Nuclear Information Service

NIS technical briefing note

August 2008

JSP 538 – Regulation of the Nuclear Weapons Programme

'Joint Services Publication 538: Regulation of the Nuclear Weapon Programme' (JSP 538) is the definitive Ministry of Defence guidance document on nuclear and radiological safety requirements within the UK nuclear weapons programme. A redacted copy of the full 522 page document was placed in the House of Commons Library in May 2008 in response to a Parliamentary Question[1]. This NIS technical briefing provides a brief summary of its contents and a commentary on some salient points.

Background

Under the terms of the Nuclear Installations Act 1965 a nuclear plant cannot operate lawfully unless the operator has been granted a site licence by the Health and Safety Executive (HSE). However, the Atomic Weapons Establishment Act specifically excludes the design of nuclear weapons from licensing and licence conditions. Nuclear weapons are also exempt from licensing requirements when they are at sites other than an Atomic Weapons Establishment (although legislation relating to radiation safety does apply at military nuclear sites).

There is therefore no independent regulator to oversee the safety and management of nuclear weapons by the Ministry of Defence (MoD). Regulation of the safety of nuclear weapons is thus the responsibility of the Head of Nuclear Weapon Regulation within the Defence Nuclear Safety Regulator at the MoD. Regulation of other aspects of nuclear activity at sites authorised to handle nuclear weapons falls to the HSE Nuclear Directorate under the respective nuclear site licence[2].

Until relatively recently, the assessment of nuclear weapons safety was carried out by the Ordnance Board at the Ministry of Defence. The Ordnance Board approved the entry into service of the Trident nuclear weapons system, but in 1997 the decision was taken to replace guidance on nuclear weapons safety from the Ordnance Board with new guidelines which were in harmony with the Health and Safety Executive's approach to regulation of the civil nuclear sector[3]. A new document on Safety Principles and Safety Criteria (SPSCs) for nuclear weapon systems was endorsed by the Defence Nuclear

[1] Armed Forces: Publications. Parliamentary Question from Liam Fox MP to Derek Twigg MP. Official Report, 13 May 2008 Column 1518W. A redacted hard copy of JSP 538 has been placed in the House of Commons Library and the document is not officially available online.

[2] 'Regulation of Weapons and Naval Programme Activity. Ministry of Defence Nuclear Safety Directorate. February 2007.

[3] Adoption of SAPs for Regulation of the Defence Nuclear Propulsion Programmes. Presentation by Commodore Andrew L McFarlane (undated). http://www.hse.gov.uk/nuclear/saps/dnsrpres.pdf

Safety Board November 2002, and the Safety Principles and Safety Criteria were eventually incorporated into JSP 538.

The current version of JSP 538 was published in March 2005. Its purpose is to:

- Promulgate the regulatory requirements for nuclear and radiological safety within the nuclear weapon programme.
- Set out the 'Authorisation Conditions' and the 'Nuclear Weapon Safety Principles and Safety Criteria'.
- Provide guidance on:
  - Compliance with regulatory requirements.
  - Nuclear Safety Justifications.
  - Nuclear safety cases.
  - Management arrangements for nuclear safety.
- Explain the role of the MoD Nuclear Weapon Regulator.

Annex F to JSP 538 is a key portion of the document that gives MoD guidelines on nuclear weapons Safety Principles and Safety Criteria. The document can be downloaded from the NIS website, and these notes provide a commentary on its content. The annex outlines the approach adopted to nuclear weapons regulation by the MoD; sets out Safety Aims, Safety Principles, and Safety Criteria for nuclear weapons systems; and explains how various external 'lines of defence' can be used to enhance nuclear safety.

The safeguards outlined in JSP 538 aim to ensure that nuclear weapon systems do not accidentally produce a nuclear yield or accidentally release radioactive material into the environment, and aim to ensure that residual risks are as low as reasonably practicable. These three fundamental nuclear safety aims help define the risks that the Safety Design Principles and the risk based Safety Criteria outlined in JSP 538 are designed to control.

System Environment Categories

JSP 538 specifies a set of three nuclear System Environment Categories which define the conditions that the nuclear weapon system may encounter, either during normal operations or in an accident scenario.

