Nuclear Terrorism: Reactors & Radiological Attacks After September 11

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Attacks on Reactors

Introduction

Reactors, with their nuclear component, are potentially attractive targets for terrorists, in large part because they offer a means for the group to achieve a spectacular attack that sets them apart from other groups and ensures that they are noticed as an organization. There are a variety of possible motivations that might lead terrorists to consider such an attack, varying from an attempt to create a barricade-and-hostage situation for the purposes of blackmail; to steal strategic nuclear material, either as a prelude to a radiological attack or as part of an effort to develop a nuclear capability of their own; or, finally, to destroy the reactor itself.[1] These various types of incidents are of variable probabilities. Terrorism is surprisingly derivative and certain tactics rise and fall in use amongst groups. For example, barricade-and-hostage attacks were, relatively, very common in the 1970s and early 1980s with the spate of embassy sieges and aircraft hijackings. However, as an increasing number of states developed their own special police or military units to deal with the threat and security at vulnerable sites was improved, the dangers of such an action rose for the terrorist and their likelihood of success and escape afterwards fell. Consequently, so did the popularity of the tactic. However, as the potential dangers of any incident at a reactor are so great, all threats or attacks have to be treated extremely seriously. This is particularly so since the terrorist attacks of 11 September, 2001 on the World Trade Center and Pentagon. The airline hijackings on this date were unlike their predecessors in the 1970s: the terrorists were not intent on escaping after the attack. The hijacking was not the principal aspect of the terrorists' action, merely a means to the greater act of violence: crashing the planes and the passengers aboard into World Trade Center and Pentagon. The attacks appeared to usher in a new era of high casualty and high consequence terrorism, unmatched even by previous incidents such as Aum Shinrikyo's release of sarin in the Tokyo subway in March 1995.

This paper will assess the threat of terrorist attacks on nuclear reactors or attacks using radiological materials. It will begin by examining the danger posed by aircraft being crashed into a reactor and compare that threat with the more familiar one posed by terrorists using truck bombs against reactors. The paper will then assess the history of terrorism directed against nuclear facilities; the problems posed by insiders, both as potential saboteurs and thieves of nuclear material; the risk to parts of the nuclear fuel cycle other than reactors; and finally, the threat

of radiological terrorism. The paper concludes that although the ramifications for the nuclear industry of the attacks on 11 September remain unclear, better protection of facilities and materials is clearly justified.

11 September

Even before 11 September, such an event was not as far-fetched as it at appeared. In November 1972, three criminals hijacked a Southern Airways flight between Birmingham and Memphis and threatened to crash the plane into AEC's research facility at Oak Ridge, Tennessee, unless they were flown to Havana, Cuba.[2] In December 1994, members of the Armed Islamic Group (GIA) hijacked an Air France plane and planned to blow it up over Paris in a suicide mission.[3]

Most of the world's 440 nuclear power reactors would be highly vulnerable to a similar attack to those launched on 11 September: a passenger aircraft laden with fuel being crashed into the building. The impact and fire caused by such an attack would likely compromise the containment system that surrounds reactors, increasing the risk of a radioactive leak. Many containment facilities are designed to withstand the impact of a small plane: the concrete dome may be 3 feet thick and heavily reinforced by steel, with a 1inch to 4 inch lining, also made of steel. There may be a further two concrete walls near the reactor vessel, each one foot thick and reinforced with steel bars. The reactor vessel itself is made of high-carbon steel, about 4 inches to 6 inches thick.[4] In the United States, reactors are designed to withstand both earthquakes and hurricanes.[5] This might or might not be enough to prevent the reactor vessel itself being broken open by a plane crashing into the facility. The exact nature of the damage caused by such an attack would depend on the size of plane, amount of fuel it carried, speed and angle of impact. Although the emergency coolant systems would ordinarily prevent an explosion, it is possible that both primary and back up systems could also be severely compromised by such an attack, possibly leading to a steam explosion at the reactor.[6] It is unlikely to be feasible for existing reactors to be engineered to withstand the impact of such a plane, although new reactors might be planned with this as one criterion.

There are suggestions also that the 11 September terrorists considered attacks on US nuclear facilities: Mohammed Atta , leader of the cell responsible for the attacks last month, sought information at Tennessee's Martin Campbell airport last Spring about local landmarks, including a nuclear reactor, a chemical plant and a dam.[7] More ominous still, United Airlines 93, travelling between Newark, New Jersey, and San Francisco on 11 September, but which crashed in rural Pennsylvania, may have been targeted at nuclear reactors in the south of the state. The plane

was hijacked in the area of Cleveland or Pittsburgh and then did a sharp turn and rapidly lost height. It crashed when passengers attempted to regain control of the plane. Original analysis suggested that the hijackers intended to fly the plane into Camp David, the Presidential retreat in northern Maryland, or into a target in Washington DC. However, it now appears that one of three nuclear reactors in southern Pennsylvania, Three Mile Island, Peach Bottom or Hope Creek, Salem, may have been the real target. The intended target may be essentially unknowable, but the rapid descent of the plane (which occurred before the passengers attempted to regain control) appears to suggest a location closer to Pittsburgh than to Washington DC. The suggestion is supported by claims that the FBI had sent a report to the British domestic intelligence service, MI5 and to several other European governmental agencies, citing a "credible source" that the hijackers had planned to hit a nuclear plant. The report alleged that Three Mile Island had been under surveillance from the hijackers and their associates in the months leading up to 11 September. In response to this threat, security at reactors in the UK and US has been significantly tightened. At the end of October, warned about further imminent terrorist attacks, the US Federal Aviation Authority placed a week-long ban on any aircraft movements within 20 kilometres of over 80 nuclear facilities. Aircraft could pass over those facilities only at heights above 5,500 metres, limiting the effect of commercial airlines but offering some degree of security to the nuclear sites.[8] Concern was fuelled by the escape of six men of Middle Eastern appearance, with Israeli passports, who were carrying detailed plans of a Florida nuclear power plant and box-cutters, the weapons used in the 11 September hijackings. The men had been detained in the Midwest and then inadvertently released.[9] French authorities suggested that airliners threatening reactors might be shot down and had installed an anti-aircraft missile system around the reprocessing facility near Le Havre.[10] In Canada too, security at nuclear facilities was tightened after a detained Kuwaiti man was found to be carrying sensitive documents on Canadian nuclear energy. Canada has 22 reactors, and radioactive material is regularly shipped by truck across the country.[11]

