

Nuclear terrorism: risk analysis after 11 September 2001

Annette SCHAPER¹

The smoke over Manhattan did not quite reach the size of a mushroom cloud. Nevertheless, the number of casualties was of the order that would be caused by a minor nuclear explosion. The idea that terrorists have access to weapons of mass destruction is a nightmare that governments and international organizations take seriously.

The events of 11 September have finally made it clear that mass murder can be a terrorist's objective—but the extent to which they have the technical ability to accomplish this is another question. The 11 September terrorists aimed to maximize the death toll they inflicted. Future attacks will always be compared to this one, therefore the ambition of successive assassins might be to beat this death toll. Nuclear weapons are particularly suited to maximizing the number of casualties and are more attractive to terrorists than biological and chemical weapons.² A nuclear explosion might therefore be the next step in the escalation of terror.

The aim of this paper is to assess the possibilities terrorists have for nuclear terrorism and to illustrate potential threats. The paper does not cover suggestions of how to cope with this threat, as this is the topic of other contributions in this issue.

In the following, an assessment is made of whether terrorists are capable of building or procuring a nuclear explosive device. In this discussion, two different terms should be distinguished.³ A *nuclear weapon*, as can be found in the arsenals of the nuclear-weapon states, has a complicated design that is the result of years of development and many tests. Such a weapon is optimized in many respects. For example, the mass of the nuclear material is minimized, the explosion energy is controlled precisely, several safety mechanisms are in place to prevent unintentional detonation and the weapons are resistant to heat, pressure and radioactive radiation. Above all, a nuclear weapon can be delivered to its target by a ballistic missile. In contrast, a terrorist group could, at best, produce a simple *nuclear explosive device* (not to be confused with a radiological weapon) that would only be capable of generating a nuclear explosion. Like the nuclear bombs dropped on Hiroshima and Nagasaki in 1945, it would have a simple design, would require a large amount of nuclear material and would have a large mass that could only be transported by ship, boat or lorry but not by a ballistic missile. Moreover, the creators of such a device could never be entirely sure that it would really explode.

The theoretical know-how

During the Second World War, thousands of scientists and ancillary staff contributed through the Manhattan Project to the creation of the first crude nuclear explosive devices. The American government

¹Annette Schaper is senior research associate at the Peace Research Institute Frankfurt (PRIF) and has a Ph.D. in experimental physics. Her main focus is nuclear arms control and its technical aspects.

recruited the best scientists and dedicated enormous logistical and financial resources to the effort. When asking whether terrorists today might be in a position to construct such a nuclear explosive device without comparable efforts, one important point should be kept in mind: the physicists of the Manhattan Project did not know if a nuclear explosion would be possible, and years were spent on basic research and essential inventions. They had to produce the nuclear material themselves. Furthermore, the operating procedures had to be developed and studied.

Today, not only are the principles of nuclear weapons identified, the fundamental theories are also published in detail and are, to some extent, available even on the Internet.⁴ These sources of information vary in their reliability and detail, and might include errors. However, they are based on information that has been declassified and that can be used to reveal and understand the relevant physical facts.⁵ Declassification is merely a consequence of the inevitable scientific progress that has been made since the beginning of the nuclear age. Since those beginnings, the subject nuclear physics has been established, many textbooks written, numerous nuclear plants designed and the functioning of nuclear weapons further researched.

The development of ignition technology

But there is still information that is secret, especially in relation to engineering. Many laborious steps separate the basic understanding of the operating principles and an actual technical blueprint.

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Terrorist organizations would have to acquire special abilities and techniques in order to build even a simple nuclear explosive device. These include, for example, the generation of shock waves with the aid of high explosives, the handling of fuel and radioactive material, electronics, radiochemistry, and the precision mechanics of metallic uranium or plutonium. Even these subjects are covered in detailed specialist publications that are available not only in libraries but also on the Internet. It is possible to study these publications and use them as a basis for acquiring the relevant capabilities. However, many crucial details are secret, especially those that are based on experimental measurements rather than theory. Development work would be necessary to figure these out.

