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Reducing the Threat of Nuclear Terrorism

Paradoxically, with the end of the Cold War – a time in history where large parts of the Northern Hemisphere could have been be annihilated in a less-than-an-hour nuclear exchange – today's nuclear security picture is as unclear as ever. Well-established nuclear weapon states still hold sizeable nuclear arsenals, juvenile nuclear weapon possessors are boosting their stockpiles, and a new set of states have revealed disturbing nuclear ambitions and a strong appetite for nuclear weapons. Prospects of renewed horizontal – and possibly vertical – state nuclear-weapon proliferation are real. And, as this wasn't enough, some sub-national groups have revealed a definitive interest in nuclear explosives.

The topic of this paper is the most novel and undefined, and probably least understood, of all contemporary nuclear dangers: the threat of nuclear terrorism. While the effects of such a scenario would be quite limited compared with an all-out nuclear exchange, the intentional use of even a single nuclear weapon in a densely populated area would leave in its wake a massive, unprecedented public health and environmental catastrophe.[1]

Assessing and understanding the risk seems essential. However, the (fortunate) lack of empirical data, limitations in terrorist trend analysis, and the inherent complexities surrounding of the issue of nuclear terrorism render any probabilistic assessments a daring endeavour. Temptations to try to identify the probability of future acts of nuclear terrorism in accurate and absolute terms should thus probably be avoided.

Through a simple stepwise risk assessment methodology, where risk is viewed as a product of probability and consequence, this paper attempts to qualitatively assess the technical aspects of the nuclear terrorism threat, and how this risk best can be reduced. The work of Bunn et al. (2003, 26) on the successive steps towards a successful act of nuclear terrorism will be used as a framework for the analysis. It will be shown that the most efficient way to reduce – and in fact even eliminate – the risk of nuclear terrorism is to initially deny terrorists access to fissile material through optimal protection, control and accounting practices. Not only seem any other countermeasures further down the line to be more costly. The effects tend to be more arbitrary and with less secure outcomes.

Throughout the paper, no attempt will be given to assess the motivational side of nuclear terrorism, to discuss possible nuclear terrorism scenarios beyond the use of crude nuclear explosive devices,[2] or to criticize any of and the current hard-driving political rhetoric surrounding the phenomenon of nuclear terror.

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[1] The number of casualties from a nuclear terrorist attack would depend on the size, sophistication and thus efficiency of the nuclear explosive device, on the location of the target, the density of the surrounding population, the extent of debris dispersal, and the possibility of escape or evacuation. As opposed to a nuclear air-burst – the preferred military method – a terrorist nuclear explosion on the ground would produce significant radioactive dirt and debris.

[2] Other possible scenarios include for instance the acquisition and use of an intact nuclear weapon, or attacks against nuclear installations.

Nuclear terrorism risk assessments

As nuclear weapons are of limited or no use for the overwhelming majority of terrorist groups (Rapoport 2001), the probability (P) of nuclear terrorism may generally be regarded as low. At the same time, however, any successfully performed acts of nuclear terrorism would leave devastating consequences (C) in its wake. Nuclear terrorism may therefore be seen as a low-probability/high-consequence event. As such, the risk is not zero, and cannot – and should not – be neglected:

$$R = P \times C, \quad => R \neq 0$$

Accordingly, it has been argued that governments should institute measures to make nuclear terrorist threats less likely to emerge, and should create operational capabilities that can give them a reasonable chance of detecting, defeating and minimizing the consequences of the nuclear terrorist threat (Falkenrath 1998, 58). From a medical point of view, however, the ability of health personnel to provide post-attack prophylaxis is limited. *Risk elimination* and *prevention* of nuclear terrorism thus seem key.

Any terrorist with nuclear ambitions will have to follow a specific stepwise path to accomplish the goal of nuclear havoc. The steps will be of both a motivational and a capability-building character (see table 1). To maximize the chances of preventing a nuclear terrorist attack, each of these successive steps should be systematically assessed.

