

British Pugwash Group
Public Discussion Meeting on
BRITAIN AND UNCONVENTIONAL TERRORISM
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Nuclear Terrorism
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Introduction

This talk is intended for two audiences:

1. The traditional Pugwash audience – professional scientists and engineers who believe that international peace and security are too important to be left to the politicians, and who wish to be informed about recent developments which threaten those objectives.
2. Members of the general public who share the same overall objectives, but who are less able to assess the truth behind the outpourings of the mass media.

I am conscious that it may inadvertently reach a third audience – those who for reasons of their own have an unhealthy interest in the potential of nuclear terrorism. I have done my best to ensure that they will find nothing here which is not already available to them through the scientific literature or the Internet.

It may be helpful to begin with some definitions.

Nuclear Terrorism is a hostile act (or a threat of such an act) involving nuclear materials (fissile or radioactive) performed by a Terrorist. That word covers a wide range of individuals. What they perhaps all have in common is that for some reason connected with their genetic makeup, or early upbringing, or education, or life experience, they have become motivated to hurt or destroy sections of society which they have come to regard as the enemy. It is very important to keep hold of the conviction that they are human beings with real (if distorted) feelings, since otherwise it is very difficult to formulate an appropriate response to their behaviour. They vary enormously in the nature of their motivation. In some cases it seems that their motivation springs from deep religious or political beliefs, in other cases it seems to derive more from some painful personal or collective experience – loss of someone they loved in a military confrontation, erosion of their personal or national self-confidence by the behaviour of occupying powers, denigration of their ethnic group by the behaviour of other groups, exploitation of their productive capacity by strong commercial groups etc. Occasionally it seems to be an essentially economic motivation – they are mercenaries being funded by some political or national power. They also vary enormously in the extent and nature of their technical/scientific education. There are, as the saying goes, ‘PhD terrorists’ and ‘Peasant terrorists’, and doubtless many intermediate cases. The nature of the threat that they represent differs enormously, and the steps which can appropriately be taken to address this threat are likewise very different.

The technology of nuclear terrorism

It is useful to distinguish a number of different approaches which the nuclear terrorist might adopt:

1. Theft or diversion of existing nuclear weapons, and their use or threat of use
2. Development and construction of a ‘home-made’ nuclear weapon
3. Dispersal of radioactive materials held by adversary on his own territory
4. Theft or diversion of radioactive materials and incorporation into a ‘dirty bomb’
5. Other means of dispersal of such materials on the adversary’s territory

Let us consider each of these options in turn.

1. Theft or diversion of existing nuclear weapons, and their use or threat of use

This option has been extensively explored in contemporary cinematographic fiction (with James Bond in *Thunderball*, *The spy who loved me*, *For your eyes only*, *Octopussy*, and *Goldeneye*, for example, or with John Travolta in *Broken Arrow*). It has also come into prominence in discussions of the extent to which it is possible to rely on the safeguarding of the nuclear weapons of the former Soviet Union, or of nuclear weapons which have been 'lost' in accidents by air or sea. It is widely believed (and may be true) that nuclear weapons are less well protected from theft now than they were at the height of the Cold War; however there have been a number of quiet inter-governmental discussions on improvements in the protection regime, and it is perhaps less plausible as an option today than it was ten years ago. It depends on either having an 'inside track' which gives information about the location, protection & movement arrangements and on the eventual use of the weapon, or an organisation (such as Smersh) which can create the required infrastructure for the theft and eventual use of the weapon. The thief has to be able to handle an object weighting up to a tonne or more, and avoid detection at normal cross-border checks, and from the massive search operations which would be initiated if/when the loss of such a weapon became known. Once it has been stolen, the terrorist's next concern has to be with the delivery system. Unless the terrorist can work within the country of origin, and make use of the indigenous delivery arrangement (rocket launching or aircraft delivery for example), he has to implement an alternative system. One option might be to dismantle the weapon, and simply use it as a source of fissile material in convenient form.

