Terrorism and the Maritime Shipment of Nuclear Material

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Contents

Preface

The following reflections on security concerns surrounding the maritime transportation of nuclear materials were prompted by the special shipment (over 2004 and 2005) of surplus weapons-grade plutonium from the US military stockpile, and the subsequent return of Mixed Oxide (MOX) fuel made from that plutonium; but the issues raised by this shipment are of much wider relevance. Particularly, they are relevant in varying degrees to the long-standing trade between Japanese power utilities and British and French nuclear enterprises that have been providing reprocessing services, and also, to a lesser extent, to shipments between the British Nuclear Group and their various customers in continental Europe and coastal nuclear shipping (in dedicated ships) around Japan and Sweden. Whatever may happen in the future to US surplus plutonium (and the US is now planning its own MOX fabrication capability) it is clear that the maritime transportation of nuclear material is likely to continue and perhaps develop further. This will be especially the case if current initiatives to establish international centres for enrichment and reprocessing come to fruition. In this connection, it may be noteworthy that, in May 2006, the Australian Government raised the possibility of offering a 'cradle to grave' service, in which (in addition to supplying increased amounts of uranium) it would take in spent fuel and then reprocess or store it. If anything of this kind did transpire, it would certainly have the consequence of increasing the maritime transportation of nuclear material. Another reason for many more transports is the near-term "nuclear revival", due to the fight against global warming and to high fossil fuel prices.

The possibilities for accidental release of nuclear materials through collision, stranding, or fire, have been well canvassed by a number of agencies. The focus of this present study is on terrorism and the fear (raised by certain activist parties) that terrorists might somehow get control of one of these shipments and then (depending on the nature of the material seized) contrive to make some sort of nuclear device, or otherwise, cause a significant release of radioactive material into the environment. It is with the plausibility of the various risk scenarios in this domain that this present report is concerned.

The author is very grateful to the various agencies and companies involved in transporting the nuclear materials (or in regulating, or otherwise providing security, or

security advice) for their willingness to talk and (in the case of the companies) to give access to various facilities and significant sites. The companies also provided financial support for the travel and other expenses entailed in preparing this assessment. A full list of those consulted is given as an appendix to the main report, although particular opinions are generally not attributed to particular individuals by name. There are delicate matters of judgement here and the full subtlety of these may not have always been captured in the text. On the other hand the author takes full responsibility for what *is* written here. The report is an objective evaluation of the security risks that attend the maritime transportation of sensitive nuclear materials on ships dedicated to the purpose, put together by someone who has never been employed in the nuclear industry and from a country (New Zealand) which has an involvement in nuclear matters limited to the use of radioactive sources in its hospitals, educational institutions and industry.

Overall, the author concludes that the security provisions that attend shipments of the kind discussed here are such as to provide a very formidable deterrent to any attempt at diversion or sabotage. As far as security is concerned, the shippers, regulators and security agencies involved set themselves a very high standard. In the words of a senior British security adviser, they take it that they 'simply cannot afford to get it wrong'. Clearly, everything that is done cannot be made public (for obvious security reasons). However, it is the opinion of this author that there is enough that *can* be put in the public domain (or is there already) to support the judgement that the supposed terrorist danger has been much exaggerated by activist critics[1].

[1] Greenpeace is the most prominent of these but it is by no means the only one. There are activist groups in many of the countries that see themselves as involved, however peripherally, although they frequently tend to rely on the same limited sources for their material Examples of ad hoc local protest groups are the (Irish) Nuclear Free Seas Flotilla and the (US) Blue Ridge Defence League. A more international objector group is the Scandinavian-based Local Authorities International Environmental Organisation (KIMO). The dominant opposition remains the ubiquitous Greenpeace organisation, which continues to be the source for the bulk of critical comment on nuclear activities generally.

Executive Summary

This report is concerned with the security of maritime shipments of nuclear material, especially those carried on vessels built for the purpose[2]. The focus is particularly on the supposed threat to this activity posed by terrorist organisations that might wish to assault the ships and perhaps take the cargo, with the intention of making a nuclear-based device, or devices. The methodology is to consider the full spectrum of possible intentions in the light of what is known of the conditions under which these cargoes are carried. Of course, there is much about the security arrangements that surround these cargoes that is not in the public domain but it is the conclusion of the report's author that there is enough that can be said to amply support an overall finding that the risk is very much smaller than critics imagine.

There is a range of possible cargoes that may be carried. At one end, there is plutonium oxide, either from nuclear weapon stockpiles, or from reprocessed civilian material. In principle, plutonium oxide (from whatever source) may be the basis for the fabrication of a nuclear explosive device. In practice, though, material from civilian sources will contain much higher proportions of contaminating isotopes of plutonium (i.e. isotopes other than Plutonium-239) and is thus much less suitable for the purpose[3]. Mixed oxide (MOX) fuel rods also contain plutonium in a diluted form (diluted with uranium oxide) and thus (again, in principle) could constitute a starting point for weapon fabrication. Historically, the genesis of much of this transportation has been the decision of Japan to reprocess in Europe the spent fuel from its (now) fifty-five nuclear reactors. This means that another common cargo material is spent fuel rod assemblies. This cargo also contains plutonium (extracting it is the point of reprocessing) and thus it is also (once again, in principle) a source of material for making a nuclear explosive device. However, in this case, there is an additional formidable problem and that is the presence in the spent fuel of the intensively radioactive products of fission.

There are a number of possible cargoes from which a nuclear explosive device cannot be made (not even 'in principle'). The most obvious of these is vitrified high

[2] Such as those operated by Pacific Nuclear Transport Limited (PNTL) for the trade between Europe and Japan. PNTL ships were also used to take material between the United States and France in 2004 and 2005.

[3] In the opinion of some, 'high burn-up' civilian plutonium is completely unsuitable for weapon manufacture.

level waste (HLW). This is the physically immobilised concentration of fission products which arise from spent fuel reprocessing. Another possible cargo is the general mixture of low-activity materials that arises from nuclear activities (Operational Waste). Both Operational and High Level wastes could form the basis of some sort of radiological attack but, as is made clear in the report, neither is very promising for the purpose and the intense radiation associated with HLW would make it impossible to deal with without specialist facilities.

All these scenarios involve seizing the ship and removing its cargo before any of the possibilities (however promising, or unpromising) can be realised. A major part of the report is concerned with the difficulties of doing this. In the first place, it is noted that when the ships are carrying cargoes involving plutonium (except spent fuel), there are two ships (one escorting the other) and both are armed. They have (each) three 30mm rapid fire naval guns and they carry members of the UK Civil Nuclear Constabulary, who have access to a range of weapons. They also have continuing contact with their home base and with appropriate security agencies, in the event of any emergency. Potential attackers would need to find their quarry, which would be no easy matter once they were away from the coast. They would then need to approach without being observed. This will be a very difficult operation since the ships are equipped with state-of-the-art monitoring and surveillance capability. Once they are observed, they will be at great risk from the guns and, as they get closer, from small arms on the ship. They are going to need armoured attack craft and must expect to take serious losses. Of course, they might improve the odds here by also using a helicopter, or helicopters. The ships have defences against this. It also needs to be noted at this point, that the assault group would need a substantial mother ship (from which to fly the helicopters and support the attack vessels) and that we are now really talking of a mid-ocean military operation which is arguably beyond the capabilities of a non-state party.

Notwithstanding this, the report goes on to consider at some length what the terrorists might be able to do, if they have somehow taken the ships (or, at least, taken a ship with its cargo and somehow neutralised the escort). The first thing to note here, is that cargoes between Japan and Britain or France are carried in shipping flasks which weigh of the order of 100 tons and that the PNTL ships, themselves, do not have the capability to lift this kind of weight. Indeed, when the cargoes contain plutonium, they do not even have the capability to remove the very substantial hatch covers. This suggests that the terrorists would need to deploy (as well as everything else) a floating crane, or, otherwise, they would need to go to a port which had the appropriate facilities; this could hardly occur without detection and with all the complications that that would entail. The conditions of transportation are different where cargoes are never far from land (as in the case of shipments around Europe or around the coast of Japan). In these cases, the crucial factor is that the ships are always close to a source of serious security support in the event of any kind of threat.

Finally, the report considers a range of threat scenarios that do not entail taking the ship. Included in this are the possibility that a ship carrying a nuclear cargo is rammed by a fast attack vessel packed with explosives, after the fashion of the attacks on the USS *Cole* and the French tanker, *Limburg*. It is noted that, in these latter cases, the ships in question were stationary and without protection at the time of the attack, whereas the nuclear ships tend to be in secured harbours or protected by floating barriers. An attack of this kind on the high seas is a different matter. Assuming that an explosion could be contrived alongside the ship, the main factors that would limit the consequences of this are the double-hull construction of the vessel and the extremely robust construction of the transportation flasks. This, particularly, would make it extremely unlikely that an incident of this kind would result in any nuclear contamination of the environment. A similar conclusion is arrived at in relation to air or subsurface assault.

Overall, the report details some of the extensive and formidable security arrangements that are maintained by the various companies involved in shipping nuclear materials on dedicated ships and concludes that the actual risk that terrorists might take material and make a bomb or radiological device (or otherwise contrive the dispersal of nuclear material into the environment) is extremely small and that there is little prospect of an attack having any serious consequences beyond the psychological. This is not a reason for complacency; indeed, it is important that defensive provisions keep pace with developments in the relevant technologies, and in the intentions and capabilities of possible threat organisations, as far as these may be determined. But it is a reason for recognising when enough is palpably enough.

Terrorism and the Maritime Shipment of Nuclear Material

Introduction

It seems that almost every maritime shipment of nuclear materials is accompanied by dramatic claims that the cargo (or ship) is vulnerable to sabotage or diversion by terrorists (with disastrous consequences), although what these terrorists might do, or attempt to do, is seldom made clear[4]. As a consequence the public is left with vague and ill-defined fears and little understanding of what the real risk might be. The purpose of this report is to review the whole range of possibilities: different materials and different quantities; and, particularly, the specific details of the transportation arrangements, with a view to identifying what might be attempted in what circumstances, and with what prospects of success.

