards for physical protection is the 1980 Convention on the Physical Protection of Nuclear Material (CPPNM). IAEA document INFCIRC/274/Rev 1, Add. 7, 22 Sep. 2000, available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf274r1a5.shtml>. It does so only for civilian nuclear material while in *international* transport, or in storage pending or after international transport, not for any material in *domestic* use, storage and transport. The IAEA is the depositary for the CPPNM. Article 1 (a) defines 'nuclear material' as 'plutonium except that with isotopic concentration exceeding 80% in plutonium-238; uranium-233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore residue; any material containing one of the foregoing'.

large airliners loaded with fuel.[3] A US Nuclear Regulatory Commission (NRC) technical report on a reactor to be located not far from a populated area listed possible worst-case power reactor accident scenarios such as sabotage might produce. It concluded that over 100 000 people could eventually die from the health effects caused by the radioactivity dispersed as a result of one such accident.[4] Moreover, research reactors tend to be less well protected than power reactors but more likely to contain weapon-usable highly enriched uranium (HEU).[5]

Reports from Russia suggest that, in general, protection practices for weapon-usable materials vary and need strengthening at some installations.[6] The IAEA experts who helped 10 smaller states, mostly in Eastern Europe, strengthen their physical protection practices said that the protections they found varied from state to state: 'Differences in culture, perceived threat, financial and technical resources and national laws are some of the reasons for variations'.[7] A survey of physical protection practices made in 1997 by the Sandia National Laboratories (SNL) in cooperation with Stanford University showed that only 11 of 19 respondent states reported that their security was designed to deal with terrorists or saboteurs.[8] Responses from 6 states to a Stanford University questionnaire in 2001 showed that none of them had planned protection against an attack involving truck bombs that 'spreads radioactive material over and beyond the protected area', for example, the fenced-in area around

[3] See, e.g., Hirsch, D., 'The truck bomb and insider threats to nuclear facilities', eds P. Leventhal and Y. Alexander, *Preventing Nuclear Terrorism* (Lexington Books: Lexington, Mass., 1987), p. 207; and Bunn, G., Steinhausler, F. and Zaitseva, L., 'Strengthening nuclear security against terrorists and thieves through better training', *Nonproliferation Review* vol. 8, no. 3 (2001), pp. 139–41. For recent calls by a non-governmental organization for higher protection standards for reactors in the USA, see the Internet site of the Nuclear Control Institute, URL <http://www.nci.org>. It includes a number of links to warnings and discussions concerning possible plans by the al-Qaeda network to use airliners to dive on nuclear reactors.

[4] US Nuclear Regulatory Commission, 'Supplement to Draft Environmental Statement Related to the Operation of San Onofre Nuclear Generating Station, Units 2 and 3', NUREG-0490, Jan. 1981, especially figure 7.1.4-4, 'Probability distribution of acute fatalities', which estimates 130 000 deaths in the event of a worst-case accident.

[5] See Bunn, Steinhausler and Zaitseva (note 3), p. 139. Because there is no international treaty requiring protection, there is limited information available on protection practices. Cases of uranium thefts from research reactors in the Democratic Republic of the Congo and Georgia are described below. Even in an industrialized West European country after 11 Sep., individuals with false identity papers gained entry to a research reactor and were not apprehended until after they had managed to get inside it.

[6] See, e.g., Bunn, M., 'A detailed analysis of the urgently needed new steps to control warheads and fissile material', ed. J. Cirincione, *Repairing the Regime* (Routledge: New York, 2000), pp. 74–77 (this chapter quotes Russian Minister of Atomic Energy Evgeniy Adamov as acknowledging that 'the weakening of our ability to manage nuclear material has been immeasurable'); and Orlov, V., Timerbaev, R. and Khlopkov, A., *Nuclear Nonproliferation in US–Russian Relations: Challenges and Opportunities* (PIR Center for Policy Studies: Moscow, 2002), pp. 37–49. In a television interview after 11 Sep., the head of the material protection and control department of the Russian nuclear regulatory agency (Gosatomnadzor), Yuri Volodin, acknowledged 'complaints' but said that no 'large thefts of nuclear material' had yet taken place in the Russian Federation. Lenta.Ru, ['Theft of nuclear material in Russia invented by journalists'], 13 Nov. 2001 (in Russian), available at URL <http://lenta.ru/terror/2001/11/13/volodin>. An earlier description of the protection, control and accounting of Russian nuclear weapons by an American and a Russian appears in Lepingwell, J. and Sokov, N., 'Strategic offensive arms elimination and weapons protection, control and accounting', *Nonproliferation Review*, vol. 7, no. 1 (spring 2000), p. 99.

[7] Soo Hoo, M. *et al.,* 'International Physical Protection Advisory Service: observations and recommendations for improvement', *Proceedings of the 40th Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

[8] Harrington, K., *Physical Protection of Civilian Fissile Material: National Comparisons* (Sandia National Laboratories: Livermore, Calif., 1999), p. 18.

the power reactor.[9] In published reports of these small surveys, the particular problems at particular facilities were not generally identified with the name of the facility, or sometimes even with the name of the country where it was located, because of the fear that saboteurs or thieves would then learn where weaknesses existed. In general, facts about particular physical protection practices are kept confidential.

It is known that the al-Qaeda network and Usama bin Laden have sought weapon-usable and other radioactive materials, as well as nuclear weapons and radioactive dispersal devices.[10] A question is whether they could or would also attack nuclear power reactors using, for example, aircraft or trucks carrying explosives. The magnitude of the destruction, the total disregard for life, both their victims' and their own, shown by the 11 September terrorists, as well as the enormity of the effort, coordination, organization, financial backing and sense of religious mission that probably went into their preparations all tend to suggest an answer in the affirmative. Other terrorist groups may well have similar goals.

The IAEA reported in November 2001 that its 'past efforts have focused largely on diversion of nuclear material by States for non-peaceful purposes, without the same degree of focus on malicious activities by sub-national groups'.[11] Thus, the IAEA's estimate of the extent of the damage to a nuclear facility from the intentional crash of a 'large, fully fuelled jetliner' was 'still a matter for analysis. Nuclear facilities vary from state to state, so studies will have to take specific plant designs into account'.According to the IAEA Director General, 'After 11 September, we realized that nuclear facilities—like dams, refineries, chemical production facilities or skyscrapers—have their vulnerabilities. There is no sanctuary anymore, no safety zone'. Moreover, IAEA experts 'are concerned that terrorists could develop a crude radiological device using radioactive sources commonly used in every day life'.[12] This could mean using radioactive materials to make 'dirty bombs' with conventional explosives to disperse the radioactivity.[13]

[9] Bunn, M. and Bunn, G., 'Nuclear theft and sabotage: priorities for reducing threats'', *IAEA Bulletin,* vol. 43, no. 1 (Dec. 2001), pp. 8–9.

