Office for Nuclear Regulation

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# “Stress Tests” for UK non-Power Generating Nuclear Facilities

# Final Report

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# Executive Summary

### Introduction

Following the events at Fukushima, Japan, on 11 March 2011, the nuclear industry in the UK responded quickly to review UK nuclear installations against seismic and flooding hazards. On 14 March 2011, HM Chief Inspector of Nuclear Installations was asked by the Secretary of State for Energy and Climate Change to produce an interim report by the middle of May 2011, with a final report six months later on the lessons that could be learnt to enhance the safety of the UK nuclear industry. The interim and final reports were published in May and October 2011 respectively and contained a number of important conclusions regarding the UK nuclear industry and regulatory regime, as well as a significant number of recommendations for further work to determine whether there are any reasonably practicable improvements that can be made. A further report is planned for the autumn of 2012 in which the Office for Nuclear Regulation (ONR) will report on progress in dealing with those recommendations.

On 24–25 March 2011 the European Council (EC) requested a review of safety at all European nuclear power plants (NPP) and the European Nuclear Safety Regulators Group (ENSREG) produced a specification and a plan for this review based on preliminary work carried out by the Western European Nuclear Regulators' Association (WENRA). The reviews are commonly referred to as the "stress tests".

Given that the EC stress tests only focus on NPPs, HM Chief Inspector of Nuclear Installations decided to extend the stress tests process to all other licensed nuclear installations within the UK. These licensed nuclear installations are designated as non-power generating nuclear facilities (NPGNF) in this report. Several other countries within the European Union have also planned to apply the stress tests process to some NPGNF.

### Stress tests requirements

The ENSREG specification defines the stress tests as a targeted reassessment of the safety margins of nuclear power plants in the light of the events which occurred at Fukushima; namely extreme natural events challenging plant safety functions and leading to severe accidents and the need to invoke severe accident management procedures. The ENSREG requirements were defined for NPPs only and do not include other nuclear installations, and ONR recognises that some aspects of the stress tests specification may not apply to every NPGNF in a straightforward manner or, in some cases, at all.

The stress tests requirements essentially follow a defence-in-depth approach looking firstly at the design to prevent earthquakes, flood and extreme weather causing safety problems at sites. Irrespective of how good these preventative measures might be, the stress tests then call for a systematic examination of loss of electrical supplies and loss of cooling capability. Again, no matter how robust these systems are, the stress tests specification goes on to require consideration of severe accidents and the management of these severe accidents. The principal aim for all the levels of defence-in-depth represented in the stress tests is to identify any additional measures or provisions to enhance safety. This aim is entirely compatible with the philosophy of continuous improvement embedded within the UK regulatory system.

### Range and nature of non-power generating nuclear facilities

The facilities captured within the scope of the NPGNF stress tests vary in terms of the nature of activities undertaken, the hazards associated with those activities and the potential hazardous consequences at those facilities. For example, this report covers the Sellafield nuclear site, one of the biggest groupings of nuclear installations within Europe, as well as small licensed sites which are close to completion of their decommissioning activities. Additionally, NPGNF include facilities dedicated to the fuel cycle, installations to support the nuclear deterrent, and conventional nuclear submarines and sites for radioactive material storage.

Certain of the sites in the Defence Nuclear Programme are managed by the Ministry of Defence (MoD) itself and activities there are exempted from some parts of civil regulation. Wherever exemptions or disapplications of civil legislation exist, the Defence Nuclear Safety Regulator (DNSR) oversees a system of regulation of those MoD duty holders who directly control nuclear activities. DNSR is carrying out its own assessment, equivalent to the Fukushima stress tests. In this report, ONR has only considered those aspects of the defence nuclear programme that are carried out by licensees and the implications for nuclear safety regarding those activities and facilities to which the Nuclear Installations Act 1965 and Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) apply.

**Conduct of the stress tests and ONR review**

The National Report on European Council "Stress Tests" for UK Nuclear Power Plants was published on 4 January 2012. This current report is the final UK stress tests report and presents the results from the stress tests as applied to UK NPGNF. In carrying out the stress tests, and independent regulatory review of those stress tests, it is recognised by ONR and the UK nuclear Industry that a sustained high standard of nuclear safety requires the application of the principle of continuous improvement and that extending the scope of the stress tests to NPGNF provides an important opportunity to look for additional safety enhancements at these sites.

As noted above, the stress tests requirements have been specifically targeted by ENSREG at NPPs and some of the requirements, which are focussed on reactors, do not necessarily apply readily to other types of nuclear installation. This is particularly so on sites where nuclear hazards, in terms of the potential for releases of radioactivity, are at a much lower level than on NPPs. The NPGNF licensees and ONR have followed the structure and contents of the stress tests report as defined by ENSREG as far as possible in order to keep consistency between NPP and NPGNF stress tests. The original requirements structure has had to be amended slightly to avoid focusing on scenarios which hardly apply, or do not apply, to NPGNF. Although the NPP stress tests process is not always appropriate for assessing NPGNF resilience, the safety purpose is identical: restricting radioactive releases so far as reasonably practicable.

In common with the earlier NPP stress tests, the NPGNF stress tests reports have been prepared by the licensees and submitted to ONR for independent regulatory review. However, unlike ONR's National Final Report for UK NPPs, the NPGNF stress tests report is a purely UK initiative and will therefore not be subject to peer review by an ENSREG team. Nevertheless, the NPGNF stress tests have followed the ENSREG specification as far as possible, and ONR has reviewed the reports using the same principles and standards as for the ONR's National Final Report for UK NPPs. Consequently it is judged that any relevant further learning resulting from the ENSREG peer review can be translated to NPGNF.

For NPGNF with relatively small nuclear inventories, ONR has introduced a specific section dedicated to a more limited treatment for the lowest hazard sites, in accordance with the proportionality principle. This is judged reasonable as such sites are incapable of giving rise to significant off-site doses, even if the worst was to happen without the benefit of any protection or mitigation measures.

**Conclusions and findings**

ONR confirms in this report that UK licensees have submitted stress tests reviews in line with ENSREG specification. Due to the number and the size of the installations at Sellafield, the licensee Sellafield Ltd has, in agreement with ONR, focussed its stress tests report on the 20 main installations on-site. Further work on wider resilience challenges is underway and is expected to be transmitted to ONR during the summer of

2012. It is likely that all Sellafield installations will be covered by the improvements and the provisions already identified or implemented on-site after completion of the stress tests. Nevertheless, ONR will examine the work on wider resilience issues in detail to ensure that any potential additional measures are properly considered. As far as the legacy facilities at Sellafield are concerned, Recommendation FR-2 of HM Chief Inspector's report remains paramount with the focus being on hazard reduction.

Neither the reviews undertaken by the licensees for the stress tests, nor the earlier national reviews, have indicated any fundamental weaknesses in the definition of design basis events or the safety systems to withstand them for UK nuclear installations. This was also a conclusion of HM Chief Inspector's final report (Ref. 2).

The stress tests process as applied by licensees has been robust and challenging for the design basis events. For beyond design basis events, the process has also been challenging due, in part, to the novel approach prescribed by ENSREG. Further work will be needed by some licensees to achieve a consistent standard for analysis of beyond design basis external hazards and beyond design basis severe accident management. In addition we are aware of relevant work that has already been carried out by licensees, but was not included in their stress tests reports.

The lessons to be learned presented in the ONR reports and the EC stress tests assessments share many common themes. Through them both, the licensees have identified a significant number of potential improvements to enhance their resilience in potential emergency situations following events, or sequences of events beyond the traditional design basis. The potential improvements identified also seek to enhance margin assessment methods with the aim of providing further confidence in the design and operation of the plants. There is also potential for improving the type or number of safety measures which, in turn, should increase the overall defence-in-depth.

The list of further studies and potential resilience enhancements, which are termed *Considerations*, are provided in Annexes 2 to 5; typical examples include:

- Flood resilience enhancements.
- Site power distribution network resilience enhancements.
- Provision of improvements to emergency back-up equipment. This equipment may include:
  - Diesel generator to provide back-up to emergency centres.
  - Means of safely accessing the site in the event of flooding.
  - Means of moving emergency support equipment in accident conditions.
  - Emergency command and control facilities including communications equipment.
  - Emergency response / recovery equipment

Further to the *Considerations* identified by the licensees, ONR has raised a number of *Stress Tests Findings* (STF) which are detailed in the table below. Some of these findings reinforce or extend *Considerations* identified by the licensees while others are additional to them. It should also be noted that the findings raised in this report generally relate to more specific aspects or elements of the broader recommendations already raised by HM Chief Inspector of Nuclear Installations. A table mapping licensees' *Considerations*, HM Chief Inspector's recommendations and ONR's STFs is included in the report to show how they relate to one another (see Annex 6).

There are 15 different licensees and one potential licensee considered in this report. Five of them operate sites, which ONR has judged to be lower hazard, given the nuclear matter inventory, these licensees are: Imperial College of Science Technology and Medicine, Studsvik Ltd, Low Level Waste Repository Ltd (LLWR), Research Sites Restoration Ltd (RSRL) and GE Healthcare (GEHC). In addition, there are no ONR stress tests findings on the Capenhurst site operated by Sellafield Ltd.

The majority of the findings require the licensees to undertake some further reviews following stress tests themes. The number of findings raised for each NPGNF licensee is also variable. However, in broad terms it is fair to say that the majority of findings are aimed at severe accident management and the back-up capability for key systems or functions. There are also a number of findings recommending that better, or more extensive, assessment of the seismic hazard, flooding and extreme weather events may be appropriate.

To avoid any confusion with the 19 STFs already raised for the NPPs (Ref. 10), which are numbered STF-1 to STF-19, the list of STFs below starts at STF-20. It contains 75 STFs. The relatively large number of findings in comparison to ONR's National Stress Tests Final Report for UK NPPs is a reflection of the number of licensees involved and the diverse nature of the facilities they operate. It is also fair to say that the level of detail in the stress tests reports varies and this has had some influence on the nature, content and number of STFs. Of the STFs identified in this report two are generic, 25 cover Sellafield Ltd, 33 cover the five defence licensees – Atomic Weapons Establishment (AWE), Rolls-Royce Marine Power Operations Ltd (RRMPOL), BAE Systems Marine Ltd (BAESM), Devonport Royal Dockyard Ltd (DRDL) and Rosyth Royal Dockyard Ltd (RRDL); six are dedicated to Dounreay Site Restoration Ltd (DSRL), three to Springfields Fuel Ltd, two to the defuelled reactors of Magnox Ltd, two to Urenco UK Ltd, one to Research Site Restoration Ltd (RSRL) and one is addressed to EDF Energy NNB Generation Company Ltd (NNB GenCo) in relation to the potential future licensed site at Hinkley Point C.

The STFs below are framed in the context of continuous improvement, and the conclusion of HM Chief Inspector's report stating that ONR sees no reason to curtail the activities of nuclear installations in the UK remains valid.

**Table 0:** ONR's Stress Tests Findings

| Finding No. | ONR's Stress Tests Findings |
|---|---|
| STF-20 | Sellafield Ltd, AWE, RRMPOL, BAESM, DRDL, RRDL, Magnox Ltd and NNB GenCo should provide ONR with the decision-making process to be applied to their *Considerations* along with a report which describes the sentencing of all their *Considerations*. The report will need to demonstrate to ONR that the conclusions reached are appropriate. |
| STF-21 | Sellafield Ltd should consider further and provide more details on how emergency arrangements to deal with a site-wide extreme event would anticipate and adapt to challenging criticality events. |
| STF-22 | Sellafield Ltd should establish if there is anything reasonably practicable that can be done to provide / strengthen the provision of basic plant information (e.g. inventory level and temperature) during / following an extreme event on-site affecting high-hazard / high risk facilities. |
| STF-23 | Sellafield Ltd should take note of NNP finding STF-2 [Ref. 10] and participate in the review as necessary where the seismicity of the area affecting the site is under consideration. |
| STF-24 | Sellafield Ltd should review the information used to inform the seismic damage assessment conclusions in light of more recent experience and detailed analysis completed for periodic safety assessments to confirm expected withstand capacity for facilities with significant inventories. |
| STF-25 | Sellafield Ltd should complete further work to assess the extent of seismic damage to local infrastructure. This work should demonstrate the extent to which local services can function following connection of temporary power supply. |
| STF-26 | AWE should consider reassessing the nuclear safety implications of consequential events, such as water ingress, multi-facility fires and loss of emergency control and co-ordination centres, following a significant seismic event to establish whether further measures are needed to reduce the associated risks. |

| Finding No. | ONR's Stress Tests Findings |
|---|---|
| STF-27 | RRMPOL should consider reviewing whether the failure of the four buildings identified in its submission, when subjected to a design basis earthquake, could undermine the higher seismic withstand of the equipment those buildings contain. |
| STF-28 | RRMPOL should consider reviewing what improvements could be made to improve the seismic withstand of equipment within the production facility that could have an impact on radiological release. |
| STF-29 | BAESM should consider reviewing whether there are any further options for minimising the potential for physical impacts during a seismic event on radioactive components during construction activities. |
| STF-30 | BAESM should consider reviewing the seismic withstand capability of the dock sills and their impact for events exceeding the 1 in 100-year return period, when the dock walls are predicted to have failed. |
| STF-31 | BAESM should consider the provision of a hardened robust emergency control centre or propose formalised alternative arrangements. |
| STF-32 | DRDL should consider assessing the possible effects of fire following a seismic event. |
| STF-33 | Sellafield Ltd should consider the range of beyond design basis earthquakes that could challenge containment to demonstrate the extent of robustness of facilities. The review can be based on reasoned engineering judgement and demonstration of ductile response rather than repeated analysis. |
| STF-34 | Urenco UK Ltd should consider the impact on resources required to respond to combinations of more extreme events that might delay or prevent emergency actions. This review should examine the effect of concurrent criticality on ability to affect safe rescue of injured personnel and the validity of assumptions on capability to mitigate a severe accident propagating. |
| STF-35 | BAESM should consider expanding its proposed assessment of the impact of a credible tsunami, to consider the effects of an earthquake exceeding the design basis earthquake for the plants and consequent flooding exceeding the design basis flood. |
| STF-36 | RRMPOL should consider assessing the challengers from increased seismically induced damage on-site and off-site and the limitations that imposes on external support and possible consequences of seismically induced fire. |
| STF-37 | Sellafield Ltd should complete further work to identify potential failure mechanisms following beyond design basis seismic events, including the possibility for sudden collapse and cliff-edge failure of safety function. |
| STF-38 | Sellafield Ltd should, in light of advances in river modelling methodologies, climate change information and the known erosion of the river bed, reassess the flow capacity of the channel of the River Calder to better inform the assessment of risk of flood. |
| STF-39 | BAESM should consider assessing the rate of water level rise and flow rate of flood waters for the site to determine if there is any erosion of safety margins during a dynamic flood event. |
| STF-40 | DRDL should review its safety cases to confirm that the effect of rapid flooding of the dock from a failure of the watertight boundary is considered. |
| STF-41 | AWE should consider reassessing the site flood model to determine the potential erosion of safety margins resulting from loss of the drainage networks. |
| STF-42 | DSRL should demonstrate to ONR the rationale with which it has considered the mobility of waste inventories in flooding events when prioritising the order with which hazard reduction activities are planned within its decommissioning strategy. |
| STF-43 | AWE should consider assessing the nuclear safety implications of consequential events including progressive loss of structures, systems and components following an extreme flooding event to establish whether further measures are needed to reduce the associated risks. |

| Finding No. | ONR's Stress Tests Findings |
|---|---|
| STF-44 | BAESM should consider providing further substantiation of the claim that there is a 1.5m margin of safety beyond the design basis flood event. |
| STF-45 | RRMPOL should consider assessing aspects of extreme weather other than snow and wind, such as high and low temperature and humidity, rainfall and lightning. |
| STF-46 | RRMPOL should consider reassessing the design basis for extreme weather events. |
| STF-47 | Magnox Ltd should carry out a review of the design basis and margins available against external hazards at each decommissioning site to ensure adequate provisions are in place throughout the decommissioning process commensurate with the remaining radiological hazard potential. |
| STF-48 | RRMPOL should consider reviewing the utilisation factors and criteria used for assessing structural performance in extreme weather. |
| STF-49 | AWE should consider assessing the nuclear safety implications of consequential events including progressive loss of structures, systems and components following an extreme weather event to establish whether further measures are needed to reduce the associated risks. |
| STF-50 | Sellafield Ltd should complete a review of the possible impact of extreme weather conditions on service networks and temporary service connection points to ensure security of supply and confirm functionality of connection points. |
| STF-51 | Sellafield Ltd should undertake regular load forecasting in order to identify likely shortfalls in the provisions for normal and back-up electrical supply in good time to plan and deliver effective remedial actions and hence avoid material shortfalls occurring. |
| STF-52 | Sellafield Ltd should ensure that the learning from its resilience review regarding vital site loads is embedded into future periodic reviews of site electrical requirements and taken into consideration in the management of change process whenever site electrical loads are to be modified. |
| STF-53 | Sellafield Ltd should complete its review of resilience, including the need for suitable event-qualified mobile diesel alternator connection points, and should undertake improvements where these would facilitate the reconnection of supplies to identified essential equipment. |
| STF-54 | Sellafield Ltd should continue to identify and address potential vulnerabilities in the provision of electrical supplies to systems that may not have an explicit nuclear safety claim in facility safety cases but whose loss could severely hinder site emergency arrangement following a severe event. |
| STF-55 | DSRL should identify and address potential vulnerabilities in the provision of electrical supplies to systems that may not have an explicit nuclear safety claim in facility safety cases but whose loss could severely hinder site emergency arrangement following a severe event. |
| STF-56 | RRMPOL should consider reviewing its strategy for demonstrating the continuing safety of the plant post incident, including a consideration of power requirements for instrumentation (e.g. criticality detection systems). |
| STF-57 | BAESM should consider whether further measures are necessary that may improve the availability of electrical power supplies on-site under a full range of fault scenarios. This should include a review of the adequacy of back-up electrical supplies on-site that would support the management and operation of an emergency incident. |
| STF-58 | NNB GenCo should consider further the ability of the site to respond to the partial or complete loss of electrical supplies and the autonomy times of systems without off-site support. |
| STF-59 | Sellafield Ltd should explore the practicality and requirements of pumping water from the sea and other water sources such as local rivers to where it might be utilised, and establish if this could indeed be done in extremis with the systems currently available on-site. |

| Finding No. | ONR's Stress Tests Findings |
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| STF-60 | BAESM should consider reviewing the arrangements that ensure suitable systems are always available commensurate with expected levels of decay heat, and that resources (fuel and water) are available on-board and onshore for replenishment where necessary. |
| STF-61 | DSRL should review the effectiveness of existing on-site communication arrangements which have not been subject to full evaluation during the stress tests process. |
| STF-62 | DSRL should coordinate with the Highland Council to review the adequacy of existing local reception centres detailed in its off-site plan. |
| STF-63 | Springfields Fuels Ltd should evaluate reasonably practicable structural improvements to its designated emergency control centre, taking into account reasonably foreseeable accidents that may hinder its availability. |
| STF-64 | Sellafield Ltd should review the severe accident guidelines taking into account improvements to the understanding of severe accident progression, phenomena and the equipment available to mitigate severe accidents (in line with STF-16). |
| STF-65 | Sellafield Ltd should develop and rehearse emergency exercise scenarios covering beyond design basis events and severe accident conditions. |
| STF-66 | Sellafield Ltd should extend its review of the resilience of the back-up supplies in support of the site data network and assess the resilience of the site communication system to design basis natural events and severe accidents. |
| STF-67 | Sellafield Ltd should extend its review of availability of external resource and review its in-plant communication systems used by site fire and rescue teams (e.g. radios) to ensure there is compatibility with equipment used by external emergency services, especially at identified radio shielded areas. |
| STF-68 | Sellafield Ltd should extend its programme for development of severe accident management strategies to its strategic non-nuclear support facilities to ensure adequate information and support can be provided to the Sellafield emergency control centre in the event of a severe accident. |
| STF-69 | Given the extent of the Sellafield site and the need for countermeasures on the site in the event of an accident, Sellafield Ltd should employ all reasonably practicable means to ensure weather forecast information can be made available to its emergency control centre / strategic management centre so that timely advice can be provided on-site. |
| STF-70 | Sellafield Ltd should take cognisance of STF-14 [Ref. 10], and confirm the extent to which resilience enhancements are to be made to existing equipment and systems that are currently installed across the site. Information should be provided on the equipment and systems that may be affected and the nature of the resilience enhancement, including the mobile back-up equipment. |
| STF-71 | Sellafield Ltd should further assess the availability and operability of electronic personal dosimeters in a prolonged station blackout, in conditions associated with design basis natural events and in severe accidents. |
| STF-72 | Sellafield Ltd should develop a strategy for incorporating all reasonably practicable measures identified as part of its resilience evaluation process in its programme for enhancing its emergency response capability. |
| STF-73 | DSRL should extend its proposed review of resilience to long-lived events taking due cognisance of the impact of widespread (off-site) disruption to local and national infrastructure, continuing to coordinate with Nuclear Emergency Arrangements Forum. |
| STF-74 | DSRL should further consider how the site might obtain technical support from the wider industry in the event of a severe accident. |

| Finding No. | ONR's Stress Tests Findings |
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| STF-75 | All defence licensees (AWE, RRMPOL, BAESM, DRDL and RRDL) should consider the approach taken by several civilian licensees of using beyond design basis containers that contain a range of equipment and materials that could be beneficial when responding to a beyond design basis accident. This finding is of a similar nature to that raised in the ONR National Stress Tests Final Report for UK NPPs (STF-15). |
| STF-76 | AWE should reconsider the provision of suitable contingencies in its emergency response to extreme external events if aggravating factors, which may impede accident management, are realised. These factors include impaired road access to both the sites themselves and to individual facilities on-site, loss of availability of co-ordination and control centres and loss of communication. |
| STF-77 | AWE should consider collating requirements placed on the site-wide infrastructure and emergency arrangements by individual facility safety cases and consider the demands that may be placed on the organisation, infrastructure and resources should a response be required at two or more facilities simultaneously, or within the same incident. AWE should consider identifying other factors that may impair the emergency response and develop suitable contingencies to ensure that the logistics of the emergency response are robust. |
| STF-78 | AWE should consider reviewing the on-site and off-site dose consequences of being unable to follow its strategy of making safe and evacuating high-hazard facilities in response to extreme external events. |
| STF-79 | RRMPOL should consider reviewing the stress tests requirements when the manufacturing site regeneration project and modifications to the Neptune facility are sufficiently mature. |
| STF-80 | RRMPOL should consider reviewing the resilience of Bronze Commands to seismic events or propose alternative arrangements. |
| STF-81 | RRMPOL should consider reviewing its emergency arrangements for coincident events. |
| STF-82 | DRDL should consider enhancing the withstand of the forward command posts to flooding and the Devonport accident control centre to seismic events or propose formalised alternative arrangements. |
| STF-83 | Magnox Ltd should review, update and issue revised severe accident guidelines in the light of changing hazard at decommissioning sites; the guidelines should include human performance / welfare issues and availability of equipment located in beyond design basis containers. |
| STF-84 | Urenco UK Ltd should review its existing emergency plans to ensure that, in relation to the response to a criticality accident, the plans incorporate further details to support the principle of extendibility for off-site response and control of reactivity through the use of neutron poisons if practicable. |
| STF-85 | Springfields Fuels Ltd should consider whether the securing of neutron poisons is a reasonably practicable improvement to emergency preparedness following a repeating criticality incident. |
| STF-86 | Sellafield Ltd should undertake safety margin analysis in order to determine relative withstand of containment structures to a beyond design basis overpressure. |
| STF-87 | Sellafield Ltd should consider, in more detail, the consequences of fire coincident with criticality and the capability of Sellafield site to respond to these events. |
| STF-88 | Springfields Fuels Ltd should demonstrate how its on-site and off-site plans cater for widespread dispersion of uranic material (in oxide form and uranium hexafluoride) predicated on concurrent seismic / hydrogen detonation events |
| STF-89 | DRDL should consider reviewing its capability for severe accident management in cases of simultaneous core damage accidents. |
| STF-90 | AWE should consider reviewing the threat posed to containment systems from fire hazards and the potential dose consequences for on-site and off-site risk groups. AWE should consider, within its review, the potential dose consequences of an extreme event leading to a loss of containment and a consequential fire. In light of the assessed consequences for workers and the public, AWE should consider any further mitigation, in addition to those measures currently in place. |

| Finding No. | ONR's Stress Tests Findings |
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| STF-91 | DRDL should consider reviewing its responses required in the event of a loss of shielding of stored fuel. |
| STF-92 | DRDL should consider reviewing the nuclear fuel and source movements on-site to demonstrate the comprehensiveness of the emergency response measures available. |
| STF-93 | RSRL should review the availability and capability to deploy diesel and generators in order to sustain ventilation of hydrogen generating intermediate and low-level radioactive waste on the site; this may be adequately addressed through a suitable deterministic argument if one can be made regarding minimal generation rates when intermediate and low-level waste is in matrix form. |
| STF-94 | Reports on the progress made in addressing the conclusions of the licensees *Considerations* and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented. |

**Way forward**

ONR anticipates that the stress tests process will finish when the improved processes, plant and procedures, resulting from the *Considerations* and stress tests findings, move into the licensees' normal procedures for change and review of safety cases in line with relevant nuclear site licence conditions. An Implementation Report, to be published by ONR in autumn 2012, will confirm progress towards this transition and STF-94 above requires the licensees to provide reports on the status of work on *Considerations* and stress tests findings in June 2012.

# Contents

# 0 INTRODUCTION

1 This report presents the UK report on the implementation of the stress tests to UK non-power generating nuclear facilities, also designated as NPGNF herein.

2 The stress tests are defined as a targeted reassessment of the relevant design bases and safety margins of NPPs in the light of the events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident. The stress tests requirements have been set by the European Nuclear Safety Regulators Group (ENSREG) members for NPPs.

3 Given that the European Council (EC) stress tests only focus on NPPs, HM Chief Inspector of Nuclear Installations decided to extend the stress tests process to all other licensed nuclear installations within the UK.

4 UK NPGNF licensees have been advised by the Office for Nuclear Regulation (ONR) to undertake the stress tests following the specifications and guidelines provided by ENSREG as appropriate to their facilities. This report details the stress tests as applied to UK NPGNF.

5 All of the UK licensees have undertaken programmes of work to complete all aspects of the stress tests and have provided contributions to the UK final report within the requested timescales. In order to fulfil the scope of the stress tests in a meaningful way, the licensees' reports necessarily include sensitive information regarding the systems necessary to ensure safety of the facility. ONR has had full and unfettered access to all of this information. ONR and the licensees have to balance the requirement to protect sensitive information with the requirement to be as open and transparent as possible. Links to published, summary versions, of all licensee contributions will be available on the ONR website.

## 0.1 Background

6 All of the UK nuclear site licensees have processes to assimilate, review and disseminate lessons learnt from significant events, both in the UK and overseas. These arrangements are part of the continuous improvement and operational experience (OPEX) feedback processes which are required by Licence Conditions (LC) imposed on all licensees.

7 The magnitude and scale of the events at Fukushima are such that all the licensees responded swiftly and proactively to review safety at their sites. In addition, they have been fully supportive and engaged in the wider UK nuclear industry responses and international lessons to learn from these events.

### 0.1.1 The Fukushima Events

8 On 11 March 2011 Japan suffered its worst recorded earthquake, known as the Tohuku event. The epicentre was 110 miles east north east from the Fukushima Dai-ichi (Fukushima-1) site. Reactor Units 1, 2 and 3 on this site were operating at power before the event and on detection of the earthquake, shut down safely. Off-site power was lost and initially emergency diesel generator (EDG) power was used to provide essential post-trip cooling. Less than an hour after shutdown a massive tsunami from the earthquake inundated the site and destroyed the

capability for nearly all[*] on-site generation of alternating current (AC) electrical power and loss of heat sinks. Sometime later, alternative back-up cooling was lost. With the loss of cooling systems, Reactor Units 1 to 3 overheated. The overheated zirconium cladding reacted with water and steam, generating hydrogen which resulted in several explosions causing damage to building structures. Major releases of radioactivity occurred, initially to the atmosphere but later by leakage to sea. The operator struggled to restore full control.

9 This was a major nuclear accident, rated at an International Nuclear and Radiological Event Scale (INES) level 7 (the highest level). The Japanese authorities instigated an evacuation zone, initially 3km but later extended to 20km, and a 30km sheltering zone and other countermeasures.

### 0.1.2 UK Response

10 In response to the Fukushima accident, the UK opened the Cabinet Office Briefing Room (COBR). The Government Chief Scientific Advisor chaired a Scientific Advisory Group for Emergencies (SAGE). HM Chief Inspector of Nuclear Installations provided significant inputs to both COBR and SAGE. The Redgrave Court Incident Suite in Bootle was staffed by ONR from early in the accident and for over two weeks it acted as a source of expert regulatory analysis, advice and briefing to central government departments and SAGE.

11 On 14 March, the Secretary of State for Energy and Climate Change requested HM Chief Inspector of Nuclear Installations to examine the circumstances of the Fukushima accident to see what lessons could be learnt for the UK nuclear industry. ONR set up a dedicated project team covering aspects of the Fukushima accident that are likely to be important for learning lessons. HM Chief Inspector of Nuclear Installations also set up a Technical Advisory Panel (TAP) of external independent experts to advise him during this work.

12 HM Chief Inspector of Nuclear Installations published his interim report on the events at Fukushima and the implications for the UK nuclear industry on 18 May 2011 (Ref. 1). This report contained 11 conclusions and 26 recommendations. HM Chief Inspector of Nuclear Installations published his final report on 11 October 2011 (Ref. 2). This report built on the findings of the interim report and added a further six conclusions and 12 recommendations. All of the conclusions and recommendations from both these reports are listed in Annex 1.

13 HM Chief Inspector of Nuclear Installations extended the stress tests required by the EC for all European NPPs – see 0.1.3 below – to include all UK licensed nuclear installations.

### 0.1.3 European Council Response

14 On 24 and 25 March 2011, the European Council declared, in relation to civil NPP, that "*the safety of all EU nuclear plants should be reviewed, on the basis of a comprehensive and transparent risk assessment ("stress tests"). European Nuclear Safety Regulators Group (ENSREG) and the European Commission are invited to develop, as soon as possible, the scope and modalities of these tests in a coordinated framework, in light of the lessons learnt from the accident in Japan and with the full involvement of member states, making full use of available expertise (notably from the Western European Nuclear Regulators' Association (WENRA). The assessments will be conducted by independent national authorities and through peer review; their outcome and any*

[*] One emergency air-cooled diesel generator remained operational but this only served reactor 6, and eventually reactor 5.

*necessary subsequent measures that will be taken should be shared with the Commission and within ENSREG and should be made public. The EC will assess initial findings by the end of 2011, on the basis of a report from the Commission*". The European Commission is to present its final report to the EC in June 2012.

15 ENSREG members agreed on the initial independent regulatory technical definition of the stress tests and how it should be applied to NPPs across Europe at their plenary meeting on 12–13 May 2011. This was based on detailed work by WENRA. The final version of EC stress tests requirements only retained NPPs.

### 0.1.4 Other International Responses

16 HM Chief Inspector of Nuclear Installations led an International Atomic Energy Agency (IAEA) high-level team of international nuclear experts in a fact-finding mission to Japan in May 2011 and reported back to a ministerial conference of the IAEA in June 2011. A report on the mission (Ref. 3) was published shortly afterwards. A crucial initial finding of the mission team was that the tsunami risk for several sites in Japan had been underestimated. It also concluded that regulatory systems should ensure that there are adequate arrangements for addressing extreme events, including periodic review of those arrangements. The EC stress tests are part of this process. The IAEA has developed an action plan, which aims to widen the scope for lessons learned to all member states. The plan was endorsed by the IAEA at its general conference in September 2011.

17 The Japanese government has provided two reports on the accident to the IAEA: to the ministerial conference, published in June 2011 (Ref. 4), and to the general conference, published in September 2011 (Ref. 5).

18 An extraordinary review meeting of the Convention on Nuclear Safety to review contracting parties' progress against the action plan will be held in August 2012.

19 The UK has contributed to a significant number of other international meetings and bilateral discussions relating to the Fukushima accident since March 2011, and this is expected to continue. ONR's staff, led by HM Chief Inspector of Nuclear Installations, play an active role in these meetings.

## 0.2 ENSREG Requirements

20 The ENSREG requirements (Ref. 6) are included in Annex 1 of the ONR progress report (Ref. 7).

21 ENSREG notes that licensees have the prime responsibility for safety, so they should perform the assessments and the regulatory body should independently review them.

22 The national regulatory bodies have been encouraged to take due account of the need for openness and transparency and to make their reports available to the public within the bounds of security and international obligations. This principle accords well with ONR's existing openness and transparency objectives. ENSREG also notes that its reports from the peer review process on NPPs will be made public.

23 As stated previously, ENSREG requirements have been defined for NPPs only and do not include other nuclear installations. Hence, the structure and the technical rationale of these requirements are specific to nuclear reactors and associated facilities (spent fuel ponds). Some aspects of the stress tests requirements might therefore not apply to every NPGNF in a straightforward manner.

### 0.2.1 Initiating Events

24 The initiating events required for review under the stress tests are earthquakes, flooding and bad weather. In each case the review considers the size and frequency of the design basis event and how it was developed, along with a review of how structures, systems and components (SSC) were designed or qualified to resist the design basis event(s).

25 In the UK, the licensees reviewed compliance with their safety cases in the first few days after the Fukushima event following a request from ONR. ONR monitored the work undertaken by the licensees. The findings were generally positive, although some minor issues were identified; these were quickly resolved by the licensees.

26 The initiating event review for the stress tests must also consider how the safety margins evaluation for each SSC was completed and what consequential effects should be considered. The evaluation of safety margins includes a requirement for licensees to consider what improvements, if any, could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects.

### 0.2.2 Loss of Safety Function

27 There are three connected key safety functions to serve nuclear safety at all nuclear facilities: containment, control and cooling. Control can be of nuclear or chemical reactions and along with adequate cooling ensures that containment is not breached. Containment can be of radioactive gases, aerosol, particulates, liquids or solids and includes shielding to contain direct radiation.

28 Two key loss-of-safety-function fault sequences must be reviewed during the stress tests, both separately and in combination. These are:

- Loss of electrical power.
- Loss of ultimate heat sink.

29 These events, which could lead to a loss of nuclear safety function, such as cooling, could be as a result of seismic activity or flooding, but other external or internal hazards, or faults could also be the initiator of these sequences. This is recognised in the text of the ENSREG requirements and has been considered by the licensees, where applicable. This means that the impact of any findings will have a broader application than just seismic activity, flooding or extreme weather.

30 For loss of electrical power, progressive loss of supplies is considered. This starts with a loss of off-site power (LOOP) – this is always considered as a fault scenario in UK design basis and resilience is provided by a range of on-site power generation and support facilities. The more severe sequence also considered for the stress tests is the loss of all off- and on-site AC power generation capacity; this is generally known as station blackout (SBO). In common with the initiating events, an evaluation of safety margins is requested along with a review of what improvements, if any, could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects.

31 For loss of ultimate heat sink, initially the normal cooling systems are considered unavailable, and then progressive loss of alternative and back-up cooling systems (BUCS) is reviewed.

32 For the final sequence, a loss of ultimate heat sink along with SBO is considered. This is an extreme fault condition and the stress tests then look for information on how the fault would escalate into a severe accident and the timescales involved. A review of potential margins and of improvements, if any, which could be applied to improve margins and to remove or reduce further the probability of cliff-edge effects, is required.

33 It is worth noting that complementary work on electrical supplies and cooling supplies is already underway in the UK as a result of Recommendations IR-17, IR-18, IR-19 and IR-20 in HM Chief Inspector's report on Fukushima (Ref. 2) (see Annex 6).

### 0.2.3 Severe Accident Management

34 The ENSREG requirements for severe accident management recognise that most severe accident management arrangements are there to mitigate the worst effects, not to prevent them occurring.

35 The review asks for the key management features to ensure control, cooling and containment along with instrumentation to confirm key parameters, and for the potential accident management measures which could be applied by the licensees to be considered in a systematic manner.

36 The review also builds on learning from Fukushima about damage to the local and regional infrastructure and communications, and the potential for a long duration of standalone activity at the site in the face of major regional disruption. As before, potential cliff-edges are to be identified, along with any potential improvements that could improve margins and remove or reduce the probability of cliff-edge effects.

37 Recommendations IR-24 and IR-25 of HM Chief Inspector's final report (Ref. 2) are relevant here.

## 0.3 Relevant Aspects of UK Regulatory Regime

### 0.3.1 Legal Framework

38 In the UK, the legal framework for nuclear safety is established principally through the:

- Health and Safety at Work etc. Act 1974 (HSWA74).
- Nuclear Installations Act 1965 (NIA65) (as amended).

39 Under HSWA74 employers are responsible for reducing risks, so far as is reasonably practicable, to their workers and others, including the public. This responsibility is elaborated further in relation to nuclear sites by NIA65, which establishes a nuclear site licensing regime. The power to grant a licence to use a site to construct and operate a specified nuclear installation, and its subsequent regulation, is vested in the Health and Safety Executive (HSE), which further delegates this authority to HM Chief Inspector of Nuclear Installations. This power includes attaching conditions in the interests of safety or radioactive waste management. These conditions are legally enforceable.

40 European legislation in the form of EC Directives is transposed into the UK legal framework outlined above. The most recent European legislation is the Nuclear Safety Directive, which came into force in July 2011.

41 ONR is an agency of HSE, and is the principal regulator of the safety and security of the nuclear industry in the UK; its independence is secured legally through HSWA74. ONR was formed in April 2011 from three former bodies: the HSE Nuclear Directorate, UK Safeguards Office and Office for Civil Nuclear Security. In addition, ONR recently took on the nuclear regulatory functions of the Department for Transport, by incorporation of the Radioactive Materials Transport Team.

### 0.3.2 Licensing

42 Regulation of the safety of nuclear installations in the UK is through a system of control based on a licensing regime within which a corporate body is granted a licence to use a site for specific activities. This allows ONR to regulate the design, construction, operation and decommissioning of any nuclear installation for which a nuclear site licence is required under NIA65. Nuclear site licences are granted for an indefinite term and a single licence may cover the lifetime of an installation.

43 NIA65 allows HM Chief Inspector of Nuclear Installations to attach to each nuclear site licence such conditions as ONR considers necessary or desirable in the interests of safety, or with respect to the handling, treatment or disposal of nuclear materials. ONR has developed a standard set of 36 LCs, which are (with minor variations) attached to all nuclear site licences. In the main, they require the licensee to make and implement adequate arrangements to address the particular safety areas identified. The LCs provide the prime legal means for ONR's day-to-day regulation of safety at licensed sites. They do not relieve the licensee of the responsibility for safety. They are mostly, but not exclusively, non-prescriptive, setting goals that the licensee is responsible for achieving.