The threat to reactors, posed by the terrorists responsible for the attacks of 11 September, was credible because it appeared to fit a pattern consistent with the organisation's other activities. The attacks on the World Trade Center and the Pentagon were high casualty events, directed at highly symbolic and visible targets. An attack on reactor or other nuclear facility with a potentially effective weapon such as a plane or truck bomb would clearly have possessed many of the same characteristics.

Truck Bombs

However, there is a risk in focusing too heavily on the specific events of 11 September, horrific as it was. It would be dangerous to assume that the next threat to nuclear facilities or the next major terrorist attack will be similar to those events. Given that access to flights may become increasingly difficult for hijackers, a more realistic long-term threat is likely to come from the more familiar issue of truck bombs. Trucks have been familiar weapons of organisations such as al-Qaida: attacks such as the 1993 bombing of the World Trade Center, the 1996 Khober towers bombings, the 1998 Embassy bombings in Tanzania and Kenya, all relied on such means. However, other relatively recent terrorist attacks, such as the 1996 Murrah Building bombing in Oklahoma City or that on Colombo's central business district on January 31 1996 (an attack that killed nearly a hundred people and injured 1,400 others), also relied on truck bombs. It may even be that associates of the 11 September hijackers acquired licences to transport hazardous materials around the United States in trucks, hinting at the possible strategy for a new assault.[12]

Such a threat has, historically, caused widespread concern, particularly in the United States. Other forms of frontal assault on reactors by terrorists have a low probability of success, particularly of creating a radiation release, largely because reactors are not only well defended but can also be shut down from several different locations. It is hard to envisage a scenario in which terrorists were able to capture an entire reactor before the process was shut down. If terrorists were to succeed in destroying or disabling both the backup and the primary coolant systems at a reactor, they might manage to cause a core meltdown, even if the reactor was shut down. This is because the decay heat generated by a reactor is so intense that cooling has to continue for days after the reactor has been shut down. Reactors are designed to withstand the failure of its primary coolant systems and have backup systems to cope with this problem: this is a design basis accident. However, the simultaneous failure of both its primary and auxiliary systems has potentially disastrous consequences. To ensure a radiological dispersal, the terrorists would also have to engineer the failure of the reactor's containment system. Although this can occur naturally, once the core melts, containment vessels are built with safety devices that hopefully ensure that its integrity is maintained for as long as possible, to minimize the consequences of such an incident. If terrorists were able to damage the containment system severely, particularly in the early stages of an attack, then that would greatly increase their chances of achieving an off-site radiological dispersal.[13]

However, since truck bombs have a more immediate effect, the threat is more pertinent. Such devices continue to be one of the most favored, and successful, tactics employed by terrorists. Its effectiveness on non-nuclear sites needs little reiteration. A similar attack on a nuclear facility would cause extensive damage and might, at worst, lead to a release of radiological material. In August 1994, the Nuclear Regulatory Commission (NRC) approved a series of measures to improve security at US nuclear power plants. However, these measures were designed to protect primarily against either a vehicle intrusion (in which a vehicle is used to crash through the perimeter fences enabling the driver to gain access to the plant) or a vehicle bomb (which would be parked outside the security fence), rather than against a moving suicide truck bomb, which was not regarded as a plausible threat in the United States. The design-basis threat (DBT) was therefore intended to protect against a relatively small suicide truck bomb.[14] Despite the concerns of some experts,[15] the DBT has not been increased to reflect the increasing lethality and violence of terrorism. This is because the DBT is not intended to protect against a worst-case scenario, but "to provide a reasonable enumeration of adversary characteristics for use in the design of protection systems."[16] This decision was a compromise between the needs to maximize security at nuclear facilities and the requirement not to burden the nuclear industry with excessive costs and hindrances to their processes. However, a 1999 US Department of Energy report noted that the barrier and vault system used by the Department was not as robust in offering protection as had been believed, but that "Although many approaches have been investigated, a promising technological alternative has not yet been identified."[17] Although, in the US, there is some protection for reactors against vehicle bombs, and employees are subject to security clearance background checks, limiting the scope for insider sabotage, even here it is clearly only a partial solution.[18]

Terrorism Directed Against Nuclear Reactors

Historically, relatively few groups have sought to cause a radiological release from a nuclear facility and such an attack provides an unlikely means of seeking to cause casualties. Where groups have actively sought to cause widespread casualties from their actions, they have attacked people directly. Crashing passenger-filled planes into the World Trade Center towers would certainly qualify as such an example. An attack on a reactor would be an indirect attack on people, one that sought to maximise the political, social and economic consequences of the attack without necessarily causing widespread casualties. Although the potential for inflicting such injuries is clearly present, the certainty is not. Any subsequent attack on nuclear facilities is therefore likely to continue this trend: its

primary purpose will be to create terror and strike at an important symbolic target, rather than to cause casualties per se.