The possibilities here range from: relatively small consignments of nuclear materials (such as radioactive sources) which are dispatched with other materials on a journey which includes a maritime component, to nuclear consignments in shipping containers, which are transported along with other containers (cargoes such as yellow cake, or uranium hexafluoride), through to substantial quantities of nuclear material carried on dedicated ships. The dominant company here is Pacific Nuclear Transport Ltd (PNTL), which operates a fleet of ocean-going nuclear carriers that have been used mainly to take material between Europe and Japan. PNTL ships were also used in the 2004/2005 transfer of plutonium from the United States to France and Mixed Oxide fuel (MOX) back from France to the United States. This latter category (large quantities of nuclear material, carried on ships specially designed for the purpose) has been the most productive of public concern (however ill-founded) and this will be the main focus of the discussion to come.

Even here, though, the range of possibilities is wide and the nature of the supposed danger different in the different cases. Cargoes in this case may be: separated military plutonium (the raw material for weapon pits, or material from dismantled weapons); separated civilian plutonium (from civilian reprocessing activities); spent fuel (containing civilian plutonium); mixed oxide fuel (containing civilian or military plutonium, diluted with depleted uranium and made up into MOX

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[4] Critics also often include concerns about the possibility of a purely accidental release of nuclear material. This was the subject of an earlier paper by this author ('The Maritime Transportation of Nuclear Materials: A view from New Zealand', *Political* Science, Vol 54 No 1, June 2002, pages 5-19) It has also been the subject of a number of extensive expert reports. The matter will not be taken further here.

fuel rods); or fission products held in solid suspension. In the case of substantial long-distance cargoes of plutonium-containing material (other than spent fuel) the relevant regulatory requirements include the provision of an escort vessel. For PNTL, this requirement is met by the utilisation of a second vessel. Consignments of Highly Enriched Uranium (HEU) are also of interest in view of their greater potential suitability (compared to plutonium) for the production of an Improvised Nuclear Device (see below). It is assumed that this highly enriched uranium is most likely to be contained in made-up fuel rods for research reactors (rather than dispatched as the pure oxide, or even the metal) and carried in shipping containers on commercial vessels, or, perhaps, consigned by air.

The range of theoretical possibilities for what terrorists might aim to do is equally wide. Most obviously, they might attempt to seize a cargo of weapons grade plutonium, or uranium, and make a nuclear weapon, or weapons. To what extent civilian ('reactor grade') plutonium is suitable for weapon fabrication is a matter for debate (to be engaged in further below) but to the extent that it is possible to create some sort of nuclear explosive device from this material, with whatever limitations, this is also a risk. As noted above, civilian spent fuel rods and fresh MOX rods also contain plutonium of one kind or another. They could thus be a starting point for weapon fabrication. However, they would require a significant amount of processing to separate the small percentage of plutonium (assuming appropriate technology to be available), and, even then, in the case of civilian-sourced plutonium the terrorists might have a material of dubious value to them. The mixture of fission products contained in shipments of separated high level waste is of no use for the production of nuclear explosive devices, though it could be used for the assembly of radiological weapons (as could any radioactive source, including the plutonium sources mentioned above). Spent fuel also contains plutonium but in this case it is mixed (amongst other things) with the very radioactive products of uranium fission. This is a very substantial barrier to diversion for nuclear weapons purposes.

There is another range of theoretical possibilities for terrorist action in regard to maritime shipments of radioactive material, which do not entail actual removal of the material from the ship. These are important since the conditions of transportation (especially in the case of dedicated ships) would make this latter operation extremely difficult. Given that the cargo remains on the ship, terrorists might attempt to take the ship to some location (or take the ship over in that location) and then sink it, or detonate a conventional explosive in it, or start a fire, or threaten to do any of these things unless demands are met. Of course, none of these activities would result in a *nuclear* explosion but they might result in the release of nuclear material into the environment. In regard to this study, there would then be several questions. How much nuclear contamination would result and with what health consequences? What would be the social, political and economic costs of such an event, if (as seems likely to be the case) the actual health effects were long term and relatively trivial? The September 2005 report of the 'Chernobyl Panel' (with experts drawn from WHO, IAEA, UNDP, UNEP, FAO and UNSCEAR) is very interesting in this respect. After all the dire reports and the claims for compensation from within a very wide area, the major effect of the Chernobyl accident was said to be psychological, with people being 'still haunted by an unfounded anxiety'. More recently, the preview to a yet-to-be-published US National Academies report on the transportation of spent fuel and high-level waste noted that 'risks were well understood and generally low' but that there were 'social' risks'.[5] The point is the same in both cases. The human health consequences of the release to the environment of radioactive material have frequently been much exaggerated in media reports and this has caused a great deal of ill-founded public anxiety. As will be seen, this report is concerned largely with examining the possibility that scenarios of the kind envisaged *could occur*, rather than with the health consequences that might follow if they did. It is nonetheless pertinent to observe that it would be in the public interest (as well as in the interests of the industry) if there was a better public understanding of the real health consequences of possible outcomes, however unlikely they may be.

The final scenario-set that is considered, is the possibility of suicide assault on the nuclear-cargo-carrying ship itself, in the manner of the attack on the American destroyer, *Cole* (2000), and the later, similar attack on a French oil-tanker (*Limburg*), or something similar, by aerial or subsurface means. Again, the possible consequences, in terms of the release of nuclear material, are evaluated. It needs to be noted that none of the possibilities outlined in the summaries above have ever been exemplified in some fifty years experience of nuclear transportation. This tells us something in general about the level of risk (although it must also be recognised that

[5] 'No Fundamental Technical Barriers to the Safe Transport of Spent Nuclear Fuel And High Level Radioactive Waste, but Challenges Remain', 9 February 2006 (news@nas.edu)

the aspirations and capabilities of terrorist groups do evolve). To go beyond this we need to look at the main possibilities in a detailed way.

A. SEIZING THE SHIP

Seizing nuclear cargoes from dedicated ships (or seizing the ships, themselves)

The scenarios that have most exercised the minds of commentators and protesters are those in which dedicated nuclear cargo ships are assaulted with a view to seizing the ship, or its cargo. This came particularly to the fore, in the case of the late 2004 shipment of weapons-grade plutonium from the United States port of Charleston to the French port of Cherbourg on the PNTL ships *Pacific Pintail* and *Pacific Teal*[6] (in an operation called colloquially, 'Eurofab'). Of this Greenpeace said, that it was 'an invitation to catastrophe: either a radioactive leak or *an attempt by a terrorist group to seize the shipment and make a nuclear bomb of its own*'.[7] This latter scenario, in which the envisaged perpetrators board the ship and take control of it, is the one that we are immediately concerned with here. The possibility that they might then proceed to make a nuclear weapon, or weapons (or make any other use of their position in control of the ship), is considered later.

The envisaged operation can be broken down into a series of stages. In the first place, the terrorists would need to locate and approach the ships. They would then need to board them and overpower the crew. So, how easy would this be? To begin with, it needs to be noted that in the specific case of the September 2004 shipment (Charleston, South Carolina to Cherbourg, France) there was no stopping at intermediate ports and no passing through narrow straits, which might have provided an improved logistical basis for interception. This is also true of MOX shipments from Europe to Japan, following reprocessing of Japanese spent fuel in Britain or France.[8] In all such cases, the attack must, therefore, take place at either end of the voyage (where extra security is available from shore-based or coastal assets, as it was,

[6] The cargo of 150kg of plutonium dioxide was on one of the ships, with the other acting as escort.
[7] Similar claims were also made by an organisation calling itself the 'Nuclear Free Seas Flotilla'.
[8] Other cargoes, such as Japanese spent fuel to Europe and occasional return shipments of vitrified high level waste, tend to utilise a shorter route via the Panama Canal. This should not be seen as necessarily a vulnerability. Approaching or leaving the Canal from either end, or transiting the Canal, itself, is not the same as passing through an insecure narrows.

for example, when the ships left Charleston[9]), or in mid-ocean. In a mid-ocean situation, the logistical burden on the terrorists is much greater (they need a larger vessel and, presumably, lighter attack-craft, as well) and, of course, they need to find their quarry. Reports of attempted interceptions by protest ships of other shipments on the high seas suggest that this may not be easy. Of course, as far as is known, there have been no *terrorist* attempts to intercept nuclear ships and it is notable that the two suicide attacks on other ships (the *Cole* and the *Limburg*) took place in harbour or close to shore.[10] Distance from land (and speed) is ultimately the best guarantee of security. This is certainly the firm opinion of New Zealand Navy Captain, John Martin.[11] Would-be attackers need to be able to place themselves ahead of their quarry, and they really only get one shot at interception. Their quarry, on the other hand, has (in mid-ocean) a wide range of possible tracks and it is to be presumed that PNTL ships would be taking full advantage of that.[12]

Notwithstanding this major difficulty, it will now be presumed for the sake of argument that the terrorists have found the ships. They now need to approach without being detected. This is going to be extremely difficult. The PNTL ships are equipped with modern radar systems and night vision capability; and there are two ships that will be hard to distinguish at sea (and only one may have the cargo). In addition, there are redundant systems on each of the ships, just in case of equipment failure. The ships also carry extra crew over what might be expected in an ordinary civilian cargo ship and the operators also err on the side of caution in the matter of personal qualifications, so that the possibility that a particular skill is not available (through accident or illness) is reduced to minimal levels. Thus, the chances that the would-be

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[9] Details of this were provided in a letter from the US Department of Homeland Security to Congressman Edward Markey on 8 September 2004. The letter refers to Coast Guard cutters, aircraft and 'other law enforcement and Navy assets'. http://www.house.gov/markey/Issues/iss_homeland_resp040908.pdf . These security arrangements, together with those for the overland shipment of the material in the United States, are described in a report prepared for Greenpeace International and accepted as more than the minimum required by IAEA regulations (and, as such, satisfactory). (http://www.wise-paris.org/english/reports/040920JointAssessmentIAEA.pdf). The corresponding arrangements at the French end were equally stringent, with French special forces on board the ships from the twelve-mile limit and extensive back-up arrangements for the land component.

[10] On the other hand, the November 2005 attack on a cruise ship off the coast of Somalia is reported to have taken place 150km off shore. As was the case with two other attacks in the same area at about the same time, the cruise ship (*Seabourn Spirit*) outran its attackers.

[11] Now on the staff of the New Zealand Chief of Defence, Captain Martin had earlier substantial experience commanding a New Zealand frigate on interception duties in the Persian Gulf. The present author is very grateful to Captain Martin for sharing his insights into the problems of ship boarding and repelling boarders.

