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TERRORIST ATTACKS ON NUCLEAR FACILITIES

In recent years there has been increased awareness of the risk of terrorist attacks on nuclear facilities, which could have widespread consequences for the environment and for public health. This POSTnote is a summary of a longer report on this issue, which has been prepared by POST, following a request from the House of Commons Defence Select Committee in July 2002 in its report on *Defence and Security in the UK*.

Background

POST's report aims to provide Parliamentarians with an overview of what is publicly known about the risk of sabotage of nuclear facilities[1] by terrorists. It begins by outlining what is known about the four stages involved in assessing the risk of sabotage:

- **Intelligence**: assessing the nature of the threat.
- **Vulnerability**: assessing the physical robustness of nuclear facilities.
- **Security**: assessing the resilience of security regimes.
- **Consequences**: evaluating the impact of an attack.

Four issues are then discussed in more detail: the operation of nuclear power plants; reprocessing plants; transport of radioactive material and emergency planning.

Limitations of POST's report

Since the report only contains information in the public domain, it is necessarily constrained because much of the information required to provide a comprehensive analysis is classified.[2] POST's report does not make recommendations. The aim is to summarise current information and to place the diverse commentary on this issue in context.

Types of nuclear activity

Commercial nuclear power gives rise to most of the UK's total radioactive inventory, of which the largest amounts are at the Sellafield reprocessing plant in Cumbria, and at Dounreay in Scotland, the site of earlier research and reprocessing activities. There are also 13 generating power plants, 6 decommissioning power plants and various other military and civilian sites across the country. The closest overseas sites are six power plants and a reprocessing plant in Northern France and two power plants in Belgium. Smaller quantities of radioactive material are used in medicine, industry and research. Most of these activities also involve transport.

Intelligence information

Although awareness of the terrorist threat to nuclear facilities existed before September 11th 2001, the threat to a wide range of facilities, including nuclear, has since been re-evaluated. Information on the type of attacks for which UK civil nuclear sites must be prepared is contained in a classified document, the Design Basis Threat (DBT). This is drawn up by the Office for Civil Nuclear Security (OCNS), based on intelligence information about potential attackers.[3] In recent years public attention has focussed on the risk of aircraft impact, but OCNS points out that other modes of attack are also considered, such as attacks involving vehicles loaded with explosives, or suicide bombers. The prevention of non ground-based attacks, such as aircraft impact, is seen as Government's responsibility, although site operators might be expected to take mitigating or preventative measures.

Physical robustness of nuclear plants

The full report desrcibes how safety measures incorporated at the design stage and during the operation of UK nuclear facilities can, in some cases, increase robustness to deliberate acts. One of the most important principles on which modern nuclear plants are based is defence in depth, whereby several different systems perform the same function, so that the safety of the plant does not rely on any single feature. All facilities must comply with the requirements of the UK nuclear safety licensing regime, but more modern facilities have more extensive safety provisions. Under the licensing regime, nuclear facilities must be designed and operated to cope with a variety of accidents predicted in the plant 'safety case'. The safety case itself is not required to take a deliberate attack into consideration. The range of accidents with which plants must be designed to cope, has been decided on the basis of their predicted *accidental* likelihood as well as the severity of their outcome. However, calculations of accidental likelihood are not relevant for terrorist acts.

For nuclear installations constructed over the last 10 years, security considerations have been incorporated at the design stage and are part of the regulatory requirement. Security considerations have not been specifically taken into account in the design of some older UK civilian nuclear installations (e.g. power plants), which have had additional security features retrofitted.

Security regimes at nuclear sites

Numerous off-site counter terrorist activities take place to prevent terrorist attacks from being launched. These include intelligence gathering; surveillance of suspect individuals and taking measures at airports to detect and prevent hijackers. However, if terrorists did succeed in launching an attack on a nuclear facility, they would have to overcome the security regime in place at the facility itself. A combination of security measures are in place, designed either to stop attackers or to detect and contain them until an armed response is able to intervene. According to the principle of 'defence in depth' such systems consist of interlocking personnel, procedural, physical and technical security systems so that damage to any one component of the system should not result in a security breach. Security regimes also address other threats including the theft of proliferation sensitive technology.