To date, threats against nuclear reactors can be readily divided into three motivations: those with an overtly anti-nuclear motivation; those that chose to attack a reactor because it was a high profile target; and those that chose a reactor because it was the most convenient target. Historically, particularly in the West, most actions directed against reactors could be classified in either the first or the second categories. Incidents of the third variety include lone lunatics such as Pierce Hye, who in February 1993, recently released from the mental ward of a community hospital in Ephrata (Pennsylvania), drove through the main gate at the Three Mile Island nuclear plant, and crashed through two closely spaced chain-link fences into the "protected area" of the plant, where he hid for four hours but caused no damage. Hye's motive was unclear, but he had no obvious anti-nuclear agenda.[19] However, it is attacks in the second category, assaults on a reactor because it is a high profile target, that have been most often caused by the groups most traditionally considered terrorist. Moreover, it is this type of attack, particularly combined with a desire to cause massive disruption or even extensive casualties, that is most worrying.

Anti-nuclear actions have been characterised by a preference for attacking property rather than people, a tendency common in single-issue terrorism. Examples of anti-nuclear violence include: a bomb planted outside the Lawrence Livermore Laboratory on 28 November 1987. It detonated just after midnight and destroyed dozens of windows and a car, damaged three other cars and scattered debris over a wide area. However, it injured no-one. Responsibility was claimed by the Nuclear Liberation Front.[20] Attacks on reactors include: five anti-tank rockets were fired at the Creys-Malville Superphoenix full-scale breeder reactor, near Lyon, France in January 1982. The reactor was still under construction and, apart from damaging the outer shell of the building, little damage was done by the attack. A previously unknown group, the Pacifist and Ecologist Committee, claimed responsibility for the attack.[21] The connection between anti-nuclear and environmental attacks tends to be a close one. The Evan Mecham Eco-Terrorist International Conspiracy conducted actions against nuclear facilities as part of wider, environmentally-driven, campaigns. The Evan Mecham Eco-Terrorist International Conspiracy (EMETIC) grew out of the most radical elements of Earth First!, a radical environmental group. EMETIC was led by Dave Forman who formed it in October 1987 with four others who had grown disillusioned by Earth First!'s increased dedication to civil disobedience as a tactic. Members of the nascent organization were probably responsible for the May 1986 attack on power lines at Palo Verde Nuclear Generating Station, although they never claimed responsibility. The

group was formed to conduct sabotage against nuclear power plants in the south-western US. On 26 September 1988, the group destroyed power lines feeding uranium mines around the Grand Canyon. Thirty-four power poles were damaged, restricting power supplies to two mines owned by Energy Fuels Nuclear. EMETIC claimed responsibility two days after the attack. On 30 May 1989, three members of the group were arrested near Wendon, Arizona, attempting to cut through a support tower that delivered power to a local substation. The attack was intended as a dry-run before simultaneously attacking the electricity transmission cables at three nuclear facilities in Colorado, California and Arizona.[22] It is worth noting that the majority of anti-nuclear campaigns are intrinsically demonstration actions, aimed at displaying the ineffective safety and security of nuclear installations and materials. Their purpose is thus to highlight the danger and interfere with the plant's operations. Consequently, such attacks are extremely unlikely to seek to threaten the integrity of the reactor, for fear of sparking the type of incident that anti-nuclear activists most fear. Groups whose primary motivation is environmental are also extremely unlikely to seek any results that would threaten the environment.[23]

Attacks in the second category, directed against a high profile target, have been motivated by both political and economic considerations. There are examples of incidents, both of attempts to extort financial gain from the threat and, alternatively, political gain: on 15 August 1975, two bombs exploded at the Mt. D'Arree Nuclear Power Plant in Brennilis, Brittany, causing minor damage. The chief suspects were Breton separatists.[24] In May of the same year, two bombs were detonated at the partially constructed Fessenheim power station, also in France, causing a fire but no casualties. The Meinhof-Puig-Antich Group claimed responsibility.[25] In 1973, a group of ERP terrorists attacked a nuclear power plant, which was not yet operational, near Buenos Aires, Argentina. ETA, perhaps more than any other politically-motivated terrorist group, has also targeted reactors. In part, this was a reaction against the imposition of two facilities, Ea and Lemoniz, on the Basque homeland by Iberduero SA (the electricity company) and the Spanish central government without widespread consultation. Although mostly nationalist-separatist in its motivation, ETA also came to subsume and dominate the anti-nuclear aspects of the fight against the two reactor. Their campaign was wide-ranging, encompassing repeated bombings of the facilities from 1977 onwards, intimidation of its employees and the assassination of a selected few when that intimidation failed. In March 1981, ETA sent death threats to 33 technicians working in the Lemoniz plant. The letter explained that the group would target all specialized personnel "because of [their] participation in the illegal Lemoniz project". The threats had little impact: the technicians continued working at the nuclear power plant, even in the wake of the assassinations of the

chief engineer, Jose Maria Ryan, in January 1981, and of the project manager, Angel Pascual Mugica in May 1982.[26] The USA has not been immune to such threats either: in 1979, the FALN (*Fuerzas Armadas de Liberacion Nacioal,* or Armed Forces of the National Liberation), a Puerto Rican nationalist-separatist group, threatened to destroy the Indian Point nuclear plant in New York. In 1980, in solidarity with the seizure of the Dominican Republic's embassy in Bogata by M-19, the Marxist Colombian group, the FALN issued a further warning to the United States: "You must remember...that you have never experienced war in your vitals and that you have many nuclear reactors."[27]