[12] The time taken for the outward voyage suggests that the ships did not take the shortest possible route.

attackers could approach undetected are extremely small.[13] This is important since the PNTL ships are known to be armed with three 30mm, rapid-fire, naval guns. These would present a considerable problem to any vessel attempting an unauthorised approach and this may be thought to be a sufficient deterrent to any but the most determined and prepared. The terrorists would need to deploy, undetected and in mid-ocean, several armoured and well-armed attack vessels, with a substantial force to man them. It also needs to be noted that the PNTL ships, when carrying plutonium cargoes (i.e. including reactor-grade material in the form of MOX), carry an additional complement of armed police officers (the Civil Nuclear Constabulary, CNC), who have access to a variety of weapons, including rifles, shotguns and handguns, etc., as well as protective equipment such as body armour and gas masks.[14] They also have available 'non-lethal response' methods, which include high-pressure water cannon. This suggests that the terrorist boarding party might have some difficulty even after it had got to its quarry. They now need to get aboard a moving vessel, with nobody likely to be throwing a rope ladder down. In fact, the attackers are going to need at this point some sort of extendable pole ladder. Operating this in the open ocean whilst travelling at around 14 knots and with the possibility of being fired upon from above would seem to present an insuperable challenge. There would be only one way around this and that would be to use helicopters for the assault. These would need to be large, in order to carry an attacking force of such a size that it would not be immediately overwhelmed by the defenders. This, in turn, would require a substantial platform from which to fly the helicopters and would raise the level of sophistication required for the operation yet another notch (although the possibility of deploying helicopters would vastly improve the search capability of the assault force). There is also the difficulty that the PNTL ships have defensive systems that would constitute a substantial deterrent to a helicopter landing, which means that an airborne assault force would need to rappel down to reach the ships. Of course, the operations envisaged here *are* within the capability of the Special Forces of major states and thus may be said to be theoretically possible for other parties. On the other hand, there are no precedents for this kind of operation by non-state parties and it is scarcely credible

[13] Though not, of course, impossible. Small boats are correspondingly more difficult to see than larger ones and rain and cloud will impair the effectiveness of radar and night-vision, or electro-optical technology. Equally, adverse weather conditions make operating small boats more difficult.

[14] All this surveillance and defensive capability is coordinated through a Vessel Alarm Station. It is from here that operations would be controlled in the event of a security threat of the kind being envisaged.

that a terrorist organisation (however well funded) could mount such an extensive and technically sophisticated operation far from shore and without being detected by the relevant security services. The possibility will therefore not be further considered here.

Inside help

There are other stratagems that might be considered at this point, including the possibility that the terrorists are actually able to plant one or more of their number on one or other (or both) of the PNTL vessels. These persons might then be able to immobilise defence systems or otherwise facilitate the assault. How significant this possibility might be depends partly on the chances of planting such a 'sleeper' (or sleepers), and partly on how effective he (they) might be if they got on board in such a role. In the first place, it needs to be noted that the turnover rate for crew members on PNTL ships is quite low (on average they are with the Company nearly eleven years) and that the vetting procedures (as might be expected) are very thorough. An operation to place such a sleeper would thus need to be initiated some years ahead of the need. More particularly, there are significant restrictions in regard to where on the ship a particular crew member may go. An access-control system regulates entry to sensitive areas and as far as operating security sensitive equipment is concerned, a 'two-man key' system applies. Both authorised operators must concur before a procedure is initiated or equipment is turned on or off.

The possibility remains that a terrorist sleeper might attempt some kind of sabotage in the areas to which he did have access. It is also conceivable that the terrorist group could blackmail or otherwise coerce a key crew member or members, on the basis of some activity or behaviour that they would not wish to be made public, or by kidnapping a family member. There are clearly dangers here and, equally clearly, there are institutional practices that would build on the initial screening process and on-going security provisions that would reduce these particular risks to a low level. It is also the case that a terrorist group attempting anything along these lines would risk their whole enterprise at a very early stage. They might be detected at the stage of being screened as a potential crew member, or as they approached a potential blackmail victim, or as they monitored a potential kidnap victim. In each case they would effectively tip their hand long before the serious part of their operation could begin. Indeed, at that stage they could not know when a chance, if ever, would come. The risks from sleeper penetration also have to be considered in the wider context. In the most sensitive cases there are (as noted) two ships; they are in constant touch with the outside world, and, even in the event that a ship is taken, there are formidable problems in moving, or otherwise utilising the cargo.

Similar considerations in regard to access apply to the Civil Nuclear Constabulary (CNC) which is deployed where plutonium cargoes are involved (plutonium oxide, as in the Eurofab case, or when MOX fuel is carried to Japan). As earlier noted, the CNC is a police force that provides armed response capability at nuclear facilities in the UK and protects high security cargoes during rail, road or sea transportation. Some of these site-based officers may then apply for further training to take on marine escort duty. This takes a further six months on top of the initial two-year training period. It is understood that there is no shortage of volunteers for 'sea-duty' from amongst the CNC ranks, so that even after the minimum two-and-a-half years, there is no guarantee that a volunteer would be selected for a crew and certainly not for a particular crew. Even if selected, such a volunteer would then be paired with someone of longer experience and a variant of the 'two-man' rule would apply. Again, it is clear that any attempt to plant a sleeper would need to have a very long time horizon. Even at the end of the process, having volunteered and having been selected for a particular voyage, CNC personnel (like the ship's crew) would generally not know precisely when the ship would sail or which of several routes it might take. Given sufficient advanced planning (say, at least three years in advance of the need), a sleeper (or sleepers) might be insinuated on to one or other of the ships. For the reasons outlined above, there would still be a major question about how effective he/they could be.

Maritime emergency ruse

In this stratagem there would be an attempt to lure the ship (or ships) to a supposed vessel in distress, which would then provide an opportunity for some sort of ambush. The terrorists might even have another vessel in the vicinity, which also purports to be coming to the aid of the stricken vessel. This is clearly a vulnerability and PNTL ships certainly recognise that, in this sort of circumstance, they would have the same obligations as any other vessel on the high seas. On the other hand, this is a risk contingency that has been the subject of considerable thought. As a consequence, there are detailed protocols to be followed, particularly as regards searching any persons who were allowed on board and allowing such persons only to come on one at a time. Certainly an event of this kind would prompt the highest degree of alert on the ship. Again, it needs to be noted that if it were a 'plutonium' shipment, there would be two ships and a higher degree of security as regards the voyage as a whole. The postulated second (non-PNTL) ship in the vicinity would also ring alarm bells, especially if the PNTL ships were away from the usual shipping lanes. On the other hand, if this second ship was confirmed to be friendly, it might take on the responsibility for the emergency.

Security in the most sensitive cases

Much of the above account of the protective measures available in the sort of case under review is taken entirely from open sources.[15] From briefings given to this author by persons in, or close to, the security agencies in the various countries concerned, it is clear that there are many other security provisions that are not in the public domain, and the total effect of these is to add greatly to the difficulties enumerated above, especially in the most sensitive of cases. Collectively, these would seem to present such a challenge to would-be attackers as to make an attack of the kind envisaged extremely unlikely to succeed (or even to be attempted). It also seems clear that the assault ship(s) in this sort of case would be very vulnerable to detection by satellite surveillance systems, or by ships or aeroplanes, depending on circumstances. In the special case of the weapons-grade plutonium shipment, it seems clear that the track of the PNTL ships was followed very closely so as to monitor the possibility that other unidentified ships were approaching. It is also clear that in this case the PNTL ships were watched over in other ways.[16] This is the sort of matter that would be included in the official threat assessments that are required for shipments of this kind. These are routinely made by persons in a variety of agencies in the countries, including departments of transport, energy and foreign affairs, as well as the various national intelligence and security bureaux, and, of course, persons from the companies concerned. These consultations and deliberation give rise to comprehensive evaluations of potential threats to the ships or the cargoes, which are

[15] These include publications of the transport company itself (PNTL) and a 1999 US State Department report to the House of Representatives Committee on International Relations (27 April 1999), as well as media reports of specific cases.

[16] Consultations with officials in Washington seemed to confirm that some kind of continuous monitoring of the ships was in place. At one point the observation was made that 'they (the ships) were never alone'.

called Design Basis Threat assessments (DBTs). These are not public documents, and, in the nature of things, they could not be so. To publish what had been anticipated (and prepared for) would merely be an invitation to potential malefactors to devise something that had not. On the other hand, not publishing DBTs means that the concerned citizen cannot assure himself that every possibility has been thought of. In the opinion of this author, the first principle is the more important of the two. This is particularly so since the second requirement (that everything has been thought of) may be logically impossible to show. How could you know that there was still not something you hadn't thought about? However, one might be satisfied that the amount of work that had been done was such as to reduce the chance of successful terrorist assault to negligible levels.

Other cases

In the case of less security-sensitive cargoes (spent fuel, or separated fission-products), there will generally be only one ship (i.e. no escort) and less need for dedicated security personnel to be carried, unless there are intelligence indications to the contrary. In the case of the separated fission products (usually transported in the form of a solid ceramic material in a steel vessel, which is, itself, contained within a very substantial transportation flask), the lower security assessment is based on the fact that the most that this material could be used for is for some sort of radiation dispersal operation, and even then it is in a most unpromising form (from the terrorists' point of view). It could not be the basis of even the most rudimentary nuclear explosive device. Spent fuel certainly contains small amounts of plutonium (in a mixture of isotopes – see below) and even smaller amounts of unused uranium-235, from which (in principle) a nuclear explosive could be fabricated, but these are, equally, in a most unpromising form. Not only are they mixed with the extremely radioactive products of fission and a large amount of uranium-238 (from which they would need to be separated), they are also contained within fuel rods from which they are not easy to extract[17]. In practical terms, the most the spent fuel could be used for would be radiological contamination. Whatever else may be said, this is a

[17] Apart from the radiation danger, there are also physical factors here. Some spent fuel rods may have been deformed by long exposure to high temperatures in the reactor core. Insofar as this is the case, their contents are not accessible in the way that the fuel pellets in fresh fuel rods would be.

significantly lesser danger, and thus, it is appropriate to treat such cargoes as less security-sensitive.