2. Development and construction of a 'home-made' nuclear weapon

This option has also been the subject of numerous works of fiction – eg in Nicholas Freeling's – 'The Gadget' or Vic Mayhew's – 'Plutonium'. It is also the option which underlies the widespread public concern about the availability of fissile nuclear materials, eg by theft from stores in countries with existing nuclear programmes or by purchasing or stealing natural uranium and developing an enrichment capability. It is widely recognised that the technology required to manufacture a weapon of sorts from highly enriched uranium or almost any plutonium is 'not rocket science', and could be mastered by a small group of PhD terrorists over a relatively short period, using published information (the Internet provides a regrettably good starting point). The key problems facing such a group are getting access to the fissile material (or to the rather less trivial technology required to enrich natural uranium) and delivering the weapon to the target. In this case, it is rather less likely that the group will have access to rocket or airborne delivery systems, so the 'suitcase bomb' option tends to be envisaged. The components of a small nuclear weapon are not very large, but getting them across a national border without detection would not be trivial (airports tend to have effective detection equipment for such material). Such weapons are not absolutely certain to work first time (some current nuclear weapon countries have had early failures in their tests), but the target country can hardly rely upon such a failure, so the threat of use may be perfectly credible.

3. Dispersal of radioactive materials held by adversary on his own territory

Countries which already have a civil (or military) nuclear programme are potentially vulnerable to a terrorist armed with conventional explosives and or rocket-launchers or a large aircraft which can be crashed onto a nuclear facility. A particular concern is the armed terrorist who can clandestinely enter a nuclear facility and place an explosive charge or accurately target a rocket on a facility such as a nuclear reactor, a reprocessing plant or a store for nuclear weapons material, spent nuclear fuel or high-level radioactive waste, is in a position to disperse millions of Curies of radioactive material into the local environment. If that is close to a centre of population, such an

event could have very serious consequences. A model for such an operation is the widely publicised SOE raid on the Norsk Hydro heavy water plant at Rjukan in November 1942. The problem facing the terrorist is that such facilities tend to be well-guarded against such intrusion. For that reason, the alternative option of crashing an aircraft into the facility has been much discussed. Most existing nuclear facilities were not designed to withstand such a crash, and the cost of retro-fitting protection is in many cases prohibitive.

4. Theft or diversion of radioactive materials and incorporation in a 'dirty bomb'

If the terrorist wishes to disperse radioactive materials in a country with no indigenous nuclear programme (or at a location distant from such facilities), there is the option of stealing the radioactive material, and then incorporating it in a 'dirty bomb' – a device containing conventional explosive and radioactive material, which will disperse the material on ignition. The technology involved is in most respects no more sophisticated than the nail-bomb of historic terrorist operations. The new problems facing the terrorist are to ensure his personal radiation protection until the bomb is used and to deliver the bomb to the target, in spite of any radiation detection systems in place.

5. Other means of dispersal of such materials on the adversary's territory

There are many other ways in which radioactive materials can be dispersed within the adversary's territory. These include deposition in sources of drinking water, incorporating it into materials sold as food, or dispersal as aerosols in enclosed spaces such as the Underground (as in the serious terrorist attack, using a chemical weapon, in the Tokyo underground). The problems facing the terrorist are again to ensure his personal radiation protection until the material has been dispersed, to prepare it in suitably dispersible form, and to deliver the material to the target.

The existing barriers to nuclear terrorism

As we have seen, none of the technical options which a nuclear terrorist might take is without problems. In this section we explore those problems in more detail, and see how far they are really a barrier to the use of that option.

1. Lack of scientific expertise and knowhow

It seems clear that most of the options discussed above require a certain minimum level of scientific and technical competence, perhaps beyond that possessed by the majority of terrorists, and some (eg the home-made bomb option) require access to information which exists within the nuclear weapon states about how to make a weapon, and what mistakes have to be avoided. However for the 'PhD terrorist', the barriers to obtaining the necessary education/information are now almost non-existent. British and other nuclear-weapons-state universities and technical colleges offering courses in nuclear physics or technology all have students from around the world, and there is nothing to stop a would-be nuclear terrorist from enrolling. This is analogous to the process by which the 9/11 terrorists learned aircraft navigation. As regards the required technical information, a great deal has been declassified, and is available to anyone who consults the Internet. Nicholas Freeling and Vic Mayhew, for example, both cite the 'Los Alamos Primer' by Robert Serber as a useful source (it can still be purchased from Amazon.com, though Los Alamos has recently withdrawn it from the Internet), and they give a range of other publicly-available sources. The many histories of the Manhattan project are full of relevant clues. There are naturally aspects which remain highly classified, but these mostly relate to the design of sophisticated weapons with high yield, light weight etc, which would tend not to be of concern to the terrorist. Information about sealed sources and radioactive waste is very largely declassified, so it is only rather specific information about location and protection of stores etc which are not in the public domain. So access to most of the

required information is not a barrier, except to peasant terrorists or to PhD terrorists in an enormous hurry.