Normal Environment: This is the range of environments to which the nuclear weapon system or elements of the system are likely to be subjected during its lifetime. It includes any credible insult to the warhead which is predicted to occur at a frequency greater than 10^{-3} per year. Within the Normal Environment the system is required to remain safe and suitable for service through the 'knocks and shocks' it might reasonably be expected to experience over its life.

Specified Abnormal Environment: This is the range of environments to which elements of the nuclear weapon system could be subjected in reasonably foreseeable accident scenarios. For inclusion in the Specified Abnormal (rather than the Normal) Environment, an environment shall be unlikely (less than or equal to 10^{-3} events per year) to occur during a particular phase in the life cycle of the weapons. In the Specified Abnormal Environment the nuclear weapon is required to remain safe but not necessarily serviceable. It should not produce a nuclear yield or release radioactive material and the risk should be as low as reasonably practicable.

Severe Abnormal Environment: This includes environments to which elements of the system could be subjected in accident scenarios more severe and less probable than those identified in the Specified Abnormal Environment category. For inclusion in the Severe Abnormal Environment category, an environment should be very unlikely to occur (less than or equal to 10^{-6} events per year). In a Severe Abnormal Environment the nuclear weapon should not produce a nuclear yield, but it may not be possible to eliminate the inadvertent release of radioactive material. However, the risk of release should be as low as reasonably practicable.

In answer to a Parliamentary Question, the Ministry of Defence has stated that:

> "No Trident warhead has experienced either a specified or severe abnormal environment. The Trident nuclear warhead system was designed against robust environmental standards that are now captured in JSP 538. In achieving approval for in-service use for Trident, trials and assessments of components and special build warheads against those standards were undertaken and passed."[4]

Lines of Defence

JSP 538 specifies that multiple independent lines of defence shall be used to protect the nuclear weapon from abnormal environments. A line of defence may be an engineered feature or a procedure that either reduces the probability of a particular threat happening or protects against the consequence of a hazardous event. Two types of line of defence are defined: full lines of defence, which provide protection to a probability of failure on demand of less than 10^{-3}, and partial lines of defence, which provide a lower level of protection. Partial lines of defence are obviously less robust than full lines of defence, and JSP 538 states that no number of partial lines of defence can supplant the requirement for a full line of defence unless collectively they conform to all the characteristics of a full line of defence and are mutually independent.

Examples given of full lines of defence for the Trident weapon system are the specialist protective container used during transportation which is designed to protect the warhead against fire; an exclusion region within the warhead which isolates any extraneous electrical signals from the firing circuits; and the configuration of high explosive and nuclear components in the warhead to ensure that, if the explosive were initiated at any single point, a nuclear explosion could not occur.

Examples of Trident partial lines of defence would be the use of high explosive which is less sensitive to abnormal environments; the provision of a fire tender as part of a nuclear convoy to protect against fire; and the safety procedures used when handling and maintaining nuclear weapons.

JSP 538 uses the concept of lines of defence to specify the following Safety Principles to prevent the inadvertent yield and release of radioactive material following an accident:

> a) There shall be at least 3 demonstrably independent full lines of defence to prevent inadvertent yield and major release of radioactive material. There shall be at least 2 independent full lines of defence to prevent release of radioactive material from the physics package and at least one full line of defence, ideally more, to

[4] Trident Missiles. Parliamentary Question from Norman Baker MP to Des Browne MP. Official Report, 14 July 2008 Column 178W

prevent release of radioactive material from components external to the physics package. Not more than one procedural full line of defence may be used to protect against a specific threat.

b) Only one full line of defence can be claimed for any single safety feature irrespective of the reliability of that feature. Full lines of defence shall be supplemented by a number of partial lines of defence as appropriate to reduce the risk to as low as reasonably practicable.

c) Adherence to the lines of defence Safety Design Principle is consistent with the achievement of the risk based Safety Criteria.

These fundamental Safety Principles must be complied with at every stage of a warhead's life cycle.