[10] See, e.g., 'US indictment: 'detonated an explosive device', *New York Times*, 5 Nov. 1998, p. A9; Weiser, B., 'US says Bin Laden aide tried to get nuclear weapons', *New York Times,* 26 Sep. 1998, p. A3; and 'Responsibility for the terrorist atrocities in the United States', 11 Sep. 2001, *New York Times*, 5 Oct. 2001, p. B4. According to the US Central Intelligence Agency (CIA), al-Qaeda and several other terrorist organizations have expressed interest in nuclear weapons. See e.g., Zakaria, T., 'CIA: threat of weapons of mass destruction up', Reuters, 30 Jan. 2002; and 'Words of the CIA chief on terror', *New York Times,* 7 Feb. 2002, p. A10. Other recent accounts are available at the Nuclear Control Institute Internet site (note 3).

[11] IAEA, 'IAEA outlines measures to enhance protection against nuclear terrorism', IAEA Press Release PR 2001/26, 30 Nov. 2001, p. 1, available at URL <http://www.iaea.org/worldatom/Press/P_release/2001/prn0126.shtml>. See also IAEA, 'Summary of report on protection against nuclear terrorism, presented to the IAEA Board of Governors on 30 November 2001', IAEA Press Release PR 2001/26a, 30 Nov. 2001, available at URL <http://www.iaea.org/worldatom/Press/P_release/2001/prn0126a.shtml>. (Both of these press releases summarized a report by the IAEA Director General to the IAEA Board of Governors, a report which was 'restricted' and was not made available to the public.)

[12] IAEA, 'Calculating the new global nuclear terrorism threat', IAEA Press Release, 1 Nov. 2001, p. 3, available at URL <http://www.iaea.org/worldatom/Press/P_release/2001/nt_pressrelease.shtml>. (This is a summary of the statements made by the IAEA Director General at a press conference on the day of an IAEA Symposium on Nuclear Terrorism.)

[13] IAEA, 'Calculating the new global nuclear terrorism threat' (note 12), p. 5. Measures being taken to address these issues are discussed in section IV.

III. Illicit trafficking in nuclear and other radioactive material

The *SIPRI Yearbook 2001* contains a summary of illicit trafficking in nuclear and other radioactive material through March 2001 based principally on the IAEA Illicit Trafficking Database.[14] All the conclusions of this summary are confirmed by Stanford University's analysis of its Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO).[15] However, in addition to the state-confirmed incidents from the IAEA database, the DSTO includes open source reports and data for the years 1991 and 1992. It thereby provides a broader insight into the problem of illicit trafficking over the past 10 years.[16]

Analysis on a global level of both the state-confirmed incidents in the IAEA database and the data in the DSTO indicates that there was a noticeable increase in the number of incidents in 1998–2000, following a sharp peak in 1993 and 1994 and a subsequent decline from 1995 to 1997 (see figure 10D.1). Preliminary data show that the number of incidents declined in 2001 compared to the period 1998–2000.

The current number of incidents involving thefts and seizures of nuclear material is considerably lower than in the early 1990s. From 1991 to 1996, nuclear material was seized or stolen more frequently than other radioactive material (see figure 10D.2).[17]

[14] Zarimpas, N., 'The illicit traffic in nuclear and radioactive materials', *SIPRI Yearbook 2001: Armaments, Disarmament and International Security* (Oxford University Press: Oxford, 2001), pp. 503–11.

[15] The DSTO is a collection of illicit trafficking incidents (e.g., thefts and seizures of nuclear and other radioactive material) that have taken place worldwide. It includes the state-confirmed incidents presented in the IAEA Illicit Trafficking Database. See 'Comprehensive list of incidents involving illicit trafficking in nuclear materials and other radioactive sources as of 1 March 2001: confirmed by states', available from the IAEA Office of Physical Protection and Material Security; see also the abstracts on all reported instances of nuclear trafficking in and from the Newly Independent States (NIS), collected by the Monterey Institute of International Studies, Center for Nonproliferation Studies (CNS) in its NIS Nuclear Trafficking Database, available at URL <http://www.nti.org/db/nistraff>. The IAEA database is missing many incidents reported in open mass media sources because they had happened before 1993, when the IAEA started its database programme, or because the involved states failed to report them (e.g., over 200 incidents collected by the CNS researchers are not part of the IAEA database). The CNS database, in its turn, does not include *c*. 200 incidents from the IAEA database, because they are either unrelated to NIS countries or were not covered by the press. By combining all the incidents from these 2 databases and from additional open sources in a single format, the DSTO has achieved a more complete international picture of illicit trafficking. The unified, user-friendly computer format allows for a quick statistical analysis of the input data. It has an added advantage of corroborating the open source information with the state-confirmed IAEA data, such as the date and location of the incident and the description and exact amount of the material involved. Additional open sources used by DSTO are books and other publications, conference proceedings, international print and electronic media, and the Internet.

Orphan radiation sources are 'sources that were never subject to regulatory control; sources that were subject to regulatory control but since have been abandoned, lost or misplaced; and sources that were stolen or removed without proper authorization'. Ortiz, P. *et al.,* 'Lost and found dangers: orphan radiation sources raise global concerns', *IAEA Bulletin*, vol. 41, no. 3 (1999), p. 18. See also US Environmental Protection Agency, 'Orphan sources initiative', available at URL <http://www.epa.gov/radiation/cleanmetals/orphan.htm>.

[16] A special parameter—reliability factor—was devised for the Stanford DSTO to define the degree of reliability of information presented in each particular case: high, medium or low. *High* denotes high credibility of data (confirmed by IAEA and/or confirmed by competent national authorities), *medium* denotes reasonable credibility of data (not confirmed to the IAEA, but confirmed by local authorities directly involved in the incidents, as referenced in mass media reports) and *low* denotes less credible or conflicting data. It should be noted that over 75% of the incidents recorded in the DSTO are in the reliability categories *high* or *medium*.