As well as the greater opportunities for material diversion, the economic and political instability in the Former Soviet Union has also caused an increased threat of attacks on the nuclear facilities themselves. Since 1992, there have been at least six attacks or credible threats directed against reactors in the post-Soviet states. In the Fall of 1996, the Russian nuclear regulatory agency, Gosatomnadzor, received a warning that an armed group of Chechens was planning to target the Balakovo Nuclear Power Plant, a facility containing four VVER-1000 reactors. Both the MVD and the FSB were alerted, preparations were made to defend the plant, and a wider warning went out to facilities across Russia to be on their guard against an incursion. However, while a group of Chechens was moving along the Volga, they stopped well short of Balakovo and it was impossible to definitively determine whether they did plan an attack.[28] The threat was credible though because, since 1991, the Chechens had consistently made threats against Russian nuclear facilities and, in March 1996, their field commanders allegedly agreed to launch a series of such assaults.[29] The threat was indicative of a wider problem: security at Russian nuclear facilities. Both before and after this incident, Russian special forces, the FSB and MVD have been deployed, and held exercises, for protecting such establishments.[30] Motivations for threats to reactors also have included economic objectives. In March 1997, five men were apprehended at the plant generator of the Kursk Nuclear Power Station. They were hoping to seize the control room and disable the plant's reactor, allegedly as part of an extortion scheme. Their threat was not treated seriously by Russian authorities because they lacked the means to implement their plan.[31] Although details of the incident remain sketchy, its veracity is strongly supported by the fact that, only four months later, in July 1997, a new system of physical protection was unveiled at Kursk. Gennadiy Pshakin, head of the bureau of the international section of the state Research center "Physical-Energy Institute" (Obninsk), stated that the new system will "substantially lower the risk of an unimpeded penetration" to the plant.[32] Ignalina Nuclear Power Plant in Lithuania has been especially prone to threats: there have been at least three since 1992. On 4 November 1994, Kestutis

Mazuika, a Lithuanian national in Sweden threatened to destroy the facility at Ignalina unless a ransom of $8 million was paid to a secret organisation (NUC-41 "W") which he claimed to represent. His threat, which supposedly would be carried out by the NUC-41 "W"'s representatives at the power plant, was contained in a letter, handwritten in Russian, delivered to the Swedish Prime Minister's office. It demanded that $1 million be handed over to Mazuika on 7 November, with the balance to be deposited in a Swedish bank account. He was arrested on 7 November when he returned to the Prime Minister's office to collect the money. He later claimed that NUC-41 "W" forced him to commit the act.[33] The group was allegedly also responsible for the theft of fuel rods from the same facility in 1993.[34] Just a few days after the Mazuika incident, on 9 November, VATESI, the Lithuanian Nuclear Safety Inspectorate, was warned by the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety of a further threat against the Ignalina installation. A local mafiya boss, Georgy Dekanidze, threatened to destroy the plant if his son, Boris, was sentenced to death in the contract murder he was then on trial for. On 10 November, the same German authorities advised that preparations for the sabotage had been made and would be committed by workers at Ignalina on 15 November if Boris Dekanidze received a death sentence. The Lithuanian Prime Minister then requested assistance from Sweden, which provided an expert search and bomb disposal team. They conducted a search between the 14 and 16 November, during which time Units One and Two of the nuclear plant were shut down and security around the reactor was strengthened. However, no indication of sabotage was uncovered. Boris Dekanidze was sentenced to death on 10 November and Georgy Dekanidze, unsurprisingly, denied all knowledge of the threat against Ignalina.[35] The threat caused the Ignalina to be shut down for three days and cost $10 million, while the reactors were thoroughly inspected for possible sabotage.[36] Since these threats, security at Ignalina has been improved: the perimeter of the plant is equipped with sensors and an observation system; entry into the facility requires a plastic card and access code which is unique for each of Ignalina's 5000 employees; and a computer monitors everybody's movements.[37] However, much of the danger continues to lie with the personnel of the nuclear industry, as well as with the technical aspects of protection.[38] If workers at nuclear facilities are demoralized and regularly denied their wages, they are likely to continue to pose a real threat to the security of these facilities.

In 2000, there were several low-level attacks on nuclear facilities. In January 2000, Steven James Romero, 27, telephoned the U.S. Nuclear Regulatory Commission three times and threatened to explode a nuclear facility. Romero called the headquarters in Bethesda, Maryland, twice as well as the regional headquarters in Lisle, Illinois.[39] Shortly after midnight on 5 November 2000, security officers conducting a random search at California's largest

nuclear plant, at Diablo Canyon, discovered what initially appeared to be a bomb placed in a support building located on the premises. The incident subsequently emerged as a prank.[40] A bomb exploded on 6 March 2000 at the Scientific Research Institute of Nuclear Physics in Rostov-na-Donu, Russia. The blast from the remote-controlled device, which injured two, was most likely tied to mafia in-fighting, officials stated.[41] On 29 March 2000, Japanese police reported that the Aum Shinrikyo cult had acquired information concerning nuclear facilities in Russia, Ukraine, Japan, and other countries. Aum stole the information by way of its computer software development companies.[42] On 6 April 2000, Sylvia Bergerova, 34, anonymously threatened to detonate a bomb at the nuclear power plant in Dukovany, south Moravia, Czech Republic. Trebic Police evacuated 1,200 people from the plant while they searched for three and a half hours for a device.[43]

The Insider Threat

One of the most common types of incident and, after the threat of truck or aircraft attacks, most potentially worrying is insider crime. Attacks by insiders are dangerous because they are, by their nature, hard to prevent and the perpetrators are more likely to know the facility's vulnerabilities.

In February 1992, Oleg Savchuk, a computer programmer, was arrested trying to introduce a computer virus into the Ignalina's system. This coincided with the breakdown of the cooling system of the station's first reactor, although no definitive link could be made. It is possible that Savchuk introduced the virus and then alerted authorities in order to receive an award for meritorius service.[44] Such a scenario would certainly be in accordance with the findings of several Rand reports, based on research in the United States, which concluded that a desire for recognition and approbation was a key factor, particularly in cases where the crime was committed by a lone insider. Conspiracies by several insiders, with no outside help, appear to be the least common variation of insider crime. Interestingly, in all of these conspiracies that were studied, the co-operation of employees appears to have voluntary, rather than compelled or otherwise coerced. As with the other types of insider crime, the overwhelming motivation for these acts was self-serving financial gain. An exception was the case of two employees of a commercial nuclear facility who vandalized fuel at the plant. They had both served on US Navy nuclear-powered vessels and this experience lead them to believe that the security at the powerplant was insufficient. Once they had vandalized the fuel, they then held a press conference to draw attention to the situation.[45] They appear to have been motivated by a

mixture of altruism and idealism, so this case offers an interesting combination of both the insider and the nuclear protest action, for demonstration purposes.