44 One of the requirements of the LCs is that the licensees produce an adequate safety case to demonstrate that facilities are safe in both normal operation and fault conditions. The safety case is a fundamental part of the licensing regime at all stages in the life-cycle of a nuclear installation. It establishes whether a licensee has demonstrated that it understands the hazards associated with its activities and has arrangements to control them adequately.

### 0.3.3 Design Basis

45 ONR has developed and published its own technical assessment principles, which it uses to judge licensees' safety cases; these are set out in the Safety Assessment Principles for Nuclear Facilities (SAP) (Ref. 8). The latest version of the SAPs, published in 2006, was benchmarked against extant IAEA safety standards. In addition to the SAPs, more detailed Technical Assessment Guides (TAG) – accessible at www.hse.gov.uk/nuclear/tagsrevision.htm – are available to ONR assessors to assist them in making judgements on licensees' safety submissions. The SAPs / TAGs also incorporate the WENRA reference levels. In the areas relevant to the accident at the Fukushima site, the SAPs and TAGs set out regulatory expectations for protection against hazards such as extreme weather, flooding, earthquakes, fire, explosion etc., and for the provision of essential services.

46 Specific SAPs and sections of the SAPs define ONR's expectations for the development of a design basis.

47 Design Basis Analysis (DBA) provides a robust demonstration of the fault tolerance of a facility and of the effectiveness of its safety measures. Its principal aims are to guide the engineering requirements of the design and to determine limits to safe operation. In this approach, the risk is not quantified but the adequacy of the design and the suitability of the safety measures are assessed against deterministic targets.

### 0.3.4 External Hazards

48 ONR's regulatory expectations for assessment and analysis of external hazards, such as extreme weather, flooding and earthquakes, are set out in dedicated principles within the SAPs (Ref. 8). These principles represent high-level requirements for identification of the external hazards themselves and the scope of analysis expected for such events. These SAPs are augmented by

more detailed guidance contained in ONR’s Technical Assessment Guide T/AST/13 (Ref. 9). As well as providing more detailed guidance on identification and analysis, the technical assessment guide makes it clear that licensees’ safety cases should include consideration of support services such as access roads, water supplies, fire mains and site communications, pointing out that they should be designed and routed so that in the event of an external hazard occurring, sufficient capability remains to perform the required safety functions. The technical assessment guide includes all of the relevant WENRA reference levels.

### 0.3.5 Fault Analysis

49 Conservative design, defence-in-depth, good operational practice and adequate maintenance and testing should minimise the likelihood of faults. The DBA should ensure that the facility has been designed to cope with or withstand a wide range of faults without unacceptable consequences by virtue of the plant’s inherent characteristics or its safety features.

50 In addition to DBA, for complex facilities, Probabilistic Safety Analysis (PSA) may also be used to confirm that the overall risk presented by the facility lies within targets set by the licensees themselves and by ONR in the SAPs (Ref. 8). PSA can also help understand the potential strengths and weaknesses of the design, particularly in light of the complex designs and interdependencies, and help secure balance.

51 DBA may not include the full range of identified faults because it may not be reasonably practicable to make design provisions against extremely unlikely faults. It may not therefore address severe, but very unlikely, faults against which the design provisions may be ineffective. This is addressed by severe accident analysis.

### 0.3.6 Severe Accident Management

52 The principle of defence-in-depth requires that fault sequences leading to severe accidents are analysed and provision made to address their consequences. The analysis of severe accident events should be performed on a best-estimate basis to give realistic guidance on the actions which need to be taken in the unlikely event of such an accident occurring. Severe accident analysis may also identify that providing further plant and equipment for accident management is reasonably practicable.

53 All of the UK NPPs and significant NPGNF installations had DBA, PSA and severe accident analysis undertaken during their design or in a subsequent Periodic Safety Review (PSR). The stress tests process effectively undertakes a targeted review of specific extreme external hazards with loss of key systems and hence, severe accident studies in a systematic manner.

### 0.3.7 Periodic Safety Review

54 In the UK the operator of a nuclear installation is required by a specific licence condition (LC15) to periodically review its safety case for the plant. This PSR usually takes place every ten years and requires the operator to demonstrate that the original design safety intent is still being met. The reassessment is performed against the latest safety standards, operational experience and technical knowledge. The operating experience of the plant is also considered in the review. If the PSR identifies any reasonably practicable safety improvements, then it is a legal requirement that these should be made by the licensee. The PSR includes a review of the safety of the plant in response to events such as earthquakes, floods, fire and explosion. ONR independently assesses licensees’ PSR reports using its SAPs and TAGs.

55 The PSRs for each site take account of modern standards and recent research findings. Over the last two decades, a number of tsunami and flooding studies have been completed by the UK nuclear industry or have been commissioned by Government. The outputs from these studies have been considered in the subsequent PSRs.

### 0.3.8 Radiation Emergency Preparedness and Public Information Regulations

56 The requirements for the preparation of emergency plans are principally covered by the site licence issued to a nuclear site under NIA65 and the Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR). Where there is a potential for an off-site release of radioactivity that would require implementation of countermeasures, detailed emergency planning zones (DEPZ) are provided around the installations. The requirements for a DEPZ are stipulated within REPPIR.

### 0.3.9 Continuous Improvement

57 This philosophy is at the core of the UK requirements for the nuclear industry through the application of the “as low as reasonably practicable” (ALARP) legal requirement, and is the way in which sustained high standards of nuclear safety are realised. It means that, no matter how high the standards of nuclear design and subsequent operation are, the quest for improvement must never stop. Seeking to learn from events, and from new knowledge and experience, is a fundamental feature of the safety culture of the UK nuclear industry.

58 All UK nuclear site licensees have processes to assimilate, review and disseminate lessons learnt from significant events both in the UK and overseas. These arrangements are part of the continuous improvement and OPEX feedback processes which are expected of all licensees.

## 0.4 Licensees Covered by the Scope of NPGNF Stress Tests

59 This report covers many licensees, more than for the NPP stress tests performed to the request of EC. The licensees and associated licensed sites have generally no common characteristics, as NPP operators may present; however, they may be gathered as necessary by similarity of activities or stage of plants in their life-cycle, as done within ONR, through several programmes (www.hse.gov.uk/nuclear/onr-programmes.htm). The wide-scope covered has called on four different ONR Programmes, including the ones who reported in December 2011 on stress tests for NPPs.

60 There are 16 NPGNF licensees covered in this report, including five of them dedicated to defence activities described below, and two of them related to former or future NPPs.

### 0.4.1 Defence Licensees

61 The Ministry of Defence (MoD) is responsible for a Naval Nuclear Propulsion Programme (NNPP) and Nuclear Weapons Programme for the purposes of:

- Producing and maintaining nuclear weapons.
- Building new nuclear-powered submarines.
- Proving and underwriting the design and performance of submarine nuclear reactors and fuel assemblies.

- Producing the fuel and core for submarine nuclear reactors.
- Maintaining and refuelling nuclear submarines.

62 MoD Ministers account to Parliament on nuclear safety matters on all these sites.

63 Certain of the sites in the Defence Nuclear Programme are owned and managed by the MoD itself and activities there are exempted from some parts of civil nuclear regulation due either to crown immunity or the formal disapplication of particular legislation, including the exclusion of NIA65 from nuclear reactors comprised in a means of transport (i.e. submarines). MoD is not exempted from HSAW74, the Ionising Radiations Regulations 1999 (IRR) or REPPIR and ONR regulates activities on those sites that are directly operated by the MoD under these and other legislation.

64 Within this report, the defence licensees are Atomic Weapons Establishment (AWE), Rolls-Royce Marine Power Operations Ltd (RRMPOL), BAE Systems Marine Ltd (BAESM), Devonport Royal Dockyard Ltd (DRDL) and Rosyth Royal Dockyard Ltd (RRDL).

65 The remainder of the sites in the Defence Nuclear Programme are managed by the private sector, contracted to provide nuclear services to the MoD through a variety of commercial arrangements – these range from the Government-owned, contractor-operated (GOCO) sites at AWE through to sites that are privately owned and managed such as BAE Systems in Barrow and Rolls Royce in Derby. The generality of activities on these sites falls under the remit of NIA65 and the sites concerned are therefore licensed by ONR, albeit due to specific disapplication of NIA65 ONR does not in any case regulate the design of submarine nuclear reactors, nor the design of nuclear weapons.

66 Wherever exemptions or disapplications of civil legislation exist it is MoD policy to ensure, where reasonably practicable, that standards are at least as good as those required by civil regulation. The Defence Nuclear Safety Regulator (DNSR) provides assurance to the Secretary of State for Defence, through the Defence Nuclear Safety Board, that standards of nuclear and radiological safety are appropriately maintained for the particular sites and activities where the exemptions and disapplications apply. To this end DNSR oversees a system of Authorisation of MoD's dutyholders who directly control nuclear activities – DNSR's Authorisation system closely parallels ONR’s Licensing system. The formal basis of the relationship is covered in a MoD / HSE Agreement and an associated Letter of Understanding which describes the working level logistics and joint regulatory framework.

67 DNSR, for MoD, is carrying out its own assessment of Authorisee responses equivalent to the Fukushima stress tests. DNSR is obliged to consider the nuclear safety implications relating to design of the MoD's naval reactor plant (NRP) and design of the MoD's nuclear weapons, which fall outside the regulatory vires of ONR due to disapplication of NIA65 for these aspects. Thus, in this report, ONR only considers the responses from licensees and implications for nuclear safety regarding those activities and facilities to which NIA65 does apply.

68 ONR has assessed the source submissions and supporting source material supplied by the defence licensees and has returned all such information back to the licensee. This report presents a summary of their submissions at the appropriate security classification for this report.

### 0.4.2 EDF Energy NNB Generation Company Ltd (NNB GenCo)

69 NNB GenCo is not currently a nuclear licensee; it has applied to become the nuclear site licensee for the proposed nuclear licensed site of Hinkley Point C. Two UK EPR™ NPPs are proposed to be constructed at Hinkley Point C. It was decided to cover the NNB GenCo Hinkley Point C site in the NPGNF report because currently no nuclear-related construction has been undertaken on-site

and as such it did not meet the ENSREG requirement for inclusion in the national final report dedicated to NPPs.

## 0.5 Process for Stress Tests Activities

### 0.5.1 Overview and Timeline

70 The assessment process was required to commence in June 2011 and the licensees were informed of this by ONR.

71 The next major step was for the licensees to submit their stress tests progress reports by the end of October 2011 – this was completed in a timely manner. ONR has reviewed the information supplied and produced the UK Progress Report (Ref. 7) on 6 December 2011.

72 The licensees continued work on their main stress tests reports and submitted them to ONR by the required date of 31 December 2011 (Refs 11 to 27h).

73 ONR assessed this information, and published the UK Regulator's Report – this report.

74 To help the Fukushima response, activities move from a unique reactive process into normal regulatory business, which can then be regulated within the existing tried and tested arrangements. The licensees have been asked to produce further reports in the summer of 2012 – responding to HM Chief Inspector's final report recommendations – to provide an update to their stress tests reports and to produce a consistent, combined overall work programme. ONR then intends to produce an Implementation Report about a year after HM Chief Inspector's final report to provide an update on progress in implementing the lessons for the UK's nuclear industry.

### 0.5.2 Licensee Processes for Producing Stress Tests Reports

75 In the UK, in line with the goal-setting non-prescriptive approach to regulation, the licensees were expected to prepare the information and the initial assessments for each site. The output has been assessed by ONR to confirm that it is appropriate and that the licensees have adequately considered the safety margins and how they might be extended.

76 The approach adopted by many licensees was to apply the arrangements made under LC15 (periodic review) to carry out a review and reassessment of safety and submit a report to ONR. This provided a structured framework for the review activities and gave clarity of roles and functions within the licensees' arrangements for the preparation, review and reassessment of safety case information.

77 The key outputs from the stress tests process, beyond the reports themselves, are the areas of potential improvement. Where potential improvements to processes or equipment have been identified by the licensees, they have reported them as "*Considerations*". These *Considerations* do not represent final or formal commitments to make specific improvements. Rather they will be taken forward by the licensees for examination by a decision-making process to determine which of the potential improvements is ALARP, and which should therefore be implemented. Licensees may still choose to implement improvements which are not required to meet the ALARP principle, perhaps for commercial or public relations reasons. The decision-making process and how it is applied and the timescales for implementation of those improvements which are adopted are clearly areas of interest to ONR. Licensees will be required to justify any decision not to adopt a particular measure, in line with ONR's normal regulatory process.

### 0.5.3 ONR's Assessment Process

78 ONR applies a targeted sampling process to almost all of its activities. In the case of the stress tests reports submitted by the licensees, a team of specialist inspectors has assessed specific sections of reports and looked at how they have been applied generically across the sites. ONR's detailed assessment has covered all of the key discipline areas of external hazards – seismic, flooding and weather – as well as electrical and system fault studies and severe accident and emergency response topic areas.

79 By using a variety of approaches to inspection and assessment, ONR has developed a broad understanding of how the stress tests were applied as well as how they are reported by the licensees. ONR has confirmed that the licensees have met the ENSREG requirements for the stress tests and its reporting, but taking a wider view of how the stress tests have been applied has given ONR a much greater understanding of the particular strengths and weaknesses reported by the licensees.

80 During the development of stress tests reports, ONR's team of specialist inspectors interacted with licensees in a variety of technical meetings and inspections; this approach secured assurance that licensee arrangements for assessment accorded with ENSREG expectations (insofar as they were relevant to their respective operations). ONR's assessment of licensees' stress tests reports has resulted in a number of *stress tests findings* as detailed in the Executive Summary. Some of these findings reinforce or extend *Considerations* identified by the licensees; others are additional to those already identified.

81 This report details a number of topics identified by some licensees during their respective assessments that require further consideration for potential areas of improvement. These are listed as *Considerations.* ONR has a strong interest in the decision-making process applied by the licensees to their *Considerations*, and the first stress tests finding is to ensure ONR retains a clear view of the process and its outputs.

**STF-20: Sellafield Ltd, AWE, RRMPOL, BAESM, DRDL, RRDL, Magnox Ltd and NNB GenCo should provide ONR with the decision-making process to be applied to their *Considerations* along with a report which describes the sentencing of all their *Considerations*. The report will need to demonstrate to ONR that the conclusions reached are appropriate.**

82 It should be noted that the findings described in this report are supplementary to the recommendations raised in HM Chief Inspector's reports in that they generally relate to specific aspects of those recommendations. They are also supplementary to the findings and *Considerations* raised in ONR's National Stress Tests Final Report for UK NPPs (Ref. 10). They do not supersede any existing issues or necessary improvements identified by ONR via the normal regulatory engagement processes. Commitments are distinguished from stress tests findings, and *Considerations*, in that ONR has already received a written undertaking for resolution of a query or issue.

### 0.5.4 ONR's Reporting Process

83 ONR has followed the structure and contents of the stress tests report as defined by ENSREG as far as possible.

84 The structure generally has a description of the information provided by the licensees followed by ONR's view of that information. This should allow the reader to be clear when a point or comment is the information supplied by the licensees or when it is the view of the Regulator.

85 A draft of ONR's report was critically reviewed by the TAP which was set up to provide HM Chief Inspector of Nuclear Installations with independent advice following the Fukushima events. Advice from the TAP has been considered in detail and the report amended accordingly.

# 1 GENERAL DATA ABOUT THE SITES AND NPGNF

86 The locations of UK NPGNF (as defined by exclusion for the EC stress tests) are shown on the map below (Figure 1). It also shows the location of one proposed nuclear power station site (Hinkley Point C) for which an application for a nuclear site licence has been received by ONR; authorised sites of the MoD are also shown on the map.


Figure 1: Map of non-Power Generating Nuclear Facilities

## 1.1 Brief Description of the Site Characteristics

Sellafield Ltd – Sellafield and Windscale

87 The Sellafield nuclear licensed site is owned on behalf of Her Majesty's Government by the Nuclear Decommissioning Authority (NDA), and is operated by the site-licensed company Sellafield Ltd under the shareholding of the Nuclear Management Partners. Sellafield is a complex and diverse site which includes decommissioning reactors, spent fuel storage ponds, reprocessing plants, waste treatment plants and waste storage plants. The site, which currently employs approximately 10,000 full-time equivalent staff, is located on the West Cumbrian coast adjacent to the Irish Sea on the western outskirts of the Lake District National Park and within the catchments of the Rivers Calder and Ehen. The site-licensed boundary encompasses an approximate area of 276ha within the Copeland District of the county of Cumbria. The major local towns of Whitehaven, Workington and Barrow are approximately 14km to the north, 25km to the north and 38km to the southeast respectively. There are about 200 people living within 2km of the site: the nearest settlement of any size is Seascale 2.5km distant, with a population of about 1800. The Sellafield site is accessed via four principal pedestrian / vehicular gates all leading from the north-south A595 single carriageway which passes within approx. 1.5km of the Sellafield site near Calderbridge. The Cumbrian coastal train line has a request stop at Sellafield station.

88 The site topographical range is 9 to 48m above ordnance datum (AOD).

Sellafield Ltd – Capenhurst

89 The Sellafield Ltd Capenhurst site is located approximately 10km to the north of Chester, approximately 6km south west of the River Mersey and 6km north east of the River Dee. The site is generally flat with a slight incline to the eastern boundary of the site. The site topographic range is 35 to 40m AOD. The licence holder is Sellafield Ltd, who operates the site under contract with the NDA. Currently there are two separate licensees within the Capenhurst site boundary (Sellafield Ltd and Urenco UK Ltd) both licensees maintain close association for a number of services, included accident management. Currently, a Site Integration Project is being carried out; this is anticipated to result in the transfer of the Sellafield Ltd Capenhurst site to Urenco UK Ltd during 2012, subject to regulatory approval.

Urenco UK Ltd

90 The Urenco UK Ltd (UUK) Capenhurst site is located approximately 10km to the north of Chester, approximately 6km south west of the River Mersey and 6km north east of the River Dee. Rivacre Brook runs close by the site. The site is generally flat and situated 35–40m above mean high water. The licence holder is Urenco UK Ltd. Currently there are two separate licensees within the Capenhurst site boundary (Urenco UK Ltd and Sellafield Ltd); both licensees maintain close association for a number of services, included accident management. Currently, a Site Integration Project is being carried out; this is anticipated to result in the transfer of Sellafield Ltd Capenhurst site to UUK during 2012, subject to regulatory approval.

91 The site contains a number of units or plants which comprise three main groups:

- Centrifuge enrichment plants.
- Cylinder storage rafts and Container Receipt and Dispatch (CRD) building.
- Other support facilities such as workshops, uranium residues store, chemical laboratories and the site emergency control centre.

Dounreay Site Restoration Ltd

92 The ex-UK Atomic Energy Authority (UKAEA) licensed nuclear site at Dounreay on the far north coast of Scotland is operated by Dounreay Site Restoration Ltd (DSRL). The complex initially comprised the Dounreay Materials Test Reactor (DMTR) followed by the Dounreay Fast Reactor (DFR). These were supported by facilities for fuel manufacture, reprocessing and storage of radioactive waste. Construction began in 1955. Criticality was first achieved in DMTR in May 1958 and in DFR in November 1959. DMTR was shut down in 1969; all of its fuel has since been removed, reprocessed and the facility is currently in a passive care and maintenance status awaiting final decommissioning. DFR ceased power generation in 1977. A second fast reactor, the Prototype Fast Reactor (PFR) became operational in 1974 and continued to generate power until 1994. Both PFR and DFR are now being decommissioned and have been subject to assessment in accordance with the ENSREG stress tests requirements for NPPs.

93 DSRL undertook a single stress test that considered, holistically, the resilience of DFR and PFR facilities that met the ENSREG definition for NPP in tandem with other NPGNF facilities. This report specifically considers DSRL's stress tests for NPGNF facilities on the site. These include DMTR and the wider variety of operations with the fuel cycle area which were carried out to support reactor operations. These included reprocessing of spent fuel and the storage and treatment of radioactive waste. Reprocessing of fast reactor spent fuel ceased in October 1996 and residues were processed until January 1997. The site also includes two facilities previously authorised for the disposal of Intermediate Level radioactive Waste (ILW) and Low Level radioactive Waste (LLW); these are, respectively the Shaft and the Low Level Waste Pits. The site also includes a facility known as the Wet Silo, in which ILW is stored underwater.

94 The site topographical range is 11 to 26m AOD.

Springfields Fuels Ltd

95 Springfields licensed site near Preston has provided nuclear fuel fabrication services since the mid-1940s. In 2005, responsibility for the assets and liabilities of the site transferred to the NDA. A new company, Springfields Fuels Ltd (SFL), was created to run the site, managed and operated by Westinghouse Electric UK Ltd on the NDA's behalf. Subsequently, Westinghouse acquired a long-term lease for the Springfields site, which transferred responsibility for the commercial fuel manufacturing business and Springfields Fuels Ltd to Westinghouse. The site's activities include manufacture of oxide fuels for advanced gas-cooled reactors (AGR) and light water reactors (LWR), manufacture of uranium hexafluoride and its conversion, processing of residues, decommissioning and demolition of redundant plants and buildings.

96 The site topographical range is 12 to 17m AOD.

Imperial College of Science, Technology and Medicine

97 The CONSORT II Research Reactor is located on a secure nuclear licensed site within the Imperial College Silwood Park campus near Ascot in Berkshire. CONSORT is a low power (100kW thermal) research reactor, and first achieved criticality in 1965. Imperial College reports that decommissioning plans are in an advanced state and that defuelling of all fuel elements should be complete within three years, and eventual delicensing of the site in 2023.

98 The site topographical range is 15 to 20m AOD.

Studsvik UK Ltd

99 The Metal Recycling Facility (MRF) operated by the license holder, Studsvik UK Ltd, is a small low-hazard facility located at Lillyhall near Workington in Cumbria. The MRF receives metallic waste items contaminated with low levels of radiological contamination from clients within the UK

nuclear industry. These items are processed on a batch basis that includes size reduction (if required) using conventional hot and cold cutting techniques with subsequent decontamination using industrial grit blasting equipment. The MRF is not located on the coast or near any surface water streams. The site is 112m AOD, approximately 3.5km from the sea. The nearest surface water feature is the River Derwent, about 4km from the site. The Environment Agency Flood Maps show that the site is not in a flood warning zone from rivers or the sea.

Low Level Waste Repository Ltd

100 The Low Level Waste Repository (LLWR) is situated near the coast of west Cumbria on a coastal plain about 0.5km from the Irish Sea. The site lies in open countryside about 0.5km from the village of Drigg and about 6km to the south of the Sellafield nuclear licensed site. There are two streams that run through the site, the Drigg stream and “east-west” stream. The licence holder is LLWR.

101 The site topographical range is 12.5 to 20m AOD.

Research Site Restoration Ltd

102 Research Sites Restoration Ltd (RSRL) is the nuclear site licence holder for the Harwell and Winfrith sites, both formerly managed by the UK Atomic Energy Authority. RSRL is responsible for the closure programme at these sites. The radiological hazards and risks on both sites have decreased in recent years following the shutdown of most facilities, including reactors, radio-chemical laboratories and other supporting facilities. There are no operational facilities at Winfrith and Harwell operations are limited to ILW waste storage and treatment and decommissioning.

GE Healthcare Ltd

103 GE Healthcare (GEHC) is the licence holder for three licensed sites in the UK:

- The Grove Centre at Amersham, Berkshire. This site is located sufficiently inland that tidal surges do not present a credible risk to the site. It is also not located within Environment Agency flood warning zones. The site is situated 50m above the groundwater at 130m AOD.
- The Maynard Centre at Cardiff. The site is 6.5km from the coast and situated 30m AOD, rendering it at extremely low risk from tidal surges. The site is adjacent to the River Taff but raised above the river level. Flood defence banks exist to protect the site and neighbouring industrial units from significant floods.
- Waste Drum Packaging plant and sealed source manufacturing facility located within the RSRL licensed site at Harwell. These facilities have been fully decommissioned and present no hazard; GE Healthcare expects to bring its licensing obligations to an end in 2012. These facilities are not included in the stress tests report.

Atomic Weapons Establishment

104 AWE provides and maintains the warheads for the UK’s nuclear deterrent. The work covers the entire life-cycle of the nuclear warhead from design, component manufacture and assembly, in-service support (except for deployment) and decommissioning.

105 AWE occupies two main sites, both located inland in Berkshire with prevailing wind directions from the south west. Neither site is situated over any major geological faults. Both sites have conducted radioactive work since the 1950s, but were not subject to nuclear licensing until the late 1990s.

106 The AWE Aldermaston site (AWE (A)) is located approximately 15km south west of Reading and is at an elevation of approx. 100 m above sea-level. The licensed site extends over a significant area (260ha) and the expectation is that it will remain a nuclear site for the foreseeable future. Only a small number of the site's buildings are directly associated with nuclear safety, or indirectly in the case of the emergency response buildings. The site's Detailed Planning Zone (DPZ), of 3km radius, includes several villages and business parks with several hundred employees.

107 The AWE Burghfield site (AWE (B)) is located approximately 5km south of Reading and is within 2km of the M4 motorway and several local villages, at an elevation of approx. 45m above sea-level. The site fence encloses an area of 105ha, but the nuclear licensed site forms a small fraction of this. The DPZ, of 1.5km radius, includes part of a village. Numerous small water courses run through the local flood plain area, with one passing through the eastern part of the site. Several water bodies are located close to the site, the nearest being 1km to the south. The AWE (B) site experienced a major flooding event in 2007. Although the flooding event had no radiological consequences, AWE responded by taking significant steps to improve building flood defences to ensure that similar events do not affect operations. The planned move of nuclear operations to a new facility, built to modern standards, will further enhance the site's fault tolerance with respect to the flooding hazard.

108 As a result of the sites' locations, i.e. more than 50km inland and away from large bodies of water, AWE considers that it is not credible that an earthquake exceeding the Design Basis Earthquake (DBE) will result in induced flooding exceeding the Design Basis Flood (DBF).

109 The AWE sites do not have a nuclear power plant or stored nuclear fuel requiring decay heat removal.

<u>Rolls-Royce Marine Power Operations Ltd</u>

110 RRMPOL operates two nuclear licensed sites at Derby, in Derbyshire, in support of the MoD Naval Nuclear Propulsion Programme. The licensed sites are adjacent to one another and are located approximately 3km from Derby city centre, adjacent to the River Derwent. Derby is situated inland, more than 50km from the sea, well away from any credible sources of marine or tidal effects.

111 At the first site, named Neptune site, the key facilities are:

- Neptune Zero Energy Test Reactor – used to support research and design of naval reactor fuels.
- Radioactive Component Facility – where components and equipment used to support the NNPP are stored.

112 At the second site, the Nuclear Fuel Production Plant (NFPP), also known as the manufacturing site, the key facilities are:

- A chemical plant.
- Fuel production – comprising two manufacturing facilities.

<u>BAE Systems Marine Ltd</u>

113 BAE Systems Marine Ltd (BAESM) is contracted by the MoD to build and commission nuclear submarines at the Devonshire Dock Complex, which is located on the coast at Barrow-in-Furness, in the north west of England.

114 The major facilities on the site, covered by the scope of this study are:

- The Devonshire Dock Hall (DDH), a building within which the submarine is constructed.

- A radioactive component facility.
- The Shiplift (including cradles and transfer system) for supporting and moving the submarine.
- Wet Dock Quay (WDQ) – where testing and commissioning of the submarine takes place.

115 BAESM holds the nuclear site licence. Adjacent to the site is a dock system, which allows the submarine to exit the site. At this point, the submarine is not subject to the requirements of a nuclear site licence in common with some activities inside the site itself when the reactor is deemed to be in a mode of transport.

Devonport Royal Dockyard Ltd

116 DRDL is part of the Devonport site, located 4km north west of the centre of Plymouth in the south west of England. The site deals with the operation, maintenance, refit and repair of UK nuclear submarines. The Devonport site consists of the Dockyard, which is owned and operated by DRDL, which is a wholly owned subsidiary of Babcock International Group plc, and an adjacent naval base which is owned and operated by the MoD. Licensed activities occur only on part of the Dockyard site, under control of the licensee, DRDL. This report, therefore, limits its considerations to these activities. It should be noted that the NRP is only taken critical off the licensed site. The MoD is carrying out its own post-Fukushima study to review such operations.

117 The key nuclear facilities considered by this study are:

- The 9 Dock complex, used for refuelling, refit and repair of the Vanguard Class submarines.
- The Submarine Refit Complex (SRC) currently used for maintenance and repair and lay-up preparations of the Swiftsure and Trafalgar submarines and is planned to accept Astute Class in future. The SRC also contains a range of support facilities, including the Low Level Refuelling Facility (LLRF) which is a facility for handling radioactive components.

Rosyth Royal Dockyard Ltd (RRDL)

118 The Rosyth nuclear licensed site is located in the Rosyth Business Park, on the north side of the River Forth, in Fife, about 50km from the mouth of the Firth of Forth. The site is operated by Rosyth Royal Dockyard Ltd, a wholly owned subsidiary of Babcock International Group plc.

119 Rosyth Royal Dockyard was used to support the refitting and maintenance of nuclear-powered submarines until such work was transferred to Devonport. The nuclear licensed site is a relatively small part of the overall dockyard and most of the nuclear-related facilities have now been decommissioned and the hazard removed. Relatively small quantities of radioactive waste are currently held in a store on the site and disposal options are currently being explored.

120 There are no longer any facilities containing nuclear fuel on the licensed site. However, the site holds quantities of radioactive waste and is therefore within the scope this report. Sections relating to decay heat removal and prevention of criticality are not relevant.

Magnox Ltd – Defuelled reactors

121 There are currently five defuelled reactor sites operated by Magnox Ltd (the licensee) in the UK at Berkeley in Gloucestershire, Bradwell in Essex, Hinkley Point A in Somerset, Hunterston A in north Ayrshire and Trawsfynydd in Gwnyedd. The details of the location of each of these sites are given in Table 1.

122 Each of these licensed sites has defuelled twin Magnox reactor units located within its respective boundaries. The reactor units are all permanently shut down and fully defuelled and operations at the sites are in various stages of their respective decommissioning processes.

**Table 1:** Location Details for Magnox Defuelled Reactor Sites

| Site | Location |
|---|---|
| Berkeley | South east bank of the Severn Estuary |
| Bradwell | South bank of the Blackwater Estuary |
| Hinkley Point A | South coast of the Bristol Channel |
| Hunterston A | Eastern side of the tidal estuary of the River Clyde (known as the Firth of Clyde) |
| Trawsfynydd | Adjacent to Trawsfynydd Lake (Llyn Trawsfynydd) in Snowdonia National Park |

<u>NNB GenCo – Hinkley Point C</u>

123 It is proposed that NNB GenCo will operate a new twin reactor unit NPP to be constructed at the Hinkley Point C site in Somerset. NNB GenCo has submitted an application for a site licence to ONR and, as such, currently has the status of a potential new licensee.

124 The Hinkley Point C site is located on the Somerset coast of the Bristol Channel. The site is adjacent to the Hinkley Point A defuelled reactor site operated by Magnox Ltd and the Hinkley Point B operational NPP operated by EDF NGL (the licensee).

### 1.1.1 Main Characteristics of UK NPGNF

<u>Sellafield Ltd – Sellafield and Windscale</u>

125 The Sellafield site has been operational since the 1940s when it was used as a Royal Ordnance factory supporting the war effort. Seven reactors have been operated on the site: the four reactors of the Calder Hall nuclear power station, Piles 1 and 2, and the Windscale AGR (WAGR). None of the reactors are currently operating and all are at varying stages of decommissioning.

126 Today the site comprises a wide range of nuclear facilities, including redundant facilities associated with early defence work, operating facilities associated with Magnox reprocessing programme, the Thermal Oxide Reprocessing Plant (THORP) and a range of waste treatment plants as summarised below:

*Decommissioning and clean-up*

- Legacy Ponds and Silos are historic facilities which house first generation Magnox fuel (as well as early reactor fuel from the Windscale reactors) and cladding swarf from early reprocessing operations on the site. Work is ongoing to retrieve and treat the material held in these facilities prior to long-term disposal so that the facilities can be decommissioned.
- Primary Separation Plant was Sellafield's first reprocessing facility, which began operations in 1952. It was used to handle early reactor fuel and support initial efforts in oxide reprocessing in the early 1970s. The facility is currently undergoing decommissioning.

- Pile 1 and Pile 2 were the first nuclear reactors at Sellafield; both were shut down following the 1957 fire in Pile 1. Work is ongoing to decommission both piles.
- WAGR was a small prototype reactor which was the forerunner to the UK's second generation of NPPs. Having ceased operations in 1981, it is now effectively decommissioned.
- Calder Hall was the world's first commercial scale NPP which was opened in 1956. The four-unit plant closed in 2003 and is currently undergoing defuelling. It should be noted that the Calder Hall reactors were discussed in the NPP stress tests national report (Ref. 10) and therefore they have not been discussed specifically in this report. However, Calder Hall is integrated into the Sellafield site, so it will directly benefit from improvements to resilience identified in this report

*Commercial operations*

- Fuel Handling Plant (FHP) receives Magnox and AGR spent fuel transported to Sellafield in fuel flasks. Upon arrival at the site the Magnox and AGR fuel is removed from the transport flasks and stored in the FHP ponds for a predetermined period prior to being conditioned for reprocessing and transfer to the Magnox and THORP plants respectively.
- Magnox Reprocessing Plant is used to reprocess used Magnox fuel from throughout the UK.
- THORP is used to process used oxide fuel from both UK and overseas.
- Sellafield MOX Plant was used to manufacture mixed oxide fuel for overseas customers. It ceased operation in 2011 and is currently undergoing run-down and post-operational clean out (POCO) activities.

*Radioactive waste treatment / processing*

- Highly Active Liquor Evaporation and Storage (HALES) presently uses evaporators A and C to concentrate highly active liquor prior to being solidified in the Waste Vitrification Plant (WVP). Evaporator D, currently under construction, will provide additional highly active liquor concentrating capacity. The initial commencement of HA liquor operations was in the early 1950s.
- WVP processes high-level liquid waste into solid form by incorporating it into glass, followed by a period of on-site storage. This process dates from the 1980s.
- Effluent and Encapsulation Plant facilities process intermediate level solid waste and liquid effluents generated across the Sellafield site prior to final encapsulation or release to the environment within the appropriate discharge limits:
  - Enhanced Actinide Removal Plant (EARP), the principal liquid effluent plant, removes radioactivity by chemical treatment and filtration from effluent streams. The liquid waste is then circulated through a series of ultrafilters until suitable for discharge to sea within agreed limits.
  - Segregated Effluent Treatment Plant (SETP), sister plant to EARP, handles low risk, low active acidic effluents arising from Magnox and THORP reprocessing operations and conditions these feeds prior to discharge to sea within agreed limits.
  - Solvent Treatment Plant (STP) receives waste solvent from Magnox and THORP reprocessing operations which is then processed into chemical and radiological forms suitable for treatment in either EARP or SETP.

- Waste Packaging and Encapsulation Plant (WPEP) encapsulates the radioactive residues from EARP into a cement matrix within stainless steel drums.
- Waste Encapsulation Plant (WEP) processes ILW from THORP in a “grout” matrix within stainless drums prior to long-term storage.
- Magnox Encapsulation Plant (MEP) processes ILW from Magnox in a “grout” matrix within stainless steel drums prior to long-term storage.
- Waste Monitoring and Compaction (WAMAC) processes LLW (from across the Sellafield site as well as from external industry consignors) by compacting it and placing it into half-height iso-freight containers, prior to dispatch to the LLWR.
- Waste Treatment Complex (WTC) processes plutonium contaminated material (PCM) generated from decommissioning and site operations into a robust form suitable for long-term storage at a minimum volume.
- Site Ion Exchange Effluent Plant (SIXEP) treats pond storage water from across the site by removing the radionuclides through filtration and ion-exchange processes from the liquid effluent prior to discharge to sea within agreed limits.
- Sludge Packaging Plant 1 (SPP1), currently under construction, will hydraulically receive legacy sludge from the first generation Magnox storage pond and store it safely, ready for future processing into a product suitable for long-term storage and eventual disposal.
- Separation Area Ventilation (SAV) project, currently under construction, will provide the new filtration and discharge capability for aerial effluents from the separation area which will replace the two current stacks and provide a long-term facility to support future decommissioning programmes.

*Radioactive waste and product storage facilities*

- Sellafield Product and Residue Store (SPRS) provides safe and secure storage for nuclear materials produced as a result of reprocessing operations at Sellafield.
- Encapsulated Product Stores (EPS) 1 and 2 are drum stores for ILW from the WEP and MEP facilities.
- EPS 3, currently under construction, will provide additional drum storage capacity.
- Residue Export Facility (REF) is used to load canisters of vitrified high active waste into flasks for export back to overseas customers.

127 The site also has a wide range of support buildings including, but not limited to, offices, workshops, flask maintenance, utilities, analytical laboratories, emergency management, fire and rescue, Civil Nuclear Constabulary, Occupational Health etc. and an on-site rail network.

128 Furthermore, Fellside Combined Heat and Power Plant (CHPP) is located on the licensed site adjacent to the Calder Gate. Fellside CHPP is rated at 176MW, has three gas turbines and one steam turbine, each turbine driving its own alternator and an auxiliary boiler. The gas supply is provided by the Pennington pipeline constructed in 1992 that connects into the UK national gas grid pipeline from Barrow to Lupton. There is also the capability to fire the three gas turbines on distillate fuel (Gas-oil) stocks held on-site at CHPP exclusively for this purpose.

Sellafield Ltd – Capenhurst

129 Sellafield Ltd Capenhurst is non-power reactor site and does not contain any nuclear fuel, or fuel storage facilities and there are no heat or hydrogen generating processes on the site. Following

initial use in the 1940s as a Royal Ordnance factory, the site was developed in the 1950s to include a gas diffusion plant and related infrastructure to enrich uranium. Subsequent development in the late 1970s to 1980s resulted in construction of a centrifuge separation plant operated and managed by UUK. The diffusion plant ceased operations in the early 1980s and the site has since been focused on decommissioning, the safe storage of uranium hexafluoride, LLW, depleted and low level uranic material.

130 The main hazards associated with the Sellafield Ltd Capenhurst licensed site are predominately chemotoxic, associated with uranium hexafluoride. The radiological hazard is low, arising from storage of LLW and depleted or low enriched uranic residue material. The low hazardous inventory at the site is such that there are no accident sequences with potential to lead to significant off-site radiological consequences or severe radiological accidents. The consequences arising from the initiating events specified in the stress tests fall below the level for which there is a requirement for an off-site emergency plan under REPPIR, with margins between these consequences and the threshold for when an off-site emergency plan is required.