[17] For the purposes of the DSTO, nuclear material is defined as uranium, plutonium, thorium or a compound containing any of these elements, and irradiated nuclear reactor fuel. Although nuclear material is radioactive, the term 'other radioactive materials' refers primarily to ionizing radiation sources (e.g., americium, cesium, cobalt, radium, strontium, etc.). See also the definition given in note 2.

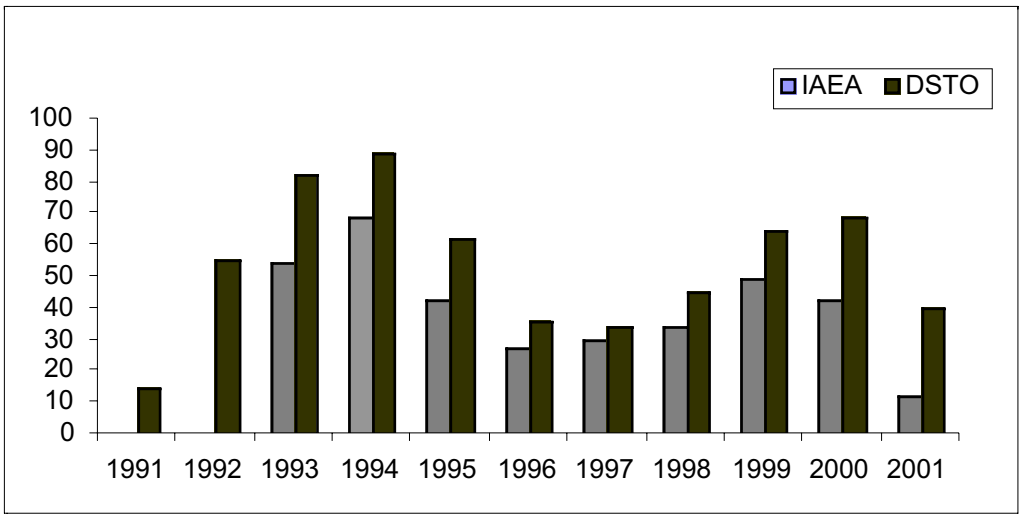

Figure 10D.1. Incidents of illicit trafficking in nuclear and other radioactive material, 1991–2001

Sources: For IAEA data: Data reported by states to the IAEA between Jan.1993 and Mar. 2001, available upon request from the IAEA Office of Physical Protection and Material Security; for DSTO data: Data include both confirmed and unconfirmed incidents with high, medium and low reliability. Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO), Center for International Security and Cooperation, Stanford University, Stanford, Calif., 2002 (restricted access).

This trend started to change in 1997 and there were fewer cases of illicit trafficking involving nuclear material in 1997–2001 as compared to incidents involving other radiation sources. In the period 1998–2001, the incidents involving nuclear material have accounted for less than one-third of the total number of illicit trafficking cases.

Of 643 illicit trafficking cases recorded in the DSTO database for the period January 1991 to December 2001, almost one-half (303) involved thefts and seizures of nuclear material. Of these, 129 incidents (42 per cent) were of no proliferation concern (e.g., natural uranium, depleted uranium, 'yellow cake'), 126 (42 per cent) of low proliferation concern (e.g., low-enriched uranium, LEU, and minuscule amounts of plutonium, including those in radiation sources) and 48 (16 per cent) of high proliferation concern (e.g., HEU and plutonium).[18] However, the majority of proliferation-significant incidents took place in the period 1991–95, suggesting that the efforts to improve the physical security of weapon-usable nuclear material in Russia and other former Soviet republics have started to bear fruit.

[18] For comparison, the IAEA database contains 168 incidents involving nuclear material over the period Jan. 1993 to Mar. 2001. Of those, 89 incidents (53%) were of no proliferation concern, 65 (38%) of low proliferation concern and 15 (9%) of high proliferation concern. See 'Comprehensive list of incidents' (note 15).

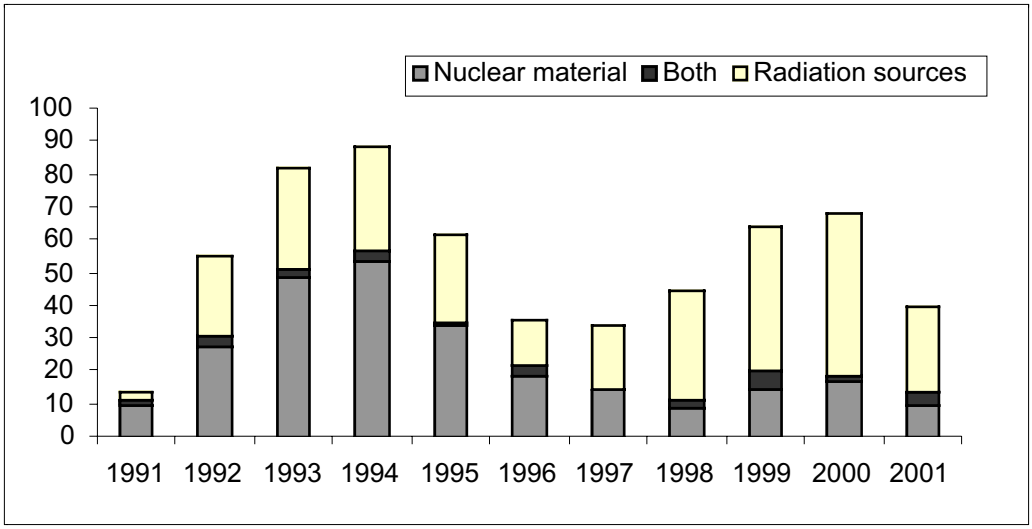

Figure 10D.2. Incidents of illicit trafficking involving nuclear material, other radioactive material and both, 1991–2001[a]

[a] Orphan radiation sources are not included because, for the purpose of the DSTO database, they are considered to be outside the illicit trafficking problem since there is no known underlying criminal intent to sell them to third parties or to use them with malicious intent.

Source: Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO), Center for International Security and Cooperation, Stanford University, Stanford, Calif., 2002 (restricted access).