It is difficult to assess the resilience of security regimes based on public domain information. The UK carries out some practical exercises to test regimes at civilian nuclear sites but details are classified. Greenpeace has breached security twice at the Sizewell B power station and states that this shows the security regime could not withstand an attack. However, according to OCNS these breaches '*would not have provided a viable means for terrorists to penetrate sensitive inner areas'.*

Recent legislation

The full report describes how security at nuclear sites in the UK and overseas has been reviewed since September 11th 2001. For example, public access has been greatly restricted and some information previously in the public domain has been withdrawn. The UK Nuclear Industries Security Regulations 2003 enabled the introduction of measures to strengthen UK civilian nuclear security regimes, described in more detail in the full report.

Guarding of sites

UK law does not permit sites to be protected by armed civilian guards. Certain civilian nuclear sites (including Sellafield and Dounreay) are protected by on-site armed police of the United Kingdom Atomic Energy Authority (UKAEA) constabulary. Other sites (including nuclear power stations) are currently protected by on-site unarmed civilian guards. Since the jurisidication of the UKAEA has recently been extended, arrangements have been made to provide mobile cover while consideration is given to stationing armed police at these sites.

Evaluating the consequences of an attack

The consequences of a successful attack on a nuclear facility would depend on:-

- The size and nature of the release, known as the 'source term'. This would in turn depend on factors such as the extent of the damage and the physical and chemical properties of the materials released.
- The movement of radioactive material through the environment and its uptake by the human body. Weather conditions would greatly influence the distribution of radioactive material.
- The efficiency of countermeasures put in place to protect people from radiation, e.g. restricting food and water supplies, sheltering, or evacuation. The area over which environmental decontamination measures were implemented would also be a key factor.

Regulation requires UK operators of nuclear licensed sites to evaluate the health and environmental impacts of accidental releases of radioactive material. In general these reports are not publicly available, although considerable information is available from the Sizewell B and Hinkley Point C public inquiries.

Attacks on specific facilities

Commercial power plants

Types of attack

The core of a nuclear reactor in a power plant contains over 100 tonnes of radioactive material at several hundred degrees Celsius. Its safety therefore relies on controlling the nuclear chain reaction, cooling the reactor core and containing the radioactive material. Terrorists might attempt to cause a release in two ways:

- Directly: reactor cores are protected by thick concrete shields, so breaching the reactor containment and shielding would require a violent impact or explosion.
- Indirectly: A release might occur if enough critical safety systems were damaged, but because of defence in depth, this would require a high degree of access, co-ordination and detailed plant knowledge.

Most published commentary focuses on the first possibility, particularly on aircraft impact. Different studies, discussed in more detail in the full report, draw different conclusions depending on the facility in question, the type of aircraft, and its speed and angle of approach. For example, studies carried out for the Sizewell B public inquiry conclude that, in a worst case scenario, if a military aircraft were to strike the reactor building, there would be a 3-4% chance of uncontrolled release of radioactive material. The US Nuclear Energy Institute rule out breach of a US style reactor containment by large commercial aircraft, on the grounds that an aircraft would be unlikely to strike at the angles and speeds necessary to cause sufficient damage.[4]

Power plants in the UK
The UK currently has three types of commercial reactor:

- 'First generation' Magnox gas cooled reactors. There are 12 reactors operating in 5 power plants.
- 'Second generation' Advanced Gas Cooled reactors (AGRs) of which there are 14 reactors at 7 plants.
- 'Third generation' pressurised water reactor (PWR). There is only one PWR, at Sizewell B in Suffolk.

Because of specific design features the UK's three oldest Magnox reactors (all of which are currently scheduled to cease operating by 2006) may be more likely to sustain physical damage than other UK reactors, in the event of an attack. However, more detailed studies would be necessary to draw more general conclusions on the relative vulnerabilities of gas-cooled reactors and PWRs.