In principle, there are two different ignition techniques. Using the *implosion method*, as was used for the Nagasaki bomb, a hollow sphere of plutonium or highly enriched uranium (HEU) is imploded to create a so-called *overcritical* mass. When a neutron enters this mass, a *chain reaction* is started that leads to a nuclear explosion. In the case of plutonium, such a starting neutron will practically always be present, as plutonium generates initial neutrons through the high rate of *spontaneous fission*. HEU has a lower rate of spontaneous fission and thus a lower *neutron background*. Therefore, in the case of HEU, neutrons will have to be added artificially at a precise moment in order to start the chain reaction. A comparatively high compression can be achieved using the implosion method, which means that large overcritical masses can be achieved with relatively small amounts of material. The production of a warhead with this method requires complete mastering of the technique of generating precise spherical shock waves. This in turn requires preliminary tests involving many conventional explosions that would probably take several years.

Using the *gun-type method*, two non-critical masses of HEU are shot at one another to generate an overcritical mass. It should be noted that only HEU is suitable for this method. The use of plutonium would lead to only a small detonation on the scale of a conventional explosion. Compression cannot be achieved using the gun-type method. Thus, several tens of kilograms are necessary and only a

relatively small overcriticality can be achieved. Nevertheless, this method can be sufficient to generate a nuclear explosion on the scale of the Hiroshima bomb. This method was used by South Africa to build six warheads.

It is not sufficient to simply 'drop' one part of HEU onto another. Although HEU generates fewer spontaneous neutrons than plutonium, to avoid pre-ignition the two parts must be combined quickly (in a time that is shorter than the average time between the emission of two neutrons). To combine the two halves at the necessary speed, the terrorists would have to develop a technique to shoot the two parts at each other in a gun barrel. This presents an engineering challenge that is not trivial, considering the large masses involved, and which would presumably require months—if not years—of preliminary tests.

But it should be kept in mind that in the now-abandoned South African nuclear weapons programme, the development of the ignition technology was only a small part of the larger programme, and it required a relatively small amount of effort.⁶ A fraction of this effort would probably be sufficient for terrorists, as they are more likely to be interested in a one-off, functional product rather than a long-term development programme.

In theory, it is possible for a highly motivated and financially well-endowed terror organization to acquire the technical abilities necessary to manufacture an ignition mechanism for a nuclear explosive device. However, this would require enormous efforts. Various specialists would have to acquire the required theoretical knowledge and technical skills, perhaps requiring university studies abroad. Revelations over the preparations undertaken for the attacks against the World Trade Center show that terrorists are prepared to go this far to achieve their aims. The organization would need shelter for several years, where their work and the necessary experiments can be carried out undisturbed. Such a base could hardly be mobile, as a test site would be needed to undertake conventional explosions, together with some research labs and offices.

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For the development of the ignition mechanism, it is not required to handle plutonium or HEU. Thus, hiding the base would be comparatively easy. Research into conventional explosives is usually realized in a military environment and, therefore, hardly accessible for outsiders, for obvious reasons. Nevertheless, the cover and protection by a state is required, as the existence of a base and the experiments carried out there would be noticed by nearby residents. Covert programmes would be much easier to undertake in a 'failed state' environment. If a state comes under suspicion, it will always face the risk of intelligence services discovering the base.

The procurement of nuclear material

Should a terrorist group master the ignition technique, then an operational weapon can be assembled quickly once enough plutonium or HEU comes their way.

The United States Department of Energy issued the warning in 1997 that:

Several kilograms of plutonium, or several times that amount of HEU, is enough to make a bomb. With access to sufficient quantities of these materials, most nations and even some sub-national groups would be technically capable of producing a nuclear weapon...⁷

It is far more difficult to get hold of the necessary nuclear fuel than to develop the ignition technology. Nuclear material exists in many different forms. Of these, only metallic plutonium or HEU can be used directly in nuclear weapons without requiring further processing. As a rough estimate, beginners would need at least 20kg of HEU or 10kg of plutonium in order to build one warhead using the implosion method. Using the gun-type method, an estimated 50kg of HEU is needed. A terrorist group would only choose to pursue the gun-type method if it was sure of having access to enough HEU.

Globally, there are about 250 tons of military plutonium and about 1,700 tons of military HEU. Civil stocks have to be added to this. Obviously, this and other nuclear material is subject to strict security measures. Additionally, nuclear material located in non-nuclear-weapon states is subject to controls ('safeguards') by the International Atomic Energy Agency (IAEA). Safeguards are designed to detect a theft as early as possible, leaving enough time for the international community to react before a terrorist nuclear device is operational.