Step	**Action**
S1	Form a highly capable group with extreme objectives
S2	Decide to escalate to the nuclear level of violence
S3	Steal nuclear weapons material
S4	Acquire nuclear weapons material
S5	Smuggle material to safe haven
S6	Construct nuclear explosive device
S7	Smuggle nuclear explosive device into target country
S8	Transport nuclear explosive device to target location
S9	Detonate nuclear explosive device

Table 1: Successive steps towards acts of nuclear terrorism with crude nuclear explosive devices. Based on Bunn et al. 2003

Each of the steps has to be performed in the order indicated, as each rests upon the previous one. The probability for a successful nuclear terrorist attack may thus be expressed as the product of the probability of all single steps S1,S2, …, S9:

$$P = P(S1) \text{ x } P(S2) \text{ x}\ldots\text{. } P(S9) = \_\ P(S_i)_{i = 1, 9}$$

Steps S1 and S2 are both of a motivational or intentional character, and fall therefore outside the core scope of this paper. Steps S3–S9, however, will all be the subject of further analysis. Each of these (technical) steps are a prerequisite for nuclear terrorist havoc – and each and every one of them depends upon the preceding step. The total probability P may thus be severely limited – even reduced to zero – if one or more of the partial probabilities $P(S_i)$ become minuscule or zero.

This is an essential point: The risk of nuclear terrorism could be (drastically) reduced – even eliminated – by installing proper barriers at critical points along the nuclear terrorist pathway. This allows, moreover, for a comparative "cost–benefit" analysis to determine where in the "nuclear terrorism chain" investments are likely to yield the highest gains (in terms of reduced probability of nuclear terrorism). The different steps and associated countermeasures – will be discussed in the following.

Stealing nuclear weapons material (S3)

The initial step towards a technical nuclear capability is to get hold of sufficient quantities and qualities of fissile material. While most of the fissile material worldwide is duly protected and accounted for, the huge amounts produced during the Cold War could make proper control challenging. As the quantity of weapons-useable material increases, so does the proliferation risk of the material (Dreicer and Rutherford 1996, 30).[3] There have been multiple documented cases of theft of kilogram quantities of weapons-useable material, especially in countries of the former Soviet Union. In February 2002, US intelligence confirmed to Congress that weapons-grade and weapons-useable nuclear materials have been stolen from some institutes in Russia (Collina and Wolfsthal 2002).

During the past decade, unprecedented co-operative work between the USA and Russia has been carried out to secure fissile material. However, much of the challenges remain. Hundreds of metric tons of nuclear material lack improved security systems. As of March 2003 – after a decade of cooperation – the US Department of Energy (DOE) had assisted Russia in protecting about 228 metric tons, or some 38%, of its weapons-useable nuclear material (United States General Accounting Office 2003, 25).

Insider thefts have turned out to be a particular problem. Soviet-era physical security systems were built on a philosophy of "guards, guns and Gulag" (Bunn et al. 2002, 35). Morale in the nuclear-weapon complex then was high, and insiders were not really a threat, as personal surveillance was tight and potential buyers of stolen fissile material absent. Post-Soviet experiences have proven otherwise (Koupriyanova 1999).

Acquiring stolen nuclear weapons material (S4)

Fresh fissile material is only mildly radioactive, with a limited level of toxicity in solid form. The material can be held safely in bare hands. It becomes hazardous only if finely divided, dispersed and ingested into the lungs. Due to the extreme density of the material, critical masses of weapons-grade uranium and plutonium occupy only small volumes – about a grapefruit size for uranium and a golf-ball size for plutonium (Harris 2001, 82). These small volumes and low toxicities could make handling of near-critical amounts of fissile material relatively uncomplicated.[4]

However, no final buyer – only sellers and middlemen – has yet been identified in what seems to be a fairly persistent black market for fissile material. According to the IAEA's Illicit Trafficking

[3] On a global scale, some 3000 metric tonnes of highly enriched uranium and plutonium have been produced since the dawn of the atomic age (Albright et al. 1997). Two-thirds of this amount (some 1750 tons of HEU and 250 tons of plutonium) has been produced for military purposes. The vast majority of the material is in nuclear-weapon states and thus outside international control. Currently, only some 1% of all HEU globally is under International Atomic Energy Agency (IAEA) safeguards.

