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The implications of 11 September for the nuclear industry

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The acts and motives of those terrorists who attacked the United States on 11 September 2001 were met with astonishment and disbelief. Perhaps this was because we had come to expect a limit on the level of outrage as terrorists have acted mainly within their own constituencies thereby applying a degree of self-restraint. However, with its attacks in the United States al-Qaeda demonstrated that it was prepared to operate outside its ill-defined constituency, being free to strike at international targets, exclusive of restraints and, with the attacks in Washington and New York, intended to maximize the loss of life and human suffering.

The other disturbing element of the al-Qaeda atrocity was that the terrorists themselves did not need to manufacture any technological device for they simply pitted one available technology (fully fuelled commercial airliners) against another (commercial office building structures). In doing so, they outwitted the designers and operators of these two diverse technological systems—neither had recognized that one could be deployed against the other with such devastating effect.

After the events of 11 September, it is perhaps just a short and logical step for terrorists to latch onto how highly hazardous nuclear plants might be triggered into releasing energy and toxins via aerial and other modes of terrorist attack. If this happens, can such plants provide a robust defence against terrorist attack and are there particularly vulnerable parts of the buildings and processes that, if penetrated, could lead to a devastating release of energy, toxins and radioactivity?

Nuclear plants and processes

Nuclear plants undertake a variety of processes, some of which involve intensely radioactive materials and highly reactive chemicals. Moreover, being nuclear there is a public perception of dread and fear (i.e. a fate worse than death) associated with radioactive release. Even if sometimes the public's perception of all things nuclear can be exaggerated, by virtue of this fear, the socio-psychological impact of a nuclear terrorist attack might be much greater, thus rendering nuclear plants even more attractive to terrorists.

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To mount an attack on a nuclear plant the terrorist cell would have to plan ahead, locate the particularly hazardous processes and stores, determine the amount and nature of the radioactive contents and how readily this might be dispersed into the atmosphere, and identify the most vulnerable aspects of the buildings and containments of the targeted plants.

Examining how and by which means those planning such a hypothetical act of terrorism might obtain this sort information and, from this, how potential target systems and processes within a nuclear plant can be identified leads to a disturbing outcome.

This is that both nuclear power stations and nuclear fuel plants (such as Sellafield in the United Kingdom) are almost totally ill-prepared for a terrorist attack from the air. For example, at Sellafield the design and construction of the buildings date from a period of over fifty years, many of the older buildings would just not withstand an aircraft crash and a subsequent aviation fuel fire, and some of the buildings, now redundant for the original purpose, have been crudely adapted for storage of large quantities of radioactive materials for which they are clearly unsuited. Even the design of the most modern nuclear plants does not seem to provide that much defence (in terms of containment surety and segregation of hazardous materials) against terrorist attack.

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Overall, the nuclear industry defends its plants against natural and accidentally occurring hazards on a basis of 'as chance would have it', and it provides protection against human error by designing the systems and equipment to be tolerant and/or independent of human action (or inaction). This combined approach of gauging the risk by probabilistic assessment and treating the human operators as inconsequential dummies may have some effect in safeguarding the plant against accidents, natural hazards and unintentional human error, but it may prove to be woefully ineffective against intentional and intelligently driven acts of terrorism.

Terrorist attack

It is an unwitting trap to assume the future *modus operandi* of a terrorist attack will follow the pattern the airliners hijacked by al-Qaeda on 11 September in the United States. Simply strengthening airport security may deter aviation terrorism for the time being and, indeed, there may have already occurred a shift towards tourism targets with the dreadful bombings at Bali and Mombassa.

So a malicious attack on a nuclear plant could be applied via a variety of means including, for example, armed insurgents forcibly entering and interfering with the plant safety systems, from an external explosive device such as a truck or four-wheel drive vehicle bomb being detonated just outside the plant's secure area, or via a passive or an active insider employed within the plant itself. Indeed, these shifts in themselves might suggest that the terrorists may be seeking out and exploring new targets and their impact.