Urenco UK Ltd

131 The UUK site consists of installations comprising centrifuge enrichment plants, cylinder raft storage areas (rafts) and buildings and support facilities. There are no nuclear power reactors or spent fuel storage ponds / facilities on the site. The main characteristics of the site are summarised below:

132 Centrifuge enrichment plants: UUK operates three centrifuge plants to deliver core uranium enrichment services. The plants were commissioned between 1982 and 2008. The process material used at the UUK Capenhurst site is uranium hexafluoride ($UF_6$). This is transported to / from the Capenhurst site, and stored on the site, in robust internationally approved transport cylinders which are ANSI N14.1 compliant. The cylinders are used for “feed” material, depleted material (“tails”) and for enriched material (“product”). Only non-irradiated $UF_6$ is used in the enrichment process on the site and the process is similar within all three plants.

133 Cylinder storage rafts and CRD: The CRD is used to store cylinders prior to despatch and to receive cylinders from off-site. The rafts are also used for cylinder storage. In addition to the main storage rafts, there are a number of smaller interim rafts which act as handover points between operations and plant support services for cylinders transitioning to / from the enrichment plants. All the rafts are essentially the same, being large open concrete storage platforms with a crane for handling the cylinders.

134 Other support facilities: There are a number of facilities that support the three centrifuge enrichment plants. The more significant of these include: workshops, chemistry services and a site emergency control centre. UUK also provides Fire and Rescue services and emergency response for the combined Capenhurst site.

135 The main hazard at the UUK site arises from $UF_6$, which is predominantly chemotoxic. On release to the environment, $UF_6$ reacts with moisture in the air forming $UO_2F_2$ and gaseous HF. The chemotoxic hazard is primarily from gaseous HF. $UF_6$ is also the principal radioactive substance on the UUK site. Tails, feed and product are all stored on-site in internationally approved robust steel transport cylinders. Product will normally be stored on-site for short periods only prior to despatch to customers. The majority of operations involve $UF_6$ at natural enrichment levels or less; hence do not present a criticality hazard under any conditions. The final product, low enriched $UF_6$ (limited to a maximum enrichment rate of 6%, although typically <5%) has a low potential to cause a criticality hazard under certain condition and is subject to criticality safety controls.

136 Containment and criticality control are therefore the core basis of nuclear and chemotoxic safety at UUK. ONR seeks assurance from the licensee during routine compliance inspections, and from targeted sampling of its safety cases, that all nuclear matter is contained according to the standards expected in the SAPs, regardless of what constitutes the dominant harm potential.

Dounreay Site Restoration Ltd

137 DSRL indicates that the main hazards that have potential to give rise to on-site and / or off-site consequences include:

- Criticality.
- Alkali metal fire.
- Radioactive Material Transport Accidents.
- Inhalation of contamination due to aircraft impact and subsequent fire.
- Inhalation of contamination due to loss of containment from a seismic event.

138 The main characteristics of DFR and PFR were discussed in ONR's National Stress Tests Final Report for UK NPPs (Ref. 10). The PFR fuel reprocessing facility was used for the safe reprocessing and treatment of mixed uranium and plutonium oxide irradiated and unirradiated fuels from PFR and DFR. This facility commenced operation in 1958 and was subject to modification and extension until 1983. Operations ended in 1997. The facility is now undergoing decommissioning in three phases, beginning with inventory reduction, to be followed by POCO and subsequent dismantling. The hazard profile in the facility will diminish significantly following completion of bulk inventory removal; the predominant focus for the licensee is to manage the hazard posed by long-lived isotopes to the workforce when undertaking each stage of intrusive decommissioning.

139 The ILW processing facility was previously used for the post-irradiation examination of fuel specimens, but is now used for the interim storage of irradiated fuel and the processing of ILW; the facility will continue to operate to support inventory removal and management of ILW until the early 2020s. The site also contains a facility for the storage of high-Alpha, low Beta-Gamma ILW that supports continued inventory removal across the site. The Dounreay Cementation Plant is an operational facility that receives and processes ILW liquors that are immobilised by a cementation process resulting in solid ILW. The Nuclear Material Store continues to provide storage of fissile material and is subject to extensive regulatory attention to secure assurance over the continued safety and security of the licensee's controls.

140 The site also has two facilities, a shaft and silo that store historic ILW waste underground. Both the shaft and silo operate in a fully flooded state; energetic inundation of water would be required give rise to material mobilisation. DSRL has examined resilience to flooding, and is subject to consideration by ONR in this report. The Dounreay site also houses an above-ground flocculation tank that was historically used to remove uranium from aqueous liquid waste streams and to reduce residual liquor activity. Settled ammonium diuranate floc material, together with the actinide and fission product activity, is retained in the tank pending final treatment. DSRL's safety case considers that the floc settling tank may be vulnerable to beyond design basis seismic or flooding events; the licensee's stress tests report identifies its strategy for severe accident management to such beyond design basis events, and this is considered later within this report.

Springfields Fuels Ltd

141 Springfields is predominantly a nuclear fuel manufacturing site, converting uranium feedstock in a variety of forms into fuel and intermediates for NPPs across the world. Principal processes include:

- Natural uranium hexafluoride ($UF_6$) manufactured from uranium trioxide feedstock provided from international suppliers and site recovery processes. This is achieved in a multi-stage chemical process: containment of hydrogen gas, hydrogen fluoride and uranic material is the core basis of nuclear and chemotoxic safety in these processes; unmitigated release of uranic material or hydrogen fluoride (HF) present a predominantly chemotoxic hazard. On release to the environment, $UF_6$ reacts with moisture in the air forming uranyl fluoride ($UO_2F_2$) and gaseous HF. The chemotoxic hazard is primarily from gaseous HF and the heavy metal toxicity of uranium. ONR nonetheless seeks assurance from the licensee during routine compliance inspections, and from targeted sampling of its safety cases, that all nuclear matter is contained according to the standards described in SAPs regardless of what constitutes the dominant harm potential. The NIA65 does not make the distinction between radiological and chemotoxic effect in the context of nuclear matter. Where the licensee cannot demonstrate SAP criteria are achieved due to the extant standards at the time of construction, ONR still expects sufficient demonstration that hazards are controlled so far as is reasonably practicable.
- Conversion of enriched uranium hexafluoride to uranium dioxide powder subsequently used in the manufacture of predominantly AGR fuel elements but also elements for LWR customers. Intermediate products are also manufactured for overseas customers.
- Natural and enriched residue processing arising from both historic and current manufacture of uranium hexafluoride. These processes extract uranic residues from waste streams and convert, using nitric acid and denitration techniques, to either re-usable uranium hexafluoride for in-specification enrichments or to the more chemically stable uranium trioxide which is stored. In addition to the chemotoxic and radiological hazards, these processes are subject to criticality safety assessment and, accordingly, appropriate criticality safety controls.

Imperial College of Science, Technology and Medicine

142 CONSORT is a “swimming-pool” type reactor and the light water acts as the moderator, reflector and coolant. At maximum power (100kW thermal) the water temperature differential for water passing through the core is very low (circa $10^{o}C$). Materials Test Reactor-type fuel elements remain in the reactor vessel; there are no other fuel storage facilities or elements present on the licensed site. Reactor operations continue intermittently, but the reactor no longer achieves criticality.

Studsvik UK Ltd

143 The Studsvik site has no fissile material, nuclear reactors, nuclear chemical process plant or fuel storage facilities. The MRF process is made up of a small number of individual industrial plant items located in a single building and one other facility that is used for the storage of non-radiological equipment. Metallic waste delivered to the site and waiting processing is stored in approved containers external to the main process facility. Due to the very low-hazard nature of the site, the consequences arising from the initiating events specified in the stress tests fall far below the requirement for off-site emergency planning under REPPIR.

Low Level Waste Repository Ltd

144 The LLWR became operational as a LLW disposal route in 1959. The purpose of the LLWR is the receipt, grouting, storage and disposal of LLW. LLW is grouted in its transport container following receipt at the site and then placed in a storage vault. The site also stores historical LLW in trenches that are now full and have high quality covers fitted.

145 The low-hazard nature of the inventory at LLWR means that no accident at the site, initiated through internal or the events a specified in the stress tests, can result in an off-site consequence that exceeds 1mSv; hence the site does not trigger the requirement for off-site emergency planning under REPPIR.

Research Site Restoration Ltd

146 The principal operations at Harwell involve decommissioning of three defuelled test reactors and associated waste storage facilities. The majority of radioactive material inventory on the site is in the form of solid waste. Solid ILW waste is stored in the site’s waste treatment complex. A range of low level radionuclides remain in a dedicated facility, mainly as drummed waste. The site also contains radioactive effluent waste stored in its Liquid Effluent Treatment Plant.

147 The Winfrith site opened in 1957 to offer additional space to the UK’s expanding civil nuclear research programme. The site operated eight reactors which most notably included the DRAGON and Steam Generating Heavy Water (SGHWR) reactor. These reactors were shut down in the 1990s following the Government’s announcement of the end to the research programme. Almost a third of the site’s clean-up programme has been completed; six of the eight reactors have been decommissioned and dismantled; the two remaining DRAGON and SGHWR reactors have been defuelled and placed into care and maintenance. The majority of inventory on the site is in the form of solid waste, which includes tritiated solids, natural and depleted uranium stock, immobilised LLW and some gamma calibration sources. The residual inventories do not pose an off-site hazard, and the radiological hazard to workers is controlled through existing shielding and containment structures in combination with managerial controls. The licensee anticipates a resumption of decommissioning activity on the site over the coming 5 years.

GE Healthcare Ltd

148 The following key characteristics relate to the GEHC sites and operations:

- The Grove Centre has a varying history of handling radioactive materials within numerous facilities since around 1940. Many of these facilities have been decommissioned. Licensed operations at the Grove Centre are centred on the management and decommissioning of legacy waste and plant, management and storage of ILW and the manufacture of radiopharmaceutical products. The latter involves short-lived radionuclides (days or hours) half-lives. This licensee’s intention is to significantly reduce its manufacturing base over the next three years, with 80% of the current manufacturing to be transferred outside the UK.
- The Maynard Centre was used to manufacture radiochemical products based on carbon-14 and tritium, which are relatively low-hazard / low radiotoxicity. Manufacturing operations ceased in 2010; the associated facilities have been substantially decommissioned and removed with completion expected by the end of 2012. The site will continue to manage and store low levels of radioactive waste (carbon-14 and tritium), making use of disposal routes to reduce the inventory over the coming years.
- The inventory at both GE Healthcare sites is such that there are no accident sequences with potential to lead to significant off-site consequences or severe accidents. The

consequences arising from the initiating events in the NPP stress tests specification (seismic, flooding, extreme weather and loss of power) fall below the requirement for an off-site emergency plan under REPPIR, with margins between these consequences and the threshold for the requirement for off-site emergency planning.

Atomic Weapons Establishment

149 There are many facilities on both AWE sites handling a range of radioactive, explosive and chemical materials, which pose varying degrees of risk. The radioactive materials used include plutonium, uranium and tritium. The facilities considered in detail for the stress tests are those that could lead to a severe accident in either a design basis event or through possible escalation following a beyond design basis event. A severe accident is defined as an off-site radiological hazard which can give rise to best estimate committed effective dose equivalents (CEDE) in excess of 5mSv.

150 AWE's response to the stress tests has used data and information from the facility and site safety cases, the facility and site emergency plans (SEP), and PSRs conducted for individual facilities and site-wide. Site-wide PSRs for AWE (B) and AWE (A) were issued in 2007 and 2010, respectively.

151 The SEPs for Aldermaston and Burghfield define reference accidents for their respective sites as follows:

- A seismic event causing significant damage to a building, or buildings containing radioactive material, such that a release of that material occurs and poses a significant hazard to persons on and off the site.
- A seismic event causing significant damage to a building, or buildings containing explosive and radioactive material, such that an explosively driven release of the radioactive material occurs and poses a significant hazard to persons on and off the site.

152 AWE has identified three operational facilities, and one waste store, at the AWE (A) site and one operational facility at that the AWE (B) site that could lead to a reasonably foreseeable severe accident using these criteria. The focus of AWE's stress tests response focuses on these facilities, which this report will refer to as "high-hazard" facilities. Replacements for two of these facilities are currently being developed, which will be designed to withstand seismic events significantly more severe than the DBE.

Rolls-Royce Marine Power Operations Ltd

153 The Neptune reactor is a zero power research reactor, used to support development and testing of fuel for the naval nuclear propulsion programme. The reactor is a light water moderated pool type, where the fuel assemblies are housed in an open topped tank. As this is a research reactor, operating at very low power levels, there is no requirement for a decay heat removal system.

154 The main facilities on the manufacturing site are:

- Chemical plant where a range of chemical processes are undertaken.
- Fuel manufacturing facilities.

155 The principal hazard for the manufacturing site is inadvertent criticality; however, even in this case there are no reasonably foreseeable fault sequences where significant off-site consequences could arise.

BAE Systems Marine Ltd

156 The BAESM site builds and commissions the UK's fleet of nuclear-powered submarines. These submarines are fitted with a NRP as a power source, which is a light water moderated pressurised

water reactor (PWR). BAESM provides a high-level description of the NRP in its submission, but the details of the design are classified above the level of this document. It should also be noted that the MoD is carrying out its own post-Fukushima review of the NRP as a separate activity.

157 The principal nuclear activities on the site comprise: assembly of radioactive components and installation into the submarine, and the testing and commissioning of the NRP. Critical operations on the site are limited to testing of the completed reactor at WDQ. These tests occur once every two to three years for, on average, a period of less than one calendar month.

158 The principal nuclear hazards on the site arises from the PWR. BAESM reports that the fundamental safety functions are:

- Control of criticality.
- Control of reactivity.
- Containment of fission products (including fuel cooling).

Devonport Royal Dockyard Ltd

159 The Devonport Royal Dockyard licensed site carries out maintenance and repair activities on the UK's fleet of nuclear-powered submarines. DRDL provides a high-level description of the NRP, in particular the on-board decay heat removal systems, in its submission, but the details of the design are classified above the level of this document. It should also be noted that the MoD is carrying out its own post-Fukushima review of the NRP as a separate activity.

160 As part of this work, the principal nuclear activities on the licensed site are:

- One graving dock is a purpose-built submarine docking facility for Ship Submersible Ballistic Nuclear (SSBN) submarines. There are decay heat removal systems, electrical supply and distribution systems and a range of cranes and facility systems to support the submarine. Nuclear-related work includes defuelling and refuelling of the PWR, maintenance, testing and repair of NRP systems and components and preparations for final testing and commissioning (note that the reactor is not taken critical on the licensed site).
- The SRC which contains two graving docks which are purpose-built submarine docking facilities for Ship Submersible Nuclear (SSN) submarines. As for 9 Dock, a range of facilities are available to support the repair activities and to support the submarine. At present, no defuelling or refuelling activities occur in the SRC.
- LLRF – a facility for handling radioactive components.
- Nuclear transfer route – A railway between the main facilities on-site for the transportation of new and used fuel and sources.

161 The principal nuclear hazard at the site arises from the PWR which is always shut down when on the DRDL licensed site. DRDL reports that the four main safety functions which protect against reactor core damage and the potential release of fission products into the environment are:

- Control of core temperature.
- Control of reactivity.
- Control of radiation doses.
- Control of radioactive material.

Rosyth Royal Dockyard Ltd

162 As the licensed activities at Rosyth are currently limited to the storage of quantities of radioactive waste, the principal hazards on the site are limited to those that could cause a leakage or escape of this waste material. The quantity of radioactive material present is insufficient to result in a severe accident, even if it were to be released from its containment.

Magnox Ltd – Defuelled reactors

163 The main characteristics of the UK's defuelled reactor sites operated by Magnox Ltd are given in Table 2.

**Table 2:** Main Characteristics of Magnox Ltd Defuelled Reactor Sites

| Defuelled reactor site | Reactor type | Status | Number of defuelled reactors | Date of first criticality | Date of reactor shutdown | Date of completion of defuelling | Date of removal of fuel from site |
|---|---|---|---|---|---|---|---|
| Bradwell | Magnox[1] | Decommissioning | 2 | Reactor 1 (R1):19 August 1961<br>Reactor 2 (R2): 14 April 1962 | R1: 31 March 2002<br>R2: 30 March 2002 | R1: 12 September 2005<br>R2: 30 December 2005 | R1: 10 August 2006<br>R2: 10 August 2006 |
| Berkeley | Magnox[1] | Decommissioning | 2 | R1: 29 May 1962<br>R2: 13 October 1962 | R1: 31 March 1989<br>R2: 27 October 1988 | R1: 15 March 1992<br>R2: 15 March 1992 | R1: 19 March 1992<br>R2: 19 March 1992 |
| Hunterston A | Magnox[1] | Decommissioning | 2 | R1: 03 February 1964<br>R2: 17 July 1964 | R1: 30 March 1990<br>R2: 31 December 1989 | R1: 08 February 1995<br>R2: 21 January 1995 | R1: 08 February 1995[2]<br>R2: 08 February 1995[2] |
| Hinkley Point A | Magnox[1] | Decommissioning | 2 | R1: 01 May 1964<br>R2: 01 October 1964 | R1: 16 April 1999<br>R2: 03 December 1999 | R1: 06 November 2004<br>R2: 25 October 2004 | R1: 29 September 2010<br>R2: 29 September 2010 |
| Trawsfynydd | Magnox[1] | Decommissioning | 2 | R1: 01 September 1964<br>R2: 01 December 1964 | R1: 20 July 1993<br>R2: 20 July 1993 | R1: 31 May 1995<br>R2: 31 May 1995 | R1: 08 August 1995<br>R2: 08 August 1995 |

NOTES

1. Each of these sites, when operational as NPPs, employed first generation gas-cooled Magnox type reactors, which utilised steel reactor pressure vessels.
2. Two recently discovered part elements were recovered from the CPP in early 2012 and are now held in safe storage in accordance with the requirements of the current safety case. The removal of these part elements from site is due to occur imminently.

164 These defuelled reactor sites have their first generation gas-cooled Magnox reactors permanently shut down and defuelled. When operational, the Magnox reactors used natural metallic uranium fuel in magnesium alloy cans in a graphite core, which was cooled by forced circulation of carbon dioxide ($CO_2$) gas. The core was contained within a spherical mild steel vessel enclosed within a concrete reactor vault that provided a biological shield. The boilers were located outside of the concrete reactor vault and connected to the reactor vessel by ducting. The reactors at each site are now vented to atmosphere via passive unfiltered ventilation systems. All means of pressurisation have been disconnected and the primary circuits are maintained in air at nominal atmospheric pressure.

165 The design of the defuelled Magnox reactors at these sites is similar with the exception of those used at the Hunterston A site. The design of the reactors at Hunterston A is unique as each reactor has been raised up to a height of 10m above ground to enable refuelling to take place from beneath the reactor. This characteristic of the reactor design enabled the use of gravity assistance during fuel removal and avoided the need for lifting machinery to be inserted into the active core for on-load refuelling during use.

166 The boiler houses were dismantled at the Berkeley site during the 1990s and the 16 boiler vessels were sealed and laid horizontally on concrete plinths, adjacent to the reactor buildings. Two boilers have since been decontaminated, size reduced and removed from site.

167 The current status of each site can be summarised as:

*Bradwell*

168 The site is operating in an accelerated decommissioning mode and is planned to enter its care and maintenance phase in 2015. The main and end bays of the spent fuel storage pond have been emptied, drained and cleaned while its centre bay has been emptied of fuel and largely drained.

169 The current inventory of radioactive waste on-site comprises:

- The spent fuel storage pond is fuel-free and contains small quantities of sludge and fuel element debris in the centre bay, which is being retrieved, drummed and placed into temporary storage in an empty waste vault.
- Active waste vaults contain approx. 620$m^3$ of ILW in the form of fuel element debris, sludge, resin, and miscellaneous contaminated items.
- Reactor cemetery holes and quarter rooms contain approx. 168$m^3$ of ILW in the form of miscellaneous activated components and miscellaneous contaminated items.
- LLW management facilities contain approx. 2$m^3$ ILW in ductile cast iron containers and LLW in drums and ISO containers.

*Berkeley*

170 The spent fuel storage pond was demolished in March 2001 and the defuelled Magnox reactors were placed into a Safestore condition in December 2010. The site is currently preparing for its care and maintenance phase after retrieval and passivation of ILW held on-site by 2019.

171 The current inventory of radioactive waste on-site excluding the Safestore buildings comprises:

- Active waste vaults (a purpose-built ILW storage facility in the form of underground chambers made from reinforced concrete) contain approx. 1700 $m^3$ of ILW in the form of graphite and magnesium alloy fittings removed from fuel elements, canned sludges and resins, and miscellaneous waste.

- Caesium removal plant contains volumes of ILW in the form of contaminated resin and sludge waste within stainless steel process tanks.
- Redundant shielded area facilities contain some solid ILW stored in stainless steel cans within heavily shielded caves. This also forms an interim storage location for approx $17m^3$ of drummed desiccant waste and drummed sludge waste.
- Active effluent treatment plant contains residual contamination within pipes and vessels in the treatment facilities that have largely been cleaned out.
- LLW Building where LLW is held pending packaging and transfer to a national LLW disposal facility.

*Hunterston A*

172 The Cartridge Cooling Pond (CCP) no longer contains fuel. Two recently discovered part elements were recovered in early 2012 and are held in safe storage in accordance with the requirements of the current safety case. These part elements are to be removed from the site imminently. The CCP is currently undergoing draining and decontamination processes that are intended to be complete by 2016.

173 In addition, the solid ILW retrieval process is currently intended to complete by 2020 with a view to the site progressing to its care and maintenance phase by 2024.

174 The current inventory of radioactive waste on-site comprises:

- Solid Active Waste Building (SAWB) contains approx. $2255m^3$ of ILW in the form of irradiated graphite ($1500m^3$), magnesium alloy from cans ($565m^3$), miscellaneous contaminated items ($110m^3$) and fuel element debris ($80m^3$).
- CCP contains approx. $40m^3$ of sludge, residual steel components, treated water and surface contamination. This waste is in addition to the two part elements described above.
- LLW management facilities contain processed LLW which is stored in ISO containers prior to transfer to a LLWR off-site for disposal.
- Reactor Pressure Vessels, which are at ambient pressure and temperature, contain non-combustible irradiated metallic items including the control rods and the irradiated graphite core and its support structure. These components will be left in place for the care and maintenance phase of decommissioning for processing during final site clearance.
- Active effluent treatment plant comprises the CCP Sludge Retention Tanks (SRT), miscellaneous SRTs and CCP final delay tanks. The active effluent treatment plant is being replaced by the active effluent treatment facility comprising the modular active effluent treatment plant, replacement miscellaneous receiving tank and replacement delay tank.
- ILW Store, which is subject to commissioning activities, does not yet contain any ILW. It is planned for ILW waste currently held in SAWB and CPP to be immobilised in robust engineered containers and transferred to the ILW Store in future.

*Hinkley Point A*

175 The spent fuel storage ponds are empty of fuel and are currently being drained of water. The main hazard remaining on-site is solid and liquid ILWs contained in vaults and tanks in the

radioactive waste management facilities. It is planned that the site will enter into its care and maintenance phase by 2025.

176 The current inventory of radioactive waste on-site comprises:

- Both spent fuel storage ponds remain filled with water and contain a small amount of redundant equipment that was used in ponds operations, plus small amounts of sludge and other debris. The Reactor 1 pond contains six cartridges of material previously used to capture radioactive caesium from the pond water.
- Reactor 1 and Reactor 2 dry Magnox vaults contain 185m$^3$ and 175m$^3$ of solid radioactive waste, respectively, in the form of magnesium alloy components, which were removed from the fuel elements prior to shipping the fuel to Sellafield for further storage or reprocessing.
- Reactor 1 and Reactor 2 wet Magnox vaults contain 218m$^3$ and 230m$^3$ of waste, respectively, in the form of magnesium alloy components, which were removed from the fuel elements prior to shipping the fuel to Sellafield for further storage or reprocessing.
- Pond water treatment plant, active effluent treatment plant and sludge canning building contain eight settling tanks with approx. 180m$^3$ of wet ILW in the form of resin and sludge.
- Reactor storage voids and disposal tubes contain items of non-combustible metallic ILW arising from reactor operations.
- Active effluent treatment plant lower vault stores LLW and approx. 3m$^3$ of ILW awaiting disposal.
- Non-combustible Active Waste Store contains LLW and a small amount of ILW held in storage drums and other containers.

*Trawsfynydd*

177 The reactors are defuelled and no fuel remains on-site. The site is operating in an accelerated decommissioning mode before entry into its care and maintenance phase that will eventually lead to final site clearance. The ponds no longer contain fuel, are drained and in the process of being decommissioned.

178 The current inventory of radioactive waste[†] on-site comprises:

- Each of the two reactor buildings contains a spherical steel reactor pressure vessel containing the defuelled irradiated core and supporting structure. The buildings also contain the partly dismantled gas circuits, the miscellaneous activated components vaults and the Mortuary Holes. The miscellaneous activated components vaults have now been emptied. The Mortuary Holes contain redundant activated plant items which are intended to be stored there throughout the care and maintenance phase. Additionally, the Gas Circulator sub-basements have been converted to provide interim storage for packages of solid ILW encapsulated in grout and contained in standard Radioactive Waste Management Directorate (RWMD) approved containers within reinforced concrete overpacks. Approx. 61m$^3$ of conditioned radioactive waste is stored pending transfer to the ILW store, a small amount of miscellaneous contaminated items

[†] The waste held in facilities at Trawsfynydd currently listed as ILW and it is possible that some items may be reclassified to LLW during processing at site.

awaiting passivation and 4693$m^3$ of radioactive items (e.g. contents of Mortuary Holes, parts of reactor vessels and cores) that will be addressed during final site clearance.

- Main Active Waste Vaults contain approx. 26$m^3$ of some loose contaminated items and various packages and drums containing a variety of ILW and LLW.
- Magnox debris handling and storage facility contains approx. 38$m^3$ of compacted fuel element debris stored in drums.
- SRTs contain a small amount of sludge from the cooling ponds and the active effluent treatment plant, and approx. 67$m^3$ of radioactive residues in resin storage facilities.
- Pond north void is used for storage of a small amount of ILW.
- Magnox storage vaults contain approx. 19$m^3$ of porous concrete and 299$m^3$ of fuel element debris formed of pieces of Magnox cladding stripped from the irradiated fuel elements before they were despatched to Sellafield for reprocessing.
- Resin Plant and Drum Stores contain approx. 1304$m^3$ encapsulated waste stored in drums.
- ILW Store provides safe passive storage for all conditioned ILW (stored in RWMD approved storage containers) for the care and maintenance period until despatch off-site for long-term storage or disposal at a national repository. The ILW Store currently contains approx. 136$m^3$ of conditioned ILW packages in this new purpose-built concrete shielded store.

NNB GenCo – Hinkley Point C

179 The NPP to be built at the Hinkley Point C site is proposed to operate twin PWR units based on the EDF and AREVA EPR™ (referred to as UK EPR™), each rated at 4500$MW_{th}$, and is subject to Generic Design Assessment (GDA) by ONR. This assessment has, to date, resulted in the issue of an Interim Design Acceptance Certificate (IDAC) to EDF and AREVA. A final Design Acceptance Confirmation (DAC) is required prior to the start of nuclear safety-related construction at the site. The issue of a final DAC for UK EPR™ is dependent upon EDF and AREVA resolving a number of regulatory issues raised by ONR during the GDA process. Further information on ONR's GDA process and its assessment can be found at www.hse.gov.uk/newreactors/. Further detailed technical information on the UK EPR™ can be found at the same location, although a summary of the information relevant to the stress tests report is reproduced herein.

180 The UK EPR™ uses PWR technology based on the most recent French N4 and German KONVOI reactor designs. The UK EPR™ has been designed to meet the safety objectives for third generation reactors which include reduced core melt frequency, enhanced protection against external and internal hazards, and significant reduction in the radiological risk to the public should a severe accident occur. The reduced risk of a severe accident, such as a core melt event, is achieved by the implementation of quadruple redundant main safety systems, such as the Emergency Feedwater and Safety Injection Systems, and provision of diverse back-up systems which can be used in case of common cause failure of the redundant safety trains. Severe accident scenarios have been taken into account at the design stage, the objective being that only very limited off-site countermeasures would be needed in a severe accident.

181 In common with other PWRs, UK EPR™ uses two major systems to convert the heat generated by a fission chain reaction within the reactor core into electrical power. Heat from the fuel in the reactor core transfers by thermal conduction through the fuel cladding into the reactor coolant system (also referred to as the primary system). The reactor coolant is then pumped into the steam generator, which acts as a heat exchanger, where it flows through numerous tubes. The

heat is transferred through the walls of these tubes to the lower pressure coolant in the secondary system which evaporates to pressurised steam. This transfer of heat is accomplished without mixing of primary and secondary coolant.

182 The primary system is a closed water-filled pressurised system installed in a leak tight concrete enclosure referred to as the Reactor Building. This building comprises a reactor, namely a steel vessel containing the nuclear fuel (reactor core) and four cooling loops, each containing a reactor coolant pump and a steam generator.

183 The UK EPR™ is a light water moderated and cooled design that utilises low-enriched uranium fuel clad in zirconium alloy.

184 The ultimate heat sink is independent of the primary and secondary systems and cools the condenser by circulating river or seawater. The system proposed for Hinkley Point C NPP is an “open circuit” system drawing water from the Bristol Channel through two offshore intake tunnels and discharging through a common discharge tunnel. The intake water is filtered as it is drawn from each forebay into a pumping station which supplies the cooling water for a single unit. Once the cooling water for each unit has served its heat removal function it is piped to a discharge pond (one per unit). Each discharge pond is internally sub-divided for safety and non-safety systems. A diverse system provides an alternative means of supplying the heat sink safety systems with water drawn from the main basin of the discharge pond in the event of loss of the normal heat sink.

185 Storage of spent fuel is to be facilitated by the presence of a cooling pool situated in a dedicated Fuel Building which forms an integral structure with the Reactor Building. It is proposed that Hinkley Point C NPP is to include an Interim spent fuel storage (ISFS) facility to allow on-site storage of long-cooled fuel removed from the spent fuel pools. While the spent fuel pools provide storage capacity for approximately ten years, the ISFS is proposed to have the necessary storage capacity to cover the full 60-year operational lifetime of the plant. The design of the ISFS is conceptual at this stage.

### 1.1.2 Description of the Systems for Delivery of Main Safety Functions

Sellafield Ltd – Sellafield and Windscale

186 Nuclear facilities classically have systems and facilities to deliver three key safety functions: control, cooling, and containment. The same principal safety functions are delivered at the Sellafield site. However the extent to which they are required and the form they take varies from facility to facility depending on the operations being undertaken, the state and phase of the radiological hazard, the age of the plants and the progress of any decommissioning / remediation being undertaken. Also, control can be in the form of nuclear reactivity control or chemical reaction control, both of which in certain circumstances can lead to loss of containment.

*Reactivity Control*

187 Although there are no operating reactors at Sellafield (Calder Hall has been discussed separately, while the Windscale Piles and WAGR are undergoing decommissioning), reactivity control, in the form of the avoidance of criticality, is an important safety function at Sellafield.

188 Depending on the facility and the form of the hazard, sub-criticality is ensured where possible by passive means:

- Safe geometry (e.g. tank shape, small size vessels, can rack shape).
- Safe mass (e.g. limiting the size of vessels and cans).

- Spacing (e.g. distances between tanks or can racks).
- Amount of moderating material within / in the vicinity of any fissile material.

189 In some operations, additional engineered controls are necessary, often by engineered passive or automatic systems, but there are some facilities / operations that make claims on administrative controls.

190 Sellafield Ltd has explained that, in general, an on-site criticality cannot lead directly to an off-site dose to the defined "critical group" in excess of 5mSv. It does acknowledge that much higher on-site doses could occur which would place significant demands on-site emergency arrangements and significantly impede some recovery operations.

191 There is the potential for criticality to occur as a result of an extreme seismic event which subsequently results in a loss of array and spacing, or through moderator ingress (i.e. water) following a flood. This is an issue that is well known on the site, and there are active programmes in place to move stores of fissile material that are in older buildings to modern facilities specifically designed against these hazards.

192 Sellafield has reported that criticality associated with pond storage is not a significant issue as fuel should be retained within its storage containers during a seismic event (preserving geometry and reactivity controls). Assessments have shown that the criticality risks from the loss of pond water are not significant.

*Cooling*

193 Sufficient time has passed and decommissioning has progressed to such an extent for the heat transfer to an ultimate heat sink not to be relevant for the reactors undergoing decommissioning on the Sellafield site. However, there are a number of facilities on the Sellafield site which rely, because of the self-heating properties (i.e. decay heat) of the materials being handled, on some type of forced water / air cooling to prevent off-site releases of radioactive material.

194 Of most significance is highly active liquor within the High Activity Storage Tanks (HAST), which is cooled by in-situ cooling coils and jackets. In normal operation, the temperature of the liquor is controlled within a narrow temperature range such that it is too warm for crystallisation of Magnox feed liquors to occur but cool enough for steam ejectors (devices which use steam to create a low pressure zone to lift fluid) to effectively empty a HASTs when required. If temperatures are allowed to rise, first the ability of the ejectors to operate will be lost (within a few hours) and within 30+ hours the highly active liquor could boil in the most extreme heat loading.

195 The HASTs have three cooling water networks described as normal, guaranteed and emergency. The normal network is intended to provide all the cooling requirements of the HASTs (including keeping the highly active liquor temperature within normal operation range), while the requirement on the guaranteed supply is restricted to just the provision of cooling functions that are necessary for safe operation. Both supplies use water that is recirculated through cooling towers. The third (emergency) system can use water on a once through basis from a range of alternative sources and pumping systems. In its stress tests submission, Sellafield Ltd has discussed some of the alternative means of providing emergency cooling following a loss of power across the site, while also recognising a need to review the arrangements for providing these alternative sources of cooling water to the HASTs in extreme circumstances.

196 There are also seven fuel storage ponds on the Sellafield site; five ponds are operational and two ponds are non-operational legacy facilities which still contain fuel inventories. Sellafield Ltd has reported that four of the ponds have no requirement for active cooling due to either the low fuel

heat loading and / or very long (>20 years) cooled fuel inventories. The remaining three ponds have pumped cooling water circulation.

197 Through bounding calculations (assuming the inventory present in March 2011), Sellafield Ltd has demonstrated that it would take in the region of one to two weeks for the pond water to boil following a loss of cooling function in three ponds requiring active cooling (also assuming no initial loss of inventory from the lowest normally permitted water level). It would subsequently take a period of weeks for the water level to fall such that fuel is exposed (assuming no make-up water is provided to top up evaporation losses). From experience, the actual water temperature rises are expected to be in the region of 1°C per day. It is therefore Sellafield Ltd's expectation that, with the current fuel inventories, the water in none of the ponds will reach 100°C following a loss of active cooling.

198 On that basis, Sellafield Ltd has chosen not to discuss the requirement for active cooling of the ponds further. It has been recognised that fuel cooling could become an issue if there is significant loss of water from a breach in the pond floor or wall. In the latter case, attempts would be made to contain the breach and bund the area, allowing mobile pumps to return water to the pond. To that end, Sellafield Ltd has identified in its submission a number of ways to improve its ability to respond to pond leaks. These are discussed further in Section 2.

199 In addition to the provision of cooling to the bulk water inventory in fuel ponds, cooling water is required for Magnox fuel loaded in skips, flasks, and magazines. Without topping up, they would dry within a number of hours and the fuel could self-ignite. Exposed fuel in skips and / or undergoing decanning must be kept wet using installed water sprays within the inlet and decanning cells respectively.

200 The final notable requirement for cooling on the site is to the Product and Residue Stores which securely store the nuclear materials produced by the reprocessing facilities on the site. There are a number of such stores across the site of varying ages and designs. The product and residue cans within the stores could potentially burst due to over-pressurisation if cooling through these stores is lost. In the newer facilities, natural circulation provides sufficient cooling without the need for active systems. Some of the older storage facilities rely on forced cooling which could be lost in some circumstances. However, Sellafield Ltd has assessed the off-site consequences from burst cans to be low and therefore has not considered the cooling requirements of such stores further in its stress tests report.

*Containment*

201 At the most basic level, all radiological hazards at Sellafield are subject to containment. Depending on the nature and form of the radiological material, this may be by the vessel or pipe containing the material, a flask or a skip, a glove box, civil structures, sumps, bunding or filtered discharge route.

202 Unlike PWRs, the facilities at Sellafield are not built within a large, enveloping containment structure which would significantly reduce the consequences of a major accident. This is not required or practicable for a site like Sellafield. The more modern facilities, like THORP, are built with structures and ventilation systems which would significantly reduce any releases, either airborne or liquid. Such provisions are not installed in some of the older facilities. The most obvious examples of this are the open air ponds. However, these issues are recognised by Sellafield Ltd, NDA and ONR, and all are actively pursuing remediation and retrieval programmes to move stored nuclear materials to more modern facilities.

203 Hydrogen build-up and deflagration is a potential threat to the integrity of containment vessels (see below). However there are other chemical threats which could lead to vessel failures or misrouting of radioactive liquors. For example, some of the solvents used in reprocessing, acids,

or nitrate salts can react exothermically if heated, generating more heat and liberating gases in a self-accelerating process. These hazards are considered where appropriate in facility safety cases.

*Hydrogen Control*

204 In a number of facilities, hydrogen gas is produced by the products being handled or stored. Therefore, systems are in place to prevent explosive atmospheres forming by removing hydrogen, removing oxygen or adding inerting gas.

205 The consequences of explosions could be significant, both in terms of defeating the integrity of containment vessels retaining radiological hazards and by the disruptive impact to emergency arrangements responding to other events around the site during a site-wide emergency.

206 The approaches adopted to control potentially explosive atmospheres vary, depending on the facility and the process being undertaken. In the Magnox swarf storage silo, forced ventilation is relied upon to maintain a safe atmosphere. If centrally supplied AC power is lost to the fans, there is battery back-up for a short period of time. Once the batteries are depleted, alternative means of powering the fans needs to be instigated or another way of removing the explosive atmosphere is required. In other facilities, hydrogen can be removed by keeping ventilation routes open. However this often requires knowledge of liquid levels in tanks (usually via instrumentation using air) and the ability to remove excess quantities if levels are too high (such that ullages do not become isolated avoiding the risk of an explosive mixture forming).

Sellafield Ltd – Capenhurst

207 The low-hazard nature of the site does not drive any requirement for nuclear classified safety functions. The Sellafield Ltd Capenhurst site does not depend on off-site or on-site power supplies to achieve safe shutdown and / or maintain safety. The main safety function consideration is containment of uranium hexafluoride, provided by robust purpose-designed internationally approved transport cylinders and nuclear industry standards in plant design.