[4] According to the Natural Resources Defense Council (NRDC), with a sophisticated weapon design a nuclear explosion could be created with as little as 2.5 kgs of highly enriched uranium (Cochran and Paine 1995, 9). Cruder nuclear weapon designs would require more uranium, ideally in the range of a bare critical mass – the mass of fissile material sufficient to sustain a nuclear chain reaction without any reflective materials is denoted a "critical mass" – (some 52 kgs for 93% HEU) or above.

Database,[5] about 600 illicit trafficking incidents have taken place since 1 January 1993. Of these, some 400 incidents have been confirmed by states. A little less than half of the confirmed cases (175) involve nuclear material, including 18 cases with highly enriched uranium or plutonium (Anzelon 2001). None of the quantities of seized nuclear material was in itself enough to produce a workable nuclear explosive. On the other hand, one successful transfer of high-quality nuclear material could be one too many, and the seizures produce a disturbing picture. The extent to which undetected illicit trafficking has occurred remains unknown.

Smuggling nuclear material to a safe haven (S5)

If the country of origin of the fissile material is different than the planned country of destination for the nuclear explosive device, the material may have to be transferred across several international borders. To customs and other law-enforcement officers this represents an opportunity for intercepting the material. Unfortunately, the low radiation signatures complicate such seizures, as do the need for specialized training and equipment, the number of legitimate border crossings, and – of course, limited opportunities and customs resources to control all travellers and goods.

Every day, more than 15 million cargo containers are moving around at sea or land, or await delivery. Inspectors examine only two percent of the containers, and often only after these have travelled long distances *(Economist* 2002). Despite comprehensive efforts and extensive international co-operation, only a fraction of the drugs smuggled is stopped, and it seems unlikely that this fraction should be any higher for fissile material. Experiences with the interdiction of drugs and other trafficking suggest that seizures represent as little as 10% – and a maximum of 40% of the gods actually being smuggled (Williams and Woessner 1995, 2).

Constructing nuclear explosive device (S6)

After arriving in their safe haven or point of destination with the nuclear material, the terrorists need to assemble the various weapons components. To construct a workable nuclear explosive device any actor – a state or a sub-state group – must follow a series of technical steps (Carnegie Analysis 2001): 1) develop a design for its nuclear device or obtain such a design from a nuclear weapon state, 2) produce the fissile material for the core of the device or obtain it from an external source and then shape the fissile material into appropriate nuclear parts, 3) fabricate, or obtain from outside, the non-nuclear parts of the device, including the high-explosive elements and triggering components that will detonate the nuclear core, 4) verify the reliability of these various elements individually and as a system, and, finally, assemble all of these elements into a deliverable nuclear armament, commonly referred to as “weaponization”.

None of these steps are straightforward. Constructing even a crude nuclear explosive device could thus be a daunting task for terrorists. However, a modest (terrorist) program aiming simply at producing crude nuclear weapons could probably circumvent the need for extensive domestic know-how and resources, and the rapid spread of technological knowledge may boost terrorists’ weaponization attempts. The design and production of nuclear weapons today is a far simpler process than it was during the Manhattan Project (Military Critical Technologies 1999).