For now, consider the terrorist attack to be centred on an airliner hijack. In assessing *accidental* aircraft crash probability the guidelines and principles set out by the United States Department of Energy[1] are generally adopted worldwide. Essentially, this approach assumes some form of loss of control of the subject aircraft, its subsequent deviation from the intended flight path and the chance of it crashing into the nuclear plant. The nuclear plant is defined as a crash area in terms of its size, locality within the terrain and the projected height of the buildings above ground level. Applied to a civil airliner operating at altitude and passing along a prescribed flight path, this *a posteriori* probabilistic approach adopts rates drawn from actual crash incidents, which yield very low accidental crash probabilities. Essentially, the whole probabilistic assessment outcome is determined by the chance of a very small missile (a commercial airliner) accidentally hitting a small target (the nuclear plant) located in a very large geographical space. Much the same approach is adopted for other accidental and naturally occurring hazards—be it a road vehicle laden with petroleum spirit running out of control into the plant, or a freak tsunami inundating the nuclear site—which will also result in extremely low and improbable chances of occurrence.

Applying this to nuclear plants suggests that *accidental* aircraft crash rates are sufficiently low (less than one in ten million per year) to satisfy the requirements that the hazard occurrence is so remote that it cannot be expected to affect the plant. Put simply, this probabilistic approach has led to plant defences against accidents and natural hazards being based on repelling or coping with events that might be best described as *unintelligent* and *unintentional*, some of which are considered to occur, as chance would have it, so infrequently that the time, trouble and cost of implementing countermeasures are not justified.

Of course the probability or chance of the occurrence of a malicious human act, such as the terrorist attack of 11 September, cannot be determined by classical *a priori* probabilistic means. This is because terrorist attacks are *intentional* (overriding probability), which have to be considered to be *intelligent* and *intentional* events that will seek out the vulnerabilities of the target system.

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Notional restraints such as no-fly zones nearby nuclear plants are to no effect once an aircraft has been commandeered and the terrorist attack is underway. If the terrorists fly to the targeted plant by line of sight (apparently the case for the World Trade Center), then visual contact at cruising altitude is achieved at about thirty miles (48km), which leaves but an impracticably short timescale (four to five minutes) for the authorities to detect, intercept, interrogate and implement the appropriate remedial action to thwart the attack. As notional restraints would be useless to deter an attack once it had started, the sole remaining option to handle the crisis is consequence mitigation.

Consequence mitigation

Two points must be kept in mind when attempting to defend nuclear plants and facilities against attack.

First, the design and construction of the buildings of these sites were likely to comply with the regulations and good practice of the times, being considered then 'fit for purpose'. So, even if the designers of the day had included within the building and containment designs (and processes within) features resistant to aircraft crash, the assessment would have related to the types of aircraft flying at that time. Similarly, the need or priority to incorporate such features would have sensibly related to the density of aircraft traffic at that time, that is, the probability of a crash event. Second, for those plants designed and regulated from a probabilistic basis, it is very doubtful indeed that any intentional aircraft crash resistance was built into the system—not just for the building structures and physical containments, but also on the resistance of safety equipment to resist impulse loading and the fire associated with aircraft crash.

Put another way, the generic designs of nuclear plants were set down in the 1950s and 1960s when commercial aircraft were typical of the relatively small size of a Vickers Viscount and similar. Today, there are no longer any Viscounts in commercial service yet all of the nuclear plants of those bygone times remain, most continuing in operation.

These two inconsistencies alone suggest that it would be impracticable for the world's nuclear plant operators to modify much of the existing plant so that it would be reasonably guaranteed to survive an aircraft crash. The severity of an aircraft crash might drive through and render ineffective the normally accepted physical systems that serve to limit the consequences, such as safe shutdown, continued availability of utilities, adequate containment integrity and on- and off-site emergency preparedness. If so, the accident would still have to be 'managed' by improvising the use of other surviving systems and resources, which requires an increased reliance upon operator intervention because accident management strategies must be implemented by plant personnel.

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Nuclear plants are designed to withstand, as far as is practicable, specified external hazards such as earthquakes, flooding, etc., but this defence is quite scenario-specific and the capability of certain items of equipment to survive depends not only on the custom engineered resistance to particular scenarios but, importantly, on the diversity of function of the safety systems and equipment involved. The point here is whether the diversity of the installed equipment is sufficiently broad to resist a common mode failure across all of the equipment and systems that could be triggered by aircraft impact, fuel explosion[2] and the subsequent fire.

Also, it is doubtful that the outcome of a consequence analysis could be practicably implemented to provide an effective consequence mitigation management regime. Moreover, accident management, even if performed as planned, might prove ineffective—leading from one severe accident sequence to another just as hazardous and it may, in certain rapidly developing situations, be counter-productive.