The Greenpeace response

It is noteworthy that these security provisions (including the most stringent, as in the weapons-grade plutonium case) inevitably fail to satisfy Greenpeace and other opponents of the trade. The grounds of this dissatisfaction are made clear in a report commissioned by Greenpeace International and conducted by their French and British consultants (WISE-Paris and Large and Associates). In their view, the security arrangements did not go far enough, given the heightened risk of terrorism since September 2001. It was said that the United Kingdom authorities, who were responsible for the maritime component of the 2004/2005 plutonium transfer, did not have a 'definitive list of DBTs' (although how they might have known this is not at all clear) and appeared to be resistant to planning for possible terrorist actions'.[18] Specifically, they noted that the regulatory requirements for this kind of shipment[19] specify that 'one or more escorts' must be provided and that, even in this most sensitive case, that was all that was provided. As noted above, this latter criticism was very wide of the mark. It was simply that the full security plan was not (for obvious reasons) made public. The 'Eurofab' shipment was a special case and there were significant additional security provisions in place. Apart from anything else, it would have been undesirable to publicly establish new norms which might then be expected in the case of less sensitive shipments, such as those containing commercial plutonium or MOX fuel.

In the general case, and from a strictly logical point of view, it is undeniable that there would be more security if there was additional security support but, equally it may be doubted whether the expense of such additional steps would be justified by the quotient of additional security that they would buy. Particularly, this would seem to be the situation, having regard to the challenges that already confront the would-be terrorist, on the basis of the known security arrangements, and in the absence of specific evidence of the possession by terrorist groups of the sort of capability that

[18] From this author's extensive discussions with those responsible for the security arrangements for Eurofab in all the countries involved, this would seem to be far from the case. As is clear from many places in this report, an enormous amount of effort has gone into attempting to anticipate security risks and to prepare for them. Of course, for reasons that must be obvious, the detail of this threat assessment work cannot be made public.

[19] IAEA INFCIRC/225 and IAEA INFCIRC/274

could overcome them. Also, it may be doubted whether Greenpeace criticisms of the specifics of the security arrangements are entirely sincere. They want to prevent the activity (shipments of nuclear material, and, more generally, nuclear operations of all kinds) and one may conclude that no amount of additional provisions would really satisfy them.

It is also worth noting that the only way that terrorists might approach a PNTL ship, with a lowered risk of violent challenge, would be if they could do this within the cover of some sort of 'protest' flotilla. In this sense, it might be said that the activities of such groups as Greenpeace may actually make more likely the event they claim to fear. Even here, though, it should be noted that the PNTL ships are also equipped with some non-lethal defensive measures (such as water-cannon) that might be appropriate to this case. Other non-lethal possibilities could also be deployed, such as the long range acoustic device (LRAD), which seems to have been used to good effect by a cruise ship in repelling pirates off the Somali coast in November 2005.

B. TAKING THE CARGO

Taking the cargo

Notwithstanding the above arguments, which tend to suggest that seizure of a dedicated ship with its nuclear cargo is very unlikely to succeed, the discussion will now continue on the basis of exactly that assumption, i.e. that the transportation vessel has been seized. At this point the scenarios diverge into those that entail separation of the cargo from the ship and those that do not. As far as the former is concerned, it should be noted that commercial cargoes of spent fuel, MOX, or HLW, on the Japanese run, are generally contained within very substantial transportation flasks, which weigh over 100 tons. The immediate issue then is whether the contents can be removed without moving the transportation flask. If they cannot, then the flask itself must be taken. As far as opening the flasks is concerned, there are two problems. The first is that there is generally insufficient space in the hold of the ship to remove the very substantial safety protection on either end of the cask and that specialist equipment is necessary to remove flask lids. The thick walls of the flask would also make cutting into it an extremely protracted exercise and, even then, the size of the internal packaging is going to make removal of the contents very difficult. This is very significant, since 'delay' is a central element in the overall security strategy. That the ship has been taken will be known from a very early stage and there are arrangements in place to alert operators to any false messages of reassurance. From the point when the first alarm report is received (or if the communications systems fail to operate as intended), serious forces are likely to be converging on the scene (depending on the circumstances and the location).

There is another factor here. If the cargo is spent fuel or separated fission products (high level waste), opening the package is likely to expose the attackers to huge doses of gamma radiation and the possibility of instant death for those involved. These sorts of materials can only be dealt with in remote handling facilities.

As far as removing the flasks unopened is concerned, it should be noted that, although the ships are fitted with a substantial hoist system that is capable of lifting the hold covers, it is not capable of lifting the flasks themselves. In the case of plutonium or MOX shipments, even these hoists are removed, so that opening the hatches in mid-ocean would require the attackers to have brought their own heavy-lifting equipment and this would have to be very substantial if it were to be also capable of swinging a 100 ton flask out over the side.[20] Even if it were, it would be a fraught operation, assuming that it is being conducted in mid-ocean (the author has some long-past but still vivid experience of unloading equipment of this sort of weight over the side of a tank landing ship and into smaller landing craft). The alternative, of course, is to take the ship and its cargo to a suitable port with appropriate lifting equipment. This course of action has its own obvious problems. It would clearly take a number of days to get to such a suitable port (still presuming that the interception has taken place on the high seas) and, all the while, the location of the ship would be hard to conceal. As noted above, PNTL vessels have a strict reporting system when engaged in these kinds of voyage, so that the fact that there was a serious problem would be known to the 24hr Communications Centre almost immediately. The risk of interception, before any unloading could take place, would thus be very great.

On the other hand, it may be argued that in the event that the ship was successfully occupied, the ship's locator beacon(s) could, in principle, be switched off, or otherwise disabled, and that weather conditions, and a remote location (as well as a bit of luck), might allow a period of undetectability. However, for this to happen

[20] This adds another monumental logistical problem if the cargo is to be removed in mid-ocean. The crane is going to be a large and towering object, difficult to get hold of and difficult to move without being noticed.

in the most sensitive cases (where plutonium was involved) *both* ships would need to be taken and, in any case, concealment would be difficult to maintain as the ship(s) came closer to land. In any event, the duress systems would have been activated long before those boarding the ship(s) could have an opportunity to disable the locator beacons, assuming the beacons could be located.

Shipments within Europe and around Japan

There is some variation in the general security arrangements for maritime cargoes (such as MOX) if the shipments are from the United Kingdom to European destinations[21]. In this case, there is likely to be a significant road-haulage element (perhaps from a French or Belgian port to an inland destination, such as Switzerland). This means that the consignment package will be smaller and lighter than the corresponding package for Japan, although it is still required to meet the same IAEA safety criteria. In this case the package is loaded in the originating site (Sellafield) on to a specially-designed High Security Vehicle (HSV) and then taken in a security convoy to the departure port. Here, the HSV and its cargo are put on a specially adapted roll-on, roll-off vessel for onward transportation. The ship in this case does not have deck-mounted weapons but the on-board security escort personnel are well armed. The crucial point is that though the ship is never far from land (and thus, in theory, easier to intercept), it is never far from a source of serious security support in the event of terrorist assault. As has been noted, the key concept in designing the security arrangements is that of delay. In the case of shipments within Europe, that 'delay' does not need to be so long, since help is nearer to hand. These considerations apply equally to the envisaged shipments of nuclear materials between the UK and Sweden (spent fuel to Sellafield, and MOX and HLW back to Sweden), although in this case there will be no significant land component, since all Swedish utilities are on the coast.

Japan has its own small fleet of dedicated ships to take spent fuel and low-level waste from Japanese power stations (which are conveniently placed on the coast) to the nuclear service centre at Rokkasho. The larger of these ships (for spent

[21] Of course, shipments of MOX from French sources to destinations elsewhere in Europe would not entail a maritime component.

fuel) is based on the same design and virtually the same size as the PNTL vessels.[22] When Japanese-made MOX becomes available (some time after 2012) these ships will be available to deliver this fuel around the coast. Since these voyages will not take the ships very far from the Japanese coastline, presumably there will be no formal need for an escort vessel (just as there is no need for this, in European waters). As it is, present arrangements include coordination with the Japanese Coastguard service. As elsewhere, the specifics of the security arrangements are determined by an assessment of the risk at the time, which would include consideration of the nature of the cargo and a specific security assessment. Japan is likely to build an additional ship before its own MOX shipments begin. The design of this will reflect advice from the Coastguard and various appropriate security agencies.

C. TERRORIST USE OF SHIP AND CARGO

Terrorist use of ship and cargo

The starting assumption here, is that the terrorists have taken control of the ship and its cargo and that, even if the position of the ship continues to be known, counter action is inhibited by a threat, from the terrorists, to take further action against it. The possibilities here are that the ship is scuttled, or set on fire, or that a large explosion is set off on the ship (which may also result in either or both of the former possibilities).

Some scenarios that involve the ship and its cargo at the bottom of the ocean have already been extensively studied in the context of accidental events, such as severe collision or grounding. In the specific case of fresh MOX fuel, the results of a series of technical studies by the Central Research Institute of the Electric Power Industry of Japan (CRIEPI) were reported in 1998[23]. The studies were on: the performance of the transport cask; the performance of the cladding around the MOX pellets; and, assuming both of these to have failed, on the rate at which nuclides in the package would leach into the surrounding water. The conclusions were unequivocal. The intact transport casks were resistant to water pressure down to 7,000m and thus the casks were not expected to rupture and expose their contents. Tests on the MOX

[22] The requirements for ships that carry radioactive materials are laid down in a number of international conventions and codes, administered by the International Maritime Organisation. Particularly, they are governed by the International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level radioactive Wastes on Board Ships (INF Code). The PNTL ships *Pacific Pintail* and *Pacific Teal* are INF3 ships.

[23] CRIEPI, 1-6-1, Otemachi, Chiyoda-ku, Tokyo, Japan

fuel tubes revealed a similar resistance to breach down to the same depth. In the extremely unlikely event that both of these barriers failed, it would be expected that radioactive material would begin to slowly leach into the immediate environment but this would only result in a dose, to the most exposed member of the public, of between one millionth and one hundred millionth of the dose-equivalent limit recommended by international radiation safety organisations (i.e. between $1.1X10^{-6}$ mSv/year and $8.1X10^{-8}$ mSv/year, as opposed to the recommended limit of 1 mSv/year). Similar studies have been undertaken of the parallel risks from casks containing vitrified fission products (high level waste).[24] Here again, the robust nature of the transportation packaging and the low leach-rate from the vitrified material suggested negligible risk. The authors of the study also noted that salvage possibilities also made it extremely unlikely that there would be any significant public exposure in any event.