The problem of insider crime, of workers within the nuclear industry attempting to exploit their position, has been extensively studied in the US, and numerically forms a major component of both nuclear material smuggling and reactor-related incidents. Obviously, insiders are capable of causing great damage and of embezzling vital material, either alone or acting in concert with other insiders or outsiders. One example of possible sabotage by an insider occurred at Turkey Point nuclear power station, in Florida, in 1983. There, someone shut the valve for the auxiliary feedwater system that supplied the two reactors at Turkey Point if the main system was inoperable or only a small quantity of feedwater flow was required. This situation went unnoticed for five days, in spite of a requirement for checks twice per shift, partly because "out for maintenance" labels were placed on the valves. If the normal feedwater flow had been interrupted in those five days, severe damage, possibly even to the core, might have resulted. It is possible that this incident was simply the result of an error, rather than malicious intent, by a worker, but it still illustrates the possibilities for sabotage to have severe consequences and to go undetected for long periods of time.[46] The threat posed by insiders is almost impossible to defend against because it is so difficult to identify likely culprits before they act and because a measure of trust in employees is vital to the effective running of the facility. An additional problem is that the success of the insider often depends not on extensive planning, so much as on the exploitation of pre-existing flaws in security, which insiders are clearly in a unique position to recognise.[47] The NRC, in a 1980 report, found that security failures are often the result of people and not system failures; that non-adherence to security regimes was more often the problem than the intrinsic nature of the regime itself.[48] A 1990 Rand report found that, of the 62 insider crimes they analysed, 41% of crimes directed against guarded facilities were committed by those supposedly charged with protecting them, the guards,[49] a clear case of *Pone seram, cohibe; sed quis custodiet ipsos Custodes?*[50] Although much of the work, to date, is based on research from US nuclear facilities, it clearly has more widespread applicability.

The most serious type of insider threat is posed when the insider conspires with outsiders. This applies to embezzlement of nuclear material as well as to violent threats against nuclear facilities. In each case, the threat posed by the external group is considerably increased if it has reliable knowledge of the plant's security arrangements, procedures, operations, physical layout and the location of the material or vulnerable point in the facility. The most likely source for such information would be from someone who works at the site: an insider.[51]

This concern would seem to particularly pertinent after 11 September as the attack clearly displayed a willingness to plan months, even years, ahead to train terrorists as pilots. It is precisely this type of patience and forethought that might encourage a terrorist group to infiltrate a member into the workforce of a nuclear facility, or to recruit a sympathetic pre-existing employee. Such a strategy would certainly increase the likelihood of terrorists succeeding in attacking a facility's vulnerabilities, either to sabotage or bombs.

However, in the RAND study, although the identity of these outsiders varied enormously, and included ideological extremists and major criminal organisations, in many cases the outsider was simply a friend or relation of the insider, someone with whom the insider already had a relationship. This is logical if the supposition is that most insiders do not come from a criminal background, but rather, they exploit the opportunity that is presented to them, so that it is unlikely that they would have pre-existing links with either criminal or ideologue groups. For this reason, and particularly in instances where the outsider did not initiate the conspiracy, the most common motivation in the Rand study was financial, rather than political gain.[52] Rand's study found only a small proportion of incidents in which outsiders approached an insider, with whom they had had no previous relationship, to assist them in their operation. However, this does not preclude such an event.

If the intent is simply to take the reactor off-line, there are far easier ways of doing so than a full-out attack on the reactor building itself. These methods include toppling a pylon on the reactor's primary distribution line, or sabotaging the transformers or switchgear at the reactor switchyard with a stand-off weapon. Other possibilities include damaging the feedwater and steam pipes or the reactor control mechanisms in the facility, using a shoulder-held rocket launcher, for example.[53] Such low-level attacks have formed the majority of terrorism against nuclear reactors to date and are still extremely expensive and disruptive to the power company.

Vulnerabilities Elsewhere Within The Nuclear Fuel Cycle

Nuclear reactors are obviously not the only parts of the nuclear complex that are vulnerable to attack. Enrichment, storage and spent fuel reprocessing facilities are also potential targets for an assault, as is the transport between them. The most dangerous target at a uranium enrichment plant would probably be the containers of liquid uranium hexafluride at the feed end. An explosion releasing the liquid would cause it to solidify and about half would vaporize, reacting with the atmosphere to form a mixture of uranium oxide and fluorine compound (UO_2F_2) and hydrofluroric acid, the products of gaseous uranium hexafluoride.[54] The effect of such a release can be seen

from the accident at a uranium processing plant in Oklahoma in 1986, in which one person died, 32 were injured, and several homes had to be evacuated when a tank of uranium hexafluoride ruptured, spilling its contents. [55] The opportunities to create an off-site radiation leak at a reprocessing facility is may be limited. Although the radioactivity of the materials is considerable, and therefore potentially attractive for radiological terrorism, it also means that they are remotely handled and are inaccessible, even to operators, due to the necessity for extensive radiation shielding. Significant amounts of explosives might conceivably rupture the spent fuel storage pool, but the likelihood is that the radiation released by such a spill would be small since the gaseous fission products would mostly plate out on the interior of the building, or would be captured by the filtration system. However, if not only the pools or tanks were ruptured, but also the fabric of the building, then the explosion has the potential to throw large quantities of highly radioactive material into the atmosphere. If a plane crashed into a reprocessing facility, the resulting fire as the fuel burned would add to the radiological release. If the cooling system was also compromised in the explosion, then, potentially, the radioactive material could overheat and further material would be propelled into the atmosphere.[56]