Single point safety

Under the guidance in Annex F of JSP 538 nuclear warhead designs should always take into account the possibility that the inadvertent detonation of the supercharge explosive at a single point could, in principle, lead to inadvertent nuclear yield rather than just a release of radioactive material. A nuclear warhead must be shown to be single point safe – an accident leading to detonation of the high explosive trigger at one point among many will not cause the warhead to go critical. This Safety Design Principle also applies to all warhead configurations that occur during assembly and disassembly processes. Nuclear warheads are designed to be single point safe such that in the event of inadvertent detonation of the supercharge initiated at a single point anywhere in its volume, the probability of any nuclear yield exceeding more than 2kg of TNT equivalent shall be less than 10^{-6}.

Popcorning

"Popcorning" is a process whereby a series of accidental detonations of a number of warheads' conventional explosives could lead to a nuclear yield. During a sequence of accidental detonations of nuclear warheads in close proximity it is possible for a very small nuclear yield from one warhead to enhance the yield of another warhead in the detonation sequence. The potential for popcorning can only exist when there is a precise timing relationship between detonations. JSP 538 concedes that, although each warhead may individually be single point safe, popcorning may have the potential to produce a significant nuclear yield.

Warhead designs take into consideration that warheads may be stored in close proximity to each other. If it is not possible to control the popcorning probability by design, it should be reduced by procedural controls such as careful management of the weapon storage arrangements and handling procedures.

JSP 538 specifies that the warhead and warhead processing, handling, transportation and stowage arrangements shall be designed so that the probability of a series of warhead detonations in close proximity and a consequent nuclear yield in excess of 2 kg of TNT equivalent is extremely unlikely (less than or equal to 10^{-9} events per year).

Nevertheless, a recent article published in New Scientist suggests that that the standard single-point warhead design might not be enough to prevent popcorning. The article also hints that the highly sensitive explosive that surrounds the warheads' plutonium cores increases their vulnerability to accidents. According to New Scientist, less-sensitive explosives are available, but they are heavier and bulkier than those currently in use, so the warheads would have to be redesigned[5].

In response, the Ministry of Defence has stated that popcorning is an extremely unlikely event and that warhead design and procedures minimise the risk of popcorning occurring:

> "The theoretical phenomenon known as "popcorning" is a process whereby a series of accidental detonations of a number of warheads' conventional explosives could lead to some nuclear yield. This is extremely unlikely and could occur only if the warheads were located in close proximity to each other without mitigation. Warheads are designed such that there cannot be a nuclear detonation without authorisation.
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> Warhead handling, transit and storage facilities, and processes are designed to reduce the risk of popcorning to 'As Low As Reasonably Practicable' levels by, for example, separating stored warheads and having physical shielding between them. Similarly, moves of warheads are planned and executed to minimise the proximity of warheads to each other.
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> Safety in the nuclear weapons programme is of paramount importance. There are well-rehearsed generic response plans in place to protect workers and the general public in the unlikely event of an accident; all measures are taken to ensure acceptable levels of safety throughout the life cycle of the Trident warhead."[6]

Curiously, the Ministry has maintained a more ambiguous stance on the issue of whether insensitive high explosive is used as the supercharge in Trident warheads. In response to Parliamentary Questions on the matter[7], the Secretary of State for Defence refused to comment, citing the need to safeguard national security. As the Secretary of State has refused to comment, rather than give an assurance that the line of defence proposed in JSP 538 has been adopted, there is speculation that the New Scientist article is correct, and that UK Trident nuclear warheads do not use less sensitive high explosive.

Nuclear weapons Safety Criteria

The Safety Criteria for nuclear weapons which are presented in JSP 538 define risks in terms of the annual frequency of accidents which would give rise to different radiological doses to a member of the public. This is similar to the approach used for the civil nuclear industry by the HSE Nuclear Directorate.

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[5] 'Could nuclear warheads go off 'like popcorn'?' by Rob Edwards. New Scientist, 26th June 2008. http://technology.newscientist.com/channel/tech/mg19826625.000-could-nuclear-warheads-go-off-like-popcorn.html

[6] Nuclear Weapons: Safety Measures. Parliamentary Question from Ann Cryer MP to Des Browne MP. Official Report, 22 July 2008: Column 1063W

[7] Nuclear Weapons. Parliamentary Question from Mike Hancock MP to Des Browne MP. Official Report, 7 July 2008: Column 1178W

Nuclear Weapons. Parliamentary Question from Dai Davies MP to Des Browne MP. Official Report, 10 July 2008: Column 120W

Safety Criteria are defined for the following conditions:

Routine conditions: Conditions corresponding to the Normal Environment when routine activities may lead to low levels of radiation exposure under controlled conditions. These Safety Criteria are expressed in terms of dose limits.