Not only is much of the basic technical information needed to construct a workable nuclear device readily available in the open literature (see e.g. Serber 1992, Barnaby 1996). States and terrorists would have highly differing requirements to their weapons (Bremer Maerli et al. 2003, 731–732). This could make weapons designed to meet the “terrorist nuclear weapon standards” less

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[5] The database is part of an information exchange programme among IAEA member states, with some 70 states participating. The member states report and confirm incidents of illicit trafficking on their territories, and provide background information to the cases. Additional information from open sources is included when appropriate.

technically challenging than traditional state nuclear weapons. The differences are briefly discussed in the following and schematically presented in figure 1.

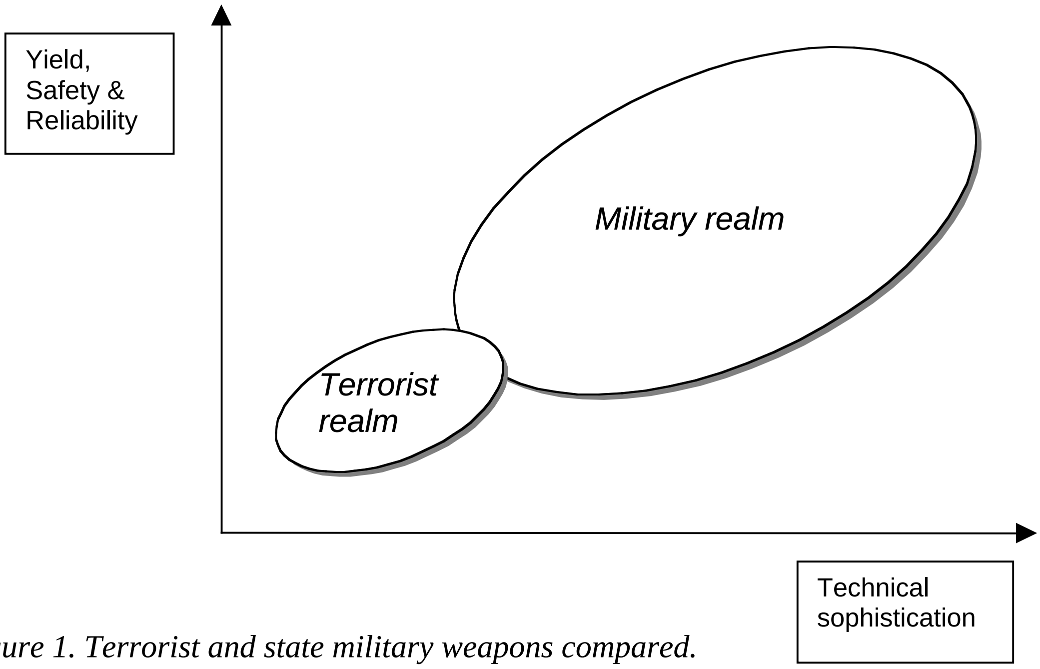

Figure 1. Terrorist and state military weapons compared.

Firstly, a state would be at least as concerned with the nuclear device not going off during storage and transportation, as with optimising the yield and detonation of the weapon. While *safety* requirements are strong for states, such concerns could be given less consideration by terrorists, especially groups with strong affection to martyrdom.

Secondly, the *reliability* concerns may be equivalently low amongst terrorists. While an ignition failure or a fizzle yield would be unfortunate from the viewpoint of terrorists, states must have some assurances that their weapons do function if they are supposed to do – e.g. during a nuclear exchange. As such, reliable nuclear weapons could be a matter of survivability for a state. Again, this will raise *performance* requirements and complicate production. Thirdly, any explosion in the lower kiloton range represents an unprecedented terrorist yield, and even failed plutonium explosives may serve as radiological dispersion devices. States on the other hand, want fairly accurate and known yields to predict damages and the number of weapons needed. Similarly should the *security* of their nuclear devices be an issue for states, and probably not for terrorists.