According to the IAEA database, the total amount of stolen and seized weapon-usable material is approximately 10.820 kg. The largest amounts were intercepted in St Petersburg, Russia, in June 1994 (2.972 kg of 90 per cent HEU), and in Prague, Czech Republic, in December 1994 (2.73 kg of 87.7 per cent HEU).[19] However, the DSTO database shows that the total could be as high as 37.158 kg if other credible proliferation-significant cases—unconfirmed by states to the IAEA—were to be included. If these 37 kg represent 10–40 per cent of the material actually smuggled, as is the case with drug trafficking in the USA, the actual situation in states with border control and law enforcement less efficient than in the USA may be a reason for serious concern.[20] Although all of this material originated in the former Soviet Union (FSU), there has been at least one known theft of enriched uranium from a state other than the FSU. In 1998, members of a smuggling ring in possession of 19.9 per cent enriched uranium (20 per cent is defined as weapon-usable) were arrested in Italy. The US-fabricated 190 g fuel rod—one of the eight reportedly missing—had been stolen from the Triga II research reactor in Kinshasa, the Democratic Republic of the Congo, where security was described as appalling.[21]

[19] Calculations are based on the data provided in 'Comprehensive list of incidents' (note 15).

[20] At best, law enforcement officials seize only 10–40% of the illegal drugs smuggled into the USA each year. See Williams, P. and Woessner, P., 'Nuclear material trafficking: an interim assessment', Working Paper 95-3, *Ridgway Viewpoints* (Matthew B. Ridgway Center for International Security Studies, University of Pittsburgh: Pittsburgh, Pa., 1995), p. 2, available at URL <http://www.pitt.edu/~rcss/viewpoints.htm>.

[21] Wrong, M., 'More wreck than reactor', *Financial Times*, 21 Aug. 1999, p. 8.

In general, research reactors around the world have been a reason for concern with regard to theft of weapon-usable nuclear material. Despite the ongoing US effort to convert research reactors using HEU to LEU and retrieve the HEU which it originally supplied, many states in the world, including 28 developing states, still operate on HEU.[22] Some of them are reportedly not well guarded, presenting a potential target for theft, especially in times of political crises. For example, during the Kosovo conflict in the late 1990s there was serious concern about the Vinca research reactor in Serbia, which holds some 50 kg of Soviet-produced enriched fresh HEU and 10 kg of low-irradiated HEU. This concern persists because of the questionable physical security arrangements at the facility.[23] About 2 kg of 90 per cent enriched HEU went missing from another research reactor in Sukhumi, Georgia, during the political unrest between 1992 and 1997.[24] Russia, which has supplied HEU for research reactors in these and many other states, is only at the planning stage for an effort similar to the US conversion programme.[25] The reactors at Sosny, Belarus, and Kharkiv, Ukraine, which hold between them some 445 kg of HEU, would be the prime candidates for the material retrieval.[26]

The regional trends in illicit trafficking of nuclear and other radioactive material have changed over the past 10 years. After the highest peak in 1993 and 1994, Western Europe witnessed a sharp decline in illicit trafficking in 1995–97 and the number of incidents has remained relatively low since then. By comparison, the decline recorded in the mid-1990s in Eastern Europe was less pronounced than in Western Europe and the number of incidents increased again significantly in 1999 and 2000. The improved border control and policing for radioactive materials in Eastern Europe may now serve as a barrier for the trafficking flow from the FSU, allowing less material to reach the West European frontiers.

A new peak in illicit trafficking was also observed in Russia in 1998–2001. However, during the period January 1998 to March 2001, only 3 incidents were confirmed by the Russian Government to the IAEA, whereas the Stanford DSTO database contains 37 incidents—most of them involving radiation sources—reported in open sources over the same period of time. The actual number of illicit trafficking cases may be higher still, because they can go unnoticed owing to inadequacies in the detection capabilities at many border crossings in Russia. For example, 61 events of radiation detection were recorded at the Sheremetyevo international airport in Moscow in 1999, after a radiation monitoring system had been installed, whereas in 1997, prior to its installation, only 2 such events were detected.[27] Because the

[22] IAEA, *Nuclear Research Reactors in the World* (note 1).

[23] In 1996 the IAEA installed an electronic surveillance system at Vinca. However, Vinca officials apparently did not consider the resulting improvement of security as sufficient and approached the USA and the IAEA with a request to remove the HEU from the country. It was considered to be at risk because of economic and political instability. So far, the material has not been removed from Serbia. See Potter, W., Miljanic, D. and Slaus, I., 'Tito's nuclear legacy', *Bulletin of the Atomic Scientists*, vol. 56, no. 2 (Mar./Apr. 2000), p. 69.

[24] Daughtry, E. and Wehling, F., 'Cooperative efforts to secure fissile material in the NIS', *Nonproliferation Review,* vol. 7, no. 1 (spring 2000), p. 100. See also the Center for Nonproliferation Studies, CNS Reports: *Confirmed Proliferation-Significant Incidents of Fissile Material Trafficking in the Newly Independent States (NIS), 1991–2001*, 30 Nov. 2001, available at URL <http://cns.miis.edu/pubs/reports/traff.htm>.

[25] Research reactors in 12 countries still use Russian/Soviet-supplied HEU. See IAEA, *Nuclear Research Reactors in the World* (note 1).

[26] Daughtry and Wehling (note 24), pp. 99, 102.

[27] Ukhlinov, L. and Bojko, V., 'Organization of customs control of fissionable and other radioactive materials', *Proceedings of the IAEA International Conference 'Security of Nuclear Material: Measures*

Sheremetyevo officials did not single out any particular seizures, it can probably be assumed that most of the detected material was of no proliferation concern. However, if someone decided to smuggle weapon-usable material on board an aircraft, as was the case with 360 g of plutonium seized in the Munich airport from passengers en route from Moscow in August 1994, he or she might have been able to do so undetected before the installation of the detection equipment.

Russia's reluctance to publicly acknowledge all the facts of continuing smuggling attempts, even if they have been successfully countered, and to report them to the IAEA may be caused by its unwillingness to be subjected again to humiliating international criticism. In addition, Russia may not want to demonstrate the weak spots in the security of its nuclear facilities in order to prevent attempts by those interested in acquiring nuclear material to do so.

Whatever the reasons are for Russia's not reporting all of its illicit trafficking cases to the IAEA, they may be shared by some other states. For example, as of March 2001, the USA has not reported a single case to the IAEA database. However, according to the US Nuclear Regulatory Commission, an average of about 200 licensed radiation sources are lost, abandoned or stolen in the USA each year and the media occasionally report thefts of radiation sources.[28] Of the other nuclear weapon states, as of March 2001 France and the UK reported three incidents each, all involving radiation sources, whereas China has not reported any. However, in July 2001, 5 grams of 80 per cent HEU—presumably a sample of a larger cache—were seized in Paris, France.[29] Given the level of enrichment, the HEU could have been stolen either from a research reactor or from a nuclear submarine depot.