The transport of spent fuel is the part of the nuclear cycle where material is seemingly at its most vulnerable. However, it would be far from straightforward for terrorists to exploit this: spent fuel is shipped in casks that protect the public from radiation, so the construction of the casks is extremely robust. Even enormous truck bombs, detonated within feet of the cask, may not be capable of penetrating it. However, Bunn and Steinhauser suggest that terrorists would have little difficulty acquiring and using anti-tank weapons capable of piercing the transport canisters.[57] Shaped charges probably could do so but by their nature, designed to penetrate deeply rather than to do massive damage, they are likely to rupture only the fuel pins directly in their path. Therefore, as with several other forms of radiological terrorism, the public reaction would probably be out of proportion to the true physical danger.[58] Nevertheless, such an attack would be a highly effective means of creating fear and disruption amongst a population. Key Russian Ministry of Defense (MOD) officials have indicated considerable concern about the possibility of nuclear weapons being stolen in transit or damaged in accidents on Russia's decaying railway system. Therefore, as part of the CTR program, supercontainers were shipped to the MOD to protect warheads in transit, as were five rail-mobile emergency support modules to help respond to attacks and accidents.[59]

Radiological Terrorism

If the terrorist group's intention is a radiological attack, then destroying a reactor is only one, albeit very public and dangerous, way to achieve this goal. Radiological materials in this category can be more easily stolen from nuclear, industrial and research facilities than can weapons-grade material.[60] The IAEA reports 380 incidents of radiological trafficking since 1993, only the minority of which involved "high end material."[61] Abel Gonzalez, the IAEA's director of radiation and waste safety reported in late October that "Security of radioactive materials has traditionally been relatively light...There are few security precautions on radiotherapy equipment and a large source could be removed quite easily, especially if those involved have no regard for their own health." Many such sources are presently without any regulatory control and are unaccounted for.[62] A radiological device would be extremely easy to construct (it need only be a aerosol can or a bomb with a radioactive coating or with a container of radioactive material next to it) and the materials for it are so widely available (cesium-137, for example, is commonly used in hospitals for X-rays). Even elements, such as cobalt-60 or cesium-137 which need a fierce fire to disperse them could be used effectively in radiological weapons if the material was surrounding a mixture of high-explosive and incendiary material. While a firebomb, of this variety, is technologically well within the reach of many terrorist organisations,[63] a group might also consider using military munitions for this purpose. Both thermite grenades and white phosphorus mortar or artillery shells could be used to ignite extremely hot fires that are resistant to water. White phosphorus would probably give greater dispersal, but does not burn as hot as thermite. However, variants of both are used by many military organisations and are therefore likely to be available on the black market.[64]

The technical feasibility of radiological terrorism, as a low-technology weapon, means that it is by far the most likely form of nuclear device, as well as the least catastrophic. However, it would still have considerable value as a terrorist weapon, since the mere fact of being nuclear would almost certainly ensure that it had a considerable impact on the publics imagination and fear, and thus on a governmental response. For the same reason, being nuclear, it conveys an added prestige and status on the perpetrators. Radiological terrorism would set a group apart and take its terrorism to a new level, so has considerable attractions. Furthermore, while the use of a radiological weapon would be more difficult than most "off the shelf" weaponry, and would be an example of technological innovation for terrorist groups, the arguments that make a nuclear-yield device an unlikely, if highly dangerous, threat apply to a much lesser degree for radiological weapons. While a nuclear-yield bomb would be an extremely

expensive and difficult mass-casualty weapon, a radiological device would be an only moderately difficult (there might be material handling problems, for example).

It is almost impossible to generalise on the extent of the risk to the public from a radiological dispersal device: it depends so much on the material used, the means of dispersal, population density, weather conditions, and the period of public exposure. However, the International Physicians for the Prevention of Nuclear War (IPPNW), in their publication on crude nuclear weapons, argue that:

> . . . [T]he consequences of a radiological weapon using plutonium in amounts that are potentially available for a terrorist attack are very largely long-term in nature: primarily increased cancer incidence, particularly of lung, bone, and liver cancer . . . Thus in health effect terms, the impact of such a weapon would be hidden for several decades, and probably would not be dramatic. However, given the public aversion to cancer risk, and the fears engendered by plutonium as a potential carcinogen, there are likely to be immediate and dramatic responses by the emergency services.[65]

To a very large extent, though, the effects of a radiological weapon are dependent on the type of material used: while weapons-grade plutonium might cause limited damage, other elements, such as cesium, or even radioactive waste, are potentially lethal, very rapidly. In 1981, an environmental impact statement by the US Nuclear Regulatory Commission (NRC) estimated that a big truck bomb used against a reactor in a highly populated area could effectively turn the nuclear reactor into a large radiological weapon, causing up to 130,000 fatalities.[66] This is a highly pessimistic estimate. A more recent estimate of the implications of a catastrophic incident at the reprocessing facility at Sellafield, in northern England, was equally worrying. It found that up to half the 2400 kilograms of cesium-137 stored in the tanks at the site might be released into the atmosphere, causing up to 2 million cancer deaths in the following 50 years, assuming a similar pattern of exposure to that after the Chernobyl disaster.[67] Such claims are highly alarmist, not least because they present worst case scenarios as the likely outcome of any incident.