Urenco UK Ltd

208 There are no NPPs or spent reactor fuel on the UUK site. Consequently, only control of reactivity (to prevent criticality) and containment of radioactivity (to prevent $UF_6$ release) are relevant to UUK.

209 The safety systems that deliver the above safety functions are subject to engineering substantiation to demonstrate that the systems will deliver their safety function. The through-life ability of the safety systems to perform their safety function, as the plants age and improvement modifications are required, is reviewed through the PSR process. UUK plant safety cases consider design basis initiating events from internal sources and both natural and man-made external hazards, including seismic and extreme weather (including flooding). Safety measures to ensure seismic withstand are identified depending on the consequences.

210 Reactivity Control: Various systems are employed to ensure that the likelihood of criticality is minimized. The adequacy of the criticality safety systems are assessed and substantiated in UUK's safety cases. These typically include: robust and geometrically favourable plant, storage and containment design, design of plant and process to limit and control moderator and fissile mass, shielding to reduce radiation dose and detection and alarm systems to monitor any area where criticality could occur and prompt evacuation of the affected area in the unlikely event of a criticality. These engineered systems are supplemented with procedural controls that set strict limits and conditions on process parameters based on pessimistic assumptions.

211 Containment: The key safety systems to ensure containment of radioactivity are:

- Robust design and integrity of cylinders (designed to withstand significant drop and impact loads) and pipework systems.
- Provision of seismically qualified buildings and enrichment plant wherever reasonably practicable.
- Sub-atmospheric $UF_6$ processes employed wherever reasonably practicable (to ensure that in the event of damage to the enrichment plant air leaks into the process more readily that $UF_6$ leaks out).
- Provision of secondary containment.
- Fail safe valves, double valve isolation and pressure trips to isolate and shut down the enrichment process.
- Use of chemical absorber traps and filters to mitigate discharges.
- Use of traps and filters to mitigate discharges.
- Provision of ventilated areas and enclosures.

Dounreay Site Restoration Ltd

212 At Dounreay, reactivity control for materials removed from the DFR and PFR reactors into appropriate storage facilities does not require use of any active mechanisms. Sub-critical conditions for spent fuel storage are achieved using a combination of physical and managerial controls according to:

- Restriction of package mass limits.
- Configuration control for package storage.
- Specification of limits and conditions for materials relating to fissile mass, enrichment, moderator mass etc.

213 DSRL reports that the most irradiated sub-assembly on the site has been assessed to generate heat to the order of 210 Watts; as such there is no requirement for specific active or administrative safety measures to maintain a heat transfer route to an ultimate heat sink. The fuel cycle area of the site contains various inventories of spent fuel in solid and liquid form; shielding and containment provide the primary basis of safety. Certain operations require movement of beta-gamma emitting material for which active protection systems are in place, such as hardwired interlocks. ONR’s inspection programmes deliberately target higher hazard operations to secure confidence that active safety systems are subject to suitable and sufficient maintenance and associated outage arrangements. Other spent fuel facilities on the site contain alpha (long-lived isotope) bearing material that has the propensity to be mobilised. Filtered ventilation systems significantly reduce the potential for mobilised airborne release of contamination being released to atmosphere by capturing any mobilised particulate. Some facilities are currently in a quiescent state and waiting for post-operation clean-out (POCO) and subsequent dismantling. ONR will seek assurance that the licensee’s proposed decommissioning plans for those facilities reduce, so far as is reasonably practicable, the particulate challenge to those ventilation systems.

214 The national report for NPP stress tests described the nitrogen blankets employed in DFR and PFR to provide an inert atmosphere and hence inhibit the ignition of liquid metal coolant. The shaft and silo facilities at Dounreay have the potential to generate small amounts of hydrogen, but installed gas analysers provide DSRL with confidence that these quantities are insignificant. Inert gas supplies are installed and maintained to provide purge capability should it be needed.

215 DSRL's safety cases consider the impact of disruption to external electrical supply and upon failures with the on-site distribution. The licensee reports that a loss of electrical supply does not in itself constitute a radiological hazard; for those hazards to be realised coincidental faults or equipment failures would have to occur to provide the necessary driving force for material to leave containment. The licensee describes its philosophy for response to a loss of electrical supply to be the evacuation of non-essential personnel from affected buildings and the cessation of operations. The licensee indicates this to affect business continuity as opposed to presenting an explicit challenge to worker or public safety. The licensee substantiates this claim on the basis that active safety systems do not have any dependency on the site electrical distribution system in order to fulfil their intended safety function. Standby electrical supplies provide back-up capability in the form of guaranteed non-interruptible systems for loads that cannot tolerate an interruption, but DSRL explains that there is no reliance on these systems to sustain the basis of nuclear safety. This position is considered further in Section 5.

Springfields Fuels Ltd

216 SFL indicates in its stress tests report that criticality safety at Springfields is guaranteed by both specific containment (safe geometric configurations) and exclusion of hydrogen bearing materials (moderator), principally water. Loss of containment and / or introduction of moderator from, for example, flooding is considered by SFL in its safety assessments.

217 SFL has indicated that containment of uranium hexafluoride is achieved in robust purpose-designed process containment vessels and internationally approved transport cylinders.

Imperial College of Science, Technology and Medicine

218 The CONSORT reactor is a relatively simple design. The reactor control system is a hard-wired system with no programmable logic. Core reactivity is controlled by stainless steel clad cadmium rods. Independent primary and secondary trip mechanisms initiate in a fault condition to allow the control rods to drop into the core under gravitational force; loss of external power will therefore result in a reactor trip. The 100kW thermal heat load leads to a steady state ten-degree temperature rise in the surrounding heat sink; accordingly no active cooling safety system is required.

Studsvik UK Ltd

219 Due to its very low nuclear hazard profile, the Studsvik site does not identify or require any safety functions in relation to the stress tests initiators or loss of power.

Low Level Waste Repository Ltd

220 The LLWR stress tests do not identify any safety function provisions in relation to the stress tests initiators or loss of power. The site does not depend on off-site or on-site power supplies or other services to achieve safe shutdown and / or maintain safety in the immediate or medium term (several days). From the nature of the hazards and operations at LLWR, it can be inferred that the main safety function is associated with containment of the LLW provided by the grouted containers and vaults.

Research Site Restoration Ltd

221 Principal hazards associated with decommissioning operations at Harwell, classified by RSRL's safety cases as having the potential to lead to a design basis accident, include:

- Hydrogen deflagration.
- Fire leading to off-site aerial release.

- Flask damage, loss of containment and subsequent fire.
- Dropped loads.

222 The licensee reports that for those faults listed above, suitable preventative and protective safety measures are identified by the safety case. RSRL identifies the complete loss of ventilation to an encapsulation facility (currently under construction) to represent the most significant design basis accident associated with a loss of service. This scenario has the potential to lead to hydrogen deflagration should ventilation not be restored, and subsequent off-site release. RSRL refers to the availability of an uninterruptible power supply to provide sufficient battery-backed power to facilitate the start-up of a diesel generator. This power supply initiates a secondary air injection system to sustain ventilation for 12 hours. RSRL indicates there is substantial margin (greater than 30 hours) afforded by very low rates of hydrogen accumulation to provide ample time to halt grouting operations (and therefore arrest further hydrogen production).

223 RSRL refers to one external event that could lead to consequences off-site of a dose of 15mSv in a seismic event; the licensee’s analysis assumes that the subsequent building collapse leads to release of the entire building inventory of solid ILW. This scenario constitutes the basis for meeting requirement for having an off-site plan in accordance with REPPIR. ONR considers that the worst-case conservative approach taken by RSRL to give an inconceivably high off-site release estimate since no “best-estimate” account is taken for the capability of existing containment and building fabric to offer at least some physical barrier. ONR has advised the licensee to undertake a review of this analysis, particularly against the context of diminishing inventory and therefore hazard posed by the site over the next ten years. Accordingly, ONR has not applied the detailed structure according to NPP requirements to RSRL sites, but has provided a proportionate assessment in Section 7 created for the lowest hazard sites.

GE Healthcare Ltd

224 The low-hazard nature of both GE Healthcare sites means there is no requirement for nuclear classified safety functions to maintain and sustain safety. The main safety function consideration is containment associated with waste storage and management. This safety function is provided by nuclear industry standard containment for ILW waste, consisting of “packages within packages” held in sealed stainless steel drums or within small concrete shielded trenches / vaults. The site does not depend on off-site or on-site power supplies or other services to achieve safe shutdown and / or maintain safety in the immediate or medium term (several days).

Atomic Weapons Establishment

225 Operations at AWE are undertaken on a batch production basis, almost wholly during standard daytime working hours with nuclear production materials stored securely over night within the nuclear facilities. Nuclear materials within the facilities are handled mainly in gloveboxes and can remain in a quiescent state for months at a time. There are no bulk quantities of highly active liquors, irradiated reactor fuel or large quantities of high level waste stored on-site. AWE explains that the majority of operations involve little or no stored energy that could disperse radioactive material off-site.

226 AWE considers that, of the three severe accident management issues considered in the NPP stress tests, only the “means to protect from and to manage the loss of containment integrity” is relevant to its sites. The AWE stress tests response does not therefore consider the severe accident management issues associated with the means to protect from and to manage the loss of cooling function, or the loss of cooling function in the fuel storage pool.

227 For most operations, glove boxes and their associated heating, ventilation and air conditioning (HVAC) systems provide the primary means of containment. One exception is a high-hazard

facility that includes civil structures that contribute to the containment safety function. For the waste stores the waste drums perform the containment safety function.

Rolls-Royce Marine Power Operations Ltd

228 RRMPOL reports that in the Neptune reactor, the main structures systems and components important to safety are:

- Fuel cladding to prevent the loss of fission products.
- Control rods for reactivity control.
- Reactor shutdown (trip), which is affected by dumping the moderator (water), although reactor shutdown can also be affected by control rod trip, even with the moderator present.
- The reactor hall, which acts as a containment structure.

229 The ventilation / filtration system also provides a contamination control function.

230 On the manufacturing site, inadvertent criticality is guarded against by :

- Careful control of fissile and moderating materials.
- Use of fixed neutron poisons and use of geometrically safe vessels.

231 Loss of containment of radioactive material is guarded against by:

- Containment systems, such as glove boxes and ventilation / filtration systems.

BAE Systems Marine Ltd

232 BAESM reports that for the radioactive component facility, the single fundamental safety function is control of criticality. The safety measures are the retention of control rods and the exclusion of a moderator. BAESM identifies the key SSCs for this facility to be the roof structure, the control rods and the control rod restraints.

233 In the DDH, the two fundamental safety functions are:

- Control of criticality (until the moderator is introduced).
- Control of reactivity (after the moderator is introduced).

234 The key safety measures are the retention of control rods and the exclusion of a moderator. The relevant key SSCs which deliver these fundamental safety functions are:

- The electric overhead travelling (EOT) crane and its supporting structure and lifting equipments (including slings).
- The DDH and its substructure.
- The submarine cradles.
- The control rods and engineered retaining features.

235 For the shiplift and transfer system the fundamental safety function is control of reactivity which is delivered by the robust design of the EOT crane, the cradles which support the submarine, the transfer system and the ship lift structure. The control rod locking mechanisms are also in use.

236 At WDQ, where operations at criticality take place in the submarine, while there remains the requirement to control reactivity, there is also a need to provide containment of fission products and core cooling. While the operations involve new fuel, there will be a small amount of fission

products generated in the fuel from these critical operations. The structures and systems that will prevent the release of fission products are:

- The fuel cladding.
- The integrity of the welded primary circuit.
- Containment boundaries built in to the submarine structure and pressure hull.
- Automatic protection systems to isolate systems which penetrate containment boundaries.

237 During the short periods of critical reactor operation at WDQ, the submarine and reactor systems are fully available in their operational (seagoing) state and the NRP is designed to be entirely self-sufficient without the need of support shore services. However, such services as electrical supplies are provided as additional defence-in-depth.

Devonport Royal Dockyard Ltd

238 The four main critical safety functions considered on the Devonport licensed site are:

- Control of core temperature.
- Control of reactivity.
- Control of radiation exposure.
- Control of radioactive material.

239 To control reactivity in the docks, control rods are inserted fully into the core and can be locked into place by various engineered means. Also, during defuelling, refuelling and long-term berthing preparations, an additional safeguard of boron (which absorbs neutrons) is provided of sufficient quantities to ensure a safe shutdown margin, even if all control rods were to be fully withdrawn. Additional assurance is provided by monitoring of the neutron flux levels during safety-critical activities. In the LLRF, sub-criticality is ensured by separation and structural boron which provides reactivity suppression.

240 To control core temperature, diverse means of decay heat removal provision are provided by the engineered systems of the NRP itself. When in dock, some of these systems may be released for maintenance, but only when the decay heat has fallen to a sufficiently low level that there is no longer any dependence upon them. In addition, the docks have several additional engineered routes for decay heat removal.

241 In the unlikely event of fuel damage the reactor pressure vessel and primary containment structure are shielded with a number of materials that would significantly attenuate any radiation hazard.

242 To prevent releases of radioactive material there are four main barriers to fission product release:

- The submarine reactor fuel is stable and encased in a high integrity cladding.
- The high integrity reactor pressure vessel and fully welded primary circuit.
- The primary containment structure of the reactor.
- The secondary containment structure (the pressure hull of the whole submarine).

Rosyth Royal Dockyard Ltd

243 RRDL explains that the main issue for this facility is loss of containment of the radioactive waste. This containment is delivered by purpose-built robust waste containers, housing waste in a

passive form, therefore very little reliance is made on other structures systems or components to deliver safety. While the storage facility does have power supplies to support handling operations, no dependency is placed upon them for ensuring safety. Battery back-up supplies provide defence-in-depth support to passive monitoring, for reassurance purposes.

Magnox Ltd – Defuelled reactors

244 This section highlights the role performed by systems and on-site facilities that are relevant to the following safety functions: reactivity control, cooling and containment. Additionally, measures for severe accident management are also briefly described.

*Reactivity control*

245 The reactors at each of the sites operated by Magnox Ltd have been permanently shut down and fully defuelled as indicated in Table 2. The control rods are fully inserted and their drive motors and mechanisms disabled. It is therefore considered that there is no potential for criticality and no requirement to control reactivity in their reactor cores.

246 In addition, while there are small quantities of fissile material (irradiated fuel swarf, defuelled cladding) present in the ILW stored on sites, criticality studies conducted by the licensee have concluded that there is now insufficient fissile material on their sites for criticality to be possible in any configuration.

*Cooling*

247 There is no fuel present in any of the reactors at Magnox Ltd's defuelled reactor sites and consequently there is no significant source of heat generation present on-site. It is therefore considered unnecessary for facilities to be available for heat transfer from the defuelled reactors to a heat sink.

248 Also, there is no fuel present in the spent fuel ponds and therefore no heat-generating source is present. It is therefore considered unnecessary for facilities to be available for heat transfer from the spent fuel storage ponds.

249 At the Hunterston A site, the CCP no longer contains fuel apart from two recently discovered part elements and the storage of these items is covered by the current safety case. It is planned that these part elements will remain in safe storage prior to being removed from the site in early 2012. The temperature of the water in the CPP follows ambient temperature conditions which supports the licensee's conclusion that no heat transfer capability is required.

*Containment*

250 When operational the Magnox reactors at each of the defuelled sites did not have a containment building around their steel reactor pressure vessel, which was considered to provide reactor containment. This spherical mild steel vessel was enclosed within a concrete reactor vault that provided a biological shield. The first generation Magnox reactors at all of the defuelled reactor sites that utilised steel pressure vessels are now permanently shut down and depressurised.

*Accident management*

251 Arrangements have been produced for the management of emergencies on the Magnox Ltd defuelled reactor sites. At each site, the emergency plan or Handbook is a document containing the site emergency arrangements and the arrangements for collaboration with external organisations, including regulators, emergency services, local government and central government. The on-site arrangements allow for the establishment of an Emergency Control Centre (ECC) staffed by at least an Emergency Controller, an Emergency Administration Officer, an Emergency Health Physicist, an Emergency Technical Officer and an Emergency

Communications Officer. In addition an Access Control Point (ACP) and a site response team are established. Members of these teams are on an emergency call-out rota using a telephone voicemail system based upon a standalone off-site server. Additional telecommunications can be made independently through BT or mobile networks.

NNB GenCo – Hinkley Point C

252 This section highlights the role that is proposed to be performed by systems and on-site facilities that are relevant to the following safety functions: reactivity control, post-trip cooling, and containment. Additionally, measures for severe accident management and spent fuel storage are also briefly described.

*Reactivity control*

253 Operational reactivity control is achieved by adjustment of soluble Boron concentration in the primary coolant and the use of burnable poisons within fuel assemblies. Shutdown in the event of a reactor trip is to be provided by 89 rod cluster control assemblies that are intended to fall under gravity into the core to shut the primary nuclear reaction down.

254 The design of the UK EPR™ also has provision for an Extra Boration System (EBS) as a diverse means of long-term reactivity control. The EBS is to comprise two fully independent trains, which can inject a boric acid solution into two primary circuit cold legs to ensure, so far as is practicable, a uniform distribution of boron in the core. The EBS and its associated tanks are to be located inside the Fuel Building.

255 Additionally, the UK EPR™ design includes a Safety Injection System (SIS) that is intended to inject borated water from an In-containment Refuelling Water Storage Tank (IRWST) into the primary cooling system to control core reactivity.

*Post-trip cooling*

256 The normal heat removal route from the reactor core is intended to be via the four main steam generators. The heat carried by the coolant in the primary circuit is transferred to the water of the secondary circuit through the walls of the tube bundles in the steam generators, which act as a heat exchanger. The steam generators are fed with water from the main feedwater system.

257 The UK EPR™ design includes a number of systems that contribute to safety functions associated with post-trip cooling functions in order to transfer heat from the NPP to the ultimate heat sink.

*Reactor cooling*

258 Prior to the establishment of the UK EPR™ residual heat removal system under start-up and post-trip operation, feedwater to the steam generators is provided from the start-up and shut down feedwater system. The main feedwater system and the start-up and shut-down feedwater system are supplied with water by two duty pumps and a standby that are connected to the plants non-essential 10kV electrical distribution system.

259 The Emergency FeedWater System (EFWS) provides feed water for the steam generators in circumstances when the main feedwater system and the start-up and shut-down feedwater system are unavailable. EFWS removes residual heat through the atmospheric relief system or the main steam safety valves to allow the reactor to achieve a safe shut-down state. EFWS comprises four identical trains located in relevant Safeguard Buildings and the Reactor Building, which are supplied by four independent electrical divisions that are appropriately segregated to minimise the potential for common cause faults.

260 The UK EPR™ design includes SIS that comprises four separate trains (i.e. one per each primary circuit cooling loop), which are located in the four safety divisions. Each SIS train consists of the

Medium Head Safety Injection (MHSI) system, the accumulator injection system, the Low Head Safety Injection (LHSI) system, a MHSI / LHSI shared suction line from the IRWST and the suction line from the Reactor Coolant System (RCS) hot leg.

261 The Residual Heat Removal System (RHRS) uses the LHSI pumps to circulate water through the core via a connection to the cold leg of each RCS cooling loop. After flowing up through the core the coolant is returned to the RHRS via a connection on the hot leg of each RCS cooling loop. The primary coolant is then cooled using an associated heat exchanger.

262 A further means for decay heat removal from the core under severe accident conditions is achieved by operating in a "bleed and feed" mode where the MHSI pumps provide makeup to the RCS and discharge through the pressuriser discharge line. The IRWST is simultaneously cooled by the SIS / RHRS heat exchangers. The Component Cooling Water System (CCWS) provides cooling for the SIS / RHRS pumps and heat exchangers.

263 Rejection of heat from the plant to the ultimate heat sink is to be achieved by two cooling systems, namely the Essential SeaWater System (ESWS) and the Ultimate Cooling Water System (UCWS). The safety function of ESWS, which comprises four segregated trains configured as two pairs, is to cool the four CCWS trains. The electrical supply to ESWS is to be backed-up by the NPPs main EDGs.

264 UCWS comprises two trains that are used in a stand-by mode to cool the Containment Heat Removal System (CHRS) through an intermediate heat exchanger in severe accident scenarios. An exception to this is the use of single train of CHRS as a preventive measure to provide cooling for relevant aspects of the Fuel Pond Cooling System (FPCS) during maintenance activities. The electrical supply to UCWS is to be backed-up by the NPPs main emergency and SBO diesel generators.

265 It is proposed that the ultimate heat sink for both UK EPR™ units at Hinkley Point C NPP will be provided by a once-through open circuit system that is to draw water through two offshore intake tunnels. This intake water is to be filtered as it is drawn into dedicated pumping stations that supply cooling water for each unit, respectively. The ultimate heat sink is intended to cool the ECWS and UCWS that perform the safety functions described above.

*Spent fuel pond cooling*

266 The FPCS is intended to be a three-train system that performs heat transfer from the spent fuel ponds to the ultimate heat sink. The FPCS cooling trains are supplied from independent electrical systems, which are backed-up by the NPPs main EDGs. The third FPCS train is also backed-up by the SBO diesel generator while the NPP operates in specified states, such as "reactor core unloaded to the spent fuel pond".

267 The FPCS is designed to operate in various modes from the first time that spent fuel assemblies are unloaded from a reactor for as long as they are stored in the ponds. A single FPCS main cooling train with a single pump operates continuously with a second train and pump as back-up. The third FPCS train is configured to start when scheduled non-availability of a main cooling train occurs for maintenance.

268 During unit shutdown the two main FPCS trains operate continuously from the start of reactor unloading to the end of reloading. These trains can be configured to operate temporarily after reloading to maintain the temperature of the spent fuel pond to less than 50°C. The third FPCS train does not operate but remains available for use.

269 Total loss of the FPCS is mitigated by the use of other make-up systems (e.g. IRWST via the pool purification system and reactor boron and water make-up system) to provide defence-in-depth against loss of water by boiling or evaporation. The use of these systems is supported by the

results of a fault analysis carried out by EDF and AREVA that indicates fuel pond boiling is not expected to occur for four hours in the absence of any cooling during refuelling operations when the reactor core is unloaded to the spent fuel pond.

*Containment cooling*

270 In normal operation heat transfer from the reactor containment building is intended to be achieved by the containment cooling ventilation system, which transfers heat to the ultimate heat sink via CCWS and ESWS. It has been designed to handle the normal heat loads of an operational UK EPR™.

271 In severe accident conditions heat removal (also pressure control) inside the reactor containment building is achieved by the CHRS. The CHRS is to comprise two trains and an intermediate cooling train that can be configured to perform a number of safety functions to reduce temperature and pressure. The CHRS has an emergency power supply backed-up by the SBO diesel generators.

*Containment*

272 In common with other PWRs, the UK EPR™ employs a concept of barriers to protect against the release of radioactive materials and the environment. Three barriers are to be used: fuel cladding, reactor coolant pressure boundary and the containment building.

273 The UK EPR™ reactor is to be housed within a containment building which limits the release of radioactivity should a beyond design basis fault occur. This is a large structure made of pre-stressed concrete which is able to withstand substantial overpressure. In the containment building heat is removed and pressure reduced by fan coolers and reactor building spray systems as outlined above.

274 A severe accident that results in a core melt condition followed by a breach of the reactor pressure vessel at the UK EPR™ is to be mitigated by means of a corium spreading and cooling area in the basement of the Reactor Building.

275 In addition, for severe accident conditions the UK EPR™ design is to incorporate pressure relief valves in the primary coolant circuit that are dedicated to preventing high pressure core melt and a combustible gas control system based on passive auto-catalytic recombiners to limit loads on the containment structure in the event of hydrogen combustion.

*Severe accident management*

276 The procedures and processes for severe accident management at Hinkley Point C NPP are to be developed in line with those used by EDF NGL at operational NPPs in the UK, which have clear responsibilities and accountabilities highlighting the specific roles assigned to manage and implement the emergency arrangements.

277 Further information on the development of severe accident management arrangements for the UK EPR™ units at Hinkley Point C is provided in Section 6 of this report.

## 1.2 Significant Differences Between Units

278 The NPP specification, which was designed with civil power generation reactors in mind, asks for a description of the significant differences in reactor units at this point of the analysis. Clearly, this is not appropriate in this report because most of the sites contain facilities which are disparate. Where it might be relevant, some of the main facilities are however described below.

Sellafield Ltd – Sellafield and Windscale

279 The Sellafield site undertakes a range of operations. While some facilities on the site were designed to perform the same operation, typically they were built at different times and to different designs and standards. Many of the older facilities are now at varying stages of decommissioning. Therefore, there are very few “units” of the same design on the site. In addition, the complex and compact nature of the site means that each facility is confronted by unique challenges from its neighbouring facilities.

280 The four Calder Hall reactor units are essentially identical. However these are beyond the scope of this report having been discussed in ONR’s National Stress Tests Final Report for UK NPPs (Ref. 10). The Windscale Piles were originally similar; however, they are now decommissioned to different extents, with unique challenges in Pile 1 following the fire in 1957.

281 In its response, Sellafield Ltd has identified the contrasting and sometimes similar essential safety functions that are required for safe operation at a selected group of significant facilities.

Magnox Ltd – Defuelled reactors

282 There are no significant differences, with the exception of Hunterston A site (see Section 1.1.1), between the defuelled Magnox reactors at the Magnox Ltd defuelled reactor sites. There are, however, differences in the stages of decommissioning reached to date at each site.

283 Notwithstanding this, the defuelled reactor sites at Hinkley Point A and Hunterston A are located adjacent to licensed sites at Hinkley Point B and Hunterston B, respectively, which contain operational NPPs that use AGR technology. The licensee for these sites, namely EDF NGL, has provided EU stress tests reports for each NPP that describes the AGR technology used at each plant, respectively, which were considered as part of ONR’s National Stress Tests Final Report for UK NPPs (Ref. 10).

NNB GenCo – Hinkley Point C

284 There are no significant differences in the design of UK EPR™ reactor units intended for use at the future Hinkley Point C NPP.

285 The Hinkley Point site contains two other power plants, namely Hinkley Point A defuelled reactor site operated by Magnox Ltd (licensee) and Hinkley Point B NPP operated by EDF NGL (licensee). The Hinkley Point A defuelled Magnox reactor is permanently shut-down and an EU stress tests report has been provided by Magnox Ltd for ONR’s assessment as part of this National Final Report for UK NPGNF. The Hinkley Point B NPP uses AGR technology and EDF NGL has provided an EU stress tests report that was considered as part of ONR’s National Stress Tests Final Report for UK NPPs (Ref. 10).

Lowest hazard sites

286 Reflecting its proportional approach, ONR has categorised the following nuclear licensed sites as ”lowest hazard”:

- Sellafield Ltd – Capenhurst
- Imperial College of Science Technology and Medicine (Ascot Campus)
- Research Sites Restoration Ltd (Harwell and Winfrith)
- Low Level Waste Repository Ltd (Drigg)
- GE Healthcare Ltd (Amersham and Cardiff – the Harwell site is awaiting delicensing in 2012 so is excluded from further consideration here)

- Studsvik UK Ltd (Metal Recycling Facility, Cumbria)

287 This approach recognises their respective radioactive inventories are not capable of producing accident or severe accident scenarios capable of giving any significant off-site consequence[‡]. These sites do not therefore meet the requirement under REPPIR to have an off-site emergency plan. Many of the ENSREG stress tests specifications relate to NPP sites. ONR therefore accepts that a proportionate and tailored response to the stress tests is appropriate for the UK lowest hazard NPGNF sites, which is what has been provided by those licensees who operate these sites. ONR's conclusion of the stress tests produced for the sites is also proportionately based and presented collectively in Section 7 as opposed to explicit consideration in Sections 2–6. These sites are hereafter referred to as 'Lowest hazard' for the remainder of Section 1.

## 1.3 Use of PSA as Part of the Safety Assessment

Sellafield Ltd – Sellafield and Windscale

288 The spectrum of operations being undertaken at Sellafield by facilities of different ages and with different hazards means that the form and scope of PSA undertaken as part of the safety cases prepared for the various facilities across the Sellafield site differs from that produced for NPP facilities. The distribution of hazards across the large site also adds a level of complexity that may not be present in e.g. reactor sites where hazards are localised in a handful of specific locations.

289 However, in its response to the stress tests questions, Sellafield Ltd has explained the role numerical analyses have played in safety cases, across the site, as a means of demonstrating, against radiological risk criteria, the safety of non-reactor nuclear plant. While the approaches have changed over the years, a combination of design basis and probabilistic analysis is still required to demonstrate that deterministic and risk criteria are met.

Urenco UK Ltd

290 PSA in line with industry good practice is being undertaken for the latest UUK safety cases as they are updated in line with the latest methodology in the UUK Safety Assessment Handbook. More limited PSA has been undertaken in some older UUK safety cases: the general approach being to quantitatively assess those faults that have not been screened out on very low consequence grounds to determine the need for safety systems and any further improvements to meet ALARP requirements. Design basis accident analysis is the primary assessment tool for considering both internal and external fault conditions and identifying necessary safety systems to prevent and / or mitigate the effects of these. A site-wide PSA will be considered once UUK has updated its safety cases in line with its latest methodology. Natural external hazards are subject to design basis accident analysis and ALARP review only. If the design basis accident analysis criteria cannot be met for new plants then consideration is given to undertaking PSA.

Dounreay Site Restoration Ltd

291 The DSRL response to the NPP stress tests reports that all of its facilities with the potential to cause an off-site hazard at the Dounreay defuelling site are all subject to modern standard safety

[‡] The Harwell site, operated by RSRL, is an exception here because the current off-site plan under REPPIR is predicated on a 15mSv reference accident. However, ONR has considered in Section 7 of this report that the licensee's approach to calculating consequence is based on disproportionate conservatism as opposed to good practice approach of "best-estimate" analysis. ONR therefore considers that Harwell should be conveniently categorised as a 'Lowest Hazard' site.

cases (operational or decommissioning as appropriate). DSRL's modern standards safety cases use a combination of quantitative and qualitative techniques to determine a facility's safe operating envelope. The combination of probabilistic hazard assessment processes with engineering substantiation (engineering review) of the as-built facilities enables suitable and sufficient hazard control and risk reduction measures to be identified, designated and verified. All of DSRL's facility safety cases are subject to PSR.

Springfields Fuels Ltd

292 While not explicitly stated in SFL's report, the licensee adopts modern standards safety case techniques that have evolved into a fit-for-purpose framework for the site, following its transition in ownership from BNFL to Westinghouse. The combination of probabilistic hazard assessment processes with engineering substantiation (engineering review) of the as-built facilities enables suitable and sufficient hazard control and risk reduction measures to be identified, designated and verified. All of SFL's facility safety cases are subject to PSR.

Atomic Weapons Establishment

293 AWE has provided summary information on its Probabilistic Safety Assessment, which it compares to the HSE Safety Assessment Principles Targets 5 and 7 for individual risks of death from accidents to persons on-site and off-site, respectively. On the basis of its assessment, AWE describes that for workers the risk of premature death from all facilities is below the Basic Safety Level (BSL) of Target 5, whereas the risk to the most exposed member of the public is below the Basic Safety Objective (BSO) of Target 7. AWE has also provided the contributions from the high-hazard facilities.

Rolls-Royce Marine Power Operations Ltd

294 RRMPOL's submissions do not provide any discussion of its use of PSA in safety assessments.

BAE Systems Marine Ltd

295 BAESM states that its safety cases include the results of PSAs which show that the radiological risk presented by the site is tolerable (as shown by compliance with relevant SAP targets). All activities, from receipt of fuel on-site up to its departure with the submarine, have been subject to the production and assessment of safety cases to modern standards. This includes a combination of quantitative and qualitative techniques to determine the safe operating envelope.

Devonport Royal Dockyard Ltd

296 DRDL reports that all the major facilities on the Devonport licensed site are covered by a PSA and include: the docks containing a submarine with a shut-down NRP spent fuel storage facilities and the transfer route. The older PSAs combine conditional risk information derived from the various submarine Class PSAs with facility specific initiating event frequencies and reliability information.

297 The submarine Class PSAs are provided by the MoD, as the design authority and operator of the NRP with Rolls-Royce as the NRP technical authority producing the PSAs. The more recent DRDL PSAs provide Level 1 (core damage frequency) and Level 2 (release frequency) information and present integrated assessments for the submarine plant and site facilities. DRDL presents a numerical summary of the individual risk to site workers and the public, and the frequency of large releases. This shows that individual risks from all facilities are below the BSL for both workers and the most exposed member of the public.

Rosyth Royal Dockyard Ltd

298 In its submission, RRDL does not provide any information on its use of PSA in safety assessments. This is a reflection of the very low radiological hazard that the site poses.

Magnox Ltd – Defuelled reactors

299 Since operation has ceased additional PSA studies have been completed for some of the defuelled Magnox reactors. These considered the most serious remaining hazards from the reactors, ponds and radioactive waste facilities. However, given that fuel has been removed from the reactors, these studies identified no significant risk to the public.

NNB GenCo – Hinkley Point C

300 A PSA model based upon the GDA Pre-construction Safety Report (PCSR) has been produced that combines Level 1 and Level 2 analyses. Level 3 PSA analysis is performed separately based upon the outputs obtained from the Level 1 and Level 2 PSA model. The current GDA PSA model contains many of the prevalent internal events and a limited number of hazards.

301 The scope of the current model is limited to the Reactor Building of a single reactor site. However, future updates of the model will include the Interim Spent Fuel Store and the Intermediate Level Waste Store. Further updates to the model will include the incorporation of additional hazards not currently considered in the GDA model. Consideration of the impact of a seismic hazard will be included, along with the impact of snow and wind.

302 The results obtained from the current GDA-based PSA model are below all numerical targets set by the ONR’s SAPs. The PSA model will be used to risk inform the design, exploring the impact of significant modifications to the design on the results and insight obtained from the PSA model.

Lowest hazard sites

303 The lowest hazard sites do not require safety case processes to the scale and breadth commensurate with larger NPGNF sites.

304 Each of the lowest hazard sites has taken a predominantly qualitative deterministic approach to the assessment and evaluation of the safety of its sites, and when considering the impact of the stress tests initiators and scenarios i.e. seismic, flooding, extreme weather and loss of power. ONR considers this to be a proportionate and satisfactory approach for sites with low radiological inventories, relatively straightforward operations and the inability to cause significant off-site consequences. It is noted that some licensees do, however, choose to use quantitative hazard analysis for both internal and external events to inform their safety decision making. Seismic, flooding and extreme weather risks in the UK around nuclear licensed sites are considered within the licensees’ safety cases for the installations on the sites. ONR gains confidence in the acceptability of the approaches taken to safety assessment by licensees through its assessment of the Hazard Identification and Risk Evaluation (HIRE) assessments submitted to ONR under REPPIR, assessment of licensees’ safety cases and arrangements for producing them made under the requirements of the nuclear site licence conditions.

## 1.4 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

*Site Characteristics*

305 The information provided by Sellafield Ltd on the main characteristics of Sellafield site has been found to be complete and accurate during ONR's review. It is recognised that it is a complex and diverse site and therefore the licensee has had to be selective and concise with its descriptions. The supplied information has been used with other data available to ONR to develop the descriptions of the nuclear facilities provided in this report.

*Description of the Systems for Delivery of Main Safety Functions*

306 ONR's review concluded that the descriptions provided by Sellafield Ltd of the main systems that implement and / or support the main safety functions are accurate and are complemented by additional information provided elsewhere in its submission. It is recognised that there are many facilities on-site, each with its own design intent, and each with different essential functions to be delivered to operate safely. It would not have been proportionate for Sellafield Ltd to describe every safety system on every facility, and therefore its approach is considered sensible.

307 On the basis of the arguments put forward in Section 1.1.2 above, Sellafield Ltd has chosen not to discuss criticality further in its stress tests response. However, given that criticality events (potentially ongoing and not one-off occurrences) are conceivable in some specific facilities coincident with other site-wide challenges following e.g. a seismic event, ONR has raised the following finding:

**STF-21: Sellafield Ltd should consider further and provide more details on how emergency arrangements to deal with a site-wide extreme event would anticipate and adapt to challenging criticality events.**

308 ONR welcomes the Sellafield report's inclusion of a *Consideration* to review the robustness of alternative means of cooling self heating materials (including the HASTs) under severe conditions, noting that Sellafield Ltd does not intend to limit its response to just responsibilities / training of personnel and the fitness for purpose of equipment. Through the actions undertaken in relation to this and other *Considerations* (or through the response to the complementary Recommendation IR-19 (Ref. 2)), it is expected that Sellafield Ltd will demonstrate the sustainability of emergency cooling in terms of water stocks (in addition to the initial establishment), fuel stocks and tolerance to equipment failures. ONR will continue to monitor and challenge Sellafield Ltd to implement these workstreams.

309 Sellafield Ltd has concluded that with the current heat loadings (as of March 2011), none of the fuel ponds are likely to reach boiling in the first seven days following a loss of heat sink (assuming no loss of water inventory) and therefore both in the stress tests report and in real emergency planning, effort can be prioritised elsewhere. While it is reassuring to know that the ponds could probably be left safely without active intervention for a prolonged period of time following many foreseeable site-wide emergencies, the accident at Fukushima highlighted the value (to both emergency responders on the site and to international observers on the other side of the world) of basic information on the status of ponds. ONR welcomes the need identified in Sellafield Ltd's submission to look at the key plant parameters retained in the SECC, including pond temperatures and levels. However, even if temperatures did not reach boiling, the habitability of the areas in the vicinity of the ponds could be "difficult" for visual inspections and subsequent recovery operations. Strengthened or additional means of determining basic parameters, such as pond temperature and water level, have been identified by ONR as an area for improvement

following the events at Fukushima through HM Chief Inspector's Recommendation IR-22 (Ref. 2), and specifically with respect to the Sellafield site, the following finding is raised in this report:

**STF-22: Sellafield Ltd should establish if there is anything reasonably practicable that can be done to provide / strengthen the provision of basic plant information (e.g. inventory level and temperature) during / following an extreme event on-site affecting high-hazard / high risk facilities.**

310 While the conclusion reached on the likelihood of pond water boiling (with the current heat loadings) is accepted, it is ONR's view that Sellafield Ltd could have said more in its submission about the initial robustness and flexibility of the active fuel pond cooling systems, and then the ability to restore some cooling to normalise pond temperatures and local conditions after a period of disruption. This has been raised as part of ONR's assessment of Sellafield Ltd's submission, and the licensee's response has been useful in expanding the informal report.

311 Hydrogen explosions played a significant part in the Fukushima accident. ONR recognises that issues associated with controlling explosive atmospheres at the Sellafield site are extensively and explicitly considered in both "design basis" safety cases and the resilience review Sellafield Ltd has undertaken in response to the events in Japan.

*Significant Differences Between Units*

312 ONR is satisfied with Sellafield Ltd's response to the stress tests question on the differences between units. It is recognised that the current Sellafield site is a unique mix of facilities at differing stages of their operational life, and therefore it is inappropriate to consider it as a multi-unit or modular reactor site.