The five nuclear-weapon states are not required by the Nuclear Non-Proliferation Treaty (NPT) to conclude IAEA safeguards agreements. Of the five, the security of nuclear material in the states of the former Soviet Union has been the subject of great concern for many years. It seems that an exact overview of stocks has been lost or never existed in a sufficiently accurate form. Moreover, many plants and storage facilities are not adequately secure today. It is not known whether terrorists or third party states have already managed to get hold of nuclear material. However, it is certain that many attempts have been made. Several cases were uncovered in the mid-1990s, where smugglers stole weapon-ready nuclear material, sometimes in kilogram amounts.⁸ In 1998, the Russian government revealed that plans had been uncovered to steal 18.5kg of HEU from one of the nation's largest nuclear weapon plants. The plan was stopped before the material had left the plant.⁹

It is, however, possible that thefts have been executed on other occasions that have never been discovered. It is not known whether potential thieves of nuclear material, smugglers and recipients have already carried out successful transactions. Thus, it is possible that a terrorist cache of sufficient nuclear material to build a weapon already exists; it is impossible to know.

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The problem of insecure nuclear material is not confined to the former Soviet Union. Even in the United States complaints about the limited security surrounding weapon-ready material have repeatedly been filed, even though the security is much more strict than in the Russian Federation and more modern regulations concerning the physical protection of nuclear material are in place.¹⁰ It should be noted that the United States, as a nuclear-weapon state, is not subject to mandatory international controls. In the first decades after the invention of nuclear weapons, the recording of nuclear materials was very incomplete. In 1996 the United States Department of Energy published a detailed account of the history of American plutonium production.¹¹ It was demonstrated that 2.8 tons of plutonium are 'missing', which means that the stocks taken by measurement and the number calculated from historical documents differ by 2.8 tons. This material has not necessarily been lost or stolen—the discrepancy could just indicate the extent to which the early recording of material was inexact. However, what becomes clear is that it is not possible to determine whether material has been taken away in the past. It can be assumed that such inaccuracies are even worse in the Russian Federation.

Metallic plutonium is difficult to process, due to its radiotoxic properties and its reactivity. A terrorist group would be unlikely to have practical experience in processing plutonium, and therefore would be taking on substantial health risks and risks of accident. However, it is assumed that they are willing to put up with these risks. The handling of metallic uranium is slightly easier.

It can be ruled out that a terrorist group has the capability to produce plutonium or HEU. At most, only a state with appropriate resources could carry out such an endeavour, and it is doubtful

whether such a programme could be kept hidden for long. Large-scale nuclear plants are necessary, the procurement and operation of which could not be kept secret. All procedures for the enrichment of uranium or for plutonium reprocessing leave traces in the environment. In case of a suspicion in non-nuclear-weapon states, illicit activities could be discovered immediately as all plants are subject to IAEA safeguards. The production of uranium or plutonium is extraordinarily resource intensive, as can be illustrated by the fact that Iraq employed thousands of members of staff throughout the 1980s in order to clandestinely manufacture HEU. Nevertheless, only small amounts of HEU were produced. At that time, the IAEA inspections were less thorough and the extent of the production activities was only discovered after the Gulf War. As a result of this deception, IAEA safeguards have been strengthened and it is considered improbable that a similar case could go undiscovered today.

A second consequence of discovering the Iraqi programme is that the industrial states now cooperate through their intelligence services, the agencies responsible for export licenses, and through control regimes to observe international procurement activities. Moreover, other pieces of information, for example from intelligence or from satellite images of individual states, may be provided to the IAEA for evaluation. The technique of collecting and collating scattered pieces of information and their interpretation has improved immensely. The IAEA maintains a database in which such information is centralized. Therefore, the IAEA is capable of drawing attention to suspicious facts at a very early stage.¹² Routine IAEA inspections can be complemented with special inspections where appropriate.