2. Access to nuclear materials

This is a much more serious barrier, especially for the home-made bomb maker. Uranium-235 is not on the open market, and even natural uranium in the quantities which are required (tonnes) is not easily procured without detection. Although the world's press is full of stories of the theft of such material, especially from the FSU (though there are also reports of the disappearance of significant quantities of U-235 from the US in the 1960s and 70s), most of these 'thefts' involve less than one critical mass of material, and are attempts by non-expert individuals to make money. In a large number of cases, they are caught. The Russian authorities are rather confident that no Russian material of military significance is now unaccounted for. Equipment for separating uranium isotopes (and in effect the centrifuge option is probably the only feasible one) is rather carefully controlled under the London Convention on dual-use technology. Evasion of those controls is possible (as the cases of Iraq and Pakistan show) but it is difficult, and there is always a risk of detection. Once the equipment has been procured, there is a non-trivial industrial-scale process to be set up and operated, which takes time and expertise, and is somewhat vulnerable to satellite detection. So the tendency is to assume that the terrorist wishing to procure U-235 will try to steal it. The potential sources are research reactors (of which there are about 1000 world-wide, many of which use highly enriched fuel), those few (about 10) nuclear submarines which use HEU (the best known examples are the Russian Alpha class subs) or nuclear weapons themselves (or stockpiles of weapons material). It cannot be claimed that the current level of protection of these sources are as good as might be desired, but there is a rapidly growing awareness of the need to address this problem.

The other nuclear weapon option – plutonium- has different problems. The material is produced in a reactor, so the terrorist has either to build and operate a reactor for some years, or to have access to material from a reactor operator. Ideally, a weapon uses 'weapons-grade' plutonium, typically material with >93% Pu-239, and this requires the reactor to be operated in a non-standard mode. However any material with more than about 20% Pu-239 (and that includes material from a conventional civil nuclear reactor) can make a 'fizzle-yield' weapon of over one kiloton yield. The plutonium does however need to be free of the fission products with which it is associated in a spent nuclear reactor fuel assembly. This implies a chemical plant which can separate off the plutonium and convert it to metallic form. So the terrorist either has to create such a facility, or steal the product from someone who does. Although the chemistry is not very sophisticated, spent fuel is very highly radioactive, so the facility has to be shielded to protect the operators, and the material has to be handled remotely. Once the fissile material has been procured there is the task of weapon manufacture. This is more difficult than making a uranium-235 weapon, because of the need for implosion of the core using carefully shaped charges. For all these reasons, this option is likely to be much less attractive to the terrorist (Vic Mayhew's book *Plutonium* is conspicuously vague about how the terrorist discovered enough to design the shaped charges).

Access to fissile materials which have already been prepared in an existing weapons programme is subject to quite strong protective measures. Weapons and fissile material stockpiles are protected by armed guards trained to cope with a determined attack. Transport of such material outside such protected sites is normally restricted so

that quantities less than the critical mass are on the road at any time. Where this is not possible, armed escort teams are used.

By contrast, access to radioactive materials for a dirty bomb or for one of the other dispersion options, is relatively straightforward. The most widely distributed material is in the form of nuclear 'sealed sources', which are widely used in medicine (~25 KCi each for radiotherapy), in marine transport (~100 KCi each, as power sources for un-manned lighthouses), in the food industry (~10 MCi each, for sterilisation plants), in the oil & gas industry (~10 Ci each, for down-hole monitoring) and in the engineering industry (~100 Ci each, for weld inspection etc). A recent US GAO survey indicated that there are some 8 million such sources in circulation worldwide, and that 745 have been lost (and 510 not recovered) since 1998. The term 'orphan sources' is used to describe sources in use whose provenance is unknown and/or which are not under any system of authorised institutional control.— some 500,000 sources in the USA, and 30,000 in the EU may be in this category, and perhaps 30% of Russian sources. In addition to this material, the existing nuclear countries now have many millions of tons of radioactive waste material (at various different levels of activity) and much of it is stored in facilities with relatively limited safeguards. The relatively low level of attention which has been given to the safeguarding of all this radioactive material is partially because such material is regarded as being to some extent 'self-protecting'. Precisely when the level of activity is such that its use in a dirty bomb would be a real threat, the level of radiation around it would be lethal to anyone who seeks to transport it without a large shielded container, which would be heavy (over 100 kg) and highly visible to the security authorities. However there is still room for concern that such containers can be moved around within certain countries without being detected.