Consequences of a release from a power plant
In the event of a release, radioactive iodine and caesium, dispersed over wide areas, would probably make the most significant contribution to the radiation exposure of the general public. Radioactive iodine can increase the risk of thyroid cancer, particularly in children. It poses a threat mainly in the first few weeks after a release. Radioactive caesium concentrates in topsoil and can be absorbed by plants and so enter the food chain. It can pose a risk for hundreds of years. Following Chernobyl (see box below), levels of radioactivity from caesium deposition led to food related countermeasures in most European countries.

Accidents at civilian nuclear power plants
The two most serious accidents at civilian nuclear power plants to date are the Chernobyl accident in 1985 and the Three Mile Island accident in 1979. At Chernobyl, where there was no effective containment structure around the reactor core, roughly half of the reactor's iodine inventory and one third of the caesium inventory was released. 134 workers suffered acute radiation sickness and 28 died within three months. The main long term effect seen to date is an increase in thyroid cancers in children exposed to fallout.[5] Over 300,000 people were resettled and the financial costs have run to hundreds of billions of pounds. However, at Three Mile Island, most of the release was contained within the reactor building. Negligible amounts of radioactive material were released into the environment and there are no established radiological health effects from the accident.

The amount of material released would vary depending on the extent of the damage, the type of reactor and its operating state. There is inherent uncertainty involved in predicting the size of a release. For example, published studies of potential accident scenarios at Sizewell B, carried out by the National Radiological Protection Board in the 1980s, indicate that if the reactor core were severely damaged, the fraction of radioactive iodine released would vary widely depending on the cause of the damage and the resulting sequence of events. In the majority of cases, less than 0.003% would be released, but the release fraction could exceed 50% (comparable with Chernobyl) in certain very extreme scenarios.

Used fuel storage
Used reactor fuel is mainly stored in cooling ponds under several metres of water. Storage takes place both at reactor sites and reprocessing plants. The main mechanism by which large releases of radioactive material could occur is by loss of cooling water. This might result in overheating and damage to fuel elements, releasing radioactive material into the atmosphere. Loss of cooling could be brought about by direct breach of the ponds and surrounding shielding (e.g. by aircraft impact). There is conflicting commentary on the feasibility of such an attack, the likely release size and the time available to take remedial action. The full report discusses how these factors depend on the mode of attack, the design of the facility, and the type of fuel in storage.

Attacks during transport
The full report discusses the risks associated with a range of different types of shipment of radioactive material, focussing on the transport of used fuel from power plants, which accounts for the bulk of the radioactive inventory transported each year. Many analysts suggest that an attack on a road or rail shipment of radioactive material might be easier to accomplish than at a fixed installation, and could take place near major population centres. However, the amounts of material involved are smaller and published studies indicate that material would probably be dispersed over a smaller area.

Reprocessing plants
Reprocessing plants extract re-usable uranium and plutonium from used reactor fuel and handle a range of radioactive materials. Public attention focuses on the storage of high level liquid radioactive waste (HLLW), plutonium and used reactor fuel, due to the the size of the radioactive inventories involved and (in the case of HLLW and plutonium) their physical state. Published commentary on the potential consequences of releases of radioactive material from these facilities is reviewed in the full report.

High level liquid waste (HLLW) at Sellafield
The largest inventories are at Sellafield, with smaller quantities in storage at Dounreay in Scotland and Cap de la Hague in France. As of July 2004 there are between 1000-1500 cubic metres of HLLW in storage at Sellafield. Certain radioactive isotopes are present in quantities several hundred times greater than in a typical reactor core. Although temperatures are far below those in a reactor core, HLLW requires constant cooling to keep it in a safe state. It is stored in tanks awaiting conversion to a more stable form.

As with a nuclear reactor, a release might come about directly, through breach of the containment and bulk shielding around the tanks, or indirectly, by prolongued damage to cooling systems. Reports in the public domain assume varying release sizes, from 1/10,000 of the contents of one tank, to over 10% of the total inventory. However, there is insufficient published information on the *likelihood* of different release sizes to judge how realistic these assumptions are. The latter is a 'worst case scenario' assumed to result from a violent impact (e.g. an aircraft) or internal explosion. Published analyses, discussed in more detail in the full report, suggest that *if* a release of the latter proportions were to occur, it could result in hundreds of thousands of long term cancers (assuming some countermeasures were imposed). BNFL[6] considers these conclusions to be unsubstantiated, on the grounds that *none of the authors have access to current engineering and construction information necessary to undertake a credible study.* BNFL has also stated that it '*does not believe that the physical effects of an aircraft impact upon this building would result in a loss of bulk shielding or containmen*t' on the basis of confidential impact studies.