The shipment casks used in the case of the US plutonium sent to France in October 2004 and in the returning MOX fuel assemblies in 2005, were significantly less massive than the casks used in other cases (1½ and 4 tons, respectively), so that, all else being equal, they would present less of a problem to move. The casks were nonetheless of very substantial construction, consisting, in the case of the plutonium oxide powder, of a concentric arrangement of 'cans', with a carbon-steel outer layer.[25] They were also in a substantial outer container (like an armoured shipping container) from which they would have had to be removed. Together, these cladding materials and the surrounding packaging would provide a substantial barrier to terrorist access to the active material, notwithstanding that they are significantly less massive than the casks used on the longer voyages to Japan.

In the case of sabotage (as opposed to accident, and thinking now of the more general case, where the nuclear material is not seen as potentially nuclear weapon material) it is to be supposed that the terrorists would wish to affect the sinking in coastal or inland waters but it seems evident from the above data that this would scarcely be worth the effort in terms of its environmental impact. Merely submerging the casks would produce no nuclear contamination and, even a systematic effort to

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[24] See for example, Sprung et al, 'Comments on a Paper Titled "The Sea Transport of High-Level Radioactive Wastes: Unresolved Safety Issues"', Sandia National Laboratories, SAND97-1130, May 1997.

[25] Full detail of the packaging and transportation arrangements is contained in National Nuclear Security Administration (NNSA), 'Fabrication of Mixed Oxide Fuel Lead Assemblies in Europe', November 2003 (DOE/EIS-0229-SA3)

breach the transportation containers and expose the contents (itself a formidable undertaking in the confines of the ship), would produce low levels of contamination. Sinking in deep waters would have an even smaller environmental impact, although salvage would be more difficult[26].

After all this, what we are left with is fire and explosion. Assuming the ship to have been taken over, fires could be started in various places, with the normal fire-fighting mechanisms disabled. Like the immersion contingencies, this contingency has also been studied in the context of accidental fire[27] and the results of this study may be applied to the supposed terrorist-sabotage case. In general, the sort of package used for the transportation of nuclear materials is resistant to all but the hottest and most persistent of fires (which are unlikely to occur accidentally in the hold of the ship)[28]. To achieve any breach of the package seals would require the contrivance of high temperatures for a prolonged period. This, in turn, suggests that there would be a need for additional combustible material, which would have to be procured from somewhere and loaded, which would, in turn, suggest further substantial logistical problems. Even at the end of all this effort, the amount of radioactive material released to the environment might be trivially small. Taking control of an oil tanker (or, better still, an LNG tanker) and setting *that* on fire would seem to be a far better bet, in terms of public spectacle.[29]

There is a final possibility to be considered, and that is that terrorists who have taken over the ship use explosive (and, especially, 'shaped') charges to breach the shipping casks and release some quantity of the nuclear material within. The Greenpeace International consultants discussed this possibility at some length in the context of the French overland component of US plutonium shipments to France. In the course of this discussion, they claimed that tests performed by the French nuclear protection institute (IRSN) show that the FS47 cask (as used in the Eurofab case) is vulnerable to breach by advanced modern shaped-charge munitions, and that this

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[26] Though not impossible. In the case of MOX, individual casks are fitted with a sonar beacon, which enables them to be found to considerable depths.

[27] Sprung et al (*op cit*) and IAEA 'Comments on MEPC39/INF.15'

[28] This issue is discussed extensively in the IAEA technical report, 'Severity, probability and risk of accidents during maritime transport of radioactive material' (TECDOC-1231, July 2001). As noted in the 'Concluding remarks' (page 61), 'a fire in the hold is unlikely to burn at a sufficient temperature, or long enough, to cause the release of radioactive material'.

[29] This point was dramatically underlined by a speaker in a June 2006 energy conference in Darwin, Australia. Professor Yea Byeon-Deok is quoted (Michael Richardson, 'Security vital in billion-dollar trade', *The New Zealand Herald*, 26 June 2006, page A 12.) that a 100,000 ton LNG tanker 'has four times the energy potential of the atomic bomb used to hit Hiroshima'.

could result in the ejection of a significant quantity of the plutonium oxide powder (although IRSN deny this). Given the consultants' further claim that such an outcome could be achieved through the deployment of a rocket-propelled grenade, it may be that there is some need for further scientific testing. The experts at IRSN are currently engaged in evaluating a whole range of scenarios involving different shipping containers and differing contents against possible modes of assault. Of course, it would not be in the interests of security to make the results of these tests public and, in any case, this can never be a static situation. As in other contexts, the security authorities need to continue to respond to innovation on the part of potential threat groups. On the other hand there is no need for them to assist the latter by telling them of the progress they have made.

The applicability of this to the maritime context is limited. Breach of the shipping flask from *outside* the ship would be impossible (the missile would lose much of its momentum and all of its accuracy passing through the double-hull of the ship, even if the terrorists knew precisely where to aim). A missile or shaped charge inside the hold might (if the Greenpeace consultants are right) displace some plutonium powder but the ejecta would be held within the hold itself. The scenario in which activities of this kind (in respect of all or most of the packages) are then followed, in a subsequent stage, by further explosions or fire intended to breach the holds, raises the whole operation to a new level of complexity and uncertainty, especially when taken with the difficulties of taking the ship in the first place. It might also add very greatly to the time that would be required to make these various preparations. For this reason, the scenario will not be taken further here.

There is a defensive possibility that might be considered in this context, and that is that, in certain circumstances, the ship operators arrange to scuttle the ship themselves, rather than allow the terrorists to retain control of the ship and its cargo. The cargo would then be recovered at some future time. Meanwhile, the terrorists will have been obliged to leave and whatever intentions they might have had will have been frustrated. Scuttling a PNTL ship would not be easy as an improvised operation (having regard to the safety features, such as the double-hull, which are designed to maintain buoyancy) but, presumably, a system could be installed that included the possibility of initiating the scuttling from a distance. Captain Martin comments here that the decision to deliberately and remotely initiate an explosion to deny terrorists the use of the vessel by rapidly sinking it, would likely result in a large proportion of the crew losing their lives – particularly if they were held below decks. The more or less guaranteed loss of the crew might well outweigh the risks of potential follow-on terrorist action. It would thus not be a very desirable response. Less drastically, the ship might be disabled by remotely destroying key elements of the propulsion or manoeuvring systems (the ships have twin rudders and twin propellers, as well as bow-thrusters). In this case, there would be minimal risk to the lives of any crew members that were left on board, although the ship would remain afloat and thus, presumably, could be taken in tow. As has been noted earlier on several occasions, delay is a crucial part of the counter-terrorist strategy. Disabling the ship in this way would certainly have this effect.

D. USING THE CARGO

Terrorist use of the cargo

Here the assumption is that cargo has been separated from the ship (and presumably put into another vessel) and that the terrorists intend to utilise the contents of the package. Depending on the exact nature of the transportation cask and its contents, this would present a number of further problems, the first of which would be opening the package and removing the contents, with some regard to the safety of those involved. Neither of these operations would be easy and the degree of health risk would vary very much according to the nature of the nuclear material itself, and would include the possibility of persons involved receiving doses of radiation that were actually lethal. (It is assumed that health-damaging effects that were longer term and not immediately fatal, might be acceptable to the ideologically-driven.) Of course, all these objections may be circumvented by assuming an unlimited technological sophistication and access to specialist resources on the part of the terrorists and their backers. However, at some point we would also need to ask how likely it is that a project as demanding as this would ever get adopted.

Supposing the transportation package to have now been opened, what could happen next would depend on the specifics of the cargo material. In the event that it was weapons grade plutonium, the terrorist could presumably move straight to the fabrication of a weapon. The oxide would need, merely, to be converted to the metal. The activities of the notorious AQ Khan suggest that weapon-design information has been quite widely disseminated, so that this stage might only require special materials and the requisite engineering and chemical expertise. The authors of *Saddam's*

Bomb: the Iraqi race for nuclear weapons, report that Iraq had a nuclear bomb firing assembly (the 'beach-ball') ready for when they had sufficient suitable nuclear material to put into it.[30] On the other hand, the relative technical sophistication of plutonium devices suggests that, even given an adequate quantity of weapons-grade metal, the assembly of a workable device is not easy. Of course, this latter is not a judgement that ought to be too heavily relied upon in such a crucial matter of security. It is infinitely preferable to make sure that the would-be bomb makers do not get hold of the material in the first place, and this consideration amply justifies the extensive security precautions that surround the shipment of weapons-grade material.

A crucial question here would relate to where this activity was taking place. It would presumably require some time to complete (depending on what assumptions are made about the state of preparedness of the terrorists and on their degree of expertise). The persistence of the tracking provisions would be crucial here. There is also the possibility that anything but the most expert handling of the material, and in ideal conditions, could cause the release of traces of radioactive material that might identify the site of operations and invite immediate intervention. In the contemporary international climate there are few, if any states, that would allow such activity on their territory[31] and in the case of any exception to this generalisation, it is very likely that concerned parties would take action from outside, with or without the acquiescence or agreement of the state concerned, once the location of the activity had been detected.

Making a bomb

In a recent paper, Harvard scholars Bunn and Weir, are quite adamant that not only are terrorists 'racing to get a nuclear bomb' but that 'the probability … that they could succeed is large enough to do "everything in our power" (quoting President

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[30] Shyam Bhatia and Daniel McGrory, London, Time Warner Paperbacks, 2002

[31] Activity of this sort (and, indeed, seizing the ship in the first place) would be illegal under the 2005 International Convention for the Suppression of Acts of Nuclear Terrorism, which characterises ships carrying radioactive material as 'nuclear facilities'. As of early 2006, the Convention is not yet in force but with 95 signatures, including all the permanent members of the Security Council, it is likely to acquire the requisite 22 ratifications quite quickly. It would then place very specific obligations on States whose territory was being used in this way.

Bush) to prevent it'.[32] They claim that making a crude nuclear weapon is not as difficult as many experts have supposed.