Fourthly, nuclear weapons for military uses are normally required in fairly large *numbers*, and they must be *delivered* by conventional military means (missiles, mortars etc.). This requires large-scale industrial structures, with a (invariable) stock of competent workers. It could, moreover, require indigenous fissile material production capacities, as dependence on (potentially perfidious) external suppliers could negatively impact the future nuclear capacity of the state. To terrorist group, a single supply of high-quality fissile material may be adequate for their (limited) nuclear ambitions.

Smuggling nuclear explosive device into target country (S7)

After a workable nuclear device has been constructed, it will have to be transferred to the location of planned detonation, a process which could also involve border crossings. Blocking such nuclear smuggling has inter alia been a major part of the US Homeland security measures to better control US borders. In the wake of rumours about Al-Qaeda's alleged progress toward obtaining a nuclear or radiological weapon in Afghanistan, hundreds of new and sophisticated radiation detection sensors were deployed to US borders, overseas facilities and points around Washington DC.

The sheer size and weight of the explosive devices could render clandestine transport difficult. The ability of the sensors to detect the devices and the nuclear materials, however, may be limited. After assembly radiation signatures from the fissile material are likely better masked due to the metal casing of the explosive device – making border detection harder and handling easier.[6]

Transporting nuclear explosive device to location (S8)

One of the most important constraining factors for state nuclear weapons is delivery. The weight capacity of delivery vehicle and the space available must be large enough to carry a military nuclear warhead. Development of reliable delivery systems and slender nuclear explosives are technically challenging and expensive, sometimes leaving nuclear bomb planes the only alternative for states. Crude terrorist nuclear weapons, however, will easily fit into a van – and perhaps even an automobile. Other non-military means of delivery could involve trucks, hot-air balloons, or ships.

The terrorist means of delivery into or against a country is thus essentially infinite. Clearly, this level of relative mobility and limited size coupled with weak gamma ray radiation (discussed above) could make detection of a crude nuclear device in a busy urban environment extremely challenging (Harris 2001, 83). To avoid transportation altogether, possible perpetrators could assemble the nuclear explosive device in an out-of-the-way downtown residence (Boutwell et al. 2002). If the device is detonated by a timer and remote control, this could provide ample time for getaway.

Detonating nuclear explosive device (S9)

The final step will be to detonate the nuclear device – releasing the devastating blasts, heat and radiation. Of course, the device may fail or fizzle – producing a limited yield. Once potential terrorists have the needed material, however, the actual construction of the ignition for the nuclear explosive device may be comparatively easier (Schaper 2002, 19). The ease of which this should happen depends upon the technical sophistication of the weapon, hereunder for instance the use of neutron triggers (Serber 1992, 51).

Compared to having a stolen intact nuclear warhead at hand, terrorists who construct their own crude devices would probably have an easier task detonating the device – knowing the device from scratch and avoiding (potential) difficulties associated with any permissive action links (PALs) to prevent unauthorised use etc. Uranium-based, crude gun-type devices could be an item of particular concern due to the low neutron-background. According to Luis W. Alvarez, a Nobel Laureate in Physics and a prominent nuclear weapon scientist in the Manhattan Project, gravity itself may suffice to set of a nuclear explosion with highly enriched uranium.

Assessing the steps and possible countermeasures

The number of steps terrorist have to perform on their way towards nuclear havoc offer governments opportunities to install a range of different countermeasures. Initial measures will focus on *risk prevention* through boosted security at facilities containing fissile material. Later countermeasures emphasises *risk responses*, e.g. through surveillance and detection of fissile material and/or of potential perpetrators.

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[6] Generally, it is easier to detect plutonium devices than uranium devices, due to higher radiation levels (Arbman et al. 2002, 7).

Each and one of the steps towards nuclear terrorist havoc will challenge possible perpetrators. The risk of nuclear terrorism would for instance be drastically reduced if the perpetrators had a hard time smuggling the nuclear explosive into the target country (S7). The probability of successfully transferring a crude nuclear device a cross a border would depend highly on the level and sophistication of the (technical) border control and terrorists' own skills. In reality, however, efforts to detect and interdict nuclear smugglers are extremely unlikely to reduce the likelihood anywhere close to zero (Allison 1995, 69). The detection of fissile material is anything but easy.