Impact and ensuing fire of an aircraft crash

Aircraft, for all of their speed and power, are relatively fragile structures. The 190 or so tonnes of each Boeing 767 that ploughed into the twin towers of the World Trade Center may have provided a colossal kinetic energy but the wings and fuselage would have shredded almost immediately, leaving just the compact masses of the engines and a few solid spars and undercarriage frames in the role of very energetic projectiles to penetrate the building structure. Accompanying this high-energy impact was the release of the 80,000 litres or so of aviation fuel, partially vaporized, that erupted into fireballs to ignite flammable materials in the vicinity.[3] Vaporized and unburnt fuel would have been squeezed into building voids by the expanding flame and pressure fronts and the remaining fuel would have gushed into the interior of the building, spreading downwards through buckled and holed floors. As the tragedy unfurled it was clear within minutes that about ten floors of each of the towers were burning furiously, so intensely that the structures buckled and progressive collapse commenced on the South Tower within one hour of the aircraft impact.

Now that a full analysis of the collapse of both the World Trade Center towers and the Pentagon has been published,[4] it is clear that both the impact and the fire phases of the crash played active roles in the destruction of the buildings. The initial impact would have destroyed or weakened the structure of the buildings and the immediately following fire was of sufficient temperature to ignite all flammable materials within, which provoked further structural member buckling and damage leading to catastrophic structural failure.

Failing the engineered structures of nuclear power plants

Obviously, the effect and outcome of an aircraft crash and fuel explosion/burning on any one of the active plant buildings or processing/storage areas of a nuclear power station would be subject to how each of the individual target buildings would perform under the impact and fire conditions.

The results of aircraft impact can be segregated into two regimes. First, at the moment of impact the aircraft can be considered to be a very large but relatively 'soft' projectile which, by 'self-deformation' will dissipate some fraction of the total kinetic energy being transferred during the impact event. Second, some components of the aircraft will be sufficiently tough to form rigid projectiles that will strike and commence to penetrate, again by kinetic energy, components of the building fabric and structure.

Setting aside localized damage in which individual structural components are removed (blasted away), the most probable failure mode of the structure overall is that of buckling and collapse in response to the impact. The types of building structures featured at nuclear power plants, for example the radioactive waste and spent fuel buildings, would not withstand the impulse magnitude delivered by a crashing commercial aircraft. Even if the building structures remain standing, relatively small and localized penetration by parts of the breaking-up aircraft will permit the inflow of aviation fuel with the almost certain fire aftermath—which, in itself, will heighten the release and dispersal of any radioactive materials held within the building structure.

It is quite reasonable to assume that the building containment would be breached—this is likely to be a justified assumption because of the absence of any extraordinary civil engineering features visibly incorporated into the building design. On this assumption, once that the building is breached it may be that the particular process and/or substances stored within will add to the damage, by explosion and ferocity of the fire (flammables).

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Damage and consequence scenarios

For a typical nuclear power plant, the following scenarios might arise.

IRRADIATED (SPENT) FUEL STORAGE

If the roof structure of the covered fuel ponds was penetrated and the pond wall structure breached, then the loss of pond water and the aviation fuel fire could lead to a breakdown of the fuel cladding and fuel itself, resulting in a high release fraction of fission products, possibly mixed with emulsions of the aviation fuel. The fuel pond radioactive inventory depends on the degree of irradiation of the fuel (the burn-up) and the post in-core period, although the quantity of fuel might represent (in mass) seven to eight times or more the reactor core load.

A crashing airliner, displacement of the fuel pond water and introduction of burning aviation fuel could result in a very significant radioactive release from the irradiated fuel pond. The subsequent dispersion range of the airborne radioactivity could be much enhanced by the high thermal energy involved (plume height) and combination of fission products with emulsions of the aviation fuel and its products of combustion.

INTERMEDIATE RADIOACTIVE WASTES

The radioactive inventories and chemical make-up of the stored radioactive wastes at nuclear plants sites is known and because of the dilemma over failure of most nuclear countries to find a national radioactive waste repository for high- and intermediate-level categories of radioactive waste such wastes will accumulate at the individual nuclear sites for the immediate and interim futures.

Certain nuclear sites carry a high burden of radioactive wastes. At the fuel reprocessing plant at Sellafield, for example, there are very large volumes in store, some of which are flammable in themselves, such as the 1,000m^3 or more of contaminated reprocessing solvent (odourless kerosene) which could add considerably to the aftermath fires of an aircraft impact. Ignition and/or chemical reaction of the radioactive wastes could serve to further increase the quantity and efficacy of the radioactive release.