*Use of PSA as Part of the Safety Assessment*

313 Sellafield Ltd has provided a high-level response which sets out the historic use of probabilistic analysis and data across the Sellafield site.

314 The form and scope of probabilistic analyses undertaken within the safety cases for the various facilities on the Sellafield site differ from that compiled and presented for NPP facilities within the UK. ONR's view on the use of PSA at Sellafield is that the effort required to develop an extensive PSA (as typically applied to e.g. an operating reactor) would be inappropriate and potentially of little benefit to most facilities on the Sellafield site. However, it is ONR's view that there are areas for improvement in terms of both methodologies and the extent / scope of application of probabilistic safety analyses for facilities on the Sellafield site. ONR is already engaged in discussions with Sellafield Ltd on this topic and expects Sellafield Ltd to address these areas of improvement in the PSR.

315 Furthermore, in response to Recommendations IR-25 and FR-4 made in Ref. 2, Sellafield Ltd is required to review its analysis of accident sequences for long-term severe accidents and ensure that adequate PSA is provided for all nuclear facilities that could have significant off-site consequences. ONR will be discussing and scrutinising the responses to these recommendations with Sellafield Ltd over the coming months.

<u>Urenco UK Ltd</u>

316 ONR considers that UUK has provided an accurate and informative account of the hazards (and associated risks) posed by its operations and extant holdings of uranium hexafluoride on the Capenhurst site.

317 ONR considers UUK's approach to PSA to be in line with the expectations of the current SAPs. UUK explains in its report that the consideration of PSA in each extant safety case is being updated in a proportionate and appropriate manner at its next PSR to address the requirements

of UUK's latest safety methodologies as detailed in its Safety Assessment Handbook. ONR considers this to be an adequate approach that can be dealt with through the site's PSR process. UUK has identified in its report that the production of a proportionate and appropriate site-wide PSA will be considered once the extant safety cases have completed their next PSR. ONR supports this and will ensure through normal regulatory processes that UUK addresses this in a proportionate and appropriate manner.

Dounreay Site Restoration Ltd

318 ONR considers that DSRL has provided an accurate and informative account of the hazards (and associated risks) posed by its operations and extant legacy on the site. The licensee's stress tests report was supported by a comprehensive appendix that was not published by the licensee on its website because of its security classification; this details essential facility-specific information on resilience to known design basis events, relevant safety functions for protection systems and the output from a review of resilience to external events.

319 ONR considers that DSRL's safety case arrangements achieve a proportionate balance between quantitative and qualitative analysis for demonstrating the safety of ongoing quiescent state and decommissioning operations. ONR agrees with the approach adopted by the licensee.

Springfields Fuels Ltd

320 ONR considers that SFL has provided an accurate and informative account of the hazards (and associated risks) posed by its operations and extant legacy on the site.

Atomic Weapons Establishment

321 ONR considers that AWE's stress tests approach, i.e. the use of REPPIR off-site dose criteria for reasonably foreseeable severe accidents, is a suitable means of establishing relevant high-hazard facilities.

322 ONR concludes that because the sites do not have reactor cores to cool, or stored fuel requiring decay heat removal, AWE's focus on the loss of containment safety function is appropriate.

323 ONR concludes that AWE's case, that a consequential beyond DBF resulting from a DBE is not credible at either site, is reasonable.

324 ONR concludes that reasonably foreseeable extreme external events are highly unlikely to lead to off-site dose consequences on the scale of the Fukushima event, in the vicinity of AWE's sites.

Rolls-Royce Marine Power Operations Ltd

325 In considering RRMPOL's submission, ONR has augmented it with other information in its possession about the site and its operations.

326 RRMPOL does not provide any discussion of its use of PSA in safety assessments. However, ONR is aware that RRMPOL applies quantified risk assessment to its operations.

BAE Systems Marine Ltd

327 BAESM gives a description of the location of the site and its characteristics. More comprehensive discussion of the nuclear fuel handled on-site, the NRP and the scope of site operations is presented in a classified document. The description of the safety functions and the manner in which they are controlled is presented at a high level. ONR considers that the information presented on the site and NRP to be accurate. ONR notes that MoD is conducting its own post-Fukushima review covering aspects of the NRP and will report on these aspects separately.

328 The brief discussion on the use of PSA means that ONR cannot conclude on the degree to which these studies have demonstrated that BAESM has complied with the stress tests specification for activities on the licensed site. However, ONR is aware of the use of PSA information within BAESM operational safety cases.

Devonport Royal Dockyard Ltd

329 DRDL's submission contains a description of the site location and characteristics. The description provided of the site facilities, the services available, and their alternatives contain considerable detail and is supported by a security classified document. DRDL also includes significant detail on the safety functions and associated decay heat removal provisions provided by the site and also provided independently by the NRP. ONR concludes that the description provides a good basis to support the stress tests assessment. ONR considers the descriptive information presented by DRDL to be adequately comprehensive and accurate.

330 DRDL provides a useful summary of its use of PSA and the risks that arise at the site.

Rosyth Royal Dockyard Ltd

331 RRDL provides a satisfactory description of the site characteristics, the nuclear plant on the site and the provision for maintaining the main safety function. ONR recognises the low-hazard potential of the site, and considers the information provided is proportionate and suitably tailored for the stress tests assessment.

Magnox Ltd – Defuelled reactors

*General Data About the Sites*

332 ONR has reviewed the general information provided by Magnox Ltd in each of the EU stress tests reports for their respective defuelled reactor sites; ONR's review has found the supplied information to be accurate.

*Main Characteristics*

333 The information provided by Magnox Ltd on the main characteristics of its defuelled reactor sites in each of the relevant EU stress tests reports has been found to be complete and accurate by ONR. This information has been used with other data available to ONR to develop the descriptions of the nuclear reactor technology provided in this report.

*Description of the Systems for Delivery of Main Safety Functions*

334 ONR's review of the descriptions provided by Magnox Ltd in each of its EU stress tests reports of the systems that implement and / or support the main safety functions at each site gives an accurate and complete analysis of each plant. The information is provided in a format that is considered to adequately cover those systems that are employed to perform, or otherwise contribute, to reactivity control, post-trip cooling, and containment.

335 It is evident from each of the stress tests reports for the Magnox Ltd defuelled reactor sites that a structured and systematic approach has been applied to identify and describe the systems that implement and / or support the main safety functions albeit that these sites have permanently ceased power generation operations.

*Significant Differences Between Units*

336 ONR's review of the information provided by Magnox Ltd in each of its stress tests reports on the significant differences between units has found that an accurate description has been given as the reactors at each site are permanently shut down and have been defuelled. There are

differences in the extent to which decommissioning operations have been undertaken and the management of radioactive materials stored at each site, respectively.

*Use of PSA as part of the Safety Assessment*

337 ONR's review of the information provided by Magnox Ltd in each of its safety assessments on the use of PSA as part of the safety assessment has found that an accurate overview has been given. Given these plant are defuelled and the hazard significantly reduced compared to an operating reactor, ONR considers the limited PSA studies that have been carried out to be generally appropriate.

NNB GenCo – Hinkley Point C

*General Data About the Site*

338 The general information provided by NNB GenCo in the EU stress tests report for its proposed twin UK EPR™ reactor NPP at the Hinkley Point C site has been found to be accurate by ONR.

*Main Characteristics*

339 The information provided by NNB GenCo in the response to the NPP stress tests criteria on the main characteristics of the proposed twin reactor NPP that is to be constructed at the Hinkley Point C site has been found to be complete and accurate by ONR. This information has been used with other data available to ONR to develop the descriptions of the nuclear reactor technology provided in this report.

*Description of the Systems for Delivery of Main Safety Functions*

340 ONR's review of the information provided by NNB GenCo in its response to the NPP stress tests criteria on the systems that are proposed to implement and / or support the main safety functions at Hinkley Point C NPP are considered to provide an adequate analysis based on the UK EPR™ design.

341 It is evident from NNB GenCo's response to the NPP stress tests criteria that a structured and systematic approach has been applied to identify and describe the systems that are proposed to implement and / or support the main safety functions at the NPP.

*Significant Differences Between Units*

342 ONR's review of the information provided by NNB GenCo in its response to the NPP stress tests criteria on the significant differences between the UK EPR™ units proposed for use at Hinkley Point C has found that an accurate description has been given for the twin reactors that are to be of the same design.

343 Similarly, ONR's review of the information provided by NNB GenCo in its response to the NPP stress tests criteria, has accurately reported that there are two other adjacent power plants, namely Hinkley Point A defuelled reactor site operated by Magnox Ltd (licensee) and Hinkley Point B NPP operated by EDF NGL (licensee). The Hinkley Point A defuelled Magnox reactor is permanently shut down and a stress tests report has been provided by Magnox Ltd for ONR's assessment as part of this report for UK NPGNF. The Hinkley Point B NPP uses AGR technology and EDF NGL has provided an EU stress tests report that was considered as part of ONR's National Stress Tests Final Report for UK NPPs (see the ENSREG website, www.ensreg.eu/node/370).

*Use of PSA as part of the Safety Assessment*

344 ONR's review of the information provided by NNB GenCo in its safety assessments on the use of PSA as part of the safety assessment has found that an accurate overview has been given. ONR's expectation is that the PSA will be further developed during the design and build of Hinkley Point

C to appropriately support its design and operation and will be a full scope Level 1, 2 and 3 PSA that is consistent with ONR guidance and international PSA standards and guidance.

Lowest-hazard sites

345 ONR's conclusion of the stress tests produced for the sites is also proportionately based and presented collectively in Section 7 as opposed to explicit consideration in Sections 2–6.

# 2 EARTHQUAKES

## 2.1 Design Basis

346 A review of instances of seismic activity within Great Britain (UK continental shelf) was completed by Principia Mechanica Ltd (PML) in 1982 and this demonstrated that there was considerable variation in both magnitude and periodicity for such events dependent on-site location. The use of the resulting database enables to define the seismic risk, at a given location, as the couple of the magnitude, provided in terms of peak ground acceleration (PGA in g approx. $9.8m/s^2$), and the frequency of exceedance, provided in terms of probability per annum (pa); it can be referred to as e.g. a 1 in 1,000-year event for a frequency of $10^{-3}$ pa or 1 in 10,000-year event for a frequency of $10^{-4}$ pa.

347 The modern criterion set up in TAG T/AST/13 (Ref. 9) requires that each safety-related building is designed to withstand the PGA that match a frequency of exceedance of $10^{-4}$ pa. Buildings designed before that criterion was set up, are not expected to meet the requirement. Their resilience was assessed by PSRs.

### 2.1.1 Earthquake Against Which the Plants Are Designed

Sellafield Ltd – Sellafield and Windscale

348 In light of the 1982 study a specific site assessment was completed by PML for the Sellafield area and this indicated that a peak ground acceleration of 0.25g had an annual probability of exceedence of $0.87 \times 10^{-4}$ i.e. less than $10^{-4}$.

349 Since 1983, the DBE for new plant at Sellafield has been derived on a conservative basis to be an event which has an annual probability of exceedence of $10^{-4}$ pa. This is often referred to as a 1 in 10,000-year event.

350 Design input has been informed by broad band PML spectra at $10^{-3}$ and $10^{-4}$ annual probability with Peak Ground Acceleration (PGA) equating to 0.125g and 0.25g.

351 Some plants on the Sellafield site were designed when seismic standards were less well defined and very early plants predate seismic standards. Facilities constructed prior to 1983 that have a release potential that could result in a public dose in excess of 1mSv have been assessed against a 1 in 1,000-year event as part of the continuing PSR process. In addition, where initial assessment indicates that public dose in excess of 5mSv is possible then strengthening works are designed against a seismic input resulting from a 1 in 10,000-year event subject to ALARP considerations.

352 To inform design assessment for possible new NPPs and the NIREX repository, a review of the seismic hazard potential of the Sellafield site was completed by the Seismic Hazard Working Party (SHWP) in 1994 and this concluded that a design basis event of 0.25g peak ground acceleration was still relevant at a return period of 1 in 10,000 years.

353 Sellafield Ltd notes that for design of new plant, the philosophy of targeting an event with an annual probability of $10^{-4}$ on a conservative basis is considered adequate by ONR and is in line with ONR's expectations in the SAPs.

Urenco UK Ltd

354 The Capenhurst site is one of the less seismically active regions of the UK with a best estimate peak free field horizontal ground acceleration of 0.19g corresponding to a 1 in 10,000-year seismic event frequency. Existing safety cases have considered the need for seismic qualification of plant and buildings depending on the consequences of failure for a range earthquake magnitudes beyond 0.19g and provisions made where appropriate. The latest UUK safety case

approach is captured in the UUK Safety Assessment Handbook. Each extant safety case is being updated at its next PSR as part of a staged improvement programme.

355 Subject to satisfying the ALARP principle, UUK adopts a “hazards staircase” approach, linking DBE levels to unmitigated dose. Where the unmitigated dose to a member of the public is less than 1mSv, no special seismic provisions are required beyond the general requirement to satisfy the ALARP principle. Where the expected unmitigated dose to a member of the public is greater than 1mSv but less than 5mSv, the plant is to be engineered to withstand the event to the extent that the expected dose to a member of the public off-site is less than 1mSv, following an event with a frequency of 1 in 1000 years. Where the expected unmitigated dose to a member of the public is greater than 5mSv, then the plant is to be designed to withstand the event to the extent that the expected dose to a member of the public off-site is less than 5mSv, following an event with a frequency of 1 in 10,000 years. This is the approach adopted in general for new plant.

356 For existing plant, UUK recognises the new build plant criteria provide a benchmark subject to ALARP considerations which may include consideration of the conservatism in the 1 in 1000-year seismic hazard. In developing these criteria, UUK has taken due account of data, advice and guidance from experts from both the nuclear and chemical industries. The data have also been reviewed against the data compiled for Article 37 of the Euratom Treaty.

Dounreay Site Restoration Ltd

357 DSRL defines the DBE for the Dounreay site to be a peak ground acceleration of 0.14g with a return frequency of 1 in 10,000 years; the licensee has judged this to be sufficiently conservative for use and acknowledges this to be lower than the generally recognised value of 0.25g for other UK nuclear licensed sites. This reflects the seismic stability of the region relative to other areas of the UK.

Springfields Fuels Ltd

358 SFL’s company radiological accident risk criteria specify that existing plants must be examined against seismic events where there is the potential to give a dose to a member of the public of greater than 1mSv following a seismic event. If a 1 in 1,000-year seismic event of 0.125g acceleration results in a radiological dose greater than 5mSv to a member of the public, SFL’s arrangements would expect reasonably practicable modifications to be considered, commensurate to a seismic event occurring with 1 in 10,000-year frequency.

Atomic Weapons Establishment

359 AWE describes that the Aldermaston and Burghfield sites lie in a region of southern Britain characterised by low seismic activity being within the stable continental region of north-western Europe.

360 AWE has used two approaches to determine the DBE at the AWE (A) and AWE (B) sites, both based on probabilistic methods that account for uncertainty in the source of earthquakes, their recurrence frequency, potential maximum magnitude and the uncertainty in attenuation of the ground motion. One method uses a generalised approach to determining the DBE and incorporates the effect of local site response in terms of the ground response spectra, this has been termed the PML approach. AWE (A) and AWE (B) have been classified as PML soft ground and medium ground sites, respectively. The other method used is based on an approach using Uniform Hazard Spectra (UHS).

361 The PML methodology has been used to derive the general seismic hazard for the AWE sites and has resulted in the values shown in Table 3.

**Table 3:** General PGA (1 in 10,000-yr) for DBE on AWE Sites

| Site | PGA for the DBE (g) |
|---|---|
| AWE A-site | 0.14 |
| AWE B-site | 0.14 |

362 Both AWE sites consist of layers of soil overlying soft rock and account has been taken that the response of the sites under seismic input may exceed the typical values inherent in the site-classified PML spectra. AWE has had site response studies undertaken for both sites using UHS based on a selection of representative empirical strong ground motion equations. These have been used in explicit modelling of the site profiles within standard site response analysis computer programs, which have provided mean horizontal PGA at the surface; these are presented in Table 4.

**Table 4:** PGA (1 in 10,000-yr) for DBE Incorporating Site Response on AWE Sites

| Site | PGA for the DBE (g) |
|---|---|
| AWE A-site | 0.16 – 0.19 |
| AWE B-site | 0.20 |

363 AWE has identified five existing facilities across the Aldermaston and Burghfield sites that fall within the definition provided in Section 1.1.1. AWE has evaluated these existing facilities against the appropriate UHS, accounting for the local soil condition.

364 For new facilities either being constructed, or about to commence construction, on both AWE sites, AWE has carried out the seismic substantiation using the appropriate PML spectra anchored to the general seismic hazard level. AWE has also given consideration to the possibility that the UHS for the location may exceed the PML spectra at some frequencies.

Rolls-Royce Marine Power Operations Ltd

365 The RRMPOL licensed sites at Derby in central Britain are situated in an intraplate region. RRMPOL reports that the DBE for the site, for a return period of 1 in 10,000 years is 0.25g PGA and all relevant plant has been qualified to this.

BAE Systems Marine Ltd

366 The BAESM licensed site is situated in an intraplate region. BAESM has determined the DBE for the site for a return period of 1 in 10,000 years to be 0.25g, and considers that this is likely to be conservative.

367 The designs at BAESM use an input motion defined by the PML piece-wise linear spectra for a medium stiffness site applied at the ground surface which is anchored to the formal 0.25g seismic hazard.

Devonport Royal Dockyard Ltd

368 DRDL reports that the DBE of 0.25g for a return period of 1 in 10,000 years for its site has been derived from a detailed seismic hazard study that included the regional geology within a radius of 60km and an investigation of the local site geology.

369 DRDL assumes that the input motion defined by the PML piece-wise linear spectra is acting at a rock outcrop remote from the facilities. The designs take account of possible modification of the motion by the material between the rock outcrop and the facilities.

Rosyth Royal Dockyard Ltd

370 RRDL licensed site at Rosyth in southern Scotland is situated in an intraplate region. RRDL reports that the DBE for the site for a return period of 1 in 10,000 years is 0.25g, with the nuclear safety-related facilities on the licensed site being built on solid bedrock.

Magnox Ltd – Defuelled reactors

371 The inclusion of design against earthquakes for nuclear structures in the UK did not become commonplace until the early 1980s. As a result, for the majority of facilities at Magnox stations, the justification against seismic loading was undertaken significantly after construction as part of the subsequent PSR process.

372 Post-construction evaluations of the hazard and withstand were undertaken as part of the PSRs. This has been an ongoing process from the late 1980s to date, and a considerable effort has been made to improve the robustness against seismic loading during this time. This initially focussed on an understanding of the most safety-critical SSCs and has progressively been refined to reach the position of a stable safety justification. Improvements to the robustness of safety-critical SSCs have been undertaken, where it has been demonstrated to be ALARP to do so.

373 For all the defuelled Magnox stations, there is no fuel left in the reactor cores or in cooling ponds and none stored elsewhere (note: two recently discovered part elements were recovered in early 2012 at Hunterston A and are held in safe storage in accordance with the requirements of the current safety case). The only radioactive inventory on the site is quantities of ILW and LLW. These are contained in vaults, drums or bespoke engineered stores. The risks posed in terms of radioactive releases are many orders of magnitude lower than when the stations were operating. A proportionate approach to the treatment of extreme hazards is therefore seen as appropriate.

374 The seismic safety case requirements for the defuelled Magnox stations are that gross collapse of the structures containing radioactive inventory should not occur. There are no requirements placed on any active systems or power sources to limit radioactive releases.

375 Magnox Ltd has provided a brief synopsis of the philosophy for definition of the DBE. The DBEs are targeted to be derived on a conservative basis to be an event which has an annual probability of exceedance of $10^{-4}$ pa. This is often referred to as a 1 in 10,000-year event.

376 For all sites except Trawsfynydd, the outputs from the DBE evaluation are typically a series of uniform risk spectra (URS) produced for annual probabilities of between $10^{-2}$ pa and $10^{-4}$ pa. The values of the PGA for the DBE ($10^{-4}$ pa) for the sites under consideration in this report are given in Table 5 below. The actual DBE used is an envelope of the $10^{-4}$ pa URS and the 0.1g PGA PML spectrum for the appropriate site categorisation.

377 For Trawsfynydd, a 0.1g PML spectrum is used as the DBE.

378 The philosophy of targeting an event with an annual probability of $10^{-4}$ on a conservative basis is considered adequate by ONR and is in line with expectations in the SAPs (Ref. 8).

**Table 5:** PGA for DBE on Magnox Defuelled Sites

| Site | PGA for the DBE (g) |
|---|---|
| Berkeley | 0.16 |
| Bradwell | 0.26 |
| Hinkley Point A | 0.23 |
| Hunterston A | 0.16 |
| Trawsfynydd | 0.10 |

379 The methodology used to derive the seismic hazard for all of the sites with the exception of Trawsfynydd is virtually identical. It was developed in the late 1980s under the auspices of the Central Electricity Generating Board by the SHWP. The methodology developed is a logic tree approach. The outputs are termed URS, produced for a range of return frequencies and for different confidence levels. The values used for the DBE are the $10^{-4}$ pa probability of exceedance with a confidence of "expected".

380 The hazard evaluation studies were undertaken over a period from the late 1980s to the mid 1990s, coincident with the timescales of individual facility PSRs. For all sites, these hazard evaluations have been revisited as part of the next round of periodic reviews.

381 No formal site-specific hazard study has been undertaken for Trawsfynydd. Reactor operations ceased in 1991, around the time that the consideration of seismic events was being developed. An initial assessment of the site was undertaken using a 0.1g PGA PML demand. Simplified studies have suggested that the 0.1g PGA spectrum is consistent at those frequencies of interest (<10Hz) with an event with an annual probability of exceedance of 1.1 x $10^{-4}$ pa.

382 Magnox considers that the SHWP methodology for deriving design basis events is robust, has appropriate conservatisms, margins and sensitivity studies employed. In addition, they also consider that the demand for Trawsfynydd, while not being as rigorously defined as for other sites, is sufficient given the levels of radioactive inventory and stage in the life-cycle of the plant.

NNB GenCo – Hinkley Point C

383 The Hinkley Point C plant will be a UK derivative of the standard EPR™ design (referred to as UK EPR™). Earthquake loading has been considered from the earliest phase of the design process. The initial generic design of the EPR™ was based on an envelope of European Utility Requirement (EUR) spectra anchored to 0.25g PGA.

384 For Hinkley Point C, there are aspects of the design which are generic (nuclear-island) and others which are site specific. The seismically qualified nuclear-island structures have been designed against the requirements of the hard site EUR spectra (Ref. 28) anchored to 0.25g PGA. This envelopes the $10^{-4}$ pa URS which has been derived by NNB GenCo for the Hinkley Point C site.

385 For site-specific structures not designed generically, the DBE is defined as a hybrid spectrum with a PGA of 0.25g, and a portion of the EUR hard site spectrum at high frequencies; however at lower frequencies it is anchored to a 0.2g PGA EUR hard site spectrum. The resulting hybrid spectrum envelopes the original SHWP work undertaken for the Hinkley Point site and more recent work undertaken specifically for the Hinkley Point C project.

386 The SHWP study from 1991 used the methodology as described above. More recent work undertaken specifically for the Hinkley Point C project has developed URS which for the $10^{-4}$ pa

exceedance level have a PGA of 0.19g. The description of the methodology in the stress tests report suggests that it is an update of the SHWP approach with different attenuation relationships and a revised earthquake catalogue.

387 NNB GenCo considers that the DBE takes account of previous SHWP work, and more recent work undertaken specifically for the Hinkley Point C project, in a manner which gives a conservative result.

#### *2.1.1.1 ONR's Assessment of the Design Basis Earthquake against which the plants are designed*

<u>Sellafield Ltd – Sellafield and Windscale</u>

388 The broad band spectra developed by PML are considered to have more than adequate levels of conservatism built in within the lower frequency regions and, as the major hazard structures constructed on the Sellafield site generally fall into the lower frequency region, there is confidence in the selected level of design basis events.

389 ONR considers that the design basis events adopted for the Sellafield area are a reasonable representation of the likely hazard level for the area. However ONR's report in relation to the stress tests completed for NPP (Ref. 10) makes a finding (STF-2) that there would be benefit in performing a detailed review of the SHWP methodology against modern standards and makes the recommendation that the nuclear industry should establish a research programme to review the SHWP methodology against the latest approaches developed by the Senior Seismic Hazard Analysis Committee. This would also be of benefit to the Sellafield site and therefore the following finding is raised:

**STF-23: Sellafield Ltd should take note of NNP finding STF-2 (Ref. 10) and participate in the review as necessary where the seismicity of the area affecting the site is under consideration.**

<u>Urenco UK Ltd</u>

390 ONR considers that the values for the DBE against which UUK's plants are designed and assessed and the methods employed are appropriate and proportionate.

<u>Dounreay Site Restoration Ltd</u>

391 The seismic demand estimated for Dounreay is considered sufficient to establish the seismic risk profile. Given the position in the life-cycle of the plant, ONR considers that the development of the hazard using modern standards and practice will be of little benefit.

<u>Springfields Fuels Ltd</u>

392 ONR considers the tapered approach to safety case seismic analysis, according to unmitigated consequence level, to align with relevant good practice.

<u>Atomic Weapons Establishment</u>

393 ONR notes that the inclusion of design against earthquakes for nuclear facilities in the UK did not become commonplace until the early 1980s, reflecting the relative inherent low level of seismic hazard in the UK. A number of the facilities at AWE's sites were built during the 1950–1980 period and were therefore not seismically qualified as part of the original design. For those facilities that did not have a seismic loading component as part of the design, post-construction evaluations of the hazard and withstand were undertaken as part of the PSRs. This has been an ongoing process from the late 1980s to date and has focused on the most significant nuclear safety-critical SSCs,

with improvements to robustness being undertaken where it has been demonstrated to be ALARP to do so.

394 ONR notes that the methodology used to derive the general seismic hazard for the AWE sites is broadly similar to that in general use, being based on the probabilistic seismic hazard analysis approach originally formulated by Cornell in the US. The basic approach used for most UK seismic hazard analysis was developed in the late 1980s, under the auspices of Central Electricity Generating Board by a body known as the SHWP. The approach incorporates the use of a logic tree methodology that provides for the application of expert judgement and a means of accounting for uncertainty.

395 ONR notes that the piece-wise linear spectra known as the PML spectra used by AWE were derived in the early 1980s and were constructed using a similar statistical based approach to that used for the United States Regulatory Commission (US NRC) RG1.60 spectra, which results in spectra generally at the 84.1% confidence level. However, the final form of the spectra is data dependent and this resulted in the PML spectra being significantly different to the USNRC RG1.60 in terms of spectral content and amplification factors. The data used to construct the PML spectra are from events recorded at sites in the near and mid field regions that were judged to be representative of the tectonic environment in the UK; the largest portion coming from California. In some cases the records were scaled in terms of the peak ground acceleration to be compatible with a generic UK event with a return period of 1 in 10,000 years derived at that time. The approach recognises the difference in the spectral content that shallow geology local to the site can produce and that has resulted in different spectra for soft, medium and hard sites. ONR considers that although the PML spectra used within AWE seismic assessment methodology has been in existence for many years, it nonetheless has sufficient in-built conservatism to be appropriate for sites that exhibit typical responses.

396 Britain resides within the European stable continental region and is therefore classified as an intraplate zone. AWE Aldermaston and Burghfield sites are situated in southern Britain, which based on over 1,000 years of observations of earthquakes, is characterised as a region of low seismic activity. Nonetheless, there has been sufficient activity in the region to be significant when considering return periods of 1 in 10,000 years or longer. In conclusion, ONR considers that AWE's description of the seismic activity relevant to its sites is appropriate.

397 In summary, ONR considers that the site-specific design basis seismic hazards derived for the AWE sites are a reasonable representation of the likely hazard level at its sites at a return period of 1 in 10,000 years. The approach taken broadly follows the IAEA expectations with the seismic hazard being determined using methodologies that follow standard probabilistic approaches. The derived DBE forming part of a UHS, which includes the local site response, is treated as an input to a deterministic substantiation of the facilities structures, systems and component that are relevant to nuclear safety.

Rolls-Royce Marine Power Operations Ltd

398 ONR considers that the site-specific DBE, as derived, is an acceptable representation of the likely hazard level in the region of the RRMPOL site, at a return period of 1 in 10,000 years. The derived DBE, in combination with a spectral representation of the ground motion (although the details of the input motion at the sites have not been specified by RRMPOL in its submissions), is treated as an input to a deterministic substantiation of the facilities' structures, systems and components that are relevant to nuclear safety and meets ONR's expectation.

BAE Systems Marine Ltd

399 ONR considers that the formal site-specific design basis seismic hazard is a reasonable representation of the likely hazard level in the region of the BAESM site at a return period of 1 in 10,000 years.

400 The derived DBE, in combination with a spectral representation of the ground motion, is treated as an input to a deterministic substantiation of the facilities' structures, systems and components that are relevant to nuclear safety and meet ONR's expectation.

Devonport Royal Dockyard Ltd

401 ONR considers that the site-specific design basis seismic hazard is a reasonable representation of the likely hazard level in the region of the DRDL site at a return period of 1 in 10,000 years, which takes account of local site response and the influence of the deep docks.

Rosyth Royal Dockyard Ltd

402 The precise methodology used to derive the seismic hazard is not presented by RRDL. However, ONR considers that the site-specific design basis seismic hazard is a reasonable representation of the likely hazard level in the region of the RRDL site at a return period of 1 in 10,000 years. The derived DBE, in combination with a spectral representation of the ground motion, is treated as an input to a deterministic substantiation of the facilities' structures, systems and components that are relevant to nuclear safety and meet ONR's expectation.

Magnox Ltd – Defuelled reactors

403 The stress tests reports provided by Magnox vary in the level of detail provided with regard to the methodology used to derive the seismic hazard. ONR considers that Magnox has provided sufficient detail in its reports given the life-cycle stage of the sites and the levels of risk presented.

404 ONR considers that the design basis events derived for the Magnox sites are a reasonable representation of the likely hazard level in the UK.

NNB GenCo – Hinkley Point C

405 ONR considers that the description of the most recent seismic evaluation work for the Hinkley Point C site is not full enough in its stress tests report. Further, it is not clear why there is a significant difference from the earlier SHWP site-specific hazard work. In addition, the adoption of the "hybrid" design spectrum for site-specific structures is not fully defined in the NNB GenCo's stress tests report. ONR is in the process of reviewing the NNB GenCo site licence application and is discussing these points with NNB GenCo. The potential licensee has reported that a comprehensive description of the seismic hazard (including the justification of the usage of the appropriate ground acceleration spectra) will be included in the external hazards sub-chapter of the site-specific Hinkley Point C pre-construction safety report.

406 Notwithstanding the above points, it is ONR's view that the DBE for the nuclear-island structures is robust, and that the DBE for the site-specific structures while lacking in some definition is appropriate.

### 2.1.2 Provisions to Protect the Plants Against the Design Basis Earthquake

Sellafield Ltd – Sellafield and Windscale

407 As the Sellafield site includes a range of facilities associated with fuel receipt, storage, reprocessing and waste storage, the concept of safe shutdown and protection offered to ensure safe shutdown does not suit all operating plants.

408 Sellafield Ltd has confirmed that all nuclear facilities have safety cases and that the safety cases identify key SSCs required to ensure nuclear safety.

409 The information provided by Sellafield Ltd includes reference to a report detailing the potential effects on buildings following seismic design basis events limiting discussion to facilities that require support services to maintain nuclear safety where loss of such services would result in an off-site dose greater than 10mSv to the critical group.

410 Protection of plant or maintenance of safety function is shown by demonstration of robustness against the application of DBEs or limitation of damage. Sellafield Ltd has provided a summary of seismic performance for facilities where full seismic qualification has not been demonstrated.

411 As the River Calder flows through the site, the potential for damage to bridges both within the site and local to site access roads has been considered. Reference is made to a 2001 study that indicated that, although damage to bridges is expected, access could be maintained.

412 The indirect consequences of seismic damage have been discussed with particular regard to loss of pond containment and spread of contaminated pond water. Major failure of pond containment is not considered probable with recent ponds being fully seismically qualified and older facilities considered to crack but not collapse. Potential weaknesses in the fuel handling plant storage ponds are noted and the First Generation Magnox Storage Facility is discussed separately.

413 The following paragraphs relate to facilities where following a seismic design basis event main structure is considered to be still effective but operation of safety-critical systems is necessary to either ensure containment or prevent further challenge to containment boundaries.

*Magnox Swarf Storage Silo*

414 The compartments within the Magnox swarf storage silo store Magnox swarf under water, and as a result of corrosion hydrogen gas is evolved. To prevent build-up of potentially explosive atmospheres hydrogen gas is removed by operation of active ventilation systems.

415 The rate of hydrogen production is discussed and noted as being dependent on the temperatures in the waste silos with base temperature taken as 30°C for the first and second extension silos and 35°C for the third extension silo. On this basis following loss of ventilation the time necessary to achieve the Lower Flame Level (LFL) of hydrogen concentration in the extensions is calculated. Although a time for hydrogen concentration is quoted for each extension, Sellafield Ltd notes that as silo temperatures are typically 20°C, actual times should be greater than those indicated.

416 Sellafield Ltd notes that the occurrence of a design basis seismic event at 0.25g level would almost certainly result in failure of some systems.

*Highly Active Liquor Evaporation and Storage*

417 The storage of highly active liquor in the HALES facility has already been discussed in Section 1 with attention drawn to the importance of cooling operations.

418 Damage to the structures of some ancillary plant following a seismic design basis event is expected with disruption of utilities and consequent loss of cooling capacity. The time to reach

boiling of highly active liquor is noted as being significant with no intervention and as such some safety margin is claimed.

*First Generation Magnox Storage Pond (FGMSP)*

419 Discussion of the protection provided to the FGMSP in the event of a $10^{-3}$ seismic challenge is based on the premise that, although pond walls will develop substantial cracks, bulk containment of pond liquor is maintained, with any major release resulting from breached pipework. This pipework is presently being isolated by engineered means. The possibility of sealing of cracks in the main concrete containment is noted with reference to systems for installation of sealing plates, location of bunds and deployment of pumps. Potential difficulties in deployment of such provisions are noted with success being very dependent on the location of cracks and breaches.

420 Work completed as part of a risk reduction project in relation to the redundant effluent sludge pipework systems provides a recovery route for releases from breached pipework into the south active drain trench. Removal of pond liquor from the south active drain trench can be achieved by use of seismically qualified pumps that were installed and tested to provide contingency support in the event of loss of containment.

421 Pumps serving the redundant effluent sludge pipework system are driven by dedicated diesel generators with either generator capable of providing the necessary electrical power. Associated diesel tanks are kept full and start-up of generators is completed as part of the standard maintenance procedure. Diesel tank capacity would need to be replenished regularly.

422 The FGMSP is constructed partially below ground level and this limits the rate of leakage from cracks in the concrete containment walls. Pond dry out is considered to be unlikely and without intervention coverage of a single layer of fuel skips can be maintained.

*Pile Fuel Cladding Silo*

423 The possibility, following a seismic event, of fire within compartments of the pile fuel cladding silo is discussed with the potential for structural collapse of the silo noted in the event of continuous burning of waste over an extended seven-day period.

424 To protect against fire, the waste within the pile fuel cladding silo is kept under an inert argon blanket with oxygen levels monitored to confirm that levels are less than 2%. Several independent systems are provided for supply and delivery of argon to the pile fuel cladding silo and, allowing for argon stocks to be at a minimum at the time of an event, the supply of gas can be maintained for approximately a month.

425 There are several argon liquid storage and vaporisation plants, including capacity which is seismically qualified. In the event of 0.25g design basis seismic activity, argon supply to the pile fuel cladding silo can be maintained for a period in excess of seven days.

426 It is noted that a targeted approach to protection against waste fire in the pile fuel cladding silo is adopted.

*Magnox Reprocessing*

427 Disruption of the Magnox reprocessing facility has been considered with the potential for exposure of fuel in the dissolver. The reprocessing dissolver is designed to safely shut down both with and without uninterrupted power supplies in the event of seismic activity. Although the dissolver is designed for safe shutdown its position and water cover of partially dissolved fuel rods cannot be guaranteed and overheating of fuel cannot be discounted.

428 Automatic gravity fed supplies can feed cooling water to the dissolver jacket and in the event of failure of such systems dry riser or pumped supplies can be connected. Water supply from cooling tower basins and ultimately the River Calder can be mobilised if necessary.

429 Should connection to the dissolver jacket be impossible, then dumping of water directly into the dissolver would be considered although this does carry a potential risk of induced criticality and inclusion of a neutron poison would be appropriate.

430 Following shutdown of the dissolver fuel temperature has to be maintained at a specific temperature to ensure safety. The current batch size for the fuel dissolver is set at <5te and at this level self heating of fuel is considered to be unlikely.

Urenco UK Ltd

431 UUK reports that original design bases and update reviews for each of the centrifuge plants have assessed their seismic withstand capability against a 1 in a 10,000-year event assuming a range of PGA up to 0.25g. Following a 1 in 10,000-year earthquake, buildings of the type of construction of the centrifuge plants are likely to experience slight to moderate damage, e.g. small cracks in walls; fall of masonry blocks. Thus, structural failure of the facility would not be expected following such an event, although the structural steel envelope may be damaged.

432 One of the centrifuge plants has a different roof construction to the others and recent work has identified the need to evaluate this further as part of its PSR process. Given the original design criteria and work programme to evaluate the options for building structural improvements as part of its imminent PSR, UUK reports that the design basis for this centrifuge plant is considered adequate.

433 The centrifuge plant safety cases also consider the potential for damage to the $UF_6$ containment pipework and cylinders within the buildings following seismic events. This ranges from no structural pipework failure or damage to the very robust cylinders or autoclaves, to a range of damage to pipework outside the autoclaves.

434 Some limited areas of the feed systems operate at slightly above atmospheric pressures. In a seismic event, or any event that causes a loss of containment or loss of power, the enrichment process is capable of automatically shutting itself down into a safe state. Whilst the plant is designed to safely shut down automatically, leakage could occur for a finite time. In recognition of the greater potential hazard from areas where liquid $UF_6$ and / or $UF_6$ at a pressure higher than 1bar can arise, the buildings housing those areas are seismically qualified. In addition, the secondary containment autoclaves are seismically qualified as necessary.

435 Following a seismic event, the worst scenario envisaged by UUK would be a $UF_6$ release on loss of containment. Automatic controls shut down the plant to a safe state. As a contingency, UUK reports that operator action would be implemented using equipments as necessary that is stationed throughout the plants to minimise any release. UUK has recognised that its emergency response resources are generally based on a single accident scenario response and the resources required for more extreme event combinations should be considered further.