The civil nuclear activities of most countries are transparent. There are, however, a small number of exceptions. Iraq is amongst these, as the IAEA has not been present in Iraq since 1998. The enrichment plants that existed before the Gulf War have been rendered useless and all nuclear material found has been removed from Iraq. As international technical cooperation with Iraq no longer exists, thorough observations are carried out by satellite. However, the technical know-how is still present, presumably including knowledge about ignition technology. Without controls, a small but significant risk remains that Iraq may obtain enough HEU for a nuclear explosive device and could decide to cooperate with or sponsor a terrorist group. At the time of writing (March 2003) UNMOVIC inspectors had not found any traces of HEU production attempts after 1998.

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A further exception is North Korea, which has attempted to produce plutonium in the past. These activities were detected by the IAEA. However, North Korea is not in compliance with its IAEA obligations, and the IAEA is not able to reconstruct North Korean past production. It cannot be ruled out that North Korea is in possession of plutonium sufficient for several warheads. However, it is extremely unlikely that Pyongyang would cooperate with terrorists or that terrorists could get access to this material.

Before South Africa signed the NPT in 1991 and submitted itself to IAEA safeguards, it had produced large amounts of plutonium in its secret nuclear weapons programme. Since then, these stocks have been completely accounted for.¹³ Today, an undiscovered theft is just as unlikely as in the other non-nuclear-weapon states. However, some amounts might have been covertly sold in the past, and they might be in the possession of criminals today. It has been reported, for example, that Osama bin Laden attempted to procure HEU of South African origin in 1993/1994.¹⁴ It is unknown whether he was successful.

In addition, for years the United States has openly voiced its suspicions that Iran is interested in secretly developing a nuclear weapon capability. The American suspicion is said to be based on the testimonies of unnamed arms dealers, which refer to Iranian representatives allegedly enquiring about the possibility of purchasing fissile material. It is also based on alleged attempts by Iranian officials to buy enriched uranium in Kazakhstan and on the purchase of dual-use goods that might indicate an

interest in the centrifuge enrichment technique. This has been supported by intelligence agencies in other countries. It has been reported that the German Federal Export Office has prohibited any delivery to Sharaf University in Tehran since 1996, after this university had attempted to purchase pieces of equipment for the manufacture of centrifuges. Another source of suspicion is Iran's recently revealed start of construction of a uranium enrichment plant.¹⁵ However, Iranian non-compliance with its NPT commitments has never been proven. Recently, the IAEA requested to inspect certain sites in Iran and, after some delay, the Director-General and technical experts were invited to visit and inspect the facilities. The issue of evidence and demonstration of compliance is likely to be contentious for some time to come. There are competing political factions in Iran, some of them interested in strengthening the non-proliferation regime and preventing the development of nuclear weapons or the support of nuclear terrorism, others aiming at the contrary.

The case of Pakistan merits particular attention. It has a small arsenal of nuclear weapons and has produced larger amounts of HEU. Its nuclear capacity is sometimes polemically referred to as the 'Islamic bomb'. However, Pakistan's nuclear weapons programme was initially independent of religious motives or fundamentalism. Rather, it was initiated by the complex relationship with India. Pakistan has repeatedly stressed that it would not pass on any of its nuclear weapons and that it would not cooperate with other states in this field.

Little is known, however, about Pakistani national security measures. Parts of the population sympathize with the Taliban and radical terrorists. It is unknown whether religious fanatics could get access to nuclear material and could pass it on to terrorists. Two retired nuclear physicists who participated in the construction of Pakistan's nuclear weapons were arrested at the end of October 2001.¹⁶ They are Taliban sympathizers, who had recent close contact with the former government of Afghanistan. It is not clear whether they passed on nuclear material. They were released after a few days, although the case will be investigated further.

Whether the Pakistani government is capable of preventing theft of nuclear materials remains unknown. In Pakistan, the army has always had control over the nuclear activities, and the various civilian governments were only marginally involved.¹⁷ The October 1999 coup eliminated the last remaining civilian influence. The army may sympathize with the Taliban in the same way as the civilian population and this support might increase, depending on how the military operation in Afghanistan develops. There are reports claiming that Pakistani officers helped protect the Taliban from American air strikes, which would be strictly against the orders of their President, General Pervez Musharraf.¹⁸