OPERATIONAL NUCLEAR REACTORS

The range of potential outcomes for operational reactors subject to terrorist attack is large.

Obviously, a direct impact on the reactor locality, breaching the reactor pressure vessel and/or the primary coolant circuit would most probably result in a radioactive release into and through the secondary containment systems that would have also been breached by the impacting airframe. Other safety-critical equipment of operational nuclear power plants include the electricity supply grid connections and the emergency diesel electricity generators, both of which provide essential electrical supplies for safety systems, reactor cooling and heat sinks, and the loss of which, particularly effective core cooling, could result in containment challenging events developing in the reactor core.

The main findings arising from these scenarios are that:

- very few, if any, of the world's nuclear reactors have containment that has been specifically designed to resist aircraft attack, although some are designed with a secondary containment dome to resist an accidental impact of a light aircraft;
- none of the radioactive waste and spent fuel facilities, at the nuclear power plants and fuel plants such as Sellafield, could withstand the directed impact of a fully loaded commercial airliner; and
- many of the radioactive waste and fuel storage facilities, again at the nuclear power plants and at Sellafield, contain massive amounts of radioactive material available for suspension and dispersal in the aftermath of a terrorist attack.[5]

Concerns

With these scenarios in mind, this paper poses three queries.

- Is there sufficiently detailed information available in the public domain for a terrorist group to plan an attack with sufficient confidence of success?

- Does the regulatory safety case requirement include for *accidental* aircraft crash and, if it does, is this sufficient to safeguard against *intentional* aircraft crash?
- Could the plant's systems and processes be modified and prepared to withstand such an intentional attack and, if so, how much of this defence would depend upon accepting intentional aircraft crash as inevitable, thereby relying almost totally upon consequence management to mitigate the outcome?

INFORMATION ACCESSIBILITY

Using the plants in the United States and the United Kingdom as yardsticks, it is relatively straightforward to obtain all of the information a terrorist would require by simply accessing publicly available documents. Ministries and agencies of central governments publish most of these sources of quite detailed information, and local authorities maintain records of planning applications that include details of extant as well as proposed plants and buildings. These records and documents are readily accessible, it being possible to obtain copies directly from the originating department of documents from the 1990s and earlier.

Also, there are a number of 'storehouses' of related information. Local, national and international environmental (and other) groups hold pools of information that they have accumulated over the years. As example, one local group was able to provide photographs of locations deep within the Sellafield fuel reprocessing site, and elsewhere fully detailed engineered drawings of buildings, and scaled site maps that included the location of essential services, are available for the UK Sizewell B pressurized water reactor from the Construction Report prepared for and published at its preconstruction Public Inquiry.

For example, when responding to requests for information and documentation, both the British government and the relevant local authority did not enquire to what purpose the information was required and, during my firm's requests, there seems to have been no verification of the bona fides and identity of the enquirer.

Within two weeks of the 11 September attacks, the United States Nuclear Regulatory Commission (NRC) closed down all of its Internet web sites to review the contents; surprisingly, the web pages relating to Sellafield (British government, BNFL, etc.) remained open and accessible.

AIRCRAFT CRASH AND DESIGN BASIS THREATS

Although this paper centres on an *intentional* aircraft crash, a future terrorist attack against a nuclear plant might be in the form of some other external, man-made hazard. However, here I have only considered aircraft crash in any detail, although a future terrorist incident might involve, for example, a truck bomb driven close to or actually into the plant secure area.

Arising from the history of considering only accidents and natural hazards for in-plant defence, the worldwide nuclear industry is almost dismissive of the risk solely on the basis that the calculated frequency renders such an *accidental* event to be entirely incredible and, hence, there may have been little incentive to include for such a remote event in the plant's design. Now, in the post-11 September era, the unpalatable likelihood of an intentional aircraft crash into a nuclear plant has to be considered and accounted for as a Design Basis Threat (DBT).

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For other DBTs, such as truck bombs and attacks by armed insurgents, the NRC requires American nuclear plant operators to submit to force-on-force trials simulating intentional malicious actions. Since 1991, the NRC has conducted about ninety trials or *Operational Safeguards Response Evaluation* tests, of which about 45% of the tested nuclear plants failed. Most disturbing is that three plants tested shortly before 11 September (Farley, Oyster Creek and Vermont Yankee) received results that were the worst on record. In another assessment, the NRC notes that between 15 to 20% of nuclear plants in the United States would sustain safety critical levels of damage from vehicle bombs accessing close to the supervised boundary of the plant.[6]

Although some British nuclear plants have been subject to mock attack exercises, nothing on their vulnerability and/or performance has been published. Recently (May 2002), however, Bradwell nuclear power station was subject to some form of trial which involved the local authority emergency planning resource and which must have involved the central government Department of Trade and Industry's Office for Civil Nuclear Security (OCNS).