Access by terrorists to facilities where radioactive material is stored or used, with a view to dispersal of the material into the immediately surrounding region, is subject to protective measures, though these are generally less stringent than those adopted for weapon-ready fissile material, and some tests of the defences around nuclear power plants have suggested less than perfect readiness. A problem facing the terrorist is that the nuclear materials inside such facilities are rather heavily shielded (typically by over a metre of concrete or in a heavy lead or steel cask). Thus to achieve release of radioactivity it is necessary to intervene in such a way as to cause some beyond-design accident (eg a major disruption of the control system leading to a power surge and eventual meltdown) or to break open a thick concrete or metal containment system. To produce such an effect reliably requires considerable knowledge of the reactor design and /or of the use of explosives.

3. Having a delivery system

Except in the case where the radioactive material is to be dispersed directly from its place of storage or use, the terrorist has to be able to deliver the weapon, of whatever type, to the target.

The alternatives are rocket or aircraft delivery systems which pass above national defences, or clandestine delivery by land or sea at ground level through any border controls that are in place. The existence of rogue states which possess (or are developing) rockets with a cross-border range has raised the threat that these might 'sponsor' terrorism by making their rocketry available to terrorist groups. This threat is one of the motivations underlying the current interest in limited-scope missile defence systems. From the terrorist perspective, one of the disadvantages of this approach is that the payload of many rocket systems is rather small, and this may restrict the feasibility of delivering a home-made bomb or a sufficiently large dirty

bomb to be of interest. Thus the alternative option of clandestine delivery at ground level through the national border controls becomes interesting. The quality of the radiation detection equipment at such borders ranges from the excellent (at many international airports) to the non-existent.

A particular delivery problem arises when the material to be used is highly radioactive. The following trivial calculation will indicate the nature of the problem.

Suppose that the terrorist wishes to threaten an action which would require a government to evacuate an area of (say) one square kilometre in the centre of London, by claiming that he has the capability to disperse enough radioactive waste to do so. For Caesium-137, one of the more active components of much radioactive waste, a layer uniformly distributed at ground level at a density of say 30 Curies per square km, would give rise to a dose at a height of 1 metre of 2 micro-Sieverts per hour – ie 18 milli-Sieverts per year. Since the maximum permissible dose to a radiation worker is currently 20 milli-Sieverts a year, it might perhaps be a reasonable act of public policy for a government following an act of terrorism to evacuate the population from a region contaminated above a level of about 30 Curie per square km. The quantity of Caesium-137 required to do this is minuscule – about 3 grams. However if that whole amount were held unshielded by the terrorist at a distance of 30cm, he would get a dose of order 1 Sievert per hour – ie a lethal dose within a few hours. So he needs both to keep it within a thickly shielded container at all times until he is ready to use it, and then distribute it reasonably evenly over a square kilometre. The manufacture of the required mixture of Caesium-137 and explosive under fully-shielded conditions, and the transport of the bomb (again in a shielded container) to the target area would not be easy.

Consequences of acts of nuclear terrorism

The various different terrorist scenarios discussed above have widely different consequences. These can be summarised as follows:

1. Theft or diversion of existing nuclear weapons, and their use or threat of use
This is the most serious of all the scenarios, with consequences which could range from 50,000 to 10 million deaths, depending on the size of weapon stolen.

2. Development and construction of a 'home-made' nuclear weapon
Assuming that the amount of material acquired is only a few kilograms, and that no attempt is made to produce a fusion weapon, the consequences of its use will depend enormously on the effectiveness of the initiation system, and could range from a 'fizzle' equivalent to a few tons of TNT up to a full Hiroshima/Nagasaki weapon of say 20 kilotons. Even the fizzle could cause radiation injuries at up to a few hundred metres, and the full scale explosion could cause destruction of 5 square miles and kill 50,000 people.

3. Dispersal of radioactive materials held by adversary on his own territory
The consequences would depend strongly on the amount of material released, and the height to which it was lifted by the initiating explosion. One example of such an event (occurring as a result of an industrial accident, not terrorism) was the so-called Kishtym incident in Russia, where about 20 MCi of fission products (Sr-90 etc) were released by a chemical explosion in a waste storage tank, and led to fall-out at a level exceeding 0.1 Ci/km^2 , extending over 20,000 sq km (the so-called East-Urals radioactive trace) within which there were some 270,000 inhabitants. Within this, an area of 1000 sq Km was contaminated to a level exceeding 2 Ci/km^2 , and a total of some 10,000 inhabitants were temporarily evacuated from this area as a precautionary measure.