At present, Pakistan possesses 585–800kg of HEU and several kilograms of plutonium. This amount would be enough for an estimated thirty to fifty warheads.¹⁹ The Pakistani government assures that it is in full control of this nuclear material and of its nuclear weapons. However, there are indications that Pakistani physical protection is inadequate. Over a year ago, Pakistan asked the United States for assistance to improve the physical protection of all nuclear material.²⁰ The parts containing nuclear material and the ignition mechanisms of Pakistani nuclear weapons are apparently stored in different locations.²¹ However, they are not protected against accidental detonation nor equipped with 'Permissive Action Links'—protective devices preventing unauthorized ignition. If terrorists were to get hold of a Pakistani nuclear weapon, then they would be able to detonate it. The locations of Pakistani nuclear sites are kept secret, in contrast to those of the recognized nuclear-weapon states, which are easily identified because of their high degree of physical protection. The reason for this secrecy is that the physical protection in place would be unable to withstand a significant attack. Immediately after the 11 September attacks, the nuclear-weapon components were transferred to other secret locations in Pakistan. The Pakistani government feared that the storage sites could be terrorist targets. These transfers also served the purpose of removing control over the nuclear weapons from religious hardliners inside the military.²²

Radiological weapons and sabotage

A variant of nuclear terrorism that is technically much less challenging would be the use of a *radiological weapon* (a 'dirty bomb') instead of a nuclear explosive device. Such a weapon is detonated by a conventional explosion and distributes highly radioactive material. Several blocks of a city could thus be made inhabitable for many years. Plutonium and HEU, which are used in nuclear weapons, are not only difficult to obtain but are also not very radioactive. Therefore, they are not suitable for a radiological weapon.

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Spent fuel elements are more radioactive than plutonium and HEU and are produced by all civil nuclear power stations. However, theft of spent fuel elements is extremely difficult; because of their high radioactivity they would quickly release a lethal dose of radiation if not adequately shielded. Moreover, they are very heavy and bulky. The theft of such elements would require the use of an appropriate form of transport.²³ In Germany, spent fuel is transported by rail in specially designed, shielded containers. It is very difficult but not entirely impossible to imagine terrorists organizing a raid to capture and remove such containers. In non-nuclear-weapon states, all spent fuel elements are registered by the IAEA and a theft would almost certainly be quickly discovered.

A terrorist would find it much easier to get hold of high-level radioactive waste emanating from reprocessing plants, or special radioactive materials and solutions used in civil research institutes and hospitals. Reprocessing plants in non-nuclear or Euratom states²⁴ are, however, tightly controlled. Moreover, detectors that can register even small doses of radioactivity are placed at all entrances and exits and at other locations. Nevertheless, there is no way of ruling out the possibility of groups of staff conspiring to illegally remove small amounts of liquid high-level waste. A more plausible scenario is the theft of material from those less secure plants that are not subject to international controls.²⁵ Liquid high-level waste could be added to drinking water, so contaminating the entire area supplied by a particular source. It might also be discussed whether powerful terrorists could manage to capture a ship transporting radioactive material. However, since such transports are heavily guarded, a terrorist group would have to be extremely powerful and highly organized, comparable to the military forces of a state. Moreover, due to the efforts and risks involved, it would be more likely that such terrorists would aim to capture separated plutonium for a nuclear explosive device, rather than radioactive waste for a radiological weapon.

A more probable scenario is an attempt by terrorists to acquire special highly radioactive sources as are used for medical, industrial, agricultural and research applications. The materials that pose the greatest security risk are Co-60 (cobalt), Cs-137 (cesium), Ir-192 (iridium), Sr-90 (strontium), Pu-238 (plutonium), Am-241 (americium) and Cf-252 (californium).²⁶ They are produced primarily in nuclear reactors. Even gram quantities contain more than enough radioactivity to raise a security concern. Depending on their application, these sources come in various forms, quantities and shieldings. Some of them are not very mobile, others are so radioactive that they would cause immediate harm to an unprotected thief. Nevertheless, these materials can be found in a large number of research laboratories, industries and hospitals all over the world. Their protection is generally mediocre, and thieves might be able to steal these types of sources. No reliable inventories of these materials exist, and a large percentage of them are no longer in use, have been discarded or are lost. Although the number of abandoned or not well-protected sources is high, only a small percentage of them pose a serious security risk—but they are the ones that might be used for a radiological weapon. In the United States, as many as 375 radioactive sources were reported lost, stolen or abandoned in a single year.²⁷ Similar numbers

can be assumed in many other industrialized states. Specific details about these sources are scarce because they are regarded as commercial secrets.