Dounreay Site Restoration Ltd

436 There are no active cooling systems claimed as part of the Dounreay safety case for any facility on the site. Safety cases are based on the integrity of the structures which house nuclear material. None of the facilities defined as NPGNF were specifically designed to withstand earthquake; rather most were designed against the codes and standards available at the time of construction. Nonetheless, DSRL's modern standards safety cases assess the seismic withstand capability for each facility, and provide engineering substantiation for relevant safety features and active safety

systems. Where seismic qualification has not been achieved for certain facilities, DSRL explains that its safety cases sufficiently demonstrate a qualitative approach to identifying ALARP improvements. Where ALARP improvements have been identified, the licensee indicates them to be successfully implemented. DSRL also refers to its arrangements for safety case periodic review on a ten-yearly cycle which requires re-evaluation of the validity of previous claims on withstand capability.

437 Certain facilities have been declared to have sufficient structural stability to resist the DBE, but that building collapse (leading to damage to internal containment structures and subsequent worker incapacitation) could not be ruled out following a "cliff-edge" event (i.e. a peak ground acceleration 40% above the DBE); DSRL argues that the frequency of a "cliff-edge" earthquake would be well below that assessed for the reference earthquake and therefore a "rare" event. Furthermore, the safety cases bound unmitigated consequence to less than 5mSv via marine discharge.

Springfields Fuels Ltd

438 The uranium hexafluoride production plant at Springfields is the only facility to have been specifically qualified to 0.1g acceleration, the extant standard at the time. However, the external hazards safety cases for the site assume structural failure of buildings and subsequent material redistribution; the safety case is not predicated on a limited magnitude of earthquake. The licensee's case is based on a limited radiological exposure off-site given the limited inventory in the event of a severe seismic event.

Atomic Weapons Establishment

439 AWE has provided a description in its reports of the key structures, systems and components identified in the seismic safety cases for five facilities. Each of these facilities carries out different functions in support of the activities at AWE's site. Four of the facilities are at Aldermaston, the other is at Burghfield.

440 Of the four existing facilities at Aldermaston, one is an old facility and is scheduled to be replaced. The others are designated as having a continuing role.

441 The first facility is relatively modern and has undergone a full structural assessment by AWE, which identifies that the building is robust against the 1 in 10,000-year DBE with only minimal damage. AWE reports that the primary containment boundary, which is within the building boundary, maintains integrity under a 1 in 1,000-year seismic hazard loading.

442 The second facility is relatively modern, with a design that considered the seismic hazard. AWE's current seismic assessment identifies that under the DBE the structure will only suffer minor structural failures in localised areas not resulting in a loss of containment. AWE judges that the plant within the facility will withstand a 1 in 10,000-year DBE without loss of containment.

443 The third facility has been demonstrated by AWE to withstand a 1 in 10,000-year seismic hazard. This is based on the buildings having a withstand of a 1 in 1,000-year hazard and a prediction by AWE that for a 1 in 10,000-year DBE the building structure may be damaged, but would not lead to a severe accident, under AWE's criteria.

444 The fourth facility is the oldest of the four at Aldermaston and is scheduled to be replaced. AWE reports that the building design will withstand a 1 in 1,000-year seismic hazard, with only minor damage to the building predicted. At longer return periods, AWE explains that the damage increases with the possibility of damage to the primary containment boundaries and this combined with additional internal damage to the building could lead to breach of the secondary containment barriers and exposure of nuclear materials.

445 The Burghfield site facility, consisting of an existing group of buildings, was designed before consideration of seismic hazard for the design of nuclear facilities in the UK was expected. A PSR was undertaken ending in 2006, which considered the seismic withstand of the facilities. AWE reports that it shows that the main buildings and the plant withstand the 1 in 10,000-year DBE with one exception, which is being addressed under the PSR improvements programme. One of the buildings could not be substantiated against the 1 in 10,000-year DBE; however, AWE describes that the nuclear materials in this building are not affected by possible impacts from a building collapse. All these buildings will be replaced by a facility currently under construction that has been specifically designed to address the seismic hazard robustly.

446 AWE has noted the possibility of more than one external hazard occurring close to one another in time, such as extreme weather following a seismic event. AWE has concluded that such a situation would be similar to a beyond design basis seismic event, but without a significant escalation in consequences.

Rolls-Royce Marine Power Operations Ltd

447 RRMPOL has identified the key structures, systems and components claimed in the seismic justifications for the facilities. RRMPOL has established that there are four relevant buildings, of which two were constructed prior to consideration of seismic hazards for nuclear facilities in the UK. These buildings comprise three production shops (on the manufacturing site) and the Neptune low power research reactor with its associated facilities. The three production shops and the Neptune reactor are located on two separate licensed sites, close to each other.

448 RRMPOL reports that the two older production shops do not have substantiated seismic withstands beyond the level of 0.05g, which corresponds to a 1 in 200-year return seismic hazard. However, specific equipment within these buildings, where the potential for significant consequences could arise from earthquake initiated failures, has improved seismic withstand capability ranging between 0.1g and 0.2g and, in a few cases, meets the site 1 in 10,000-year DBE.

449 The other production shop and Neptune reactor were constructed to take account of the seismic hazard and have been demonstrated to meet the site 1 in 10,000-year DBE. However, in this production shop, some of the internal equipment may only meet a seismic withstand capability of between 0.1g and 0.2g.

450 On the Neptune licensed site, the reactor building, reactor tank, crane, fuel storage, and control room are qualified to the DBE level. Although the reactor control systems are not qualified against earthquake loadings, failure of the relays would result in a controlled shutdown of the reactor by control rod insertion.

451 The site ECC is designed to meet the site 1 in 10,000-year DBE. As communication and power supplies to the facility are considered to be lost in the DBE, the ECC has a dedicated diesel back-up as an additional measure to maintain essential safety functions.

BAE Systems Marine Ltd

452 BAESM has provided a description in its stress tests submission of the key structures, systems and components claimed in the seismic safety cases, with this covering the various build stages and testing of the submarine. Four facilities are considered in relation to the nuclear safety together with the submarine.

453 Prior to loading the fuel into the reactor it is stored in a facility, which has no formal seismic withstand due to its relatively light structure. However, this has minimal implication for nuclear safety as BAESM advises that nuclear safety is reliant on the restraints in the fuel assemblies to withstand any impacts from building and plant collapse.

454 The fuel is transferred to the DDH for insertion into the reactor. BAESM reports that the construction hall has a withstand against a seismic event with a 1 in 1,000-year return period. A seismic event above this level could lead to the collapse of the building and the EOT cranes onto the submarine. Prior to the reactor head being installed, BAESM makes a claim on the restraints in the fuel assemblies to withstand any impacts from dropping loads or from building and the EOT crane collapse. Once the reactor head is installed, other devices take over the role of restraining the control rods.

455 Once the build is completed the submarine is transferred to the WDQ via a shiplift. BAESM explains that this shiplift and transfer system has a withstand against a seismic event with a 1 in 1,000-year return period. The restraining devices discussed above provide the withstand should the shiplift collapse in a seismic event and they also provide a safeguard against excessive submarine roll away from the vertical. BAESM advises that the shock loading caused by a collapse of the shiplift and transfer system, as a result of a seismic event, is bounded by the shock due to collapse of the construction hall EOT crane.

456 At WDQ, where the submarine is moored, the quay has a withstand against a seismic event with a 1 in 100-year return period. Although failure of the quay itself during an earthquake will not result in an impact on the submarine, it could result in the submarine being subjected to forces through the mooring lines from the collapsed structure. BAESM had previously recognised the possibility of a significant impact from an existing dockside crane and, as an ALARP measure, removed this large crane and substituted lighter cranes, whose collapse is within the impact safety envelope. BAESM advises that should the water retaining boundary collapse the devices which restrain the control rods would maintain the reactor in a safe state.

457 While the dock system is not part of the licensed site, BAESM provided a summary of the seismic performance of the system, treating it as a hazard to its facility at WDQ. The dock system itself has a withstand against a seismic event with a 1 in 100-year return period and a failure could result in the dock becoming tidal. BAESM advises that in the event of the dock system becoming tidal there is still sufficient depth of water to support cooling of the submarine. This is due to sill structures at the base of the docks which would retain the water.

458 BAESM considers that the failure of the dock at a 1 in 100-year return period seismic event would not result in sufficient movement of the submarine to lead to the possibility of an impact exceeding the safe envelope.

Devonport Royal Dockyard Ltd

459 DRDL describes the key SSCs in the seismic justifications which underpin its safety cases. These cover a submarine in a dock, both while it is afloat (an afloat submarine) and with it resting on a supporting cradle on the dock bottom after the dock has been drained of water (a docked down submarine) with a caisson in place across the dock entrance. It also includes the effect of the shoreside facilities.

460 DRDL identifies that, for a submarine afloat in a dock, a seismic event could cause waves within the dock due to movement of the adjacent walls. DRDL concludes that these movements and the resultant wave motion would be small and no more severe than wind-induced waves, which the submarine is designed to cope with.

461 DRDL identifies that the only threats to an afloat submarine as a result of a DBE arise from indirect effects, including impact to the submarine from adjacent structures and loss of shore supplies (to the shut-down NRP).

462 For a submarine docked down on its supporting cradle in 9, 14 or 15 Docks, the effects of the DBE on the submarine are attenuated by the cradle and DRDL reports that the submarine systems necessary to support a safe shut-down state will not be compromised by the DBE.

463 A docked down submarine is usually undergoing a significant maintenance programme, during which the submarine’s systems may become unavailable for operation. Hence, shore electrical supplies and cooling water services are connected to provide defence-in-depth to the on-board Decay Heat Removal (DHR) systems. DRDL describes the redundant and diverse supplies are provided and how these have been justified against the DBE.

464 DRDL notes that prevention of flooding of a dock caused by a seismic event is assured by the robustness of the dock structure, including the caisson, and measures in place to ensure isolation of large bore water inlets, e.g. by the use of seismically qualified stop-logs. DRDL identifies one outstanding issue for a dock flood for 14 and 15 Docks that relates to the seismic response and potential collapse of the central promontory structure. DRDL submits that the performance of the CPS as a result of a seismic event is being addressed as part of an ongoing work programme and the outcome of this will be progressed through normal regulatory arrangements.

465 DRDL notes that the need for 9 Dock to be resilient against a DBF is achieved by a seismically qualified dock drainage system.

466 DRDL considers that the pump flood main will remain operable beyond a DBE and provide back-up cooling water to support decay heat removal. In the event of a pump flood main failure, the docks also have access to a portable emergency cooling water pumping system (PECWP), which is stored away from collapse zones.

Rosyth Royal Dockyard Ltd

467 RRDL reports that the radioactive waste is stored in robust sealed containers. The waste store has solid concrete foundations which are constructed directly onto the bedrock and the walls and roof are designed to withstand the DBE. The waste is stored away from the collapse zones of the walls.

468 RRDL concludes that there are no special requirements in order to respond to a seismically induced failure of the building and that the waste store is not susceptible to the indirect effects of an earthquake, such as fire or explosion.

Magnox Ltd – Defuelled reactors

469 Magnox has provided a description in its reports of the structures claimed in the seismic safety cases for operating reactors. A range of techniques were used for the seismic qualification of the structures. A graded approach was adopted where conventional linear approaches were used initially, and more complex non-linear methods adopted only where adequate margins could not be guaranteed using the conventional approaches.

470 The seismic safety case requirements for the defuelled Magnox stations are that gross collapse of the structures containing radioactive inventory should not occur. There are no requirements placed on any active systems or power sources to limit radioactive releases. Therefore, there are no claimed operator actions required in the seismic safety case.

471 Further, loss of external power (National Grid connection) is assumed to occur at the instant that a seismic event occurs. There are no claims made over on-site power supplies required or in terms of a period to reinstate the grid connections as no active systems are required to maintain nuclear safety.

472 Magnox Ltd has discussed the protection against indirect effects, following a seismic event, in varying levels of detail across the sites. The effects of a seismic event on a broader scale which may impact the site access and egress are not discussed in the reports. However, the argument is made that there are no operator actions required and this is therefore not an issue.

NNB GenCo – Hinkley Point C

473 The seismic classification of the structures, systems and components is outlined in the Hinkley Point C stress tests report, along with the design rules to be applied to individual classes of structures. There is a high-level discussion on the design codes to be used for plant, equipment and pipework.

474 It is intended to have seismic monitoring equipment on Hinkley Point C such that a rapid evaluation of an event magnitude can be undertaken and appropriate action taken.

475 It is assumed in the design and fault sequences that there will be a simultaneous LOOP with a seismic event. There are four trains of back-up and emergency plant available on-site for all key safety functions. The emergency arrangements have not been developed in detail, however it is anticipated that as a minimum there will be sufficient stocks for 24 hours' operation of all four trains; this is discussed further in Section 6 of this report.

476 Access and egress around the proposed plant has been considered and shown to be adequate following a postulated seismic event. Broad arguments are made over the likelihood of site access and egress, and measures which could be taken to ensure this is achieved on a tolerable timescale.

477 All passive and active fire protection measures for class 1 systems will be qualified as seismic class 1. The design incorporates separation of non qualified flammable inventories from classified equipment. In addition, seismic isolation valves will be provided on non-qualified fire systems to prevent drain down of the water reserves.

478 The potential for seismically induced explosions is currently being examined by NNB GenCo.

#### *2.1.2.1 ONR's Assessment of the Provisions to Protect the Plants Against the Design Basis Earthquake*

Sellafield Ltd – Sellafield and Windscale

479 As noted previously, the concept of safe shutdown as applied to NPP is not readily applicable to many facilities on the Sellafield site. Sellafield Ltd has identified facilities where maintenance of a safe state as opposed to safe shutdown is dependent on continued operation of support services i.e. those requiring cooling and ventilation.

480 The potential for loss of containment of radioactivity is considered broadly but the effects of spread of contamination and consequent effects on access and continued operation of support services is not well developed at this stage.

481 Protection against the DBE is in many instances derived from demonstration of withstand capability with varying levels of damage accepted. The assessment of seismic withstand capability has been based to a limited extent on recent detailed analysis with a greater reliance placed on seismic damage walk down and expert review completed in past years. The extent of information used to inform the early seismic damage assessment was limited and although the conclusions reached have been revisited in light of current experience, further work is needed.

482 ONR considers that the review of seismic withstand undertaken by Sellafield Ltd has been relatively high level and although limitations in high-hazard facilities have been identified the

validity of seismic damage assessment conclusions for facilities with significant inventories should be tested in light of detailed information compiled in completion of continued operation safety reviews and subsequent PSRs. As a result, the following finding has been raised:

**STF-24: Sellafield Ltd should review the information used to inform the seismic damage assessment conclusions in light of more recent experience and detailed analysis completed for periodic safety assessments to confirm expected withstand capacity for facilities with significant inventories.**

483 The review of seismic damage to pond structures has focused on the consequences to stored fuel and the extent and level of spread of contamination and hence associated dose to workers has been less well developed. Sellafield Ltd has noted a need to contain local flooding around FHP and considered provision of skid mounted diesel pumps with capacity of 100–300m$^3$ / hour for potential deployment in FHP following a severe seismic event.

484 The current stress tests undertaken for pond structures is primarily aimed at a demonstration that fuel cooling can be maintained and the potential for fuel fire is controlled. The potential for fuel fire within ponds is limited and structures used for storage of relatively “fresh” fuel are more robust than legacy facilities and generally have been subject to detailed seismic assessment with demonstration of adequate withstand capacity.

485 ONR considers that the potential for fuel fire within storage ponds has been given due consideration and that a combination of robustness of more recent pond structures, age of fuel stored and diversity in water make-up facilities, leads to the conclusion that the risk of such instances is low.

486 Although seismic damage to aged high-hazard facilities has been recognised, consideration of the extent of disruption and effects on services and distribution networks is limited. The following finding has been raised:

**STF-25: Sellafield Ltd should complete further work to assess the extent of seismic damage to local infrastructure. This work should demonstrate the extent to which local services can function following connection of temporary power supply.**

487 The requirement to look at the availability of local infrastructure following a seismic event is complementary to the finding raised in ONR’s National Stress Tests Final Report for UK NPPs (Ref. 10) and reiterated in Section 5.1.4 of this report: to investigate the provision of event-qualified connection points to facilitate the reconnection of supplies to essential equipment for beyond design basis events.

488 It is noted that, for certain facilities, the practicality of enhancing direct protection measures is limited and decommissioning and waste retrieval have been adopted as the best way forward.

Urenco UK Ltd

489 ONR considers that UUK has adequately described the seismic withstand of its buildings and plant, a number of which had provision within their original design for seismic loading. In addition, future work activities, including revised assessments and procurement of seismically qualified equipment are described. ONR considers the licensee’s response to the impact of earthquake to be comprehensive and measured.

490 UUK identifies operator actions as part of the site’s resilience to ensure that faults induced by DBE and larger earthquakes do not persist for an extended period. The licensee has recognised that its extant emergency planning scenarios and arrangements are currently based on a single accident scenario, hence has identified the need to consider the implications of and resources

needed for combination events. ONR supports this and, as part of this consideration, has secured commitment from UUK to address a number of specific detailed issues in greater detail.

Dounreay Site Restoration Ltd

491 Most facilities on the site that contain significant radiological inventories are adequately demonstrated to be structurally resilient to the site reference DBE. In cases where the facility is not demonstrated to be structurally resilient to a cliff-edge seismic event, ONR is satisfied that the licensee has implemented reasonably practicable improvements and articulated an appropriate balance of risk argument. ONR also considers that the licensee has demonstrably challenged the current design basis for cliff-edge effects which has demonstrated possible structural vulnerabilities.

Springfields Fuels Ltd

492 ONR is aware that the Springfields site has facilities of varying age and therefore standards of building construction with respect to seismic resilience. ONR has historically permissioned and given Consent, under SFL's nuclear site licence, to the construction and operation of the more modern facilities on the site that comply with more recent standards of seismic design. Other facilities are operated by the licensee, for example to process legacy uranic residues in facilities that were constructed circa 50 years ago, primarily to support the conversion of uranium ore to uranic intermediates needed for fuel manufacture. Evidently those facilities cannot be substantiated to a particular ground acceleration in accordance with modern standards analysis. Nevertheless, the licensee operates those facilities to safety cases for which ONR is confident demonstrates that the principles of uranic material containment and criticality prevention are addressed; these facilities are important for conversion of uranic residues into a safe, passive form. ONR accordingly inspects those facilities and their respective safety cases as part of routine compliance inspection to sustain the necessary regulatory assurance as to their safe operation.

Atomic Weapons Establishment

493 ONR notes that a number of the facilities at AWE's sites were built during the 1950–1980 period and were therefore not seismically qualified as part of the original design. For those facilities that did not have a seismic loading component as part of the design, post-construction evaluations of the hazard and withstand were undertaken as part of the PSRs. This has been an ongoing process from the late 1980s to date and has focused on the most significant nuclear safety-critical SSCs, with improvements to the robustness being undertaken where it has been demonstrated to be ALARP to do so.

494 ONR considers the results presented by AWE for the first facility are adequate with only minimal damage occurring to the building at the DBE. ONR notes that the building analysis has taken account of the effects of soil structure interaction in addition to the effects of local site response.

495 ONR considers the evaluation of the withstand of the second facility at Aldermaston site is adequate as it meets the DBE with minor localised structural failures that do not affect the containment function of the building.

496 For the third facility, further information will be provided to support the claim that damage to the building would not lead to a severe accident in the periodic review of safety.

497 ONR supports the replacement of the fourth facility at the AWE (A) site with a new one designed to modern standards.

498 ONR supports the upgrade of the group of buildings on the AWE (B) site that were designed before consideration of seismic hazard for the design of nuclear facilities in the UK was expected. These facilities are being replaced by a new facility designed to modern standards. ONR is aware

that AWE is pursuing improvements to the exception that arose during the PSR that was undertaken ending in 2006. Although one of the buildings could not be substantiated against the 1 in 10,000-year DBE, ONR is satisfied that the nuclear materials within the building are protected from possible impacts from a building collapse.

499 AWE has noted the possibility of more than one external hazard occurring close to one another in time, such as extreme weather following a seismic event. AWE has concluded that such a situation would be similar to a beyond design basis seismic event but without a significant escalation in consequences. ONR recommends that AWE should substantiate that water ingress through buildings damaged by a seismic event cannot lead to an escalation in consequences. This is covered by STF-26.

500 Both AWE sites are multi-facility and consist of both nuclear and non-nuclear facilities. The possibility of seismically-induced fires exists for both types of facilities. There is therefore potential for this to stretch on-site fire services and prevent support from external services. ONR recommends that AWE should consider investigating the possibility of multi-facility fires in combination with the disruption caused by a significant seismic event. This is covered by STF-26.

501 AWE identifies that the Aldermaston site Situations Co-ordination Centre is located in a facility which is reported as having a seismic withstand against a 1 in 1,000-year event. AWE has not provided information on the ability of any other emergency control or co-ordination centre to withstand the seismic hazard. No information is provided on the ability of such emergency centres to withstand the seismic hazard in combination with other hazards. ONR recommends that:

**STF-26: AWE should consider reassessing the nuclear safety implications of consequential events, such as water ingress, multi-facility fires and loss of emergency control and co-ordination centres, following a significant seismic event to establish whether further measures are needed to reduce the associated risks.**

Rolls-Royce Marine Power Operations Ltd

502 ONR considers that, in reviewing its sites, RRMPOL has identified correctly that two of the four facilities covered by the submission were constructed before the need to seismically justify them was introduced.

503 ONR recognises RRMPOL’s statement that specific equipment within these buildings has a higher seismic withstand capability, but ONR could not see any consideration of whether failure of these buildings could undermine the withstand of this equipment.

**STF-27: RRMPOL should consider reviewing whether the failure of the four buildings identified in its submission, when subjected to a design basis earthquake, could undermine the higher seismic withstand capability of the equipment those buildings contain.**

504 ONR recognises that the production facility that is designed to meet the DBE contains equipment that is predicted to fail at seismic loadings below the DBE.

**STF-28: RRMPOL should consider reviewing what improvements could be made to the seismic withstand of equipment within the production facility that could have an impact on radiological release.**

505 ONR considers that the automatic control rod insertion in the Neptune reactor following failure of the relays in the reactor control systems in a DBE is adequate.

506 While RRMPOL considers the effects of fire for most facilities and concludes that it is bounded by the consequences from other hazards, ONR concludes that RRMPOL has not considered the

scenario of a fire following a seismic event, recognising that a fire could result from the seismic event. This is covered by STF-36.

BAE Systems Marine Ltd

507 ONR considers that BAESM has appropriately identified the relevant facilities on its site for the seismic considerations of the stress tests. It has also considered the adjacent dock system, which while not under its control, act as an external hazard to its facility.

508 ONR accepts that nuclear safety for the radioactive component facility is delivered by the restraints in the fuel assemblies, coupled with the exclusion of a moderator. BAESM asserts that a criticality in these accident scenarios is not credible.

509 ONR agrees that the DDH has a withstand against an event with a 1 in 1,000-year return period and that the nuclear safety is assured by features associated with the fuel assembly and reactor pressure vessel and recognises that there is a necessary construction period where it is not possible to have restraints in place.

**STF-29: BAESM should consider reviewing whether there are any further options for minimising the potential for physical impacts during a seismic event on radioactive components during construction activities.**

510 ONR supports the conclusions of the seismic assessment of the shiplift and transfer system, the dock system and the submarine mooring are reasonable.

511 ONR notes that the ongoing safety of the submarine following collapse of the dock system is based on water being retained in the dock system due to the dock sills.

**STF-30: BAESM should consider reviewing the seismic withstand capability of the dock sills and their impact for events exceeding the 1 in 100-year return period, when the dock walls are predicted to have failed.**

512 ONR concludes that on-site emergency control facilities may be lost in the DBE.

**STF-31: BAESM should consider the provision of a hardened robust emergency control centre or propose formalised alternative arrangements.**

Devonport Royal Dockyard Ltd

513 ONR recognises that DRDL has identified that a seismic event could lead to some possible indirect effects and some localised potential weakness and is investigating these. ONR supports this approach.

514 ONR considers the qualification level of the key SSCs to prevent fast and slow flooding of the dry docks to be appropriate and notes that DRDL is currently investigating a possible weakness in specific locations.

515 ONR considers the justification against the DBE of the DHR systems, supplemented by shore supplies, for a docked down submarine to be adequate.

516 ONR considers that DRDL has made adequate provision for maintaining cooling for reactors with low decay heat.

517 ONR concludes that DRDL has not provided any information within its stress tests submission in relation to the effect on a facility or the site in the event of a fire or fires following a seismic event.

**STF-32: DRDL should consider assessing the possible effects of fire following a seismic event.**

518 ONR recognises that the Forward Command Posts may be lost in the DBE. This is considered further in Section 6.

Rosyth Royal Dockyard Ltd

519 ONR agrees with RRDL's assessment of the seismic effects on the waste store.

Magnox Ltd – Defuelled reactors

520 The summaries of the individual cases for each station are sufficiently detailed to gain a high-level appreciation of the nature of the seismic safety case against the DBE.

521 The key issue from an induced hazard perspective is fire. This is discussed to varying degrees, depending on the site in question. ONR considers that the responses provided do not demonstrate a clear position on seismically-induced fire. However, it is noted that for each station there is a *Consideration* raised to "consider the fire safety case for ILW facilities". This should include the potential for seismically induced fires. ONR will monitor progress against this *Consideration* in line with STF-20.

522 ONR judges that the submissions for the Magnox defuelled sites are considered to be broadly acceptable, given the stage in their life-cycle.

NNB GenCo – Hinkley Point C

523 ONR believes that the responses provided by NNB GenCo are adequate, and demonstrate that if some aspects have not been considered as yet in the design, they are being undertaken currently, or it is the intention to do so as part of the longer term development of the site safety case.

### 2.1.3 Plants' Compliance with Their Current Licensing Basis

Sellafield Ltd – Sellafield and Windscale

524 In formulating adequate arrangements and completing assessments and designs against LCs, Sellafield Ltd notes that work completed has been guided by memorandum of understanding drawn up following meetings with NII in 1995, commonly known as the Winter Seminar. At that time, the guiding criteria for design basis assessment was agreed and the agreements were recorded in a document referred to as the L99 series of understandings. The L99 series of understandings was reviewed in 2008 and considered to be still relevant subject to minor amendment.

525 Both design of new plant and assessment of existing plant are guided by seismic input criteria recorded in the L99 understandings.

526 Following the events at Fukushima, Sellafield Ltd undertook a series of inspections to confirm compliance with hazards safety cases.

527 In addition to licensing requirements for site-based plant, Sellafield Ltd confirms that site equipment designed for severe accident mitigation is routinely inspected, although full functionality is not confirmed.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

528 UUK, DSRL and SFL each have a number of processes in place to ensure that safety-critical SSCs remain available in accordance with licence condition requirements. These processes include the site and facility maintenance arrangements, the procedures for the control of modifications and the use of PSRs. These licensees do not provide a detailed summary of these arrangements in

their respective stress tests reports; however the ongoing licence condition inspection regime on each site aims to secure continued regulatory assurance that SSCs on those sites are maintained to an appropriate level commensurate with their required safety functions.

Atomic Weapons Establishment

529 AWE is required to demonstrate compliance with the 36 nuclear site LCs, and regularly reviews the safety of facilities through the case for continued operations process. Facility and site safety cases are reviewed every ten years in accordance with LC15.

530 In terms of the seismic hazard the DBE has been defined for both the Aldermaston and Burghfield sites. All of the AWE nuclear-related facilities addressed in this report have been assessed against these DBEs. New facilities to replace older facilities are being designed to withstand the DBEs.

531 All SSCs that are claimed for nuclear safety within the seismic assessments have safety functional requirements and are categorised as safety or safety-related systems. These engineered systems require appropriate through-life management during all modes of operations to ensure that the design intent is not compromised or eroded. Central to this is the requirement that they are subject to appropriate examination, maintenance, inspection and testing (EMIT) in accordance with LC28 of the nuclear site licence and that plant essential for safe operation is correctly configured and operated in accordance with LC27.

Rolls-Royce Marine Power Operations Ltd

532 RRMPOL notes that its inspection and maintenance activities are linked to the requirements of the existing site safety case and that these arrangements will be improved as a result of the current PSR activities. Similarly, the site’s safety functional requirements are linked to the existing site safety case. The re-issue of the site safety case as part of the PSR safety improvement plan will see these links significantly enhanced.

533 Following a seismic event, the site’s safety management arrangements dictate that rigorous visual inspections of key structures and equipment on-site are undertaken and any necessary action taken prior to restart of operations.

BAE Systems Marine Ltd

534 BAESM has not provided specific information about the licensing basis in its stress tests submission. ONR is aware that arrangements are in place to ensure appropriate maintenance of plants and facilities occur.

Devonport Royal Dockyard Ltd

535 DRDL reports that they have arrangements in place to ensure appropriate maintenance is undertaken of plants and facilities using a computerised maintenance management system, with the prime source for scheduled maintenance requirements being the design authority for the plant or equipment. DRDL advises that all maintenance, repairs and routine servicing are conducted to conform with good engineering practice and in accordance with the maintenance plan.

Rosyth Royal Dockyard Ltd

536 RRDL reports that the radioactive waste store is regularly maintained to ensure that it and the systems and services within it continue to meet their design intent.

Magnox Ltd – Defuelled reactors

537 Magnox has provided a summary of the processes to ensure that the safety-critical SSCs remain available. These are based on maintenance arrangements, procedures for the control of modifications and the PSR process.

NNB GenCo – Hinkley Point C

538 NNB GenCo has provided a summary of the proposed processes to ensure that the safety-critical SSCs remain available.

#### *2.1.3.1 ONR's Assessment of the Plants' Compliance with Their Current Licensing Basis*

Sellafield Ltd – Sellafield and Windscale

539 ONR considers that the facilities on the Sellafield site are essentially compliant with the requirements of the safety case. There are clearly some areas where the full implementation of the case is subject to change as modifications and standards advance. This is recognised by ONR and is tracked through routine regulatory business, particularly the PSR process.

540 The seismic hazard safety assessment for plants designed prior to the implementation of seismic standards recognises the difficulties to be addressed in applying modern standards to structures never designed to withstand seismic activity. For such plants, PSRs are completed in line with modern standards and shortfalls are reviewed to ensure that all reasonably practical measures are taken to maintain risk ALARP.

541 The need to ensure operability of emergency equipment not in normal use is recognised and ONR is progressing a review of inspection and maintenance arrangements. Sellafield Ltd has included within its review a *Consideration* to:

- Procure temporary mobile units for provision of either welfare support or to augment the management of emergencies.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

542 As previously indicated, ONR's licence condition inspection regime on Urenco Capenhurst, Dounreay and Springfields aims to secure continued regulatory assurance that SSCs on those sites are maintained to an appropriate level commensurate with their required safety functions.

543 ONR considers that the facilities on these sites are essentially compliant with the requirements of their safety cases produced in accordance with LC23. There are clearly some areas where the full implementation of the case is subject to change as modifications and standards advance. This is recognised by ONR and is tracked through routine regulatory business, particularly the PSR process.

Atomic Weapons Establishment

544 ONR considers that AWE statements meet ONR's expectations for considerations of the seismic hazard under the LCs.

Rolls-Royce Marine Power Operations Ltd

545 ONR considers that RRMPOL's maintenance arrangements meet the expectations for ensuring that plant systems, structures and components needed for achieving safe shutdown after a seismic event meet their required safety function.

BAE Systems Marine Ltd

546 BAESM have a number of processes in place to ensure that safety-critical SSCs remain available in accordance with licence condition requirements. These processes include the site and facility maintenance arrangements, the procedures for the control of modifications and the use of PSRs. BAESM did not provide a summary of these arrangements in its stress tests submission. However, ONR's ongoing licence condition inspection regime aims to secure continued regulatory assurance that SSCs on those sites are maintained to an appropriate level commensurate with their required safety functions.

Devonport Royal Dockyard Ltd

547 ONR considers that DRDL's maintenance arrangements meet the expectations for ensuring that plant systems, structures and components needed for maintaining a safe shutdown after a seismic event remain in a faultless condition.

Rosyth Royal Dockyard Ltd

548 ONR considers that RRDL's statement meets the expectations for ensuring that plant systems, structures and components needed for achieving safe shutdown after a seismic event meet their required safety function.

Magnox Ltd – Defuelled reactors

549 ONR considers that the Magnox defuelled sites are compliant with the requirements of the safety case.

NNB GenCo – Hinkley Point C

550 The response from NNB GenCo on Hinkley Point C is considered adequate given its position in the licensing process.

## 2.2 Evaluation of Safety Margins

### 2.2.1 Range of Earthquake Leading to Severe Nuclear Matter Damage

Sellafield Ltd – Sellafield and Windscale

551 Sellafield Ltd's *Consideration* of the range of earthquakes leading to severe nuclear matter damage takes the form of high-level reporting of the scale of damage that could be expected following either a 0.125g or 0.25g seismic event.

552 As the potential for damage to nuclear material is limited, Sellafield Ltd has additionally considered potential radiological release as a result of loss of containment of nuclear wastes or process liquors.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

553 The impact of an earthquake on stored nuclear material at Urenco Capenhurst, Dounreay, Springfields is considered and bounded by Section 2.2.2.

Atomic Weapons Establishment

554 As part of the PSR process, the seismic withstand requirements of the facilities have been established by AWE based upon conservative consequences.

555 AWE has used engineering substantiation to show that the buildings can meet these design basis requirements and, where they cannot, appropriate engineered enhancements have been implemented in line with the ALARP principle.

556 The response of individual buildings to seismic hazard levels beyond their design basis may result in progressive collapse and the possibility of subsequent fire. AWE has taken account of the fact that the sites are multi-facility with cumulative effects being taken into consideration. These cumulative releases do not give rise to doses in excess of 5mSv at distances greater than 3km from the centre of the site, from reasonably foreseeable beyond DBE external events.

<u>Rolls-Royce Marine Power Operations Ltd</u>

557 RRMPOL has considered a maximum free field acceleration that is 40% greater than the DBE for the Neptune reactor. RRMPOL indicates that the Neptune building will withstand the beyond DBE and that there is no resultant criticality issue.

558 RRMPOL has not considered a maximum free field acceleration that is 40% greater than the DBE for the NFPP but concludes that the two older facilities and plant are likely to have failed above the DBE and that the newer production shop is likely to undergo progressive failure beyond the DBE.

559 RRMPOL has identified a *Consideration* on how to improve the resilience in this scenario.

<u>BAE Systems Marine Ltd</u>

560 BAESM's approach to a beyond design basis seismic event, called the beyond DBE, is to consider a maximum free field acceleration that is 40% greater than the DBE.

561 BAESM concludes that the facilities would collapse before the DBE is reached, with the features within the submarine design providing protection in the beyond DBE against criticality in the same way as for the DBE. The detail of this additional protection is the subject of the separate DNSR review.

<u>Devonport Royal Dockyard Ltd</u>

562 DRDL identifies the Seismic Margin Earthquake (SME) as an extreme seismic event for the Devonport site, characterised by maximum free field accelerations 40% greater than the DBE; this is judged by DRDL to be equivalent to a seismic hazard with a return frequency of 1 in 100,000 years.

563 DRDL reports that an afloat submarine is seismically isolated from the seismic event and hence the loss of on-board systems is highly unlikely and therefore will not present a challenge to the shore-based facilities.

564 In the case of a docked down submarine, shore electrical supplies and cooling water services are connected to support the on-board DHR system. DRDL predicts a complete loss of grid supplies in an SME, with site-derived supplies then providing the only back-up to the submarine's installed systems. However, DRDL considers that the majority of these are unlikely to survive an SME. Those facility safeguards required to survive an SME have been demonstrated to do so and additional services are identified that may survive which would provide defence-in-depth.

565 DRDL advises that in the case of a submarine in dry dock undergoing defuelling, the submarine's pressure hull is cut open and the reactor pressure vessel head removed to permit access to the reactor core, which is at very low decay heat levels. Should an extreme seismic event at the SME level occur and result in a dropped load or the collapse of lifting equipment on to the core, DRDL concludes that this has the potential to result in mechanical damage to the fuel. Notwithstanding the fact that criticality is dismissed as a credible fault sequence and therefore not a source of

potential off-sire release, it is important to note that the primary circuit remains boronated throughout the fuelling and defuelling process ensuring sub-critical status even if all the control rods are removed.

Rosyth Royal Dockyard Ltd

566 RRDL’s approach to beyond design basis seismic event is to consider a maximum free field acceleration that is 40% greater than the DBE and show that no sudden deterioration in nuclear safety would occur.

567 RRDL states that consideration of severe nuclear matter damage is not relevant to the radioactive waste stored at Rosyth.

Magnox Ltd – Defuelled reactors

568 None of the defuelled Magnox sites have nuclear fuel stored in their cores, fuel handling or cooling ponds (note: two recently discovered part elements were recovered in early 2012 at Hunterston A and are held in safe storage in accordance with the requirements of the current safety case). The hazards posed by these facilities are therefore heavily reduced when compared with their operational life. The radioactive waste remaining on-site represents a lower hazard and is either in a non mobile form or contained in robust facilities. No active systems are required to contain or maintain the material. Information has not been supplied on the magnitude of earthquake which could damage the material stored on-site; however, damage to this material is unlikely to have severe radiological consequences.

NNB GenCo – Hinkley Point C

569 The response given by NNB GenCo identifies a number of areas of conservatism in the deterministic design of the nuclear-island. This is based on a comparison of the ground conditions at Hinkley Point C with the more extreme values used as part of the generic design. In addition, the effects of embedment, deconvolution and ground incoherence are considered. A factor of up to 1.4 is claimed for these effects.

570 The design load case for the containment structure which includes the non-coincident loads from a Loss of Coolant Accident (LOCA) with a seismic event is cited as providing considerable margin against the seismic loading alone.

571 Assorted research is quoted to support claims of considerable margin beyond the design basis for robust structural elements, plant and equipment and pipework.

#### *2.2.1.1 ONR’s Assessment of the Range of Earthquake Leading to Severe Nuclear Matter Damage*

Sellafield Ltd – Sellafield and Windscale

572 In the main, Sellafield Ltd’s assessment reiterates damage and consequent radiological release from facilities reported in Section 2.1.2 with the addition of consequences to aged residue storage facilities.

573 The assessment is limited to consideration of the extent of damage that can be expected following a design basis seismic event. There is no discussion of seismic withstand capability or the level of confidence inherent in such assessments. There is no consideration of beyond design basis events and the potential for progressive failure or sudden collapse of containment structures.

574 Sellafield Ltd’s periodic review of seismic assessment of facilities includes assessment of beyond design basis events which may be addressed by applying an arbitrary test against a 0.35g seismic

event (DBE+40%) or consideration of conservatisms including the potential for ductile response. However this is not reported and hence the benefits are not included in the stress tests review.