4. Theft or diversion of radioactive materials and incorporation in a 'dirty bomb'

Fortunately, there has not yet been a real-life incident of this kind, though the event in November 1995, where Shamil Basayev, the Chechen rebel leader, directed a Russian television crew to Moscow's Izmailovsky Park, where they found a container with a small amount of Cs-137, is often cited as an indication of the credibility of this kind of threat. A number of hypothetical scenarios can be found in the testimony of Dr Henry Kelly, President of the Federation of American Scientists to the US Senate Committee on Foreign Affairs in 2002. He envisaged three conceivable incidents, with consequences which he describes as follows:

- 1.** A medical source containing 2 Ci of Cs-137 exploded in Washington, DC in a bomb using ten pounds of TNT. He concluded that the initial passing of the radioactive cloud would be relatively harmless, and no one would have to evacuate immediately. But residents of an area of about five city blocks, if they remained, would have a one-in-a-thousand chance of getting cancer. A swath about one mile long covering an area of forty city blocks would exceed EPA contamination limits, with remaining residents having a one-in-ten thousand chance of getting cancer. If decontamination were not possible, these areas would have to be abandoned for decades. If the device was detonated at the National Gallery of Art, the contaminated area might include the Capitol, Supreme Court, and Library of Congress, as seen in figure one.
- 2.** A cobalt source from a food irradiation plant, containing 10,000 Ci of Co-60, dispersed by an explosion at the lower tip of Manhattan. Again, no immediate evacuation would be necessary, but in this case, an area of approximately one-thousand square kilometers, extending over three states, would be contaminated. Over an area of about three hundred typical city blocks, there would be a one-in-ten risk of death from cancer for residents living in the contaminated area for forty years. The entire borough of Manhattan would be so contaminated that anyone living there would have a one-in-a-hundred chance of dying from cancer caused by the residual radiation. It would be decades before the city was inhabitable again, and demolition might be necessary.
- 3.** A typical americium source used in oil well surveying, containing 10 Ci of Am-241. If this were blown up with one pound of TNT, people in a region roughly ten times the area of the initial bomb blast would require medical supervision and monitoring. An area 30 times the size of the first area (a swath one kilometer long and covering twenty city blocks) would have to be evacuated within half an hour. After the initial passage of the cloud, most of the radioactive materials would settle to the ground. Of these materials, some would be forced back up into the air and inhaled, thus posing a long-term health hazard, as illustrated by figure five. A ten-block area contaminated in this way would have a cancer death probability of one-in-a-thousand. A region two kilometers long and covering sixty city blocks would be contaminated in excess of EPA safety guidelines. If the buildings in this area had to be demolished and rebuilt, the cost would exceed fifty billion dollars.

It has to be said that Dr Kelly's assessment of the consequences of his three scenarios has been challenged by the US NRC as unduly pessimistic, though their reasons for thinking so do not appear to have been published.

5. Other means of dispersal of such materials on the adversary's territory
A number of the most significant fission product isotopes (in particular Sr and Cs) can readily be put into the form of salts which are highly soluble in water. So it is possible to envisage that the terrorist might clandestinely insert these into a public water supply (eg a reservoir or a purification plant). If this were undetected, it could cause serious doses to 10,000 or more individuals: if it were detected, and the water supply were disconnected, it could cause a major water shortage in any area which is largely dependent on a single main source of supply.

Other fission products (eg I-131) are volatile, and could be clandestinely introduced into the air-conditioning plant of a major building or an underground transport system (the vulnerability of which to terrorist action was well illustrated by the incident in the Tokyo underground in March 1995, in which terrorists introduced the chemical agent Sarin in which 12 people died and over 3000 were hospitalised. A volatile radioactive weapon could have had a similar effect.

Psychological aspects of nuclear terrorism

One of the most disturbing aspects of nuclear terrorism is that it is not actually necessary for the terrorist to possess a usable weapon for him to achieve his objective: it is sufficient that enough people in the target group should believe that he has. Thus 'nuclear blackmail' is a highly credible weapon. The best defence against this is a well-educated and informed public, which can form a realistic assessment of the probability that the terrorist can actually do what he claims, and of the probable consequences, and hence of the credibility of such a threat. Given the present state of public opinion about nuclear matters generally, and about radiation threats in particular, this may be a somewhat utopian objective. In this respect, the public is not helped by much of the material published in the media. As an indication of the problem, a recent paper presented at the Russian-American Seminar on High-Technology Terrorism (Moscow 2001) shows a table in which the various media reports on the radiological consequences of the Chernobyl disaster are compared with the best available scientific evidence, which concludes that 67 cases of thyroid cancer and 50 cases of leukaemia are all that can reliably be attributed to the disaster. However the NTV channel stated that there had already been 100,000 deaths, and that a further 200,000 would follow, and Prof Yablokov had proclaimed to the Social-Ecological Society in 2000 that there had been 2,337 million victims of the nuclear age due to cancer, genetic damage and neonatal abnormalities. So perhaps the media exaggeration factor is about 10,000. It is perhaps not surprising that in the aftermath of Chernobyl, the incidence of 'radiation neurosis' reached epidemic proportions in Kiev, a city 120km away and up-wind which was at no stage subject to any real radiation threat.