Accident Conditions: Any unintentional event which results in, or has the potential to result in, a release of radioactive material or nuclear yield which in turn may give rise to significant, uncontrolled radiation exposure. These Safety Criteria are expressed in terms of risk based limits.

Under routine conditions, the individual radiation dose for personnel associated with nuclear weapon systems should not exceed that specified by the Ionising Radiation Regulations 1999. The risk to an individual worker of death attributable to exposure to radiation or yield from an accident is the same as the level specified by the HSE Nuclear Directorate for the civil nuclear industry. However, under emergency conditions these standards can be exceeded, and JSP 538 states that the Safety Criteria do not apply to workers returning to perform recovery operations after an accident. The document states that the specific circumstances associated with an accident are difficult to predict, and consequently the immediate action to be taken by the senior responsible officer at the scene is left to his knowledge and judgement.

For radioactive releases under accident conditions, the risk based Safety Criteria are defined so that the individual and societal nuclear risk posed by a nuclear weapon system, is no greater than the corresponding limits placed on the risk from a single civil nuclear power reactor or a single submarine reactor.

MoD policy for the planning and management of nuclear accidents is contained in another Joint Services Publication: JSP 471: Defence Nuclear Accident Response (March 2004)[8].

Conclusions

Public disclosure of the definitive Ministry of Defence guidelines on nuclear weapons Safety Principles and Safety Criteria is to be welcomed. The release of JSP 538 sheds some light on the intricacies of regulation of nuclear weapon safety and the principles adopted by nuclear weapons engineers to reduce the risks of an accidental nuclear yield or radioactive release. This information has long been the preserve of an elite few in the military establishment, far away from the spotlight of external scrutiny. As well as indicating the steps taken by the military to minimise the risks of a nuclear accident, JSP 538 also gives us an insight into the enormous consequences of such an accident. Although the document lays down standards limiting the exposure of personnel working with nuclear weapons to radiation, these rules would be summarily abandoned in the event of an accident involving a nuclear weapon – a sobering reflection on the immense task of coping with and recovering after such an event.

In the light of the content of JSP 538, NIS proposes three recommendations to further increase the transparency of nuclear weapons safety arrangements at the Ministry of Defence:

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[8] Available at: http://www.mod.uk/DefenceInternet/AboutDefence/CorporatePublications/HealthandSafetyPublications/JSP471/

- The regulation of nuclear weapons safety should be the responsibility of an independent external regulator outside the Ministry of Defence. The move to harmonise nuclear weapons Safety Principles with the approach adopted by the HSE Nuclear Directorate for the civil nuclear power sector represents a general shift in this direction, and although NIS would not necessarily agree with assumptions on the tolerability of risk which underpin the HSE approach, this shift is to be welcomed.

  Many aspects of nuclear safety at nuclear weapons establishments are already regulated by staff with appropriate security clearance from the HSE Nuclear Directorate, and bringing the regulation of nuclear weapons safety under the control of a specialist team within the HSE Nuclear Directorate would simplify the current complex arrangements arising from the involvement of more than one regulator, as well as resolving the inherent conflict of interest posed through the Ministry of Defence regulating its own operations.

- The Ministry of Defence should unequivocally confirm whether current nuclear weapons design and safety procedures comply with JSP 538. Ambiguity over, for example, the nature of the high explosive used in the supercharge of the Trident nuclear warhead does little to enhance national security, but gives rise to fears that safety standards are being side-stepped.

- Again, in order to demonstrate that safety guidelines are being met, the Ministry of Defence should publish the authorisation conditions, safety cases, and compliance statements which control the handling of nuclear weapons. Such conditions apply to every stage of the nuclear weapons cycle: their manufacture by AWE plc; road transport between sites by units from Defence Equipment and Support; HM Naval Base Clyde, who operate the Coulport nuclear weapons store; and the Royal Navy, who have authority over nuclear weapons deployed at sea. Publication of authorisation conditions and compliance documentation will demonstrate that operators involved in the handling of nuclear weapons are following safety guidelines and are employing appropriate lines of defence.