Of special concern is the increased illicit trafficking from Russia and other former Soviet republics through the Southern Tier.[30] In 1992–98, the number of incidents detected in this region remained low (on the average, 4 cases per year) and then sharply increased in 1999 and 2000 (18 and 11, respectively). Six incidents were reported in 2001. Although these incidents represent only a fraction of the number of cases recorded in Eastern Europe or Russia, the quality of the material smuggled through the Southern Tier in terms of its proliferation potential is noticeably higher. This may indicate that better educated traffickers are using the southern routes. For example, of 60 trafficking incidents that took place in Eastern Europe from January 1999 to December 2001, 19 involved nuclear material, including 2 seizures of minuscule amounts of plutonium in radiation sources and 2 seizures of LEU. A total of 35 incidents were reported to have taken place in the Southern Tier over the same period, of which 18 involved nuclear material, including 3 confirmed and 2 unconfirmed seizures of HEU and plutonium and 10 seizures of LEU.

to Prevent, Intercept and Respond to Illicit Uses of Nuclear Material and Radioactive Sources', Stockholm, 7–11 May 2001, p. 80, available at URL <http://www.iaea.or.at/worldatom/Press/Focus/Stockholm/sw-papers010402.pdf>. For a review of illicit trafficking in Russia in 1989–2000 see Orlov, Timerbaev and Khlopkov (note 6).

[28] Dicus, G., 'USA perspectives: safety and security of radioactive sources', *IAEA Bulletin*, vol. 41, no. 3 (1999), p. 22. The DSTO lists 11 thefts of radiation sources in the USA.

[29] Reuters, 'French arrest 3 for nuclear trafficking', 22 July 2001, available at URL <http://www.wise-paris.org/english/intro/othersnewsarchives.html>. See also Anzelon, G., 'Improving the knowledge base on nuclear terrorism threats', Paper presented at the IAEA Special Session on Combating Nuclear Terrorism, 2 Nov. 2001, URL <http://www.iaea.org/worldatom/Press/Focus/Nuclear_Terrorism/anzelon.pdf >.

[30] For the purposes of the DSTO database, the Southern Tier includes the Caucasus (including the adjacent republics in the south of Russia—Dagestan, Karachaevo-Cherkessia, North Ossetia and Chechnya), Central Asia and Turkey.

The above evidence suggests that southern routes are used for illicit trafficking more than before. The borders of the region are still not up to the challenge. Of the 18 seizures of nuclear material that took place in the Southern Tier over the past three years, 15 were reported to have resulted from police or intelligence operations and one was intercepted at a border crossing by a US-trained official.[31] Of the 17 seizures of radioactive material, 6 took place at border crossings, 2 of which using the detection equipment provided by the US Customs Service.[32] Despite these successes of the US assistance programmes, more remains to be done to have a significant impact on curbing illicit trafficking in the region, particularly in Turkey, where only 2 of the existing 120 border posts are reportedly equipped with radiation detection systems, both donated by the USA.[33]

In all of the cases with an adequate description, the intention of the traffickers was to sell the material for profit. The scenario that appears to be most frequent is obtaining the material in Russia or Kazakhstan and transporting it through Georgia to Turkey for the final sale to end-users. As for the possible buyers in the region, the most frequently reported destinations of the smuggled nuclear material over the past 10 years have been Iraq (6 incidents), Iran (5), Libya (5) and 'a Middle Eastern country' (5).[34] Iran seems to have at least three different supply routes: from the Caucasus via Georgia and Turkey, from the Caucasus via Armenia and from Central Asia via Afghanistan. The end-users, however, are the least known link in the supply chain because of the lack of hard evidence connecting them to particular incidents. Therefore, one can only guess about the final destination of the smuggled material by the route its traffickers take.

IV. International efforts after 11 September to improve security against terrorists

Is the physical protection of nuclear power reactors against suicide attacks such as those carried out on 11 September by several large fuel-laden jet airliners beyond what is financially feasible? As seen by the IAEA, these reactors are 'industrial facilities and as such are not hardened to withstand acts of war'.[35] Better security for commercial airliners, their passengers and their airports may be the most likely way of dealing with this threat—except, perhaps, when warnings permit the use of protective fighter aircraft or when the nuclear facility is so dangerous that installation of anti-aircraft weapons is justified.[36] However, diving smaller, medium-sized rental air-

[31] Since 1998, there have been 8 significant seizures of nuclear material by customs or police agencies outside the USA which could be attributed to non-proliferation training carried out under the auspices of the US Customs Service. See US Customs Service, 'US Customs kicks off training to help former Soviet republics combat spread of weapons of mass destruction', Washington, DC, 21 Aug. 2001, URL <http://usinfo.state.gov/topical/pol/arms/stories/01082203.htm>.

[32] US Customs Service (note 31); and US Department of Defense, Federal Bureau of Investigation and US Customs Service Counterproliferation Program, 'Success stories', available at URL <http://www.dtra.mil/os/fbi-uscs/os_successstor.html >.

[33] Frank, D., 'Nuclear booty: more smugglers use Asia route', *New York Times*, 11 Sep. 2001, p. A1.

[34] Database on Nuclear Smuggling, Theft and Orphan Radiation Sources (DSTO), Center for International Security and Cooperation, Stanford University, Stanford, Calif., 2002 (restricted access).

[35] IAEA, 'Calculating the new global nuclear terrorism threat' (note 12), p. 3. See also IAEA, 'Summary of report on protection against nuclear terrorism' (note 11), p. 2.

[36] IAEA, 'Calculating the new global nuclear terrorism threat' (note 12). The Cogema fuel cycle complex at Cap La Hague in France has installed anti-aircraft missiles primarily to protect its large storage ponds for highly radioactive spent fuel and for the waste from its reprocessing plant. More radio-

craft flying from private airfields and loaded with high explosives and fuel onto a nuclear site could not be controlled by better public airport and airline security and might cause a major release of radioactivity. The same concern holds for trucks loaded with high explosives attacking the reactor or its spent fuel pond. In some countries, protections have been planned against an attack involving one truck bomb.[37] However, if there are two trucks and the bombs from the first truck blow up the outer protection facilities near the gate, and the second truck is then able to reach the spent fuel pond or reactor before it explodes, these protections could be inadequate.