Assuming – probably far too generously – that customs and others are indeed able to seize 60 to 70% of the nuclear gods, this could still leave one third of the illicit nuclear material outside the hands of law enforcement officials. Experiences from drug trafficking, moreover, suggests that when law enforcement is increased along one route, this tends not to result in less trafficking, but rather a re-routing along new routes that involves less risks for the perpetrators (Williams and Woessner 1995, 3). Since 1994, reported illicit trafficking incidents in Europe have declined. Simultaneously, however, since 1999 there has been a revival in such incidents in the Caucasus, Central Asia, and Turkey (Zaitseva 2002).

Similar considerations could be made for detection of a readily assembled nuclear explosive device inside a country or a city. The radiation emitted from the device is limited and possible hideouts numerous. For any hopes of a successful detection, rescuers need to be fairly close to the object.[7] The possibility of higher neutron backgrounds due to lower enrichment levels and the relatively higher amounts needed for more fissile material in crude nuclear devices than intact nuclear warheads, could increase radiation levels, and thus ease detectability. However, for a hidden crude nuclear explosive device, the shape, material composition, and shielding is unknown – further complicating detection.

Nuclear terrorist risk assessments need, moreover, to take into consideration the differing standards between possible terrorist nuclear explosive devices and state nuclear weapons. While military nuclear weapons must meet an array of requirements before fielded, terrorists' obstacles to constructing a nuclear explosive device may be lower than anticipated. While responsive countermeasures like border-control, intelligence, sting operations, etc. clearly have a role to play in fighting nuclear terrorism, law-enforcement officers and others may thus fight in vain – and against the clock – the closer the potential nuclear terrorist perpetrators are to succeeding.

A key factor that, moreover, should affect decisions about nuclear terrorism threat reduction activities is that the nature of the terrorist threat and the targets, weapons, and means of delivery will change over time, often in response to successful countermeasures (Committee on Science and Technology for Countering Terrorism 2002, 36). Terrorists will adapt to the defences in place and seek the weakest known spots. Reducing vulnerability by protecting particular targets may therefore be neither prudent nor desirable.

Anther option would be detection of suspects and possible perpetrators. This may call for rigours countermeasures including extensive public surveillance. Such surveillance could, however, be at odds with fundamental civil liberties and should be used with care.

[7] If close enough, such a crude nuclear device could probably be detected within a few minutes of measuring time with a hand-held monitoring device (Arbman et al. 2002, 9).

Conclusion

From an assessment of the various steps on the nuclear terrorism pathway, it seems clear that that the most effective countermeasures are those focusing on the early steps – and in particular those that can prevent fissile material from being stolen in the first place.

Highly enriched uranium and plutonium are the essential ingredients of any nuclear device. Possession of a sufficient amount of fissile material establishes a critical step and the primary impediment towards accomplishing a functioning device (Arbman et al. 2002). Denying terrorists access to these materials would thus effectively reduce the risk of nuclear terrorist havoc to zero, independent of other technical capabilities and competence (associated with subsequent steps) that the terrorists might have. As such, it represents *the* nuclear terrorism chokepoint and probably the most cost-effective way to avoid nuclear terrorism. Denying terrorists fissile material could thus be the be-all and end-all of efforts to prevent nuclear terrorism. Technical barriers should by itself no longer be regarded sufficient to avoid large-scale nuclear havoc.

In sum, only preventive, and not responsive, countermeasures are likely to provide the long-term and sustainable nuclear security solutions that everyone is looking for. Averting acts of nuclear terrorism are likely to be much more cost-efficient than dealing with its consequences. Therefore, the stocks of highly enriched uranium and plutonium should be duly protected – and drastically and urgently reduced.

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