Having said that, it has to be recognised that the public health authorities sometimes play their part in maintaining a high state of public alarm. Consider the notorious incident in Goiania, Brazil, in September 1987, in which scavengers broke into an abandoned cancer clinic, and took a metal canister containing 1.3 KCi of Cs-137, which they then broke up and distributed among their friends, and then abandoned the remainder in a junkyard. The resulting dispersion of the Caesium caused four deaths and one amputation, and some radiation burns to a further 28 individuals. However in the ensuing panic, encouraged by the local press, the authorities felt obliged to monitor 110,000 individuals. The recently-published US NRC advice to the public on how to respond to an incident of nuclear terrorism:

- Move away from the immediate area--at least several blocks from the explosion--and go inside. This will reduce exposure to any radioactive airborne dust.
- Turn on local radio or TV channels for advisories from emergency response and health authorities.
- If facilities are available, remove clothes and place them in a sealed plastic bag. Saving contaminated clothing will allow testing for radiation exposure.
- Take a shower to wash off dust and dirt. This will reduce total radiation exposure, if the explosive device contained radioactive material.
- If radioactive material was released, local news broadcasts will advise people where to report for radiation monitoring and blood and other tests to determine whether they were in fact exposed and what steps to take to protect their health.

suggests that they may not yet have faced up to the implications of their advice.

Economic aspects of nuclear terrorism

A number of authors have published estimates of the economic cost of a nuclear terrorist attack. These estimates tend to be measured in Billions of dollars for even a comparatively minor attack, and are based on the assumption that the reaction of the public and/or its advisors will be to demand wholesale evacuation and radical decontamination or reconstruction of the affected area, whenever the current 'reference levels' are exceeded. In my view, these are incorrect assumptions. Such an attack is an act of war, and under wartime conditions, normal peacetime responses are often seen to be inappropriate. The actual risk to life or health from even quite high levels of contamination is small compared with the risk of death on the roads or other non-military causes of mortality. So the reasonable (and the only economically feasible) approach would surely be to move away from the extremely cautious peacetime radiological safety reference levels towards more realistic levels. Areas requiring evacuation or decontamination would then become much smaller

Conclusions

This is a large subject, and one which is occupying the minds of many serious scientists and government officials around the world at this time. It is too early to draw many very definitive conclusions. However my personal view is that the following conclusions are already fairly evident:

1. The most serious threat comes from the potential ability of terrorists to steal or manufacture nuclear weapons of mass destruction (eg capable of causing thousands of deaths). In this respect, Pandora's Box cannot be repacked: the knowledge of the existence of these weapons, and of the way in which they might be manufactured, is in the public domain, and accessible to any PhD terrorist. So unless we can quickly remove the underlying causes of terrorism, we have a duty to mankind to make terrorist access to such weapons, and to the nuclear materials (U-235 and Pu) which are their essential ingredients, as difficult as possible. Not nearly enough is being done at this time to protect or relocate vulnerable sources of fissile material, especially research reactors which use HEU, or certain civilian fuel cycle facilities.
2. All other nuclear terrorist threats are relatively minor, and the greatest danger is public over-reaction to such threats. The media never fail to overstate their significance: the average over-reaction factor (in terms of consequences and probabilities) may be as high as 10,000. We all have a duty to demand from the media balanced and accurate quantitative information, and to demand from government a balanced strategy for the management of such incidents. To monitor 100,000 individuals following the dispersal of 1 KCi of Cs-137 is not a balanced reaction
3. We should improve the arrangements for denying unauthorised access to radioactive material, with the protective measures made proportionate to the number of Curies at risk and the likelihood of a terrorist initiative. An important first step is to know where these are - the reported incidence of 'orphan sources' is a matter of concern. The preventative measures, sadly, need to take account of the possibility that the terrorist will use lethal force to access the material.

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