Nuclear security in the largest nuclear weapon states

Despite efforts to improve the security of US military weapon-usable materials going back to 1970, army and navy commando teams recently demonstrated that they were able to penetrate security systems at a number of government-owned nuclear facilities and escape with significant quantities of weapon-usable nuclear materials.[38] The situation in Russia is thought to be worse.[39] The security system that Russia inherited from the Soviet Union relied on a closed society with closed borders, well-paid nuclear workers and personnel under the surveillance of the KGB (Komitet gosudarstvennoy bezopasnosti, the security services of the FSU). It began to break down with the increasing freedom and declining living standards of the past decade. As in the USA, Russian nuclear weapons, which are readily accountable, remain under what appear to be high levels of security. For Russian weapon-usable material, however, the security is generally lower and varies greatly from place to place.[40] Since 1994 the USA and a number of other industrialized countries have been providing financial assistance to help Russia install improved protection systems at many sites, both civilian and military, where nuclear materials are used and stored. However, as of late 2001, rapid security upgrades had been completed on facilities containing less than one-third of the hundreds of tons of weapon-usable nuclear materials in Russia, and programme managers in the USA estimated that completion of these upgrades would take until the end of 2007, assuming the current assistance to Russia is continued at the present levels.[41]

While Russia and the USA are believed to have some 95 per cent of the nuclear weapons in existence, the rest of the world has a much larger than 5 per cent share of weapon-usable material—including that in civilian facilities. Enough military or

activity is present at such a plant than at most nuclear power reactors. See Jeffries, S. and Brown, P., 'France positions missiles to protect nuclear plant', *Manchester Guardian*, 20 Oct. 2001, available at URL <http://www.guardian.co.uk/archive/article/0,4273,4281424,00.html>. An earlier report contains an analysis of the extent of the larger possible danger from the huge storage ponds. See Coeytaux, X. *et al*., 'La Hague particularly exposed to plane crash risk', World Information Service on Energy (WISE), Paris, 26 Sep. 2001, p. 5, URL <http://www.wise-paris.org/english/oumews/news2.html>.

[37] Bunn, Steinhausler and Zaitseva (note 3), pp. 139–40.

[38] von Hippel, F., 'Recommendations for preventing nuclear terrorism', F.A.S. Public Interest Report, *Journal of the Federation of American Scientists*, vol. 54, no. 6 (Nov./Dec. 2001), p. 4, available at URL <http://www.fas.org/faspir/2001/v54n6/index.html>.

[39] See the discussion and authorities in note 6. A special report on 'Assessing US nonproliferation assistance to the NIS' appeared in *Nonproliferation Review*, vol. 7, no. 1 (spring 2000), pp. 55–125.

[40] Bunn, M. and Bunn, G., 'Reducing the threat of nuclear theft and sabotage', *Journal of the Institute of Nuclear Materials Management*, vol. 30, no. 3 (2002, forthcoming).

[41] von Hippel (note 38); and Spector, L., Testimony before the Subcommittee on Internal Security, Nonproliferation, and Federal Services, US Senate Committee on Governmental Affairs, 14 Nov. 2001. Rapid security upgrades include such measures as installing sensors and cameras to detect intruders and alarms to warn the guard forces as well as bricking up windows.

civilian plutonium for many nuclear weapons exists in Belgium, China, France, Germany, India, Israel, Japan, Switzerland and the UK. In addition, according to estimates made in 2000, more than 2 tonnes of civilian HEU exist in research reactors in 43 countries, sometimes in quantities large enough to make a bomb.[42]

International efforts to strengthen physical protection

Nuclear materials and facilities

At the centre of new international efforts to strengthen worldwide physical protection is the IAEA. Its admission that security against terrorists such as those who carried out the 11 September attacks had been neglected in the past is quoted in section II. Its November 2001 report stated that IAEA activities for the protection of nuclear material had been severely limited by lack of funds.[43] One of the most important IAEA programmes to strengthen physical protection is the International Physical Protection Advisory Service (IPPAS), which sends teams of experts to requesting states to provide advice on the adequacy of their security systems. When the experts have advised strengthening, the state has often gained financial help to do so from the European industrialized countries, just as Russia has been receiving such help from the USA and others to strengthen nuclear security for its many nuclear facilities. However, because of lack of resources, the IAEA has been able to conduct IPPAS missions in only 12 states since the initiation of the programme in 1995.[44] Other important IAEA physical protection services include training, guidance publications and information exchange. However, for example, reviews and tests of emergency responses to sabotage and terrorism have not been conducted because of the inadequate budget. The physical protection programme had received less than $1 million in the regular IAEA budget plus somewhat less in non-budgetary voluntary contributions from the USA and several other industrialized states. This was far from enough to provide adequate assistance to IAEA member states for their physical protection efforts.[45]

Lack of information on important security practices also hindered the IAEA from finding out what was necessary for improvement, emphasizing its urgent need 'to identify the most vulnerable locations and see that they get the necessary security

[42] Bunn and Bunn (note 40); and IAEA, *Nuclear Research Reactors of the World* (note 1). A discussion of potential problems for research reactors in former Soviet republics other than Russia appears in Daughtry and Wehling (note 24).

[43] IAEA, 'IAEA outlines measures to enhance protection against nuclear terrorism' (note 11).

[44] IAEA, 'Summary of report on protection against nuclear terrorism' (note 11); IAEA Working Group of the Informal Open-Ended Expert Meeting to Discuss Whether there is a Need to Revise the Convention on the Physical Protection of Nuclear Material, 'Final Report of the Working Group', 2 Feb. 2001, p. 5. (This final report is to be distinguished from the final report which reflects the final consensus on amending the Convention on Physical Protection of Nuclear Material, 'Final report' of 23 May 2001, which invited the IAEA Director General to convene an open-ended group of legal and technical experts to prepare a draft amendment to the convention. It was based on the 2 Feb. 'Final report of the Working Group', which contains information on many issues besides whether to amend the Convention). Two reports of the IAEA Secretariat to the Working Group describe IAEA and country assistance programmes for physical protection: IAEA Secretariat Paper no. 9, 'IAEA International Physical Protection Advisory Service (IPPAS) Programme', June 2000; and IAEA Secretariat Paper no. 15, 'Bilateral physical protection support—compilation of input from member states', Nov. 2000.