Apparently (because nothing is publicly available), OCNS has evolved a new procedure to assess security threats, which are to be incorporated into a DBT document. This document is to be the key planning aid for plant operators. The DBT will provide intelligence about the 'motives, intentions and capabilities'[7] of potential adversaries against which the plant operator is to 'beef-up' the plant management, contingency planning and physical security measures. Once all of this is in place, the Director of the OCNS will evaluate the robustness of each of Britain's individual nuclear plants; this information was to be made publicly available in the OCNS's first annual report.[8]

At the governmental level in the United Kingdom, there is the recently formed Chemical, Biological, Radiological and Nuclear (CBRN) cabinet sub-committee. The role of CBRN is to review the contingency arrangements in place to protect against terrorist attack, although its findings are classified restricted and above, and nothing is publicly available on its membership and how and to whom it communicates its recommendations.

At local level, local authorities are presently preparing off-site plans as required by the government's Radiation (Emergency Preparedness & Public Information) Regulations (REPPIR). For this the nuclear plant operator is required to prepare a Report of Assessment upon which the Health and Safety Executive (HSE) determines the need and coverage of any off-site emergency planning. REPPIR was prepared and enacted before the events of 11 September so, not surprisingly, it is silent on the specific need to include DBTs in the Report of Assessment. Indeed, the overseeing government agency (HSE) considers it unnecessary to specifically plan for terrorist acts since both the probability and mode of attack are not 'reasonably foreseeable' and, in any event, it assumes that the local authority off-site plans are extendible to cover such acts. Just how and to what effectiveness poorly resourced local authorities would deal with a terrorist attack in the United Kingdom, particularly if the terrorist also harried the implementation of the off-site countermeasures, remains a matter of conjecture.

Like many other nuclear countries, Britain has been jarred into action by the events of 11 September. New committees have been formed, assessments are being made and there is now, via REPPIR, a real opportunity to put in place—resources permitting—effective emergency planning and consequence management measures.

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However, it has to be acknowledged that modifying the existing plants to improve their physical invulnerability is just not practicably feasible. In place of this, there must be effective intelligence gathering on the ground in advance of any planned attack and this must be communicated to the operators and the emergency planners.

Although informed in advance of the threat, the Bush Administration was unable to thwart the 11 September attacks. A similar failure in acting upon gathered intelligence could not be tolerated again, particularly if it was believed that a nuclear plant had been identified as a target.

DEFENDING NUCLEAR PLANTS—CONSEQUENCE MANAGEMENT

In summary, nuclear plants are poorly prepared for a terrorist attack from the air. Many of the buildings would not withstand an aircraft crash and subsequent fire. Even the design of the most modern plants does not seem to provide that much defence (in terms of containment surety, dispersion of stocks to different localities, and segregation of hazardous materials) against an aerial attack.

It would not seem to be practicable for each and every building and process at such nuclear plants to be modified to provide adequate protection against aircraft crash. The investment required would be enormous and the practical difficulties challenging indeed—many of the processes would have to be relocated, possibly to underground caverns and bunkers, which in itself might introduce other safety related detriments. Nor would this change the fact that an intentional airline crash is but one of numerous scenarios that would disrupt the functioning and safety of a nuclear plant or facility.

If a terrorist group planned to intentionally crash an aircraft onto a nuclear power station then the probability of the event becomes a certainty and it is inappropriate to mitigate the chance of such an intentional attack occurring by probabilistic based assessment. Considering an intentional aircraft crash as a certainty, rather than as some remote probability, requires the event to be assessed in terms of its consequence management alone and this consequence management is the only form of mitigation available. In other words, there are no practicable measures that might be implemented on-site to provide a defence in depth to avert such an event.