A serious concern are sources that are strewn throughout the former Soviet Union, most of them left behind by the Russian army during its return to the Russian Federation. In the 1970s, Soviet scientists working with the military developed scores of radioactive sources and dispatched them to the countryside in order to deliberately expose plants to radiation and measure the effects.²⁸ All of the experiments used Cs-137 in a shielded canister containing enough radioactivity to contaminate a small city. The material is highly dispersible—ideal for terrorists who seek to construct a radiological weapon. Meanwhile, international nuclear experts have searched for the devices, and found some in Georgia and Moldavia. But there is no accountancy, it is unclear how many are still out there and whether

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terrorists are searching too. Radioactive sources have turned up repeatedly on the black market. They are also known to have been acquired by Chechen rebels in the Russian Federation.²⁹

Depending on where it was detonated, a radiological weapon would initially cause few casualties and cannot be regarded as a weapon of mass destruction. Nevertheless, the psychological impact and its social and economic consequences would be enormous and the contamination would have dreadful long-term consequences. Radiological weapons have never been used. However, it is thought that in 1980 Iraq produced and tested conventional bombs filled with radioactive material, presumably from spent fuel elements.³⁰

In a computer simulation of a dirty bomb attack on New York City, the detonation of 3,500 curies of cesium chloride in Lower Manhattan would spread radioactive fallout over sixty city blocks. Immediate casualties would be limited to victims of the immediate blast. The after effects, including relocation and cleanup, would cost tens of billions of dollars.³¹

Nuclear plants have frequently been the focus of terrorist and criminal interest. Attempts at invading, attacking or threatening nuclear power stations have been reported in Argentina, the Russian Federation, Lithuania, South Africa, South Korea and even in the United States and France.³² Not all such attempts are classified as large-scale acts of terror, as some of them are 'only' sabotage attempts by discontented staff or bomb scares in nuclear power stations. There have, however, been cases of threatened suicide attacks by plane hijackers, for example in November 1972, when three hijackers threatened to bring a plane down on a nuclear research plant in Oak Ridge.³³ Another widely discussed scenario involves a passenger plane, with full fuel tanks, being crashed into a nuclear power station.³⁴

The containment design of German nuclear power stations takes into account the possibility of a combat aircraft crashing but not of a plane with full fuel tanks. An IAEA spokesperson recently confirmed that this also applies to other countries' designs.³⁵ The containment would probably not withstand such an attack. The core of the reactor is unlikely to be hit but the cooling system might be destroyed. If the emergency cooling system, which is designed to flood the reactor in such a situation, were to fail, it could lead to overheating of the core and a Chernobyl-type catastrophe. Whole regions would be rendered uninhabitable. However, to succeed in releasing the radioactive contents of a nuclear power station, terrorists would have to be capable of hitting the reactor shield vertically—in a nosedive—rather than just scraping it from the side. This is a far greater challenge than directing a plane into a high building and is very unlikely.

A more likely scenario is sabotage of a nuclear plant with the aid of insiders. The Chernobyl accident was caused by fatal errors of the personnel during an experiment. Similar actions might be conducted deliberately by malevolent staff, either for non-political reasons (such as psychological problems), or by political motivation and collaboration with terrorists.

Conclusion

In sum, the threat that terrorists might detonate a nuclear device or conventional explosive to disperse radioactivity is real. It is unknown whether concrete preparations to do so are already underway. In addition to the current anti-terrorist armoury, strategies must be implemented that would, in the long term, reduce this risk. These strategies include international cooperation to improve the security of nuclear materials as well as legally binding commitments that have the effect of increased shared international security standards, collaboration and transparency. These approaches will be further elaborated in the following contributions.