Where the cause is a radiological dispersal device rather than a disaster at a nuclear facility, the consequences appear substantially smaller. In 1987, in Goiana, Brazil, two adults broke open a cesium source, found abandoned in a clinic, and allowed children to play with the glowing material inside. Within days, four people died, and 249 others were contaminated. There was public hysteria, and thousands of cubic metres of soil had to be removed for decontamination.[68] Nevertheless, radiological devices are not ideal for creating mass casualties because the quantities of highly radioactive material required to cause powerful results over even a moderate area are likely to be so great that it would pose considerable problems for terrorists to acquire and then work with the material.[69] To

achieve widespread casualties, terrorists would probably be obliged to find a way of manufacturing very small particles of radioactive material, exacerbating the handling and production risks and difficulties, or finding an effective means of dispersion, as discussed earlier. During the 1940s and 1950s, the US military experimented with radiological dispersal devices but ultimately decided that such weapons were not militarily useful. They found that disseminating gamma-emitting radiological agents in air posed considerable difficulties because of the heat generated by the material and the problems of dissipation.[70] Radiological weapons might, therefore, be used by groups as weapons of terror, rather than as an effective means of causing mass casualties for which other types of non-conventional weapon might be used instead.

Further questions about whether terrorists are likely to seek to use radiological weapons are raised by Brian Jenkins who noted over twenty years ago that:

> Scenarios involving the deliberate dispersal of toxic radiological material which could cause a number of immediate deaths, a greater number of serious and protracted illnesses, a statistical rise in the mortality rate, and ultimately an increase in the number of birth defects among the affected population do not appear to fit the pattern of any terrorist actions carried out thus far...
>
> Terrorist actions have tended to be aimed at producing immediate dramatic effects, a handful of violent deaths - not lingering illness, and certainly not a population of vengeance-seeking victims...If terrorists were to employ radioactive contaminants, they could not halt the continuing effects of their act, not even long after they may have achieved their ultimate political objectives. It has not been the style of terrorists to kill hundreds or thousands. To make hundreds or thousands of persons terminally ill would be even more out of character.[71]

Although recent reports of groups such as al-Qaida or Chechen separatists planning attacks with radiological weapons appears to undermine Jenkins argument, it is a worthwhile caveat that such attacks are not tactics that many terrorist groups have historically sought to use, and remain unlikely tactics for the majority of groups. Radiological weapons would have a vast impact and could, potentially, pose a considerable problem for an extended period. Therefore, an incident that is not intended to cause mass casualties, but is intended to achieve political or economic extortion, is the most plausible type of radiological terrorism. Once aware of the problem, it would probably be possible to clean up the radiological effects of a device, but restoring public confidence would be very difficult.[72] Clearly, the disruption would be immense and somewhat similar to the situation in Tokyo on April 15, 1995, when the Aum cult threatened fresh attacks on the subway, bringing the entire city to a grinding halt for the day, and mobilising an estimated one third of Japan's police force to defend the city. Commuters stayed at home, refusing to take the risk of being the victims of another sarin attack.[73]

The use of lower-grade nuclear material for terrorism or extortion is obviously already a reality. In April 1985, a letter addressed to mayor Ed Koch was sent to the New York City Water Authority, threatening to place plutonium trichloride in reservoirs serving New York. The perpetrator demanded that murder charges be dropped against Bernard Goetz, who shot four black youths allegedly attempting to mug him on the subway. When the U.S. Department of Energy tested the city's drinking water, they found elevated levels of plutonium, from the usual 0.1 to 0.6 femtocuries per litre to 21 femtocuries per litre. However, no proof of contamination, or a definitive link between the threat and the test results, was found. Moreover, the danger posed by this type of attack was small: the Federally-determined safe level for drinking water is 5000 femtocuries; and while plutonium trichloride is soluble, along with other types of plutonium, it is poorly absorbed through the stomach and intestinal walls compared to being inhaled.[74] Furthermore, most types of plutonium are largely insoluble, and so an ineffective means of contaminating water supplies.[75] The dubious effectiveness of such a tactic has not precluded other similar threats being made. In October 1974, the Italian Government announced that a plot, by right-wing terrorists, to contaminate a number of Italy's aqueducts with radioactive waste had been uncovered. The material was alleged to have been stolen from a nuclear centre in the north of the state. However, details of the attempt remained sketchy and no incident occurred.[76] Using radioactive material to contaminate water supplies has relatively little chance of causing fatalities: the quantities of material required to have a lethal effect, even in a small reservoir, are so vast that it seems a highly implausible tactic. However, as with other types of radiological terrorism, the effects on public confidence and behaviour are, potentially, enormous: in the New York case, purchases of bottled water doubled, despite the low risk to the public and the fact that the event was several months past before the public became aware of it.[77]

Additional cases of possible radiological terrorism include: the Russian mafiya alleged killing of a Moscow businessman in 1993, using gamma-ray emitting pellets, placed in his office[78] and the June 1996 attempt by three men in Long Island to kill local Republican Party officials, using radium placed in the victims' cars, food and, bizarrely, their toothpaste. The three perpetrators, John Ford, Joseph Mazzuchelli, and Edward Zabo, were members of the Long Island UFO Network and were enraged by a supposed conspiracy by Republican leader John Powell, Brookhaven Town Public Safety Director Anthony Gazzola and Legislator Fred Towle to hide evidence that a UFO had started a forest fire. Ford had tried to run for office to reveal this conspiracy, but had been blocked by Powell. Zabo supplied the radium, which he claimed came from a friend, although Zabo worked for as a Defense Department employee at Northrop Grumman and police found five storage canisters around his house. Ford was

found unfit to stand trial; Zabo plead guilty to supplying the radium in exchange for a reduced sentence; and Mazzuchelli was convicted of second-degree conspiracy.[79] Incidents have also occurred outside the United States. On 17 April 1974, a man claiming to represent the "Justice Guerrillas" called police in Vienna, alleging that radioactive material had been place on the train to Rome. Police found a large but non-lethal quantity of Iodine-131 under a seat in the first class compartment. The three packets of material had been stolen from Vienna's main railway station on April 12, from where they were due to be shipped to a hospital in Linz. Police later arrested a man with a history of mental illness who claimed his actions were a protest against the treatment of mentally ill patients in Austria, rather than being politically motivated.[80] Radiological threats have also been issued in the USA: in 1975, a Puerto Rican group (probably the FALN) threatened to detonate 100 bombs against US targets, 25 of which would contain radiological material.[81]