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However, the idea that a severely damaging event, arriving like a bolt out of the blue, could be 'managed' by improvising the use of other systems and resources is doubtful, particularly because ad hoc decisions and actions (taken in unpractised and highly stressed situations) might lead from one severe condition situation to another just as hazardous.[9]

Conclusion

Most nuclear plants worldwide were designed and constructed without direct concern for a terrorist attack. These plants are huge, complex structures housing sophisticated processes that can rapidly degrade to chemical and nuclear instability. Forceful interference with the physical containments and the safety and control systems of a nuclear plant by terrorist action could result in a massive release of radioactivity into the environment, spreading for tens if not hundred of kilometres from the nuclear site. The resulting human suffering could be immense, at a Chernobyl scale, perhaps crossing national borders, involving thousands of individuals, contaminating vast areas of land in the long-term—the social and economic consequences could vastly outstrip the impact of the terrorist events of 11 September.

That said, there is little that can be done to strengthen the defence of these plants against terrorist attack. To resist aerial attack, the only practicable recourse is to increase vigilance at airports to prevent terrorists from boarding, but this would have to apply worldwide in states that might be thousands of kilometres from the targeted plant. If terrorists were effectively prohibited from boarding at airports, their modus operandi might switch from air to attack by truck bomb. If the plant perimeter was strengthened and expanded to resist this mode of attack, then the vulnerability of the plant to an insider or fifth columnist might be exploited, and so on and so forth.

The choice of solution to this problem (if, that is, a solution exists) is not at all easy. It has to be accepted that whatever measures are implemented to improve the defence of existing nuclear plants that once a determined terrorist group or individual has identified its target, it might get through. If there is a solution it is surely a combination of addressing the underlying fundamental conflicts that drive terrorism, together with both states and peoples maintaining an eternal vigilance which is, after all, the price of liberty.

References and notes

1 United States Department of Energy, 1996, *Accident Analysis for Aircraft Crash into Hazardous Facilities*, DOE-STD-3014-96, available at <http://tis.eh.doe.gov/techstds/standard/std3014/std3014.pdf>; see also for practical application United States, Nuclear Regulatory Commission, 1981, *NUREG-0800, Section 3.5.1.6 Aircraft Hazards*, Nuclear Regulatory Commission, which suggest a crash rate in the absence of other data to be $3.66x10^9$ per flight mile. The great majority of nuclear power plants worldwide are based upon American designs so the approach of the United States to accidental aircraft crash is generic in all of these plants.

2 Commercial jet fuel typically has a heat of combustion of about 38 MJ per litre against, for comparison, 4.2 MJ of energy for the same mass of TNT. If conditions are right, some part of the combustion process of the aviation fuel during the impact could be in the form of a fuel-air explosion which could be quite violent, generating a high energy blast wave which could add to the destruction (locally and in addition to the impulse loading of the impact).

3 The fuel load and aircraft mass could be significantly larger. For example, applied to Sellafield there are about 250 flights of Boeing (Jumbo) 747 airliners per week passing over the northwest region of England. Flying from Amsterdam a Boeing 747 would commence its flight with about 175 tonnes of aviation fuel and fuel consumption for taxiing, take-off, climb and cruise to Sellafield would leave about 155 tonnes of fuel at impact.

4 American Society of Civil Engineers (ASCE) for the Federal Emergency Management Agency (FEMA), 2002, *World Trade Center Building Performance Study: Data Collection, Preliminary Observations, and Recommendations*, available at <http://www.fema.gov/library/wtcstudy.shtm>.

5 For example, at Sellafield there is in store, in powdered dioxide form, approximately seventy-two tonnes of plutonium-239 which has been recovered over the years from irradiated fuel reprocessing. This plutonium stockpile is stored in two adjacent buildings—details of which have been readily accessible from the local planning authority.

6 E. Lyman, 2002, *Terrorism Threat and Nuclear Power: Recent Developments and Lessons to be Learned*, International Symposium on Rethinking Nuclear Energy and Democracy after 09/11, PSR/IPPNW/Switzerland, Basel, April, available at <http://www.nci.org/PDF/Lyman.pdf>.

7 Sunil Parekh, Assistant Private Secretary to John Denham, Home Office Minister, 10 May 2002.

8 The OCNS's first report has now been published but it contains no details whatsoever about the performance of the individual nuclear power plants, although it notes that it itself is experiencing staffing difficulties that do not permit it to carry out its function completely.

9 This paper has concentrated on nuclear plants and processes on a nuclear site itself. It should also be noted that a nuclear plant depends upon the continuous import of services, particularly electricity and mains water, to maintain safety on the site, and—if imported electricity supplies fail—solely on the on-site emergency plant supplies. These imported services (the national grid electricity lines, emergency generators and water pipelines) may also be susceptible to terrorist attack.