Notes

- 1 This article is based on parts of a translation of Alexander Kelle and Annette Schaper, 2001, *Bio- und Nuklearterrorismus – Eine kritische Analyse der Risiken nach dem 11 September 2001*, HSFK-Report, 10/2001, Frankfurt, December. An English translation is forthcoming.
- 2 See Morton Bremer Maerli, 2000, Relearning the ABCs: Terrorists and Weapons of Mass Destruction, *The Nonproliferation Review*, vol. VII, no. 2 (Summer), p. 108.
- 3 Tom Shea, 2001, *Proliferation, proliferation resistance and proliferation barriers*, presentation at the Workshop on Innovative Directions for the Future Development of IAEA Safeguards Technology, Landau Network – Centro Volta, Como, Italy, 2–6 July.
- 4 An example is Carey Sublette, 2001, Nuclear Weapons Frequently Asked Questions, 9 August (version 2.25), available at < <http://www.fas.org/nuke/hew/Nwfaq/Nfaq0.html> > .
- 5 An example of such a document containing declassified information is United States Department of Energy, Office of Declassification, Restricted Data Declassification Policy 1946 to the Present (RDD-6), 1 January 2000 < <http://www.osti.gov/opennet/rdd-6.pdf> > . The following publication is amongst the first concerning the function of nuclear weapons to be declassified: Robert Serber, 1982, *The Los Alamos Primer—The First Lectures on How To Build an Atomic Bomb*, Berkeley (written in 1943, declassified in 1965).
- 6 David Albright and Corey Hinderstein, 2001, *South Africa's Nuclear Weaponization Efforts: Success on a Small-Scale*, ISIS Working-Paper, 13 September, available at < <http://www.isis-online.org/publications/terrorism/safrica.pdf> > .
- 7 United States Department of Energy, Office of Arms Control and Nonproliferation, 1997, *Final Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, DOE/NN-0007, Washington, DC, January, p. vii.
- 8 A. Schaper, 1998, Nuclear smuggling in Europe — real dangers and enigmatic deceptions, in V. Kouzminov and M. Martellini (eds.), *Illegal nuclear traffic: risks, safeguards, and countermeasures, Proceedings of the International Forum*, Science for Peace Series, vol. 4, no. 4, Venice. Most cases that were discovered and published in Germany and Central Europe in the 1990s turned out to be harmless, as the material used was not weapon-ready.
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- 10 United States, President's Foreign Intelligence Advisory Board, 1999, *Science At Its Best, Security At Its Worst: A Report on Security Problems at the Department of Energy (the Rudman Report)*, Washington, DC, President's Foreign Intelligence Advisory Board, June, available at < <http://www.fas.org/sgp/library/pfiab/> > .
- 11 United States Department of Energy, 1996, *Plutonium: The First 50 Years. United States plutonium production, acquisition, and utilization from 1944 to 1994*, Washington, DC, February, available at < <http://www.fas.org/sgp/othergov/doe/pu50y.html> > .
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- in New York trial, *Jane's Terrorism & Security Monitor*, 14 March, available at <http://newsite.janes.com/security/international_security/news/jtism/jtism010314_1_n.shtml> .
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 - 18 Jon Wolfsthal, 2001, U.S. Needs A Contingency Plan For Pakistan's Nuclear Arsenal, *Los Angeles Times*, 16 October.
 - 19 David Albright, 2001, *Securing Pakistan's Nuclear Weapons Complex*, paper for the 42nd Strategy for Peace Conference, Warrenton, Virginia, 25–27 October, available at <<http://www.isis-online.org/publications/terrorism/stanleypaper.html>> .
 - 20 Carnegie Endowment for International Peace, 2001, *Pakistan's Nuclear Dilemma*, Non-Proliferation Project Roundtable, 2 October, transcript available at <<http://www.ceip.org/files/events/Paktranscript.asp>> .
 - 21 Albright, 2001, *op. cit.*
 - 22 Pakistan Moves Nuclear Weapons, *Washington Post Foreign Service*, 11 November 2001, p. A01, available at <<http://www.washingtonpost.com/wp-dyn/articles/A9038-2001Nov10.html>> .
 - 23 This is why the concept of the 'spent fuel standard' is used in the discussion of the disposition of plutonium that stems from disarmed nuclear weapons. If the plutonium has been transformed into a state that is equivalent to that of a spent fuel element, then it is acknowledged to correspond to the spent fuel standard. At this stage, the disarmament process is to be regarded as completed.
 - 24 Euratom monitors the civil nuclear power stations of two nuclear-weapon states, the United Kingdom and France.
 - 25 States that are not subject to international controls of their plants are the United States, the Russian Federation, China, India, Pakistan and Israel. The levels of physical protection in these states differ to a great extent.
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