> A detailed examination in 1977 by the US Office of Technology Assessment, drawing on all the relevant classified information, summed up the situation: "A small group of people, none of whom have ever had access to the classified literature, could possibly design and build a crude nuclear explosive device. They would not necessarily require a great deal of technological equipment or have to undertake any experiments. Only modest machine-shop facilities that could be contracted for without arousing suspicion would be required. The financial resources for the acquisition of necessary equipment on open markets need not exceed a fraction of a million dollars. The group would have to include, at a minimum, a person capable of researching and understanding the literature in several fields and a jack-of-all trades technician.[33]

The authors also make it clear that they are talking here of a 'crude, unsafe, unreliable terrorist nuclear explosive that might be delivered by truck or boat' rather than a 'safe, reliable and efficient nuclear weapon suitable for delivery by a missile or fighter aircraft' and that this would be a significantly easier operation if the terrorists had access to sufficient Highly Enriched Uranium (HEU)[34] to construct a crude 'gun-type' device. Is HEU a possible cargo? The answer seems to be, 'Yes'. Research reactors around the world, including medical isotope production facilities, are still using highly enriched (up to 90%) material. Although there is some anxiety about this, and some intention to convert such facilities to operate with low-enriched fuel or targets, there is no expectation of a change in the situation any time soon. As of July 2006, it was anticipated that it would take more than a decade to complete the enrichment reduction programme. A major source for this highly-enriched uranium is the United States. A significant proportion of this material goes to Canada but other

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[32] Matthew Bunn and Anthony Weir, 'The Seven Myths of Nuclear Terrorism', *Current History*, April 2005, pages 153-161. Note also Graham Allison of the same university (Harvard) who is offering an 'even' wager that a terrorist nuclear strike will occur somewhere in the world in the next ten years.

[33] *Ibid*, page 156.

[34] Natural uranium contains less than 1% of the fissile isotope Uranium-235 (the rest is U-238). For most civilian nuclear purposes it is enriched to around 5%. By definition HEU is 20%, or more, U-235. For weapon-making purposes an enrichment of greater than 95% is desirable.

consignments go to Europe[35] and elsewhere. If these consignments are sent by sea, they are presumably in shipping containers, which would make them more vulnerable than if they were sent on dedicated vessels. On the other hand, they are likely to be loaded well down in the cargo (as a matter of policy) and thus there would be a need to remove the containers above them. The relatively smaller quantities of fuel for research reactor purposes could also be transported by air. The relatively small quantities involved in this trade[36] might also mean that the proliferation risk is low, since experts suggest that at least 50kg of HEU might be required for a single device.[37]

A number of critical assumptions lie behind estimates of this kind, including particularly, assumptions about the proportion of uranium-235 present in the material. The Hiroshima bomb contained 60kg of 80% enriched uranium but it is estimated that a chain reaction might be achieved by as little as 25kg of 'weapons-grade' uranium in a simple 'gun' device with a beryllium reflector.[38] On the other end of the continuum, some experts contend that even 20% enriched uranium (by definition, still HEU) is 'practicable' for bomb construction. In this case the critical mass required is said to be 800kg.[39] The same experts report an opinion that, given sufficient weapons-grade uranium and a would-be suicide bomber, a blast of 5-10ktons could be achieved by merely dropping one 100lb mass onto another from a height of 6ft. It is hard to know what to make of these claims. Probably the most prudent conclusion to draw, is that maintaining the security of HEU (especially material towards the weapons-grade end of the concentration spectrum) is a continuing priority, if the possibility of an IND explosion is to be minimised

As noted above, the Bunn and Weir argument concerning the ease with which nuclear weapons may be made, is different if the material is weapons-grade plutonium. It is different, again, if the material seized is *reactor-grade* plutonium. The latter kind of shipment (in the oxide form) has taken place between Europe and Japan (though it is unlikely to be repeated). It is also envisaged as 'pay-back' by the

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[35] Particularly to Belgium and Holland.

[36] A recent assessment suggests that US exports of HEU declined from around 3 tons to 'a few tens of kilograms' by the early 1990s (Alan J Kuperman, 'Bomb-grade Bazaar', *Bulletin of Atomic Scientists*, March/April 2006).

[37] See, for instance, Gavin Cameron, 'Nuclear Terrorism: weapons for sale or theft', *Foreign Policy Agenda*, March 2005, US State Department, page 18.

[38] Charles Ferguson and William Potter (*et al*), *The Four Faces of Nuclear Terrorism*, Monterey, Center for Non-Proliferation Studies, 2004, page 132

[39] Ferguson and Potter, page 107

British Nuclear Group to French and Belgian MOX manufacturers[40]. In this case it will also, presumably, go by sea. Where the cargo is reactor-grade plutonium, the crucial considerations concern the suitability of such material for making nuclear weapons. As far as this is concerned, there are widely divergent and strongly held opinions. On the one side, it is maintained that some kind of nuclear explosive device can be made from reactor-grade plutonium (and some experts, including weapons experts, say just this). Commentators use the term 'weapon-usable' for this situation. However, this material is most unsuitable for the purpose and (as a matter of fact) no proliferator has ever gone this way.

States that have embarked on covert nuclear-weapons programmes have always set up dedicated operations to produce nuclear-weapons-grade material. The reason for this is quite clear. The use of reactor-grade plutonium introduces a number of major complications into a process that is anyway not easy. In the first place, the chances of a 'fizzle' yield[41] (through pre-initiation) are very much greater, due to the elevated neutron flux produced by the presence of the shorter-lived isotopes. However, the greater problems are produced by the very much higher heat and radiation output of reactor-grade material as opposed to weapons-grade. These factors make working with the material extremely dangerous (due to the six-fold increase in radiation) and they make any resulting device unstable and liable to physical distortion, due to the heat generated by the relatively rapid disintegration of the less stable isotopes and the potential of plutonium for phase change.

Some experts suppose that these difficulties can be overcome by a series of technical fixes, such as mechanisms to conduct excess heat through the explosive outer layer and away from the core, and by better radiation shielding.[42] The United States National Academy of Sciences also suggests that the problem can be addressed by 'delaying assembly of the device until a few minutes before it is to be used'[43].

The seizure of a consignment of MOX fuel could, in principle, give rise to the same possibilities as for a shipment of plutonium oxide but with significant additional

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[40] WNA News Briefing, 05.23.

[41] This may be about 5% of that of the Nagasaki bomb but, according to Carson Mark, this is still enough to produce blast, thermal and prompt radiation effects over up to half a mile (compared to the mile for Nagasaki). [Reference J Carson Mark, 'Explosive Properties of Reactor-Grade Plutonium', *Science and Global Security*, 1993, Volume 4, pp. 111-128.]

[42] Marvin Miller and Frank von Hjppel, 'Usability of Reactor-grade Plutonium in Nuclear Weapons: A reply to Alex De Volpi; *Physics and Society*, Vol. 26, No. 3, Page 11.

[43] Committee on International Security and Arms Control, Management and Disposition of Excess Weapons Plutonium, Washington, *National Academy Press*, 1994, p 33.

complications for the would-be bomb-maker (depending on the source of the plutonium). The fuel would, first of all, need to be removed from the alloy rods (this would presumably present little difficulty, since it is present in the form of discrete pellets). The plutonium would then have to be separated from the dominant (95%) uranium component, before warhead fabrication could begin. This would entail further technologically sophisticated processing (a form of 'reprocessing') which would add significant time and also add to the possibility of detection (through the requirement of power and key raw materials (chemicals).

If the intercepted cargo was spent fuel, this would add two further substantial difficulties. In the first place, getting the fuel itself out of its cladding would be more complicated (since the rods are likely to have been affected by their long exposure to high temperatures). There would also be the very considerable problem caused by the presence of the short half-lived fission products that would also be present. These would present an immense radiological hazard unless the operations were being conducted in a properly designed and operated reprocessing plant.

In the opinion of this author, doubt still exists regarding the practical utility of high burnup plutonium for the construction of a nuclear explosive device. Thus, whilst it is prudent to maintain a high degree of security when such material is being transported, it is also practical for assessments of the security risk to reflect the substantially greater difficulties of using it, compared to weapons-grade material. This particularly applies where the proportion of Pu-240 exceeds 30% and (for different reasons) where the cargo is in the form of MOX fuel assemblies.

E. TERRORIST ATTACKS ON NUCLEAR CARGO SHIPS

There remains the possibility that a ship carrying a nuclear cargo is attacked by ramming it with a small, fast vessel carrying a substantial explosive charge: a maritime suicide-attack. This sort of attack has been exemplified in the case of the assault on the USS *Cole* in Aden in 2000 (12 October) and in the subsequent attack (in October 2002, off Yemen) on the French oil tanker, MV *Limburg*. Some commentators predict that this is a mode of attack that will become common in the years ahead, on the grounds that maritime transportation is presently more vulnerable than air transportation. Indeed, it is claimed that 'al-Qaeda may have developed a terrorist naval force of 15-20 vessels' for just this sort of purpose.[44] Other reports, citing 'US intelligence officials', talk of 'between 12-300 ships' having been identified.[45] In the Pacific region there is thought to be a particular threat from the very active terrorist groups in the Southern Philippines (Abu Sayyaf and Jamaah Islamiyah) who are said to have vessels suitable for the purpose[46] and who have already engaged in maritime terrorism (the attack on Superferry 14).

The question for this study is: what might be the dangers to ships carrying nuclear cargoes from an attack of this kind? As far as shipments on dedicated-ships, are concerned, the first need is to assess their vulnerability to the sort of attack experienced by the *Cole* and the *Limburg*. In both cases, media reports suggest that some 400 to 500 lbs of TNT-equivalent explosive, packed in a small fibre-glass or inflatable craft, was used to tear a hole several metres across in the hull of each ship. The impact of the attack in each case suggests that the explosive might have been in the form of a shaped charge.[47] The *Limburg* was of a modern, double-hull construction, with 20mm thick side-plate. Despite this, inner compartments were breached and there was a severe fire from leaking oil.[48] By contrast, the hull plate on the Cole was only half the thickness, at 10mm, and in this case there was limited fire. On the other hand, damage to the *Cole* may have been more structurally severe. Neither ship sank.

It is reasonable to suppose that a similar attack on a PNTL ship would cause similar damage, although the system of 20mm steel horizontal collision-reinforcement plates between the inner and outer hulls might be expected to very considerably dissipate the blast effect. With no inflammable cargo, significant fire is unlikely and the double hull construction of PNTL ships suggests that there would be a very low risk of sinking. As noted earlier, the extremely robust construction of the transportation casks (forged steel up to 250mm thick, in the case of cargoes to and from Japan) suggests that it is extremely unlikely that these would be breached,

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[44] Curtin University academic, Alexey Muraviev, at a security conference in Sydney, as reported in the Sydney Morning Herald, 30 March, 2004. Muraviev was also reported as saying that he expected an attack of this kind 'within a year'. Now, more than two years later, nothing of the sort has occurred. No formal text for the paper is available.