[45] IAEA, 'IAEA outlines measures to enhance protection against nuclear terrorism (note 11); and IAEA, 'Summary of report on protection against nuclear terrorism' (note 11).

upgrades'.[46] Because there were no treaty-required IAEA inspections for security measures as there were for control and accounting measures for non-nuclear weapon parties to the 1968 Non-Proliferation Treaty (NPT), the IAEA did not regularly collect confidential information on security, as it did on accounting and control. As indicated above, IAEA member states regarded this information as confidential. What information exists suggests major variations in the protection of similar facilities from state to state.[47] Thieves and terrorists desiring to steal weapon-usable material are likely to seek out the places where it is least well guarded on the basis of what they can see from the outside or learn from cooperative insiders. In order to judge the scope of the problems, the IAEA intends to make an immediate attempt to gain more information about what the actual physical protection practices of states are insofar as they are willing to report that confidentially.

The November 2001 IAEA report on protection against nuclear terrorism describes threats ranging from terrorist acquisition of nuclear material to make a nuclear weapon to attacks on facilities containing nuclear materials (reactors and fuel enrichment, fabrication, reprocessing and waste management facilities). For some time, the IAEA has assisted efforts by some members to strengthen international standards for physical protection of nuclear material. The IAEA Director General convened a group of experts in 1998 to consider strengthening the one multilateral treaty that deals with physical protection, the 1980 Convention on the Physical Protection of Nuclear Material (CPPNM). The most important reason for doing so was that the CPPNM's protection requirements apply only to nuclear material in international transport—not to that in domestic use, storage and transport.[48] In May 2001 the expert group reported a consensus on amending the treaty to apply to nuclear material within a state—material that was not in international transport.[49] Among the reasons for the amendment, according to the report, was that none of the illicit trafficking reports in the IAEA database described theft of nuclear materials in international transport; they all appeared to involve trafficking from domestic storage and use of material for which the CPPNM provided no standards.[50]

While the expert group agreed to extend the CPPNM to include domestic nuclear materials, it reached no agreement on *required standards* for protection except that protection should be offered against sabotage of nuclear facilities as well as theft of nuclear material. The group did agree on some 'fundamental principles' for physical protection, which have been approved by the IAEA conference of member states and by its Board of Governors.[51] On 19 March 2002 the IAEA announced pledges of funds for this effort totalling almost $3 million from several countries, the largest being from a US foundation, the Nuclear Threat Initiative.[52] However, the IAEA reported at the same time that it required an estimated $12 million to carry out the work that was needed.

[46] IAEA, 'IAEA outlines measures to enhance protection against nuclear terrorism' (note 11).

[47] See Bunn and Bunn (note 9), pp. 8–9; and Soo Hoo *et al*. (note 7).

[48] Bunn, G., 'Raising international standards for protecting nuclear materials from theft and sabotage', *Nonproliferation Review,* vol. 7, no. 2 (summer 2000), pp. 152–53.

[49] IAEA, 'Final report', 23 May 2001 (note 44).

[50] IAEA, 'Final report of the Working Group', 2 Feb. 2001 (note 44), p. 2.

[51] IAEA General Conference, *Measures to Improve the Security of Nuclear Materials and Other Radioactive Materials,* GC(45)/INF/14 (14 Sep. 2001), available at URL <http://www.iaea.or.at/worldatom/About/Policy/GC/GC45/Documents>; and IAEA, 'IAEA General Conference adopts resolution on the physical protection of nuclear material and nuclear facilities: Agency to redouble efforts to combat nuclear terrorism', IAEA Press Release PR 2001/21, 21 Sep. 2001.

[52] See URL <http://www.nti.org/>.

The CPPNM now contains general standards for the protection of weapon-usable material when it is stored temporarily, awaiting international transport. According to the CPPNM, for example, more than 2 kg of unirradiated plutonium or more than 5 kg of HEU must be stored in a 'protected area' with access restricted to 'persons whose trustworthiness has been determined', and with surveillance of this material by guards in communication with response forces.[53] The experts' consensus report does not state whether this requirement would continue in an amended treaty. Except for the general principles, the consensus report does not suggest any specific requirements for protection of such facilities as (*a*) nuclear storage buildings or reactors, (*b*) nuclear separation, fuel fabrication or reprocessing plants, or (*c*) spent fuel or waste disposal facilities.

One of the general principles approved by the IAEA Board of Governors is that a state should base physical protection 'on a graded approach, taking into account the current evaluation of the threat, the relative attractiveness, the nature of the material and the potential consequences associated with the unauthorized removal of nuclear material and with the sabotage against nuclear facilities or nuclear material'.[54] Under this principle, if state officials decided that terrorists are not a threat to their state, they could choose to provide no protection against terrorist attacks. These states could become weak points from which terrorists could steal weapon-usable material or sabotage reactors. The consensus report on amending the CPPNM also rejects all forms of international oversight—from IAEA inspection to peer group review to periodic reports or periodic meetings of the parties to discuss practices.[55]

The IAEA publishes recommended rules for the protection of nuclear material and facilities from theft and sabotage.[56] Although many bilateral nuclear assistance agreements call for the application of these rules by the state receiving assistance, there are still major variations in physical protection by these states.[57] However, the experts' consensus opposed any requirement in the CPPNM that states follow these recommendations—or even that they be given 'due consideration'.[58]

The November 2001 IAEA report called for a revision of the IAEA recommended standards after the CPPNM amendment is agreed upon. However, that will probably not happen for a while. The amendment discussions are going slowly because, despite the 11 September terrorist attacks, most participants have not been prepared to go beyond the pre-11 September consensus described above, although they have been encouraged by the IAEA to do so.

Other radioactive material

'Other radioactive material' in IAEA regulations and policies means radioactive sources that are not uranium or plutonium but are used for industrial, medical and other uses not involving fission.[59] The November 2001 IAEA report described the

[53] CPPNM, Annex 1 (note 2).

[54] IAEA, 'Final report of the Working Group', 2 Feb. 2001 (note 44), Attachment 4, Secretariat Paper no. 13, 'Physical protection objectives and fundamental principles', Principle H, p. 3.

[55] IAEA, 'Final report', 23 May 2001 (note 44), p. 3.