575 Conservatisms inherent in deterministic assessment are not discussed.

576 Sellafield Ltd has limited the plants considered by screening on consequence basis, i.e. only plants capable of releasing nuclear matter that produces dose to the critical group higher than 10mSv on a best estimate basis are considered. This starts from a basis that a proportion of plants are seismically robust and hence do not warrant investigation. However, while such plants may withstand the DBE without distress, the level of seismic challenge that could threaten containment is unknown.

577 ONR considers that the work undertaken by Sellafield Ltd has been led by application of design basis seismic events and that further work is needed to better understand potential withstand capability and the range of earthquakes that could seriously threaten sensitive facilities. The following finding has been raised to provide the more detailed information required:

**STF-33: Sellafield Ltd should consider the range of beyond design basis earthquakes that could challenge containment to demonstrate the extent of robustness of facilities. The review can be based on reasoned engineering judgement and demonstration of ductile response rather than repeated analysis.**

Atomic Weapons Establishment

578 ONR supports the approach AWE has taken in making improvements to the existing facilities, where they are shown to reduce the risks and be reasonably practicable. ONR also supports AWE’s approach of replacing the older of the nuclear facilities with new ones to modern standards. These facilities are designed to perform in a ductile manner with a substantial margin beyond the DBE.

Rolls-Royce Marine Power Operations Ltd

579 ONR endorses RRMPOL’s *Consideration* on how to improve the resilience against a possible criticality in a beyond DBE.

580 ONR recognises that RRMPOL is evaluating the seismic withstand of facilities as part of the ongoing PSR process and considers that potential improvements will be considered as part of that process.

BAE Systems Marine Ltd

581 ONR acknowledges that a complete collapse of the facilities represents the most severe condition and this occurs below the DBE, therefore a beyond DBE will not lead to an escalation in the challenge on-site. ONR notes that at levels beyond the DBE, the capability to withstand facility collapse is incorporated within the engineering of the submarine.

Devonport Royal Dockyard Ltd

582 ONR considers that the DRDL approach is adequate.

Rosyth Royal Dockyard Ltd

583 ONR considers that the approach of showing that no sudden deterioration in nuclear safety would occur with seismic loadings increased from the DBE to 40% above the DBE is adequate.

584 ONR agrees that severe nuclear matter release could not occur at Rosyth due to the lack of radioactive waste inventory.

Magnox Ltd – Defuelled reactors

585 The aim of the question was to assess if there was a significant increase in the potential for off-site releases if the demand from the hazard increased. ONR considers that the question has not been answered adequately within Magnox's stress tests submission. However, ONR notes that as there is no driving mechanism (heat generation) on the defuelled sites that could result in an off-site release other than fire. Magnox Ltd has already reported within the submission that they will consider reviewing the fire safety case for the ILW stores. ONR believes that this should cover seismically induced fire. ONR will monitor the progress of Magnox's *Consideration* in line with STF-20.

NNB GenCo – Hinkley Point C

586 The response is generic in its nature; however it does provide confidence that there is no immediate cliff-edge effect. There has not been an attempt to try to estimate the values of ground motion (deterministic or probabilistic) at which fuel damage may start to become apparent. It is considered by ONR that given the state of the design this is a reasonable approach, and that sufficient confidence has been provided that there is an appropriate level of margin beyond the DBE before the onset of fuel damage.

### 2.2.2 Range of Earthquake Leading to Loss of Containment Integrity

Sellafield Ltd – Sellafield and Windscale

587 Loss of containment integrity is considered in all sections of Sellafield Ltd's seismic assessment reporting and as such it is not repeated in this section.

Urenco UK Ltd

588 The Capenhurst location is one of the less seismically active regions in the UK with a "best estimate" PGA at the $10^{-4}$ annual exceedance frequency of approximately 0.19g. No structural failure of the centrifuge enrichment plants has a significant probability of occurrence at 0.19g. The capability of some of the site's facilities beyond the DBE is discussed in the UUK report and estimated as above 0.25g PGA.

589 The cranes on the rafts and in the CRD building are not seismically qualified. UUK assumes that the cranes on the rafts and in the CRD building will collapse following a 1 in 10,000-year earthquake. UUK's extant safety case reviews process has previously identified the need to procure new cranes with the necessary level for a number of rafts.

590 The concept of resilience to cliff-edge effects has also been considered by UUK in the context of its emergency response as required by REPPIR. The bounding reasonably foreseeable radiation emergency is based on a $UF_6$ release from a single cylinder. Radiation emergencies arising from a criticality and larger consequence releases are currently planned for through the concept of extendibility of the emergency plans. However, UUK has identified the need for consideration to be given to further documenting the details of the emergency arrangements to support the principle of extendibility, in response to the unlikely event of a criticality incident. ONR supports this and, through normal regulatory processes, will review any UUK proposal for variations in the bounding radiation event upon which emergency planning is based. This will be considered in accordance with existing arrangements for the REPPIR and HIRE assessments.

**STF-34: Urenco UK Ltd should consider the impact on resources required to respond to combinations of more extreme events that might delay or prevent emergency actions. This review should examine the effect of concurrent criticality on ability to affect safe rescue of injured personnel and the validity of assumptions on capability to mitigate a severe accident propagating.**

Dounreay Site Restoration Ltd

591 The facility-specific detail of seismic withstand capability has been subject to security classification and so is not published in DSRL's stress tests report; the classified report provides detail of a systematic test of the seismic withstand capability for each facility according to a 40% increase in peak ground acceleration to 0.2g. DSRL identifies, at a high level, the expected behaviour of external and internal structures (and hence areas of potential containment breach) for the beyond DBE tested. The internal structures and certain facilities (and hence the waste packages therein) are considered potentially vulnerable to the beyond design basis peak ground acceleration of 0.2g. DSRL has however demonstrated that such a scenario would not lead to a criticality. While the integrity of containment for those inventories cannot be guaranteed, the licensee refers to reasonably practicable improvements in the form of additional restraints that have been implemented following PSRs.

Springfields Fuels Ltd

592 SFL reports in its stress tests report that external hazards safety cases for the site assume structural failure of buildings and subsequent material redistribution would occur, and are not predicated on a limited magnitude of earthquake. The licensee exemplifies this approach by reference to the site reference accident in which a beyond design basis seismic incident occurs coincident with the most onerous mode of operation, leading to the release of 25 tonnes of uranium hexafluoride. This scenario constitutes the basis of the site's on- and off-site emergency arrangements. Following initial submission, SFL has since indicated that with removal of conservatisms in the design and the application of the input spectrum for calculation of the seismic action, the Oxide Fuels Complex can withstand a seismic event of a PGA 40% above the design basis at 0.14g, which can be approximated to a 1 in 1,300-year event.

Atomic Weapons Establishment

593 For AWE, refer to Section 2.2.1

Rolls-Royce Marine Power Operations Ltd

594 RRMPOL has considered a maximum free field acceleration that is 40% greater than the DBE for the Neptune site.

595 RRMPOL has not considered a maximum free field acceleration that is 40% greater than the DBE for the NFPP.

596 RRMPOL reports for the NFPP, that a seismic event could lead to a very small release of radioactive material of little consequence, with this being the case even for complete collapse of a facility.

597 Nevertheless, RRMPOL has identified that there are some glove boxes where resilience could be improved and has informed that it will consider this further, but details of how this will be taken forward are not part of its submission.

598 The Neptune reactor is not a pressurised system and the containment has an integrity of at least 40% beyond DBE. The fuel is such that there would not be loss of radioactive material from the fuel, even from a beyond DBE.

BAE Systems Marine Ltd

599 BAESM's approach to a beyond DBE is to consider a maximum free field acceleration that is 40% greater than the DBE.

600 BAESM explains that, during the early phases of submarine construction, there is no need for containment integrity other than protecting against uncontrolled water ingress during the period when the fuel is loaded into the reactor vessel. Once the reactor head has been installed there is full containment integrity. Referring to the discussions under a DBE, the reactor system containment is not challenged by a seismic event.

601 BAESM concludes that the facilities would collapse before the DBE is reached, with the features within the submarine design providing containment integrity in the beyond DBE in the same way as for the DBE.

Devonport Royal Dockyard Ltd

602 DRDL identifies the SME as an extreme seismic event for the Devonport site, characterised by maximum free field accelerations 40% greater than the DBE; this is judged by DRDL to be equivalent to a seismic hazard with a return frequency of 1 in 100,000 years.

603 DRDL reports that an afloat submarine is seismically isolated from the seismic event and hence the loss of on-board systems is highly unlikely and therefore does not provide a challenge to shore-based facilities.

604 In the case of docked down submarine, shore electrical supplies and cooling water services are connected to support the on-board DHR systems. DRDL predicts a complete loss of grid supplies in an SME, with site-derived supplies then providing the only back-up to the submarine's installed systems. However, DRDL considers that the majority of these are unlikely to survive an SME, with the exception of some of the equipment-specific diesel generators.

605 DRDL advises that in the case of a submarine in dry dock undergoing refuelling or defuelling, the submarine's pressure hull is cut open and the reactor head removed to permit access to the core, which is at very low decay heat levels where no decay heat removal demand is required. Should an extreme seismic event at the SME level occur and result in a dropped load or the collapse of lifting equipment on to the core, DRDL concludes that this has the potential to result in mechanical damage to the fuel. When undergoing refuelling or defuelling operations, the primary circuit remains boronated throughout the fuel / defuel process thus ensuring sub-critical status even if all the control rods are removed. Furthermore, DRDL reports that, during normal operations, the external structure of the reactor access house would provide a degree of confinement in the unlikely event of a release of radioactive material, although no claim is made for this in governing safety case.

Rosyth Royal Dockyard Ltd

606 The approach at the licensed site at Rosyth for the beyond design basis seismic event is to consider a maximum free field acceleration that is 40% greater than the DBE, as explained in Section 2.1.2.1.

607 RRDL explains that the severity of a seismic event leading to a release of radioactive waste would be at least that corresponding to a return frequency of 1 in 10,000 years. RRDL concludes that increasingly severe earthquakes would not result in the release of more than a small proportion of the radioactive waste and the consequences would not constitute a severe accident.

Magnox Ltd – Defuelled reactors

608 The defuelled Magnox Ltd stations do not have any “containment” in the terms that the stress tests have been written. The steel pressure vessel and its attached circuit acts as the containment when fuelled; however, since there is no longer any fuel, in core, the question in terms of the reactor is somewhat redundant and considered by Magnox Ltd to be not applicable.

NNB GenCo – Hinkley Point C

609 NNB GenCo has provided a table in its stress tests report which provides a summary of margins against failure of assorted aspects of the containment. This concludes that there is a seismic capability in excess of 1.0g PGA. It is noted that given the engineering studies currently available, a more precise definition is not possible.

#### *2.2.2.1 ONR’s Assessment of Range of Earthquake Leading to Loss of Containment Integrity*

Sellafield Ltd – Sellafield and Windscale

610 ONR’s assessment of the range of earthquakes leading to loss of containment integrity is considered in previous paragraphs and as such it is not repeated in this section.

Urenco UK Ltd

611 ONR considers the UUK response to this aspect of the stress to be appropriate and measured and shares the judgements made. While it has been identified that one of the building roof structures has a lower withstand than others, the licensee intends to conduct further work to evaluate this and the need for modifications. New cranes with seismic withstand are also being procured for a number of the rafts.

Dounreay Site Restoration Ltd

612 DSRL’s stress tests have sought evidence of cliff-edge effects on its facilities according to a single “broad-brush” 40% increase in peak ground acceleration of 0.2g. This has successfully identified facilities that are potentially vulnerable to a beyond DBE. The licensee did not undertake a structured review to ascertain the exact location of the cliff-edge for each facility (in terms of peak ground acceleration and associated frequency). However, ONR considers the approach taken to be a proportionate basis on which to test for vulnerabilities in the design basis. ONR is satisfied that the arguments presented are sufficient to demonstrate the licensee has implemented all reasonably practicable measures to minimise those possible vulnerabilities for a remote possibility of a 0.2g beyond DBE. ONR further agrees with the licensee’s argument that there is limited opportunity to develop practicable improvements given the identified timescales for achieving interim end-state.

Springfields Fuels Ltd

613 Following submission of its stress tests report, SFL has provided sufficient demonstration that existing safety cases challenge the design basis for earthquakes according to a 40% increase in peak ground acceleration for facilities that have been seismically qualified. ONR considers that this approach adequately addresses the intent for the design basis to be “stressed” for cliff-edge effects. ONR recognises that evaluation of a cliff-edge for the much older uranic processing facilities would add very minimal value given their design to much earlier standards and the remaining facility lifetime being limited (contractually to 2016).

Atomic Weapons Establishment

614 For AWE, refer to Section 2.2.1.1.

Rolls-Royce Marine Power Operations Ltd

615 ONR considers that the RRMPOL approach is adequate.

BAE Systems Marine Ltd

616 ONR considers that BAESM's approach and conclusions are adequate as the containment integrity is provided by the submarine.

Devonport Royal Dockyard Ltd

617 ONR considers that DRDL's approach and conclusions are adequate.

Rosyth Royal Dockyard Ltd

618 ONR considers that RRDL's approach and conclusions are adequate.

Magnox Ltd – Defuelled reactors

619 The response by Magnox Ltd to this question is rather literal, and does not fully answer the question. The aim of the question was to assess if there was a significant increase in the potential for off-site releases through loss of some form of "containment" if the demand from the hazard increased. The low level of inventory on the sites means that there is a limited potential for off-site releases.

NNB GenCo – Hinkley Point C

620 The claims that the seismic capability is in excess of 1.0g PGA are seen as somewhat optimistic. At this level of demand the foundation behaviour will become non-linear and extrapolation of the DBE results in a linear manner is not practicable. However, ONR agrees that there is a reasonable margin beyond the DBE where containment integrity will not be compromised. It is agreed by ONR that a more accurate estimation cannot be provided at this stage in the design / construction process.

621 NNB GenCo has provided a further statement clarification, saying that the tabulation of seismic margin was a feature carried over from the equivalent stress tests report produced for the Flamanville 3 NPP. It was not intended that it would provide a definitive quantitative assessment of the magnitude of the margin but rather provide an indication of the sources of margin and their associated indicative values.

### 2.2.3 Earthquake Exceeding the Design Basis Earthquake for the Plants and Consequent Flooding Exceeding Design Basis Flood

Sellafield Ltd – Sellafield and Windscale

622 Sellafield Ltd has considered the potential for beyond design basis earthquakes remote from site causing changes in land form that in turn could produce flooding of the site.

623 The potential for changes in river and groundwater flows is discussed together with a review of seismically induced tsunami.

624 Disturbance of lakes, Wastwater and Ennerdale is considered and distances from the site in combination with river flow patterns are such that flooding of the site is considered to be improbable.

625 Sellafield Ltd notes that the higher reaches of the River Calder include steeply sided valleys that could be affected by land slip. Such effects could cause a hold-up of river flow with possible sudden release of larger volumes of water.

626 Having discussed the potential for seismically induced tsunami, Sellafield Ltd concludes that the position of the site in relation to seismically active zones that have the potential to induce tsunami is such that any wave reaching the site would not threaten nuclear safety.

Urenco UK Ltd

627 The potential for seismically induced flooding at the Capenhurst site is discussed and dismissed as not credible by UUK. Earthquake intensity of the magnitude experienced at Fukushima is not considered credible in the UK. While smaller earthquakes are credible these have been addressed as far as is reasonably practicable in the plant design and safety cases. The combination of distance from the sea and height above sea-level of the site provides confidence that a tsunami or significant flooding, which may affect safety, is not a credible initiating event at the UUK site.

628 UUK has given consideration to a number of potential means for an earthquake to cause local flooding on the site. This includes collapse of Cheshire salt mines and fracking giving rise to local earthquakes and flooding expectations from rivers, on-site ponds and local water works. The licensee has judged that none of these has sufficient potential to give rise to flooding that could in any way impact operational safety. The only possible impact was as a hindrance to emergency response but this is of minor significance. These arguments as presented by UUK in its stress tests report are considered by ONR to be reasonable.

Dounreay Site Restoration Ltd

629 A 2003 study by Coventry University examined the risk of seismically induced tsunami at Dounreay. The tsunami risk was shown not to be seismic driven due to the region’s relative seismic stability. DSRL refers to a subterranean slide that took place in the Storegga region of the North Sea west of Norway circa 7,200 years ago which is discussed further in Section 3.

Springfields Fuels Ltd

630 The licensee’s stress tests adequately demonstrate that there is no credible scenario that could affect the site due to a flooding event occurring as a direct consequence of a DBE.

631 SFL’s stress tests report briefly acknowledges the potential for floodwater inundation of facilities that have suffered structure collapse following a seismic incident, and indicates that such circumstances could favour a criticality incident under the correct geometric conditions. This scenario would be the result of coincidental rainfall-induced flooding that is considered further in Section 3.

Atomic Weapons Establishment

632 AWE explains that as a result of the location of Aldermaston and Burghfield sites it is not credible for an earthquake exceeding the DBE to result in consequential flooding exceeding the DBF. The reason is that there is no large enough body of water external to the site.

Rolls-Royce Marine Power Operations Ltd

633 RRMPOL reports that at levels beyond the DBE, toppling of the contents from racking in one of the production shops on the manufacturing site could occur, resulting in rearrangement of materials. If this were followed by a 1 in 100-year flood, there is a possibility of a criticality occurring. The shortfalls associated with this facility were identified as part of the PSR process and are being actively addressed through the identification and implementation of ALARP

improvements. RRMPOL's intention is to replace this existing facility with a modern standards facility within the next four years.

634 For the Neptune site, RRMPOL advises that the combined beyond DBE and beyond DBF will not cause a criticality in the reactor building.

635 RRMPOL also considers a combination of an earthquake and snow and concludes that this is not substantially more severe than a combination of an earthquake and flooding.

BAE Systems Marine Ltd

636 BAESM provides a qualitative argument that a design basis tsunami will not represent a significant hazard to the site and identifies a *Consideration* that an assessment is made for a tsunami.

Devonport Royal Dockyard Ltd

637 DRDL considers the effects of both a seiche and tsunami as a result of a seismic event. DRDL concludes that the wave height of a seiche within a dock will be small. DRDL concludes that the margin above the design basis for a tsunami is so large that it is not considered credible that it would affect the site.

Rosyth Royal Dockyard Ltd

638 RRDL reports that the only potential for flooding caused by an earthquake is from a tsunami and that the site has not considered a tsunami as part of the design.

639 RRDL notes that, in the event of a tsunami, the structure of the radioactive waste store, which is seismically justified, would withstand substantial wave forces, although the building would be inundated.

Magnox Ltd – Defuelled reactors

640 The possibility of consequential flooding as a result of earthquakes is reviewed to greater or lesser degrees in all the stress tests reports and the conclusion reached that there is no credible threat to any of the Magnox defuelled sites.

NNB GenCo – Hinkley Point C

641 NNB GenCo reports that this aspect is currently being studied for the site.

#### *2.2.3.1 ONR's Assessment of Earthquake Exceeding the Design Basis Earthquake for the Plants and Consequent Flooding Exceeding Design Basis Flood*

Sellafield Ltd – Sellafield and Windscale

642 ONR considers that the assessment of the potential for seismically induced flood of the Sellafield site has been completed to a good standard and the review has demonstrated that the probability of flooding is extremely low.

643 In particular, the potential for seismically induced tsunami is shown to be very low with consequences that could not threaten nuclear facilities. The conclusion that a seismically induced tsunami poses little threat to the site is accepted on the basis of:

- The remoteness of the site from major seismically active zones.
- Protection offered by land masses including Great Britain and Ireland.

- The bathymetry of the Irish Sea (shallow compared to the open oceans).
- The absence of coastal features that could magnify wave height.
- The topography of the site and AOD level of nuclear facilities.

644 Although possible disturbance of flow in the River Calder as a result of off-site land slip has been considered, Sellafield Ltd's assessment is to be reviewed to confirm that instability of river banks within the boundary of the site has been considered. ONR notes that the channel of the River Calder within the site was straightened in 1974 and, as such the banks have been subject to engineering improvement and may not be sensitive to seismic activity.

645 In light of the above comment the possibility of instability of the River Calder channel within the Sellafield site has been reviewed and Sellafield Ltd has confirmed that realignment of the channel in 1974 included terracing of the river banks and as a result the potential for instability is very low. Recent work to remove vegetation from the river banks has allowed closer inspection of the river channel and ensured that any changes in bank profile is detected.

Urenco UK Ltd

646 ONR notes its satisfaction with UUK's response in Section 2.2.3.

Dounreay Site Restoration Ltd

647 ONR is satisfied that DSRL's dismissal of seismically induced flooding is based on verifiable evidence.

Springfields Fuels Ltd

648 ONR is satisfied that SFL has demonstrated that the geographic location and topography of Springfields is such that there is no credible beyond DBE induced flooding scenario. The impact of floodwater inundation occurring coincident to a seismically induced building collapse is considered further in Section 3.

Atomic Weapons Establishment

649 ONR concurs with AWE's claim that it is not credible for an earthquake exceeding the DBE to result in consequential flooding exceeding the DBF.

Rolls-Royce Marine Power Operations Ltd

650 ONR considers RRMPOL's argument that the combination of earthquake and snow is not substantially more severe than the combination of seismic and flooding to be reasonable.

BAE Systems Marine Ltd

651 As BAESM currently only has a qualitative assessment for tsunami, ONR supports BAESM's *Consideration* to carry out an assessment of the hazard resulting from a credible tsunami, but concludes that it should be extended to consider the effects of an earthquake exceeding the DBE for the plants and consequent flooding exceeding DBF.

**STF-35: BAESM should consider expanding its proposed assessment of the impact of a credible tsunami, to consider the effects of an earthquake exceeding the design basis earthquake for the plants and consequent flooding exceeding the design basis flood.**

Devonport Royal Dockyard Ltd

652 ONR considers that DRDL's claims that the wave height of a seiche within a dock will be small and that the margin above the design basis for a tsunami is so large that it is not considered credible that it would affect the site are both valid.

Rosyth Royal Dockyard Ltd

653 ONR acknowledges that the DBF for the waste store does not include a tsunami, but notes that the robust design of the waste containers means that this is not an issue.

Magnox Ltd – Defuelled reactors

654 The view that local earthquake induced flooding (tsunami, seiche or failure of impounding structures) is non credible for all the sites is supported by ONR.

NNB GenCo – Hinkley Point C

655 ONR considers that the response is adequate given the stage in the design process.

### 2.2.4 Measures Which Can Be Envisaged to Increase Robustness of the Plants Against Earthquakes

Sellafield Ltd – Sellafield and Windscale

656 Sellafield Ltd's *Consideration* of measures available to increase the robustness of facilities has focused on work underway or completed in relation to relocation of stored nuclear material and waste with some discussion of improvements to aged storage and containment plants.

657 Relocation of reprocessing product and residue cans from old stores to seismically qualified storage is noted together with mention of the Stores Inventory Retrieval Project and completion of phase 1 of the relocation of nuclear material to more seismically robust locations.

658 The ongoing work in relation to the FGMSP that will increase the robustness of containment of pond liquor and radio active sludge is discussed with further works envisaged as part of the Integrated Risk Reduction Project.

659 Deficiencies in the seismic robustness of the Magnox swarf storage silo second extension annex have been identified and design of a seismic restraint structure has been completed with construction programmed for 2012–2013.

660 Removal of radioactive floc from fragile storage tanks together with encapsulation is noted as ongoing with over 50% of active inventory treated and the most vulnerable tank emptied. Sellafield Ltd notes that work has already been completed to install steel jackets to strengthen the floc tanks together with installation of an overbuilding to provide further containment.

Urenco UK Ltd

661 In general those facilities on the UUK site that could lead to consequences requiring seismic qualification have been qualified. The remaining potential consequences are assessed as low enough to be considered ALARP without the need for any further practicable improvements.

662 UUK has identified a number of measures to be considered to increase the robustness of its plants against earthquakes. These include further evaluation of the need to improve seismic withstand of the roof structure of one of the centrifuge plant buildings; procurement of seismically qualified cranes and a revisit to the means for retaining sub-criticality post-seismic events.

Dounreay Site Restoration Ltd

663 DSRL has not identified any modifications which may increase the robustness of the plant against DBEs following this review. DSRL has however reported that during the production of the facility safety cases, improvements were considered and implemented where reasonably practicable in the context of remaining focus to achieve POCO and decommissioning to bring the site to an interim end-state.

Springfields Fuels Ltd

664 SFL does not refer in its report to any further reasonably practicable measures that could be implemented to increase robustness of its plants against earthquakes. Nevertheless, SFL has since confirmed it has sought reasonably practicable improvements to seismic withstand capability during safety case review, and implemented where demonstrated to be reasonably practicable.

Atomic Weapons Establishment

665 AWE has been carrying out engineering substantiation as part of the PSR process to show that the buildings can meet the design basis requirements and, where they cannot, appropriate engineered enhancements have been implemented in line with the ALARP principle. The older existing facilities which were built before an expectation that the seismic hazard should form part of the design requirement for nuclear facilities in the UK are being replaced by new facilities designed to modern standards with consideration of margins beyond the DBE.

Rolls-Royce Marine Power Operations Ltd

666 RRMPOL has identified a specific *Consideration* to improve the resilience of particular areas to combinations of earthquake and flooding. This includes reviewing bunding, racking and glove boxes. RRMPOL is also considering locating some materials in more robust locations within the sites.

667 RRMPOL has identified a number of other *Considerations*. These include *Considerations* relating to the operating period of the diesel generators, the holding of health physics instrumentation and Personal Protective Equipment (PPE) and the storage of neutron poisons.

BAE Systems Marine Ltd

668 BAESM has identified a number of *Considerations* that relate to the seismic hazard for further work to determine whether any specific measures should be implemented. Key *Considerations* for the seismic hazard include alternative access routes if the Wet Dock Quay fails and the consequences of major damage to the dock system.

Devonport Royal Dockyard Ltd

669 DRDL has considered 11 possible enhancements to the robustness of the site against earthquakes with detailed analysis and *Consideration* to follow. Of these, three are applicable to the parts of the Devonport site that are regulated by MoD. The remaining eight include improvements to shelter provision, command posts and emergency response personnel, the provision of alternative electrical generation equipment and the relocation of portable emergency response equipment.

Rosyth Royal Dockyard Ltd

670 RRDL has not identified any practical measures to enhance the robustness of the waste store.

Magnox Ltd – Defuelled reactors

671 No measures have been identified.

NNB GenCo – Hinkley Point C

672 It is reported that the design is generally seen as robust, however two aspects are identified for further consideration related to the qualification of the raw water system to provide a further water supply system in the event of a severe hazard, and the seismic qualification of any volumetric floodwater retaining structures.

#### *2.2.4.1 ONR's Assessment of the Measures Which Can Be Envisaged to Increase Robustness of the Plants Against Earthquakes*

Sellafield Ltd – Sellafield and Windscale

673 The report prepared by Sellafield Ltd reflects the nature of the main facilities on the site, i.e. the predominance of high-hazard plants associated with storage of nuclear material and waste in varied forms arising from receipt and reprocessing of nuclear fuel elements.

674 The robustness of plant against earthquake activity is measured by the extent to which containment can be maintained and the mobility of stored material. The age of many facilities on-site is such that rather than seek to improve robustness of old plants, a focus is maintained on waste recovery, encapsulation and storage in modern qualified structures.

675 The PSR process has identified deficiencies in plant robustness and potential leakage of pond liquors is highlighted. Limitation of leakage is claimed, as the thickness and strength of main containment structures is such that cracking rather than major component failure is envisaged. Practical measures that could improve the seismic robustness of legacy major containment structures are limited and Sellafield Ltd's focus on waste recovery and decommissioning is justified.

676 The impracticality of improving containment robustness of aged facilities places greater demand on mitigation and emergency response measures and the ability and adequacy of such response in the event of site-wide demand is an issue needing investigation. This issue is addressed in Section 6 of this report.

Urenco UK Ltd

677 The proposed improvement measures along with those *Considerations* for enhancing resilience at the UUK site are supported by ONR.

Dounreay Site Restoration Ltd

678 ONR is satisfied that the licensee has undertaken an adequate review, during the production of its facility safety cases, of possible improvements to enhance resilience to DBEs. ONR agrees that its further pursuit of improvements for beyond DBEs would be disproportionate.

Springfields Fuels Ltd

679 SFL does not refer in its report to any further reasonably practicable measures that could be implemented to increase robustness of its plants against earthquakes. ONR is satisfied that the licensee's safety cases demonstrate appropriate evidence that reasonably practicable improvements have been sought; ONR will examine SFL's safety case LC15 periodic reviews to secure confidence that ALARP reviews take due cognisance of remaining facility lifetime.

680 ONR acknowledges and welcomes the licensee's commitment to review the resilience of the site emergency control centre in the event of a seismic incident; this is considered further in Section 6.

Atomic Weapons Establishment

681 ONR supports AWE's approach of carrying out engineering substantiation as part of the PSR process to show that the buildings can meet the design basis requirements, and where they cannot, appropriate engineered enhancements have been implemented in line with the ALARP principle. ONR supports the replacement of the older facilities by new facilities designed to modern standards with consideration of margins beyond the DBE.

Rolls-Royce Marine Power Operations Ltd

682 ONR supports the *Considerations* identified by RRMPOL.

683 ONR notes that the ECC is seismically qualified, but there could be limitations on its operational capabilities as a result of off-site seismic damage.

**STF-36: RRMPOL should consider assessing the challengers from increased seismically induced damage on-site and off-site and the limitations that imposes on external support and possible consequences of seismically induced fire.**

BAE Systems Marine Ltd

684 ONR concludes that the *Considerations* identified by BAESM are appropriate.

Devonport Royal Dockyard Ltd

685 ONR supports DRDL's *Considerations* to enhance the seismic robustness.

Rosyth Royal Dockyard Ltd

686 ONR considers RRDL's conclusion to be appropriate for the type of facility.

Magnox Ltd – Defuelled reactors

687 The conclusion that for defuelled Magnox sites there is little benefit in increasing robustness against seismic events, other than for what are seen as simple, quick modifications given the stage in their life-cycles is supported by ONR.

NNB GenCo – Hinkley Point C

688 ONR agrees with the NNB GenCo position.

## 2.3 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

689 As noted in previous paragraphs few, if any, of the facilities on the Sellafield site fit neatly into the trip, shutdown, cooling and hold-down concept applied to NPP and, as a result, the range of questions applied as part of the stress tests assessment have been adjusted to suit the context of nuclear chemical plant operation.

690 ONR considers that the level of seismic hazard (0.25g free field peak horizontal ground acceleration) used to represent a 1 in 10,000-year event is justified and forms a robust challenge to structures on-site.

691 To obtain full value of the stress tests, the basis of assessment of seismic damage needs to be reviewed in greater detail. Further work is required for plants with significant radiological inventory to establish withstand capability and safety margin in addition to reporting of consequences following design basis events. This has resulted in STF-33. The ENSREG NPP report,

and in particular STF-5, identified the additional need for consideration of beyond design basis events. This conclusion is also applicable to Sellafield Ltd, and is reiterated as a new of finding here:

**STF-37: Sellafield Ltd should complete further work to identify potential failure mechanisms following beyond design basis seismic events, including the possibility for sudden collapse and cliff-edge failure of safety function.**

692 STF-33 and STF-37 are linked and it is expected that work completed to address the former will also inform the assessment identified in STF-33 on the potential for sudden collapse and cliff-edge failure of safety function.

693 ONR recognises that for certain legacy facilities constructed before the development of seismic hazard guidance the potential for increasing robustness and safety margin is very limited. Sellafield Ltd has initiated projects to decommission such facilities and ONR will maintain scrutiny of the work completed and overall progress to ensure that declared timescales are maintained.

694 Although the extent of threat to major containment structures has been identified and the potential for large-scale failure shown to be low, further consideration in relation to secondary effects on support services, distribution networks and ventilation systems is needed. It is expected to be addressed in the response to STF-33.

695 The work completed by Sellafield Ltd demonstrates that nuclear facilities are not threatened by seismically induced flooding events and, in particular, tsunami activity is shown to be of little consequence.

696 Although further work is required, in light of the extensive range of facilities and varying levels of hazard present on the Sellafield site, ONR considers that Sellafield Ltd has applied stress tests logic, demonstrated the adequacy of design basis criteria, and identified areas where improvements can be made.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

697 ONR is satisfied that UUK, DSRL and SFL have undertaken proportionate assessments of their respective site resilience to DBEs; where facilities have not been demonstrated to withstand the DBE, ONR is confident that licensees' safety cases provide adequate demonstration that reasonably practicable improvements have been or are being sought to further enhance resilience. ONR recognises that for ageing facilities that have either irrevocably fixed operational lifetimes or are due to be subject to decommissioning, the opportunities to improve protection systems in line with modern standards are limited and generally impracticable.

698 ONR is satisfied UUK, DSRL and SFL have demonstrated, either explicitly in their respective reports or through subsequent regulatory interaction, that existing designs, where relevant, that there are no cliff-edge effects that could challenge the existing design basis for earthquake scenarios.

Atomic Weapons Establishment

699 ONR considers that AWE has an appropriate representation of the seismic hazard for its sites in the south east of Britain that takes into consideration the regional tectonics, which are characterised by low seismic activity.

700 ONR notes that a number of the nuclear safety-related facilities were constructed before there was an expectation that the seismic hazard should form a part of facility design. However, all facilities exhibit a seismic withstand capability to some degree and this has enabled AWE to demonstrate reasonable withstands for the facilities with improvements where practicable to

enhance the withstand capability. ONR notes that improvements to seismic resilience of facilities at the AWE sites are being carried out under the PSR process and that further improvements will be achieved when the new facilities are in operation, as these have been designed to modern standards with particular emphasis on ductile response to earthquake loading, which will result in significant beyond design basis capability for key nuclear safety-critical parts of the facilities. ONR supports this approach to improving nuclear safety with respect to the seismic hazard.

701 ONR concludes that some of the combined hazards suggested for consideration under stress tests are not applicable to AWE. In particular a combined DBE and flood to a significant depth is not considered by ONR to be relevant to AWE's sites as there are no sources of large quantities of water that could be mobilised as a result of the seismic event.

702 ONR encourages AWE to take into consideration the limitations that the potential collapse and fires from the numerous non-nuclear facilities may have on limiting access to and movement around the site.

Rolls-Royce Marine Power Operations Ltd

703 Although RRMPOL did not provide details of the seismic hazard assessment for the sites as part of its stress tests submissions, ONR considers that the site-specific DBE is an acceptable representation of the likely hazard level in the region of the RRMPOL site when considered in comparison with other studies for Britain.

704 Of the facilities considered at the RRMPOL sites, two production shops were constructed prior to consideration of seismic hazards for nuclear facilities in the UK, while the seismic hazard has been taken into consideration at the newer facilities. The older facilities may fail in a seismic event below the DBE, with specific equipment within these buildings having a higher withstand than the building structure, but still below the DBE. RRMPOL's current PSR is considering improvements to the seismic withstand of plant items. RRMPOL has indicated that this could involve replacing older facilities. ONR supports this approach to improving nuclear safety.

705 RRMPOL has presented information on the Neptune reactor that indicates that it is robust up to a seismic event that is 40% in excess of the DBE. ONR considers that this is a robust installation.

706 The building for the newest production shop meets the DBE, but some internal plant items do not. ONR recognises that the significance and feasibility of potential improvements are being considered by RRMPOL as part of the PSR.

707 ONR recognises that combined events occurring at frequencies below the 1 in 10,000-year return period could challenge nuclear safety and that RRMPOL will consider this as part of the PSR.

BAE Systems Marine Ltd

708 ONR considers that BAESM has an appropriate representation of the seismic hazard for its site which takes into consideration the regional tectonics and incorporates the appropriate degree of conservatism.

709 The nuclear safety of the site is based upon the resilience of the submarine to withstand various levels of seismic input and the potential induced consequences. The case presented by BAESM reports that, even although the various facilities would collapse in a seismic event below the DBE, the submarine's nuclear safety would be unaffected. Key to this is the submarine's on-board systems on which reliance is placed. The safety of these systems is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

710 ONR notes that BAESM has identified a number of *Considerations* to take forward and supports its approach. ONR has raised some additional recommendations; some of these are associated with the level of robustness of the facility and consideration of alternative approaches to improving safety where it may not be possible to directly improve the facility withstand.

Devonport Royal Dockyard Ltd

711 ONR considers that DRDL has an appropriate representation of the seismic hazard for its site at Devonport which takes into consideration the regional tectonics and incorporates an appropriate degree of conservatism.

712 DRDL has provided information that covers the submarines when both afloat in a dock and in dry dock.

713 In general the afloat submarine ultimately relies on its on-board systems to maintain it in a safe state during and following a seismic event. The capability of the submarine is the responsibility of the MoD, which is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review the licensees position in light of the MoD's conclusions.

714 In the case of a submarine in a dry dock, DRDL has presented information that all of the docks have seismic withstands that meet the beyond DBE, although at that level reliance is placed upon single systems. DRDL has previously recognised some weakness in the seismic aspects of the safety case for some of the docks and is working to resolve them. ONR considers that this is an appropriate approach. DRDL has identified a number of *Considerations* and ONR supports DRDL in taking them forward.

715 DRDL has not provided information on combined events which may be due to the margins that DRDL has identified. ONR believes that DRDL should be more specific about combined events.

Rosyth Royal Dockyard Ltd

716 ONR considers that RRDL has an appropriate representation of the seismic hazard for its site at Rosyth which takes into consideration the regional tectonics and incorporates an appropriate degree of conservatism.

717 The facility at Rosyth is a radioactive waste store and has no reactor associated with it. The facility is seismically robust to well beyond the DBE with a well-considered layout to limit consequences and has low radioactive waste inventory.

Magnox Ltd – Defuelled reactors

718 Overall, ONR concludes that the response to the stress tests is adequate given the stage of the plants in the sites' life-cycle and the low levels of risk posed by these sites.

NNB GenCo – Hinkley Point C

719 ONR is satisfied that the response to the stress tests is adequate given the stage of the plant in its design process.

# 3 FLOODING

## 3.1 Design Basis

### 3.1.1 Flooding Against Which the Plants Are Designed

Sellafield Ltd – Sellafield and Windscale

720 The review of Sellafield site flood potential is reported in detail including consideration of:

- Site Hydrology – interaction of the Rivers Calder and Ehen.
- Groundwater abstraction.
- Tidal patterns.
- Fluvial – Maximum river flow and channel capacity.
- Pluvial – Extreme rainstorm and effects of run-off and surcharging of the surface water drainage system.

721 The potential for a tsunami event as a consequence of remote seismic activity has been considered in Section 2 of this report and is not repeated in this section.