[45] JINSA Online, 'Hazardous Seas: Maritime Sector Vulnerable to Devastating Terrorist Attacks', April 01 2004. Other commentators are somewhat sceptical about this sort of claim.

[46] X&Y, 'On Terror's Frontline', *Investigate*, August 2005.

[47] The report in the London *Times* (reporter Ian Brodie) hints that the technical sophistication of the attack suggests professional or 'government' involvement.

[48] http://heiwaco.tripod.com/limburg.htm

although a large hole and a substantial list might permit a container that had become detached to slip out into the sea. Many of these scenarios have been the subject of expert evaluation in the context of accidental damage from collision or grounding. It also needs to be noted that both the *Cole* and the *Limburg* were stationary at the time they were attacked (they were alongside, or moored at a buoy). As noted above, PNTL ships in French harbours are adequately protected by a floating barrier, which is intended to prevent just such an assault[49].

It may be that there is a practical limit to the size of the explosive that can be accommodated in a fast-attack vessel of the sort used in the *Cole* and *Limburg* incidents but that in other circumstances, a much larger charge might be envisaged. In June 2003, the *Baltic Sky*, a merchant ship with false registration, was intercepted in Greek territorial waters and found to have on board six or seven hundred *tons* of ammonium nitrate-based explosive (ANFO) as well as a large number of detonators. The ship, itself, could have constituted a bomb and it is possible to imagine that it could be used to attack another ship, though not, of course, in fast-attack mode. In the event that such a vessel got alongside a PNTL ship and was able to detonate its full cargo, it would clearly cause immense damage. In this case the PNTL ship might receive such damage that it actually sank, and it is even possible that transportation casks could be breached, though even then, it is much more likely that they would be simply dislodged and end up on the sea floor with the other debris. The latter risk could no doubt be more precisely calculated, although at this point there would seem to be another issue that is more pressing. Why would terrorists planning a spectacular event bother with the complications of adding a nuclear ship and its cargo to the equation, when they could much more securely get the same impact with the explosive ship alone?

There is also the possibility of assault by air, as by a small plane packed with explosives (i.e. an aerial suicide attack). Such a plane would be vulnerable to the naval cannon and small arms carried in the case of sensitive cargoes but these could not guarantee that such an attack would fail. In this case, there could be significant damage to the ship, although it is very unlikely to cause much (if any) release of radioactive material. Again, the extremely robust character of the transportation casks would prevent this. Probably the ship would not sink as a result of such an attack,

[49] In other cases the mooring is completely enclosed.

having regard to its special buoyancy features, but even if this happened, the consequence would merely be that the cargo (still in its flasks) would be on the bottom of the sea. If we are presuming attack by a small plane, we must also presume that the attack has taken place not far from land (bearing in mind the likely range of a small plane with a heavy load of explosives). As noted earlier, this would mean that salvage would be relatively straight-forward. We might also note, that the further the ship was from land, the greater would be the difficulty (for the attacker) in finding it in the first place. There is also the question of where (in relation to the likely track of the ship) the attack aeroplane is actually flying from. Given that we are talking of a light aircraft, this may need to be nothing more than a grass strip. On the other hand, this would significantly restrict the payload and range.[50]

At the other end of the scale, there has been speculation about the possibilities for terrorist attacks using scuba divers. Whatever effect they might have in other circumstances, it seems clear from the considerations brought forward in the above discussion, that an attack even by several suicide divers, operating together, could hardly deploy sufficient explosive to significantly damage a PNTL ship. In port, the security authorities are also likely to deploy some kind of underwater deterrent capability, which would make an attack of this kind very difficult if not impossible. Of course, it is accepted that whatever turned out to be the reality in a particular case, any attack on a nuclear cargo vessel would be productive of a great deal of comment and potential public alarm (especially if it occurred close to land).

The case of a maritime terrorist attack on a container ship that has, amongst its containers, some containing radioactive substances, is different again. If such a ship were set on fire there is clearly a possibility that nuclear matter would find its way into the environment. How big this possibility is, and what the danger would be, would depend on the nature of the cargo and the number of containers there were that actually contained nuclear material. It also needs to be noted that container ships frequently carry significant quantities of hazardous material that is non-nuclear and

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[50] If it were assumed that the attack plane was a large commercial aeroplane, specially hijacked for the purpose (i.e. the 9/11 scenario), the consequences of the impact would be greater, though it would still not breach the transport flasks. There would also be greater difficulty in coordinating the attack and finding and hitting the target.

that the effect of a terrorist assault of the kind envisaged may be more significant for the chemical toxicity of what is released, than it is for any radioactive component.[51]

[51] The possibilities for this sort of attack are thoroughly explored in Michael Richardson, 'A Time Bomb for Global Trade: Maritime-related Terrorism in an Age of Weapons of Mass Destruction', Institute of South East Asian Studies, February 2004 (http://www.iseas.edu.sg). Richardson does not discuss the possibility that the nuclear material comes from cargoes on dedicated ships, or that such a ship is 'commandeered' to be used as nuclear 'weapon'.

F. RADIOLOGICAL POSSIBILITIES

Considerations brought forward in earlier discussions suggest that, even with the most promising starting material, the intending nuclear terrorist would face significant problems in contriving a nuclear explosion. However, the content of any of the cargo types reviewed above, including the high level waste, could, in theory, provide the basis for a radiological weapon[52]. Of course, *in practice*, there would be very considerable problems. As noted, HLW is carried dispersed in a solid, vitrified form, encased in steel, from which it would be very difficult to extract. Perhaps the best that could be done in this case would be to grind it to a very fine powder and attempt to disperse it in that form. (This operation would have to be done behind heavy shielding because of the intense radioactivity of the material. The same would apply to storage of the made-up radiological device, before use.) Even in this case, the highly radioactive fission products are still held in a solid, from which they would leach only slowly. Again, if the particles were small enough, they might be inhaled, with potential health consequences if they lodged in the lungs. This possibility would crucially depend upon particle size. They could also be ingested: a process less dependent on particle size. In this case they would be the source of gamma and beta radiation for the time that they were in the alimentary canal, with health consequences that would depend on the actual amounts ingested. Since the ceramic material is insoluble, little of its content would be absorbed. So far as the present author is aware, no expert studies of this scenario have been undertaken.

Fresh MOX fuel could be extracted from its containment and cladding (with all the problems described in earlier discussions) and then ground to a fine powder, which would then become the active principle of a radiological device. Turning a shipment of spent fuel into the basis of some sort of radioactive dispersal device would have the general problems of getting at the material (already discussed), plus it would share with HLW as a source, the problem that the intensity of the radiation would make it impossible to handle without specialist facilities.

Notwithstanding these difficulties, there is no doubt that if some sort of dispersal device was activated in a populated area, there would be enormous public

[52] This is a device that causes the release into the environment of radioactive material in such quantities, and in such a manner, as to give rise to a significant health hazard. This may be contrived, either by mixing the radioactive material with conventional explosive and then detonating it in the target area, or by mechanically dispersing the active material over a designated area.

anxiety, whatever the source of the radioactive material and whatever the actual public risk. On the other hand, there are clearly much more accessible sources of radioactive material (from medical, industrial and educational uses) than the cargoes of dedicated nuclear ships.

G. CONCLUSION

The arguments above have largely concerned shipments of nuclear material on dedicated ships and, particularly, those of Pacific Nuclear Transport Ltd. Rightly or wrongly, this has been a focus of public concern, and, as such, it has been the focus of this report. It will also be the main focus of these concluding remarks.

The substantive discussions above have encompassed, broadly, three possibilities for terrorist action against these ships and their cargoes: terrorists might aim to take the ship and separate its cargo; they might take the ship and create some incident involving the ship and cargo together; or, they might aim to assault the ship from outside by explosive or missile (including a suicide aeroplane attack). In the first case, the terrorists need to find the ship, approach it, and successfully board it and subdue the defenders. After this they need to unload the cargo, either in mid-ocean, or by taking the ship to a suitable port without being intercepted. The very formidable problems entailed in each of these stages have been elaborated in some detail. It is hard to resist the conclusion that, taken together, they add up to an operation that has a very low probability of success, having regard to the known defensive capabilities of the ships concerned and the capabilities that would be required to overcome them. It was also argued that there are significant problems in turning the material thus secured into a usable device and, if the device is a radiological one, doubts about whether the actual consequences of its use would be worth all the effort. Even if the cargo that has been seized is plutonium in the form of MOX fuel, there would be a great deal of technically sophisticated processing required to turn that into bomb material, and further difficulties in assembling and delivering the weapon.

Many of the same considerations apply to the second envisaged scenario. Again, the ship needs to be taken and the defenders subdued but in this case there are crucial difficulties in turning ship and cargo together into a plausible threat. In great part, these concern the nature of the cargo itself and the way it is held. The most likely cargo to which this scenario is applicable is vitrified high level waste. This is very radioactive material but there is considerable doubt that it can be turned, easily (or at all), into a form that might constitute an environmental threat in the event that it was somehow dispersed. There would be broadly the same problems in separating MOX fuel from its container and cladding, with the added drawback that it is only feebly radioactive. Spent fuel, on the other hand, is certainly highly radioactive (through the presence of the fission products) but it, too, would be difficult to get at and, like the high level waste, very dangerous in the attempt. Without getting any of these materials out of their containment, it is not at all evident that a terrorist event involving significant contamination of the environment could be contrived.

These latter arguments (and the ones at the end of the previous paragraph) are very much subsidiary to the crucial considerations with which the conclusion begins. The major difficulty that the terrorist faces is in taking control of the ship in the first place. It is this factor that provides the main reason for confidence that the security provisions for these shipments are completely adequate for any threat that may be presently envisaged.

Scenarios in the third category do not require that the ship (or ships) be taken. In this case, there is merely an assault from the 'outside' by missile, fast attack vessel, aeroplane, or frogman. Considerations of what could actually be achieved by such an operation suggest that the effect of the attack is unlikely to be anything more than superficial damage to the ship (although such an assault could have an impact on the operation of the ship by damaging equipment and/or killing crew). On the other hand, the possibility that a dedicated nuclear cargo vessel could be struck by (say) a missile, cannot be excluded. This would be most likely when the ship was close to shore and, perhaps, when 'protest' activity provided the cover for a firing position. More generally, it is also possible that considerations of restraint and proportion on the part of security personnel could inhibit or condition the response to an apparent assault which threatened only minimal damage. However, it does need to be noted here, how far this hypothetical outcome is from the scare scenarios with which we began.