The most important sub-state use of radiological material occurred on 23 November, 1995, when Chechen guerrilla leader, Shamyl Basayev, informed the Russian television network, NTV, that four cases of radioactive cesium had been hidden around Moscow. NTV discovered the 32 kg case, wrapped in a yellow plastic bag and giving off 310 times the normal amount of radioactivity in Ismailovo park. Basayev had repeatedly threatened to attack Moscow with nuclear or chemical weapons, and had already proved his ability to create "terrorist spectaculars" by taking 1500 people hostage in Budennovsk in June. Russian officials largely dismissed the nuclear threat, claiming that the material was cesium 137, used in X-ray equipment or some industrial processes, capable of emitting only 100 times the background amount of radioactivity.[82] However, the truth about the material is less important than the credibility of the threat, as demonstrated by the precautions the Russian authorities took, sending emergency search teams out around the city with Geiger counters.[83] If the Chechens had sought to inflict harm on the city's residents, they could have left the container open, and allowed the contents to disseminate through the park. Dzhokar Dudayev, the Chechen leader, did claim that there were conventional explosives with the nuclear material, threatening radiological dispersal, but this was a hoax. Basayev was intent on displaying capability and on ensuring that this threats to launch further attacks against Moscow, unless Russia withdrew from Chechnya, were taken seriously.[84] His warning was plausible because the state of the Russian nuclear industry made it impossible to rule out the possibility that the Chechens had indeed acquired dangerously radioactive material.

In the wake of the 11 September attacks in the United States, it has also emerged that al Qaida may have sought the means to build a "dirty bomb".[85] Although there have been previous allegations relating to the

organisation's attempts to acquire material to build a nuclear-yield bomb,[86] the claims over a radiological weapon represent a significant departure. British intelligence forces are currently investigating allegations, made by a Bulgarian businessman, Ivan Ivanov, that in April 2001 he was approached by a middleman for bin Laden, seeking to obtain radiological material. Ivanov allegedly had a series of meetings near Pakistani border with Afghanistan, including one with bin Laden. He then met with a "chemical engineer", near Rawalpindi, and was offered $200,000 to help the scientist acquire spent nuclear fuel rods from the Kozlodui nuclear electricity plant in Bulgaria. The plan would have involved buying the rods legally, through a newly established environmental front company that would deal with nuclear waste. Ivanov declined the opportunity and reported the contact once he returned to Europe.[87]

Earlier this year, customs officials seized 10 lead-lined containers on the border between Uzbekistan and Kazakhstan. The containers held a substantial quantity of radioactive material, ostensibly intended for a company in Quetta, Pakistan. The precise type of materials remains unclear, but it seems unlikely to have been a legitimate shipment and it does seem possible that bin Laden's al-Qaida was a potential end-user.[88] There must also be concerns that the main threat in this respect may not be leakage from the Former Soviet Union, but assistance to al-Qaida from Pakistani sources. In October, two key former members of Pakistan's nuclear program were detained as a result of their connections to the Taleban. Bashir uddin Mahmood was project director before Pakistan's 1998 tests and has since been running a relief organisation, sympathetic to the Afghan regime. Abdul Majid was a director of the Pakistan Atomic Energy Commission in 1999.[89]

Conclusion

The full implications of 11 September for nuclear security and the nuclear industry remain unclear. Although concerns at truck bomb attacks on reactors have been present for several decades, 11 September 2001 may be the closest example to date of an existential threat to a reactor. However, given that the uncertainty over where United Airlines flight 93 was being directed, it may equally be that nuclear reactors were simply one of several possible categories of target that were considered. It is possible to state though that 11 September indicates such attacks on reactors are more likely than had been thought previously. The attack represents a new level of high casualty, high profile, long-term action. Other groups may or may not follow al-Qaida's lead towards this new type of assault, but clearly an attack on a reactor, and potentially radiological terrorism, would fall within the patterns of action established by that network.

Mohamed ElBaradei, head of the IAEA, summed up the uncertain situation as follows: "The tragic terrorist attacks on the United States were a wake up call to us all. We cannot be complacent. We have to and will increase our efforts on all fronts - from combating illicit trafficking to ensuring the protection of nuclear materials - from nuclear installation design to withstand attacks to improving how we respond to nuclear emergencies."[90] Physical protection measures for nuclear materials and facilities varies widely from country to country, and even within states. It is vital that the security of both facilities and all nuclear materials (including those that might be used to make a radiological dispersal device) be ensured to the highest possible level. In the longer term, nuclear plants need to be built as target-hardened, stand-off facilities to combat the threat of truck bombs. New designs need to be considered as counters to the danger of aircraft being crashed into facilities. In the shorter term, more limited physical protection measures need to be pursued, but the problem of insider crime, with its potential for sabotage and theft, needs to be readdressed. In the new, uncertain, world of international terrorism, both facilities and material are simply too vulnerable to exploitation, with potentially devastating consequences. The IAEA needs to be at the forefront in calling for more effective physical protection for both facilities and materials. Dr. ElBaradi's statement to the United Nations General Assembly on 22 October is an important declaration of intent to prioritise these areas.[91] This has to be followed through, a process that is likely to require extended commitments of effort, money and thought to successfully implement. Nuclear security is too important to allow anything else.

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