Plutonium at reprocessing plants
The reprocessing plants at Sellafield and Cap de la Hague store separated plutonium in the form of powdered plutonium oxide. There are few published reports evaluating the impact of sabotage of a plutonium storage facility. In a worst case scenario this could result in atmospheric dispersal of particles containing plutonium, in a fire or explosion. If these particles were small enough to be inhaled, people would have an increased risk of developing lung cancer. BNFL recently constructed a protective wall around the plutonium storage facility at Sellafield.

Long term management of radioactive waste
There is currently no long term management strategy for the UK's intermediate and high level radioactive waste. In 2003 the Government set up the Committee on Radioactive Waste Management (CoRWM) to advise on strategies. CoRWM anticipate presenting final recommendations to Ministers in late 2006. Options include deep geological disposal or storage, which many commentators believe provides better protection from terrorist attack than surface storage.[7]

Emergency planning
Existing measures to protect the public in the event of accidental releases would also be called upon if there were a deliberate attack. In the UK, detailed off-site plans are in place within a few kilometres of nuclear sites which are designed to be extendible to 10-15 km if necessary. However, some analysts believe that the UK should strengthen arrangements for dealing with releases which could affect wider areas.[8] The full report discusses a range of issues raised in published commentary, relating to existing emergency planning arrangements. It also discusses the Civil Contingencies Bill, which aims to increase UK resilience to emergency situations.

Overview

- There is sufficient information in the public domain to identify ways terrorists might bring about a release of radioactive material from a nuclear facility, but not to draw conclusions on the likelihood of a successful attack, or the size and nature of any release.
- There are few detailed published assessments of the physical robustness of nuclear facilities to terrorist attack. Those carried out by the nuclear operators are usually classified and although they are subject to regulatory scrutiny, they are not subject to a public peer review process due to their sensitivity.
- Nuclear power plants were not designed to withstand attacks such as large aircraft impact, but existing safety and security regimes provide some defence.
- Published reports draw widely different conclusions about the consequences of attacks on nuclear facilities, due to differing assumptions about the size and nature of the release, weather conditions and efficiency of countermeasures.
- Reports have been published which suggest that in a worst case scenario, the impact of large aircraft on certain facilities could cause a significant release of radioactive material. Some analysts argue that accurately targeting these facilities would be difficult.
- A successful attack would be highly unlikely to cause large numbers of instant fatalities. Although it would have the potential to affect extensive areas of land and cause large numbers of long-term cancers, its impact would depend on how effectively appropriate contingency plans were implemented.
- Even an unsuccessful attack could have economic and social repercussions and affect public confidence in nuclear activities such as power generation.
- While there is a framework for quantifying the likelihood of accidental releases of radioactive material from nuclear facilities, it is not possible to acccurately assess the likelihood of a terrorist act as this depends on factors such as terrorist intentions and capabilities.

Endnotes

1 For the purposes of POST's report the term 'nuclear facility' is also used to refer to shipments of radioactive material.

2 The UK nuclear operators, regulators and other official bodies have assisted POST by providing staff with access to sensitive inner areas at Sellafield and with classified background briefings.

3 The Office for Civil Nuclear Security within the DTI is the UK's civil nuclear security regulator.

4 The US Nuclear Energy Institute is the policy organisation of the nuclear energy and technologies industry in the US.

5 *Exposures and effects of the Chernobyl accident,* United Nations Scientific Committee on the Effects of Atomic Radiation, 2000

6 British Nuclear Fuels plc.

7 *Managing Radioactive Waste: the Government's consultation,* House of Lords Science and Technology Committee, 2001-2002.

8 *Local Authority Emergency Planning in the locality of UK nuclear power plants,* Large and Associates, 2002.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology.

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