There is plenty of evidence that terrorist groups have sought nuclear material at various times and with an apparent intention to make and use nuclear weapons (Al Qaeda, Aum Shrinrikyo, are only the most prominent examples)[53]. As far as radiological weapons are concerned, it is clear that such groups could have made and used radiological devices had they chosen to do so (in the sense that radioactive

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[53] See, for instance, Charles Ferguson and William Potter, *The Four Faces of Nuclear Terrorism*, Monterey Institute of International Studies, 2004.

isotopes for medical and industrial uses are widely held in conditions of limited security). It is interesting to speculate why none of these things has happened. In the case of nuclear weapons *per se*, it may be that they could not get sufficient suitable material, or they were daunted by the technical demands of fabricating a usable device. There is another possibility, and that is (as suggested earlier), that such an enterprise could hardly be engaged in without at least the tacit acquiescence of the state on whose territory the work was being done, and no state (even the most committed supporter of international terrorism) could risk being found out in this[54]. This consideration might also apply to radiological weapons (and chemical and biological weapons, though these are outside the scope of the present discussion).

On the whole, contemporary terrorists seem to be satisfied that they can achieve their objectives with the simpler, and well-tested, techniques of bombing, shooting and hostage-taking, with, perhaps, the added possibility of terrorist attacks on commercial shipping, if Muraviev and others are right. Certainly, these activities are more conducive to the protection of terrorist organisational security through the maintenance of a diffuse cell structure. By contrast, the relatively large technological requirements of a nuclear weapons programme would inevitably lead to much greater vulnerability for the terrorists.

But even if this were not the case, and notwithstanding the difficulties and counter-indications hinted at above, a terrorist group *was* intent on getting nuclear material for (say) radiological weapon production, it is clear that (as noted above) there are sources of nuclear material for the purpose that are much more accessible than shipments on the high seas. The acquisition of sufficient fissile material for nuclear explosive purposes is a different matter but, even here, there are persistent anxieties about the security of weapon grade material in the former Soviet Union and regular reports of the interception of smuggled consignments. Certainly, the persistent expressions of concern about nuclear security in Russia, and, for different reasons, in Pakistan, suggest that this is the greater vulnerability. It may also be noted that separated civilian-plutonium is regularly transported across France by road. Of course, there are extensive security arrangements for these operations as well, and it

[54] Recent events in Lebanon may call this conclusion into doubt. In this case it is clear that a state (Iran) was willing to supply advanced weaponry (and training) to a terrorist group (Hezbollah). Given the extremist character of the present Iranian regime it is not so evident that they (or other regimes like them) would decline to cooperate in a terrorist plan to seize and 'process' nuclear material. Again, the greater danger still might be that they give to a terrorist group nuclear material that they have produced themselves, rather than cooperate on the seizure of such material on the high seas.

may be moot where the greater vulnerability lies. Either way, the defences are formidable, and the prospects for a successful terrorist assault are extremely small. In this connection, it is noteworthy that the extensive 2004 Monterey Center for Non-Proliferation Studies' report on prospects for nuclear terrorism[55] makes no mention at all of the possibility that terrorists may obtain relevant material from intercepting cargoes on the high seas. This seems right. As argued here, obtaining nuclear material from maritime consignments is fraught with difficulties and it is hardly surprising that it has not been attempted. This should not be a reason for complacency but it is a reason for recognising where the greater dangers lie. It is important to avoid perfectionism, even in such a serious domain as this.

More generally, it needs to be recognised that no strategy is without risk and the degree of risk needs to be evaluated and then taken into account with alternative strategies. As far as the safe disposal of plutonium from weapons-grade stockpiles is concerned, the choices are simple. The material may be held secure for an indefinite period, or it may be incorporated with high level waste in vitrified form, from which it would be very difficult to extract. The third possibility is to destroy it by burning it in a nuclear reactor. This latter process does provide some return on the cost of creating it in the first place and, more particularly, it eliminates the risk that it is ever made up into weapons again, since the isotopic composition of resulting plutonium makes it very unsuitable for such a purpose.[56] This outcome needs to be balanced against the risks entailed in its transportation, should that happen again.[57]

Perceptions of security cut both ways. On the one hand, the sight of heavy calibre weapons (such as 30mm naval guns) and the obvious presence of armed personnel can give rise to the apprehension of great danger (or why else would they be there?). On the other hand, the apparent *lack* of overt security precautions may suggest that obvious dangers (as of terrorist attack) have not been seriously considered (or not considered seriously enough). In the case of nuclear shipments of

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[55] Charles Ferguson and William Potter (*et al*), *The Four Faces of Nuclear Terrorism*, Monterey, Center for Non-Proliferation Studies, 2004

[56] In the specific case of the shipment of weapons-grade plutonium from the United States in 2004 and the return shipment of MOX in early 2005, it is noteworthy that by mid-2005 the material was already in its designated reactor (Duke Power's Catawba 1 in South Carolina). It was thus already beyond any serious proliferation risk. For all the ostensible anxieties of the opponents of this operation, this seems to be a most acceptable outcome from a security point of view.

[57] The United States is now building (at Savannah River) its own MOX fuel fabrication capability and may thus not need to use French facilities again. The 2004/2005 shipments also served the important purpose of allowing US authorities to get ahead on the regulatory and acceptance processes that needed to be completed before US utilities could burn MOX.

the kind being considered here, this is far from the case. Enormous thought and effort have gone into threat scenario assessment and into appropriate counter-measures, and this is reflected in the security arrangements that have been described. Equally, there is a desire not to cause unnecessary alarm and not to commit to defensive measures that may not be justified by a realistic assessment of the actual risk. Thus, the guns are generally covered in port and the armed security forces maintain as low a profile as they can. In the same way, resistance to suggestions that warships ought to be used for escort purposes is not simply a matter of saving expense.

There is another aspect to all this. Any kind of assault on a maritime shipment of nuclear material might be seen to reflect on the safety of the civilian nuclear industry as a whole, and this might apply even if the consequences of such an assault did not include the actual diversion of material, or any significant environmental contamination. However, insofar as this was so (and the nature of the media response would clearly reflect the actual nature of the event as well as its well-recognised tendency to hyperbole), it would, in all probability, be a short-term effect. The comparison with 9/11 is a better guide here than the effect on public sentiment of the Three Mile Island and Chernobyl accidents in the 1980s. In the aftermath of the attack on the Twin Towers and the Pentagon, there was a marked down turn in air travel but within a short while passenger volumes started to return to what they had been. The reason for this is quite straight forward. Individuals conducted their own informal risk/benefit analysis and they found ‘benefit’ that justified whatever risk they saw in continuing to fly. In this, they may have been influenced by a perception of enhanced security at airports and in the air, which enabled them to support a decision to continue to enjoy the benefits of air travel.

In the first decade of the twenty-first century, people are increasingly seeing civilian nuclear power as important, as concerns about energy security and climate change continue to grow. This gives them a reason to seriously reflect on their interests and to be much more resistant to being stampeded by antinuclear activists. There is also the fact that we now know that the health consequences of Chernobyl (whilst serious) were much exaggerated, especially in regard to long-term effects[58]. For these reasons, a major rejection of nuclear power as a consequence of some accident or terrorist attack on a nuclear cargo is not to be expected. It is thus not

[58] See, for instance, Elizabeth Cardis et al, ‘Estimates of the Cancer burden in Europe from radioactive fallout from the Chernobyl accident’, *Int. J. Cancer*, Volume 119, pages 1224-1235, 2006.

likely that terrorists would engage in such an action simply to undermine the energy security of the developed world. Again, this is not a reason for complacency, or lessening standards of safety or security, but it is a reason for not fearing industrial calamity if such a thing did occur.

In a certain sense, the substantive discussion about what terrorists might do in the way of taking ships or material, or contriving incidents in which radioactive material is released, is beside the point. As a matter of fact, none of the various intelligence organisations of the countries concerned with the 'Eurofab' shipments thought that there was any terrorist organisation that had the capability to even attempt the sort of operation hypothesised in the substantive discussion above (and the same probably applies generally to shipments in dedicated ships). The threat was really Greenpeace (or some other anti-nuclear protest group) and what they threatened was embarrassment, in the event that they had succeeded in getting to close to the consignment, or if, however temporarily, they had succeeded in halting its progress. To a degree, Greenpeace may be said to perform a public service in causing the authorities responsible for security to maintain their guard and occasionally exposing areas of weakness. On the other hand, their activities are undoubtedly the cause of a great deal of unproductive expense; part of the cost of democracy, perhaps. Insofar as this is the case, it may be noted that the 'cost of democracy' here falls upon the nuclear operators.

None of this alters the basic concern that this report has sought to address. There are clearly definable risks to the maritime shipment of nuclear materials and there are potentially significant consequences if terrorists were to succeed in the sorts of scenario that have been outlined. It is thus important to maintain standards of security and to monitor, as far as possible, changes in the apparent intentions and capabilities of terrorist groups that might at some time constitute a threat. As noted earlier in the report, Greenpeace and similar groups are also significant in that they may (wittingly or carelessly) provide 'cover' for a terrorist assault. This is the cause of some equivocation in the 'rules of engagement' provided for the security of nuclear facilities generally.

As noted earlier, there is a renewed interest in civilian nuclear power. In the context of a growing anxiety about climate change and increasing uncertainty about oil and gas resources, more countries are acquiring (or intending to acquire) nuclear capacity[59] and countries that have it are planning further developments. These factors, together with a desire to internationalise the more sensitive nuclear technologies, seem likely to bring on more shipments of nuclear material to more destinations. It will be important to make sure that this is done as safely as it can be, both as regards accidents, and as regards the terrorist threat. Present regulatory standards and practices, especially in regard to dedicated ships, such as those operated by PNTL and the Japanese and Swedish utilities, provide very considerable assurance that this is so. There is very little prospect of attacks of the kind envisaged in the above scenarios having any serious consequences beyond the psychological.

September 2006

[59] Apart from the well-known case of Iran, civilian power reactors are proposed, planned, or actually under construction for Egypt, Indonesia, Turkey and Vietnam. (http://www.world-nuclear.org/info/reactors.htm).

Appendix

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