[56] IAEA, The Physical Protection of Nuclear Material, IAEA document INFCIRC/225/Rev. 4 (Corrected) (May 1999), available at URL <http://www.iaea.org/worldatom/Documents/Infcircs/index.shtml>.

[57] Bunn and Bunn (note 9), p. 8.

[58] IAEA, 'Final report', 23 May 2001 (note 44), p. 3.

[59] See the definition in note 17.

dangers of terrorist acquisition of such radioactive material.[60] These materials are often so poorly guarded that they become 'orphaned' from control by the licensed users or those responsible for disposing of them as waste after their creation or use. They cannot be used for making nuclear weapons but can be combined with conventional high explosives to make 'dirty bombs' that scatter radioactivity over a populated area. A container in which there were radioactive materials attached to a landmine was found in Chechnya in 1998.[61] Dirty bombs of this sort are much less dangerous than nuclear weapons but easier to make[62] and could cause panic, and probably long-term injury to some people, if radioactivity were dispersed over a populated area.

The November 2001 IAEA report on protection against nuclear terrorism urged better security for this radioactive material, stating that security was lax in some places.[63] The most important of the treaties that are relevant to this problem is the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. This convention requires parties to maintain a national regulatory framework to govern radioactive waste management.[64] The IAEA, in cooperation with other international organizations and interested states, has adopted International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radioactive Sources. These and related safety standards contain recommended rules for states to adopt in their national regulations or legislation to improve the security of radiation sources.[65]

The IAEA has provided some assistance to states to strengthen practices for maintaining control over radioactive material of this sort. In general, this assistance has not been designed to address the use of these materials for malicious purposes such as for

[60] IAEA, 'Summary of report on protection against nuclear terrorism' (note 11).

[61] 'Container with radioactive substances found in Chechnya', ITAR-TASS, 29 Dec. 1998. Other 'dirty bomb' threats are described in Orlov, V. and Khlopkov, A., 'Super-terrorism: an immediate threat to the world', PIR Center for Policy Studies, Nonproliferation and Arms Control Hotline, Moscow, 13 Sep. 2001, p. 7; and Albright, D., O'Neill, K. and Hinderstein, C., 'Nuclear terrorism: the unthinkable nightmare', Institute for Science and International Security Issue Brief, 13 Sep. 2001, available at URL <http://www.isis-online.org>.

[62] Albright, O'Neill and Hinderstein (note 61); and O'Neill, K., 'The nuclear terrorist threat', Institute for Science and International Security Issue Brief, Aug. 1997, pp. 6–8, available at URL <http://www.isis-online.org>. Following the June 1996 attack on US troops stationed in Saudi Arabia, Secretary of Defense William Perry warned that US military personnel had to prepare for a possible attack by terrorist groups using radiological weapons. US Department of Defense News Briefing, 17 July 1996.

[63] IAEA, 'Summary of report on protection against nuclear terrorism' (note 11).

[64] IAEA, The 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, IAEA document INFCIRC/546, 24 Dec. 1997, available at URL <http://www.iaea.or.at/worldatom/Documents/Legal/jointconv.shtml>. E.g., when a party proposes to establish a new spent fuel management facility or radioactive waste management facility, it must consult other parties in the vicinity of the proposed facility and provide them, upon request, with data enabling them to evaluate the likely safety impact of the facility on their territory. Articles 6.1(iv) and 13.1(iv). The party locating such a new facility must take 'appropriate steps to ensure that such facilities shall not have unacceptable effects' on other parties by locating the facility in compliance with the general safety requirements of the convention. Articles 6.2 and 13.l2.

[65] IAEA, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, Safety Series no. 115 (IAEA: Vienna, 1996). These standards were accepted by other international organizations having some regulatory responsibility for radioactive materials. These include, e.g., the UN Food and Agriculture Organization, the World Health Organization and several other international organizations. The standards are described in IAEA, *Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety*, IAEA Safety Standard Series no. GS-R-1 (IAEA: Vienna, 2000), available at URL <http://www.iaea.org/worldatom/Books/FeaturedSeries/generalsafety.shtml>.

a 'dirty bomb'. The November 2001 IAEA report proposed a new peer review programme to evaluate state regulatory structures, to assess the new threats relating to malicious acts involving radioactive waste, to find ways to help states regain control over large orphan sources, to review the existing standards and their implementation, and to consider what new norms might be needed.[66] This will also require a major increase in the IAEA budget, which members have been unwilling to provide in the past.[67]

V. Conclusions

Since 1995 there have been fewer cases of illicit trafficking of significant quantities of weapon-usable nuclear material recorded than in earlier years. This suggests that the security of such material in Russia and other former Soviet republics has been improved—probably due in large part to the collaborative efforts of Russia and other former Soviet republics with the USA and other industrialized countries. However, only about one-third of the hundreds of tons of Russian weapon-usable material outside of nuclear weapons has been secured so far as a result of the security upgrades accomplished to date. In addition, given the increased illicit trafficking through the Southern Tier over the past three years, intelligence, law enforcement and border control need to be strengthened in the Caucasus, Central Asia, Turkey and the southern regions of Russia. Moreover, security needs to be strengthened at research reactors using weapon-usable material worldwide.

The most important recommendations on strengthening security fall into three categories. First, the major existing Russian–US bilateral programmes to improve the security of Russian weapon-usable nuclear material need to be continued at the present level or a higher level. Second, multilateral efforts such as those involving the IAEA are at least as important if terrorists are to be prevented not only from acquiring weapon-usable material, but also from sabotaging reactors and causing death, illness and panic through the release of radioactivity. The most important of these efforts are: (*a*) the plans of the IAEA to determine where security assistance is needed in the many smaller countries around the world with weapon-usable material and nuclear facilities; (*b*) expansion of the bilateral financial assistance from industrialized countries to pay for such improvements; and (*c*) a major multilateral effort to amend the CPPNM and to gain as many adherents to a stronger amended version as possible. Third, the planned IAEA programme for peer review of state regulatory structures for dealing with other radioactive materials in order to prevent them from being either 'orphaned' or stolen for 'dirty bombs' should be funded by the member states, and a major multilateral effort should be made to evaluate existing international standards for these materials to consider whether new norms are needed.

[66] IAEA, 'Calculating the new global nuclear terrorism threat' (note 12), pp. 5–7; and IAEA, 'Summary of report' (note 11), p. 2.

[67] IAEA, 'IAEA outlines measures to enhance protection against nuclear terrorism' (note 11).