722 Flood assessment has been completed for 1 in 10,000-year events with tidal range increased for wave height and the possible influences of climate change. Sellafield Ltd reports that the sea-level corresponding to a 1 in 10,000-year event with wave action and climate change effects is 9.73m AOD. The site topography ranges from 9m to 48m AOD and flooding from tidal action is not considered to be problematic.

723 The fluvial assessment has considered maximum flow in the River Calder for a 1 in 10,000-year event and output indicates that a flow rate of $326m^3/s$ could occur. Sellafield Ltd notes that the passage of the River Calder through the site was realigned (straightened) in 1974 to discharge a flow of $310m^3/s$. The topography of the river north of the site is considered to provide protection to the site and it is noted that the river has cut into its bed to a depth of 1.5m since realignment increasing the flow capacity of the channel.

724 Sellafield Ltd has noted that sudden discharge of both Brow Top and Meadley reservoirs would affect flows in the River Ehen but the passage of the river does not pose a threat to the site.

725 The design assessment of extreme rainfall has considered both high intensity short duration summer events and longer duration winter events at a 1 in 10,000-year return period with the addition of possible climate change influences.

726 The load on the subsurface drainage system has been based on rainfall intensities of 35mm/h and 24mm/h increased by 30% to reflect Department for Environment, Food and Rural Affairs (Defra) advice in relation to climate change. The depth of rainfall affecting the site is calculated as 124mm and 148mm for one- and two-hour durations. Although of a lesser total magnitude, the one-hour duration event giving 124mm depth of water challenges the sub-surface drainage network to a greater extent and this has been input to proprietary software packages to model flow and discharge characteristics.

727 Sellafield Ltd's pluvial (extreme rainfall) assessment has included combination effects from both maximum fluvial conditions and extreme tide events to allow for potential loss of flow capacity at surface water outfall locations. The combination of maximum pluvial and fluvial flows has conservatively assumed that the entire Calder catchment is subject to a 1 in 10,000-year rainstorm.

Urenco UK Ltd

728 The design basis for flooding (and any other natural hazard) considered credible for the UUK site is essentially the same as that for a seismic event, being based on an assessment of the unmitigated dose consequence to the public (from all pathways) following a DBA with a frequency of 1 in 10,000 years. As for seismic assessments, a worst case approach is adopted which is demonstrably conservative whilst avoiding excessive pessimism. The “hazards staircase” approach is employed with ALARP considerations.

729 UUK provides a site-specific flood assessment and details of the data sources. The UK Environment Agency flood map shows that the whole of the UUK Capenhurst site is in an area which falls outside the extent of the extreme flood. For UUK, this means that the chance of flooding each year from rivers or the sea is 0.1% (1 in 1000 years) or less. A flood area is located approximately 4km from the site. The highest undefended flood level reported for the area is 13.7m. The minimum height of the Capenhurst site in metres AOD is 35.5m AOD.

730 Any water ingress to plants would be spread across the floor and a localised build up would be difficult to foresee. The licensee judges it to be incredible that water levels could accumulate to such an extent that significant ingress to a product cylinder could occur. The licensee’s criticality safety case takes into account water reflection and as such flooding has no effect on the calculated safety margins. For the above reasons, no safety significant cliff-edge effects would be expected for less likely flooding of increased severity.

731 UUK has considered the risk from tsunami and concludes, based on the geologically passive nature of north west Europe and the site location / topography that tsunami presents no credible risk. Flood hazard is generally considered to be insignificant at the UUK site and is not considered any further.

Dounreay Site Restoration Ltd

732 A Coventry University study was commissioned in 2003 by DSRL to assess the tsunami risk at Dounreay; this determined the maximum credible tsunami run-up height to be 7.95m associated with the Storegga slide event that occurred circa. 7,200 years ago. DSRL has considered the tsunami to occur coincident with a storm surge occurring on a ten-year return frequency. The combined effect of a tsunami, coincident with a ten-year storm surge would result in approximately 11m run-up that would only reach a very limited number of facilities. None of these facilities has sufficient inventory that would lead to an off-site release greater than 1mSv.

733 DSRL has separately considered a DBF occurring due to storm surge, leading to approximately 6m run-up (again insufficient run-up to challenge the site’s inventory of nuclear material); this takes into account expected sea-level rises by 2100 due to climate change. The licensee has not however challenged this design basis frequency to establish if there is a cliff-edge effect due to storm surge. This is discussed further below.

734 Heavy rainfall has historically been the primary cause for flood events on the Dounreay site, exacerbated by historical drainage problems. DSRL has only considered the impact of flooding due to rainfall in the context of a 1 in 100-year return frequency. The licensee accepts that for such a return frequency it would still not be possible to state categorically that a flood would not occur due to rainwater ingress. This is discussed further below in the context of adequate provisions for such an event.

Springfields Fuels Ltd

735 SFL has referred to a range of flooding sources and evaluates for each scenario whether floodwater inundation could deterministically challenge the design of existing plant; however the

licensee does not explicitly describe a particular flood height against which individual facilities are designed. Floodwater inundation as a result of tsunami, tidal surge or storm surges of nearby water courses are regarded as insignificant by SFL on the basis of site topography and physical distance.

736 The licensee notes its confidence that plant-specific safety cases adequately address the scenario of drains becoming overwhelmed which leads to a general design constraint for vessels containing uranic materials to be held above floor level. The licensee further dismisses the credibility of rainwater accumulating to such a depth (>100mm) to present a nuclear safety hazard. SFL has since elaborated on the natural topography of the site, which slopes towards the central Deepdale Brook valley E-W and then towards the lower farmland to the south of the site, and will ensure no significant depth of water can accumulate over time. In addition, building slabs are laid at an elevation above the surrounding ground to further divert rain water away from the buildings.

737 The licensee acknowledges the potential for an extreme rainfall event to be a mechanism for providing sufficient moderator to lead to a criticality in the event of a seismically induced building collapse. SFL's stress tests indicates that off-site doses would be "markedly lower" than 100mSv but does not specifically quantify the reasonably foreseeable off-site radiological exposure in its report. Since submission SFL has demonstrated that the off-site radiological consequence of a liquor discharge is bounded to less than 1mSv to the most exposed member of the public.

<u>Atomic Weapons Establishment</u>

738 AWE has conducted a flood risk assessment of a number of buildings and emergency access routes considered to be critical to the operation of the site. The model considered flooding due to high rainfall resulting from a 1 in 10,000-year flood event with one-, four- and 12-hour durations.

739 Twenty-one of twenty-seven buildings examined are predicted to suffer from internal flooding. Significant flood depths were also predicted for many of the emergency access routes examined.

740 Of the twenty-seven buildings examined, AWE has assessed that only five have the potential to create a greater than 5mSv consequence off-site. However, subsequent assessment of the flooding withstand has concluded that no severe accident can result from this hazard.

<u>Rolls-Royce Marine Power Operations Ltd</u>

741 RRMPOL is located on the floodplain of the River Derwent, more than 50km from the coast. Potential causes of flooding on the site are from the River Derwent, failure of dams on the river Amber and River Derwent upstream of the site, and heavy rainfall.

742 RRMPOL reports that there is no DBF defined for the sites. The sites are protected by flood defences that offer resistance to flooding for river flows up to the 1 in 100-year event; this is in essence the design basis performance of the sites against flooding.

743 For the manufacturing site, the 100-year flood water depth is estimated by RRMPOL to be about 0.2m, while for the Neptune site it is estimated to be 0.12m in the reactor hall. For a 10,000-year flooding event, floodwater depths are estimated to reach 1.45m and 1.08m for the manufacturing and Neptune sites respectively.

744 A detailed site flood modelling study has been performed by RRMPOL and is currently undergoing peer review.

<u>BAE Systems Marine Ltd</u>

745 BAESM reports that the worst case 10,000-year flood hazard at the site is comprised of the highest astronomical tide and storm surge, and takes account of climate change. The level

attained during such an event is 6.94 m AOD. BAESM judges that the effect of a tsunami is minimal.

746 A site flooding study has been conducted but no information other than flood level has been presented as part of the stress tests submission.

Devonport Royal Dockyard Ltd

747 DRDL reports that it carried out a flood hazard analysis in September 2008. That work considered the predicted effect of storm surge, general rise in sea-level and the magnitude of wind induced waves and applied contemporary statistical analysis to good quality data.

748 DRDL subjected the flood hazard assessment to an independent technical assessment by nationally recognised specialists. This assessment included an in-depth review of supporting data and the statistical techniques employed.

749 The flooding report recommended that data quality should be reassessed as measuring techniques improved in line with interest in global environmental effects, and DRDL agreed that the work would be revised at five-yearly intervals rather than the usual ten-year requirement for natural hazards.

750 The normal DBF, corresponding to one-year return period, was determined to be at 2.88m AOD. This is the highest astronomical tide level local to Devonport.

751 DRDL explains that the extreme DBF, corresponding to a 10,000-year return period, was determined to be at 4.30m AOD. This is the highest predicted water level over the period up to 2055 taking full account of water level trends and storm surge potential.

Rosyth Royal Dockyard Ltd

752 RRDL describes that the radioactive waste store is designed to withstand steady-state flooding to a height of 5.2m AOD. At that water level, the surrounding land will be inundated and may be susceptible to fluidisation by seismic aftershock. However, the nuclear facility is built on a solid concrete island foundation resting on bedrock and is not vulnerable to the effects of fluidisation.

753 The DBF defined by RRDL does not include a tsunami. The radioactive waste store is not designed specifically to resist a transient wave rising above 5.2m AOD, although its robust construction to withstand seismic forces would contribute significantly to its survival. External electrical power supplied to the facility would be lost at a water level reaching 5.1m AOD and battery backed services would be lost at approximately 6.2m AOD. However, RRDL reports that these effects will not impair the key safety function of containment of radioactive material.

Magnox Ltd – Defuelled reactors

754 The DBF for the defuelled sites was originally developed during the operational period and has been updated at subsequent PSRs. Following the removal of nuclear fuel from site, the radiological consequences of a severe flooding event affecting the site would be substantially reduced from that of an operational reactor. The current external hazards assessment concludes that the radiological consequences of DBF are not significant and that risks are ALARP.

*Berkeley*

755 Flooding from the Severn estuary was assessed for the Berkeley site in 2006, taking into account the possible effects of climate change. It is predicted that the $10^{-4}$ per year peak flood level is 10.7m AOD and the $10^{-3}$ per year flood level is 10.2m AOD. These values will not alter significantly as a result of climate change or other mechanisms during the next several years.

*Bradwell*

756 The potential for flooding from external sources to affect the Bradwell site was not assessed as part of the original design basis and was first evaluated as part of the long-term safety review carried out during the mid-1980s.

757 The latest flooding assessment for the Bradwell site was produced in 2010. The reassessed flood levels for 2010 at exceedence frequencies of $10^{-2}$, $10^{-3}$ and $10^{-4}$ pa were 4.48m AOD, 4.98m AOD and 5.48m AOD respectively. The $10^{-4}$ pa exceedence frequency flood could result in minimal water ingress on the site, but this could be prevented by simple barrier methods. Instruction to protect potentially affected plant in such a way is contained within the site flooding plan.

758 The flooding assessment also concluded that there was no credible tsunami risk to the Bradwell site based on its location on the south-east coast of the UK.

759 There are no off-site water retaining structures (dams, reservoirs etc) whose failure could credibly lead to site flooding.

*Hinkley Point A*

760 The $10^{-4}$ combination of maximum astronomical tide, surge height and wave height is approximately 11m AOD. This is considered suitably pessimistic since it is highly unlikely that maximum astronomical tide, maximum surge and maximum wave heights would occur simultaneously.

761 In defining the design basis water levels for Hinkley Point A site no explicit account has been taken of potential tsunami risk. The tsunami threat is considered to arise primarily from large distant earthquakes. Any residual tsunami wave affecting Hinkley Point A site is expected to be small. At the $10^{-4}$ pa exceedance frequency the risk from both the flooding and kinetic effects of a tsunami is bounded by the existing design basis sea-levels considering extreme tide and surge combinations.

762 The $10^{-3}$ pa exceedance frequency extreme rainfall event is assessed to be a total of 63mm of rain in one hour. It is recognised that extreme precipitation events and the expected levels of water on-site as a result of $10^{-4}$ pa rainfall events have not been estimated.

763 There are no off-site water retaining structures whose failure could credibly lead to site flooding. The nearest reservoirs to the site at Durleigh (12km) and Hawkridge (11km) are small in flooding potential and drain eastward and southward away from the site into the river system.

*Hunterston A*

764 The identification of hazards originating from events external to the site was originally taken from the safety review guidebook ME/S/063. This safety review guidebook has now been replaced by the decommissioning safety case handbook which has very similar requirements for the consideration of external hazards.

765 The flood level for the $10^{-4}$ flood is 4.52m AOD giving a flood depth above the general site ground level of 640mm. This is based on a $10^{-4}$ highest astronomical tide combined with a storm surge.

766 In defining the DBF levels for the site no explicit account has been taken of potential tsunami risk. The tsunami threat is considered to arise primarily from large distant earthquakes. Any residual tsunami wave is expected to be extremely small compared to that at Fukushima. At the $10^{-4}$ pa exceedance frequency the risk from tsunamis will be bounded by the existing design basis sea-levels considering extreme tide and surge combinations.

*Trawsfynydd*

767 The potential for and consequences of flooding from sources external to the site and its effects on nuclear safety were extensively explored for the long-term safety review in 1991, assessed by a hydrogeology report by Golder Associates in September 2000, and further assessed by the 2001 PSR. It was concluded that, although overtopping of the adjacent dams was possible during the predicted maximum flood (based on an event based probability of $10^{-4}$), flooding from Llyn Trawsfynydd was not a threat to nuclear safety due to the topography of the surrounding land which would route the water away from the nuclear safety-related structures. It is noted that the lake levels are self limiting due to the retaining dams.

768 During the subsequent PSR in 2001 and 2011 again the safety case was revisited but no changes or additions to the case were made. Over the life of the station there have been no recorded flooding events of any consequence.

NNB GenCo – Hinkley Point C

769 To determine the DBF NNB GenCo has used the same flood methodology as presented in its PCSR, July 2009 (Ref. 29). This describes the pre-construction safety analysis for the UK EPR™ NPP in the framework of GDA. However, the study presented in the NNB GenCo stress tests submission employs information used in the specification of the design basis originating from work which has been or is being carried out in support of the development of the Hinkley Point C site-specific PCSR.

770 NNB has considered the following design basis phenomena for the Hinkley Point C site:

- Flooding from the sea.
- Heavy rainfall (long and short duration).
- Rise in water table.
- Sudden changes (transient effects) in water level caused by valve or pump action in systems linked to the sea.
- Rupture of a structure or system linked to the sea.
- Flooding from failure of non-seismically qualified equipment on the site (tanks, pipes, etc.).
- Combination events (e.g. extreme sea-level with long heavy rainfall).

771 The DBF levels for the Hinkley Point C site for extreme sea height and extreme rainfall are given in Tables 6 and 7; several levels have been calculated based on different combinations of the contributing flood components, with the most conservative one selected as the DBF. DBF values are claimed as calculated at the 84% tile confidence level at $10^{-4}$ pa; climate change information has been considered during the determination of the DBF.

772 ONR has reproduced NNB GenCo's discussions on a number of relevant hazards / phenomena relating to site flooding on the Hinkley Point C site below.

*Extreme Seawater Levels*

773 The extreme seawater level without waves, calculated using the criteria described above, is given in Table 6 below. This has been used as a design criterion applied to buildings and structures that are not impacted by wave effects.

774 Due to the location of the site NNB GenCo has concluded that there is not a strong correlation between high water levels and waves at the Hinkley Point site. This is because:

- High surge conditions at the site are typically associated with south-westerly winds blowing up the Bristol Channel.
- High wave conditions at the Hinkley Point C site are associated with a very narrow range of wind directions between 290°N and 305°N. In all other wind directions, including south-westerly up the Bristol Channel, the Hinkley Point C site is shielded by land.

775 NNB GenCo has provided detailed information on the expected values of combined high sea-levels and waves at a return frequency of $10^{-4}$ pa at the Hinkley Point C site; these are reproduced in Table 6 below.

**Table 6:** Hinkley Point C Site Extreme Sea Heights

| $10^{-4}$ pa Extreme sea-level (m AOD) | | | | Influence of climate change |
|---|---|---|---|---|
| Still water | Wave | Tsunami | Seiche | |
| 8.62 | 10.26 | N/A[1] | Not provided[2] | +1.0m sea-level<br>+0.25m wave[3] |

*Notes*

*(1) Bounded by the combined effect of high tide and surge (see Tsunami section below).*

*(2) Seiche effects may be included as part of historical tide data already considered.*

*(3) Wave heights and associated climate change effect quoted in the NNB report is peak to trough, therefore divide by two to add to still water level.*

*Tsunami*

776 Defra has commissioned two assessments (Refs 30 and 31) of the tsunami threat to the UK, both of which make conclusions of interest to the Hinkley Point site. The first of these assessments concluded that threats were possible from a number of sources: earthquake in the North Sea, earthquake in the western Celtic Sea, tsunami associated with the plate boundary west of Gibraltar (referred to as the Lisbon-type event), and a landslide associated with the Canary Islands. A follow-up study reviewed in more detail the hazard for the UK and Irish coasts associated with the Lisbon-type event and the North Sea event. This assessment concluded that only the most south-westerly coast of the UK may incur a 2m tsunami, which is significantly lower than the 1 in 10,000-year extreme sea-level predictions used within the DBA of flooding depths at the Hinkley Point C site.

777 Further, NNB GenCo has performed an initial appraisal and has reported that it appears highly unlikely that there are any sources of coastal landslide close to the Hinkley Point C site which could be triggered by a local earthquake and have the potential to generate a significant tsunami at the Hinkley Point C site.

778 These assessments show that the hazard presented by tsunamis at the Hinkley Point C site can be considered as very low effect. Their frequency and magnitude are sufficiently well bounded by combined high tides and surge that there is no need for them to be considered as a separate flood hazard.

*Extreme Rainfall*

779 NNB GenCo has provided detailed information on the expected values of extreme rainfall at the Hinkley Point C site; these are reproduced in Table 7 below.

**Table 7:** Hinkley Point C Extreme Rainfall

| Duration | $10^{-4}$ pa Extreme rainfall (mm) |
|---|---|
| 15 mins | 171.7 |
| 1 hour | 197.5 |
| 1 day | 294.8 |

780 NNB GenCo has reported that different solutions are being developed in order to mitigate this kind of external hazard event; this information will be presented within the Hinkley Point C PCSR (for publication in 2012).

*Snow Melt*

781 Historical records show that snow covers the ground for an average of less than ten days per year. The Hinkley Point site is coastal and exposed to prevailing SW winds, therefore it is unlikely to attract deep lying snow and no historical record of more than a "few inches" at Cannington or Brymore has been found.

782 There being so little data on snowfall, the broad assumption by NNB GenCo has been made that, if there is an extreme snowfall requiring clearance to get vehicular traffic into the station to operate it, then the roads will also be operable as open channel drains. The risk of site flooding due to snowmelt is therefore judged by NNB GenCo to be insignificant and is bounded by the extremes of rainfall. It is therefore judged by NNB GenCo that there would be no threat to safety-related equipment at either station due to snowmelt.

*Ground Water*

783 NNB GenCo reports within its stress tests report that, in order to protect the foundation of the safety-related buildings of the Hinkley Point C site, a dedicated water table drainage system is included in the design to limit the groundwater to reach a level no higher than 8m AOD. As this system, consisting of the underground gallery and catching pits is seismically classified it will provide a robust protection against any kind of flooding event caused by groundwater.

*River*

784 NNB GenCo has dismissed river flooding onto the site as a non-foreseeable hazard, although they acknowledge that temporary flooding of the site access road is a possibility. The possibility of alternative access is being considered by NNB GenCo.

#### *3.1.1.1 ONR's Assessment of Design Basis Flooding Hazard*

<u>Sellafield Ltd – Sellafield and Windscale</u>

785 ONR considers that the work completed by Sellafield Ltd to review the potential for flooding of the site is comprehensive and based on accepted engineering methodologies and relevant data.

786 The hazard from rise in sea-level and extreme tide events including allowance for wave height has been assessed and although storm surge has been discounted on a probability basis i.e. the potential for a combined 1 in 10,000-year tide and storm surge is considered to be very low, the topography of the site and the base level of nuclear facilities is such that the reported results are insensitive to this approach.

787 The detailed assessment of surface water threat from intense rainfall was completed in 2008 and represents a whole site study completed for a range of return periods and storm durations. The output from the study has been presented in a series of flood maps for the site, indicating possible surface water depth in areas where the sub-surface drainage is surcharged. Further interrogation of the site model is possible with depths of water detailed on a square metre basis. In completing the assessment, Sellafield Ltd included advice from Defra to increase rainfall intensity in line with climate change predictions over an 80-year period. The 2008 study updated work done in 2004 and a review cycle is in place with the next study programmed for 2013. The site model includes ten individual catchment areas including direct representation of the separation area.

788 The passage of the River Calder through the site presents a direct hazard of flooding in the event that flow capacity of the river channel is exceeded. The assessment of potential river flow at a 1 in 10,000-year return period indicates that demand exceeds capacity by a small margin and partial flooding of low lying regions within the decommissioning Calder Hall power station site is predicted. The assessment of maximum river flow was completed when realignment and construction of an amended river channel was being progressed in 1974. Although the assessment of river flow considered extreme events with a return period of 1 in 10,000 years, the possible consequences of climate change were not appreciated at the time.

**STF-38: Sellafield Ltd should, in light of advances in river modelling methodologies, climate change information and the known erosion of the river bed, reassess the flow capacity of the channel of the River Calder to better inform the assessment of risk of flood.**

789 The work completed by Sellafield Ltd provides a good basis for the initial assessment of flood risk, and the programmed activities in combination with further assessment proposed by ONR will allow the level of threat to the site to be fully established and kept concurrent.

Urenco UK Ltd

790 ONR considers that UUK's design basis for flooding is comprehensive.

Dounreay Site Restoration Ltd

791 The 1 in 100-year return frequency for rainfall induced flooding, does not accord with the SAP defined design basis of 1 in 10,000-year frequency; ONR recognises that multiple variables influence potential accumulation of rainfall floodwater, and that constant changes to drainage capability due to ever-changing decommissioning activities render the development of a facility specific design basis to such a frequency impractical. ONR is therefore satisfied with the approach taken to define the design basis for all flooding initiators, and the pessimistic assumption of rainfall induced floodwater ingress to facilities. This is sufficient evidence that cliff-edge effects have been adequately considered.

Springfields Fuels Ltd

792 ONR considers the licensee's deterministic arguments against floodwater inundation associated with tsunami, storm flooding of local water courses and due to extreme rainfall are rational and defensible.

Atomic Weapons Establishment

793 ONR expects licensees to consider extreme flooding events on a 1 in 10,000-year basis; this expectation has been met. However, it is also an expectation that credit should not be taken for drainage networks as these are likely to become blocked due to ingress of debris introduced by

flood waters. Without an assessment of the flood model study, it is not possible to determine if the model is appropriately conservative. ONR recommends that AWE should consider whether it is appropriate to include the drainage network as part of the site flood model. This is covered by STF-46.

794 AWE's consideration of consequential events is presented in a set of tables in the annex of the stress tests submission. There is insufficient detail for ONR to make an appropriate assessment of the adequacy of these *Considerations*. ONR recommends that AWE should consider identifying and assessing the consequential events arising from a severe flood event. This is covered by STF-43.

Rolls-Royce Marine Power Operations Ltd

795 It is ONR's expectation that for each external hazard, which cannot be excluded on the basis of either low frequency or insignificant consequence, a design basis event should be derived; that design basis should consider an initiating event frequency of $10^{-4}$. Furthermore, it is expected that nuclear facilities should withstand those external hazards that meet the design basis criteria.

796 While RRMPOL has undertaken a flood modelling study up to and including a 10,000-year flood event, this is still undergoing peer review and the details have not been presented as part of the stress tests submission. While no assessment of the adequacy of this study can be made, ONR supports the ongoing work to further understand the flood hazard potential of both sites and will review the results of the study once issued. It is also noted that a comprehensive regeneration programme is underway to replace existing nuclear facilities on the manufacturing site, with facilities built to modern standards.

BAE Systems Marine Ltd

797 ONR concludes that the rationale for selecting the DBF has been justified in the flood hazard study. However, as the methodology has not been presented as part of the stress tests submission, it is not possible for ONR to judge the adequacy of the DBF at this time.

798 Furthermore, no information has been given in BAESM's submission regarding the rate of water level rise or flow rate of flood waters. ONR believes that this information could help to inform safety margin assessment and give an indication of the action response times required in an emergency.

**STF-39: BAESM should consider assessing the rate of water level rise and flow rate of flood waters for the site to determine if there is any erosion of safety margins during a dynamic flood event.**

Devonport Royal Dockyard Ltd

799 ONR notes that DRDL has considered various flooding scenarios including extreme high tide, rainfall, snow melt, tsunami and storm surge. Although the limiting case has been found to be storm surge, DRDL's assessment has given consideration to all of these potential flooding mechanisms.

**800** In its submission, DRDL explained the docks have a high integrity water tight boundary that is justified within its design basis. However, it has not reported on the effect of caisson failure which would lead to rapid flooding of a dock, although ONR recognises that this possibility is addressed in site safety cases. This flood mechanism is different to the other mechanisms as the speed with which water enters the dock is significantly greater than the effects of direct natural events.

**STF-40: DRDL should review their safety cases to confirm that the effects of rapid flooding of the dock from a failure of the watertight boundary is considered.**

801 ONR is satisfied that the methodologies used by DRDL are appropriate, and use of an independent technical assessment is considered to be relevant good practice. Site-specific data has been used, which is preferred to generic data. This data is suitably conservative and of sound provenance. Contemporary models and modern statistical methods have been applied.

802 DRDL has put in place arrangements to review new and emerging data and trends in weather patterns due to changes in the climate, every five years. ONR supports this approach.

803 DRDL has taken account of predicted sea-level rises to 2055. This is both currently appropriate and over an adequate period of time given that modern methodologies become significantly less reliable beyond this timescale.

804 ONR accepts that the approach taken by DRDL has considered a combination of the highest normal water level, a 10,000-year storm surge and associated wind induced waves; ONR is satisfied that is appropriately conservative.

Rosyth Royal Dockyard Ltd

805 RRDL has not provided any information in its submission on the derivation of the DBF event; therefore ONR cannot make an assessment at this time, but agree that these fault conditions do not threaten the key safety function on the site of containment of radioactive material.

Magnox Ltd – Defuelled reactors

806 It is apparent that the significant effects of flooding would be water ingress to buildings or storage facilities containing radioactive waste. In general the licensee has concluded that, due to the absence of fuel on-site, the nuclear consequences are low or insignificant. ONR considers that the radiological hazard is greatly reduced due to the removal of fuel from the site. Consequently, it is important to define the hazard potential in order to control the radiological hazard during the decommissioning process and to form the basis of specific plant modification proposals.

807 There is a general acceptance that limited flooding is acceptable and dependence is placed on engineered barriers and waste packages. ONR also notes that because these sites are in the process of decommissioning, the safeguard provisions may be subject to disruption.

NNB GenCo – Hinkley Point C

808 The NNB GenCo stress tests submissions have calculated the DBF levels compatible with the ONR SAPs. The detailed interpretation of confidence levels has come from ONR TAG T/AST/13, which supports the external hazard SAPs.

809 NNB GenCo has included a number of contributors to flood hazard from the sea in its analysis, including: tide, surge, wind-driven wave and tsunami. ONR has noted that the effects of seiche are not specifically mentioned in the NNB GenCo report; however, it is likely that the effects of seiche are accounted for automatically in the historical flood data used within this analysis; ONR will confirm this with NNB GenCo.

810 ONR agrees with this methodology; however, it has challenged NNB GenCo on whether wave refraction has been fully considered during this analysis. Further interactions are ongoing between NNB GenCo and ONR to confirm this issue has been handled correctly by the potential licensee.

811 ONR has noted that a number of flood hazards are identified in the NNB GenCo stress tests report that would normally be considered internal flooding hazards on the basis that the occurrence of the hazard can be controlled by licensee arrangements. This includes transient effects caused by valve or pump action in systems linked to the sea; rupture of a structure or system linked to the sea; flooding from failure of equipment on-site. It is not clear why these hazards have been

highlighted within the stress tests report, which is focused on external hazards. Their inclusion does not detract from the stress tests report; however, the assessment of these hazards will not be considered further by ONR at this time, this will be done as part of normal review of internal hazards as the design progresses.

812 The NNB GenCo stress tests submission has considered various combinations of flood hazards and various return frequencies. The effect of still sea-level / wave combination has been based on a comprehensive joint probability calculation; ONR considers this is reasonable. Indeed, ONR has had this work assessed by a competent contractor who was content except for some climate change-related issues, which are currently being resolved as part of normal regulatory exchange with NNB GenCo. The combination, extreme sea-level with heavy rainfall, attracts exceedance frequencies whose justification is unclear; e.g. extreme adverse weather and high storm surge clearly have the potential to be highly correlated. ONR will seek from NNB GenCo a justification supporting each combination of flood hazard presented.

813 With regard to river flood, ONR considers that a very detailed flooding analysis underpins NNB GenCo's conclusions and these are generally acceptable to ONR, although they are still being considered in detail by Environment Agency and ONR as part of the preparation for the legal planning process for the new site.

814 Extreme levels of groundwater are correctly identified as an external flood hazard by NNB GenCo. It is claimed this will be limited to 8m AOD by virtue of a bespoke drainage arrangement, therefore no extreme natural value is specified. ONR questions whether this is the case even though extreme still water sea-levels can rise beyond this height. Further, ONR seeks information on what is the natural groundwater level without the drainage system in place and what would be the potential consequences if the groundwater level rose above 8m AOD. The use of a safety classified groundwater system is novel in the UK and this and other issues are currently being considered by ONR as part of normal regulatory business.

815 In addition it is noted that NNB GenCo explains the groundwater drainage system is robust because it will be seismically classified. While ONR accepts the drainage system would be more robust to imposed loads from the surrounding soil and rock, it is not clear that seismic design, by itself, confers an enhanced ability to withstand blockage of drainage holes and outfalls by debris or movement of the surrounding ground.

816 The NNB GenCo stress tests submission indicates that there is limited amount of information on snowfall at the locality due to limited historical occurrence and therefore they conclude that this is bounded by rainfall. While the use of historical data in this way is indicative, it is not clear how this constitutes a robust statistical analysis of the relevant weather data sufficient to extrapolate to frequencies of $10^{-4}$ pa. A further consideration is that snow melt can present additional hazards to that of rainfall, including blocking of drains and changing of the site topology. ONR will confirm that these issues are being considered by NNB GenCo in the design of the Hinkley Point C site.

### 3.1.2 Provisions to Protect the Plants Against the Design Basis Flood

Sellafield Ltd – Sellafield and Windscale

817 As part of the report on the risk of flooding and consequent threat to safety systems and components, Sellafield Ltd has concluded that extreme rainfall in combination with 1 in 10,000-year river flow forms the bounding threat to the site. The topography of the site provides natural protection from extreme tides and hence incursion from the sea is discounted.

818 The site slopes from north to south and surface run-off will follow this general direction with subsurface drainage discharging at outfalls at the River Calder, river Ehen and the Sellafield Tarn. In addition to the designed surface water discharge arrangements, Sellafield Ltd notes that the site will benefit from storage and attenuation of overland flows by the network of open service trenches that cross the site.

819 The Sellafield Ltd report includes flood maps of the site giving an indication of the depth of surface water and its disposition around the site. The combined flood map of the site has been available since 2003 and recent location of facilities and selection of base mat levels takes account of the available data.

820 For new facilities, protection measures are considered at the design stage and it is noted that the design for the Sellafield Product and Residue Store (SPRS) includes a flood channel to direct flows away from the building.

821 For existing facilities where the surface water drainage system is expected to be overcome in extreme events, retro-fitting of flood protection measures is considered including use of flood protection doors. As the main threat arises from high intensity rainfall Sellafield Ltd has arrangements in place with the Environment Agency and the Meteorological Office for early warning to allow implementation of contingency measures including temporary bunding.

822 Interrogation of the surface water drainage model has indicated that potential flooding from the north of the HALES facility is driven by surcharging of a manhole in the area and re-engineering of the flood defence system is proposed.

823 Potential flooding within the Separation Area has been considered and note taken of the extent of hard paving, run-off of rainwater and the dependence on the capacity of the surface water lagoon and associated pumping discharge rate. The resilience of the pumping arrangements provided for discharge of water held in the lagoon is to be reviewed.

824 Attention is drawn to a series of buildings in the north of the site that effectively block the general north / south flow pattern and holds water to a depth locally in excess of 1m as a result of surcharging of the drainage system. Sellafield Ltd notes that a project is in place for design of protection measures to the inner area and intends to review the potential for redirection of surface water flows as part of this project.

<u>Urenco UK Ltd</u>

825 The case against DBF and beyond design basis flooding causing any significant consequence on the UUK site is based on a combination of factors. These include a lack of credible threat based on current and historical flood data, site topography and location, drainage paths away from plants and rafts and on the robust cylinder design.

<u>Dounreay Site Restoration Ltd</u>

826 DSRL reports that, in the event of substantial floodwater inundation, normal and back-up electrical supplies would be compromised. This is considered further in Section 5. However the most hazardous material on the site (ILW) is contained within substantial concrete structures (caves or stores) which DSRL’s safety cases consider to be able to withstand any credible wave impact.

827 The Dounreay safety case pessimistically identifies the potential for off-site release due to energetic inundation of a Floc settling tank, irrespective of the initiator. The worst case scenario of total escape and migration of the Floc settling tank contents to sea have been assessed to give a worst case dose of less than 5mSv to the most exposed member of the public. While this strictly exceeds the SAP Target 8 1mSv design basis threshold for off-site release, it is predicated on the

basis of complete mobilisation of ILW that takes no account of building containment that would be reasonably expected for best-estimate analysis.

828 The potential for rainwater ingress cannot be discounted completely. The licensee notes it has already embarked upon an off-site water diversion project, designed to minimise the amount of rainwater running through the site. This will include re-engineering of the Mill Lade run-off channel (planned for spring 2012) and re-engineering of pipework.

Springfields Fuels Ltd

829 SFL has not specifically identified design provisions to protect plant against a DBF, but has since demonstrated adequately that the site's topography and passive drainage features would facilitate sufficient drainage capability.

Atomic Weapons Establishment

830 AWE has identified two engineered systems to mitigate severe flood events: the foul waste system and the surface water waste system. A number of other provisions are claimed but not elaborated on.

Rolls-Royce Marine Power Operations Ltd

831 A system of warnings from the Environment Agency, transmitted via Derbyshire County Council, is in place to notify RRMPOL of a developing potential flood hazard. Direct monitoring of rivers is also carried out on-site by RRMPOL personnel.

832 RRMPOL reports that progression from flood warning to eventual site flooding should not be less than "a few hours", giving sufficient time, in most cases, to complete the relocation of fissile materials to safe areas and evacuation of personnel.

833 RRMPOL explains that sand bagging of building openings offers protection up to water depths of approximately 0.9m; beyond this, loads on the walls from water pressure will potentially cause structural damage.

834 For the Neptune site, the Neptune reactor hall and control room are elevated compared to the adjacent ground level. The reactor tank extends from the finished floor level to approximately 2m. The module store is raised to a slightly greater degree, such that the base of the storage boxes is approximately 0.5m above floor level. However, the fuel storage rack is located only marginally above floor level and RRMPOL assesses that this represents a flood issue.

BAE Systems Marine Ltd

835 BAESM states that Barrow town flood defences protect against tide levels of 5.0m AOD. The site is elevated from the town sea defences, with the floor level of the shore structures at 8.5m AOD.

836 Once the submarine is afloat at Wet Dock Quay, the NRP is not directly affected by flooding. For activities in the preparations for and following initial criticality, the submarine is in its seagoing state and the NRP is designed to be entirely independent of shore services even in the event of loss of dock water, with the crew on-board maintaining appropriate manning levels.

Devonport Royal Dockyard Ltd

837 DRDL states that the SSCs that ensure nuclear safety for a shut-down NRP will not be affected by the 10,000-year return period high Hamoaze level.

838 In the SRC, the DBF may lead to a degree of overtopping of the cope by wind induced waves, which would cause some localised ingress of water to the subways running across the facility. This

will impact electrical, control and instrumentation (EC&I) systems. Prior to the stress tests process a programme of work had already been initiated to resolve this issue.

839 DRDL explains that submarines within the confines of a dock will be isolated from the effects of increasing water level by the water retaining boundaries.

840 On the licensed site, submarine hatches may be left open for access purposes, or to enable operating and maintenance activities. Administrative measures are in place to ensure these hatches can be closed at short notice.

Rosyth Royal Dockyard Ltd

841 RRDL reports that the radioactive waste store is adequately protected against the DBF by virtue of its position. For the same reason, it is adequately protected against the $5x10^{-3}$ per year flooding event caused by a particularly high tide, tidal surge or wind induced waves. The waste packages are capable of withstanding immersion in deep water and no additional safety provisions are required.

842 In the event of a tsunami, the reinforced concrete structure of the seismically justified walls of the radioactive waste store will withstand substantial wave forces well beyond the design basis event, although the building would be inundated. The storage room for the significant radioactive waste lies behind three seismically qualified walls that protect it from the seaward direction.

Magnox Ltd – Defuelled reactors

843 On the defuelled decommissioning sites, no systems, structures or components are required for achieving or maintaining a safe shut-down state because the reactors are defuelled. The primary issue following the design basis event would be associated with containment of radioactive materials in the radioactive waste facilities on the sites. Dependence is placed on engineered barriers, many of which utilise structures dating back to the original construction of the plant, waste packages and temporary barrier arrangements.

*Berkeley*

844 Specific flood protection measures have been taken in respect of the reactor Safestores and the Active Waste Vaults.

845 The roofs of the Active Waste Vaults are at approximately 10.1m AOD which is similar to the general ground level of the site. In the absence of flood protection the vaults would be flooded in a $10^{-3}$ per year event. The erection of a proprietary flood barrier 0.9m high is sufficient to protect the vaults against the $10^{-4}$ per year flood and beyond. The flood barrier has sections that are left open to allow access for maintenance and inspection. To complete the flood protection the openings in the barrier must be manually closed using modular sections stored nearby.

846 Flooding of the Safestores basements and the void beneath the reactors was assessed in the Safestores safety case. Radiological consequences are so low as not to justify on an ALARP basis any measures to protect against the DBF. Flood water would be of sufficiently low specific activity that it could be pumped into storm drains after the flood has passed. The only significant issue from having the Safestores flooded is the potential for increased corrosion of vessel supports over the long period following contact with salt water. For this reason the Safestores have been protected against the $10^{-2}$ pa site flood by raising the threshold level to at least 10.15m AOD.

847 The consequences of flooding any of the other facilities on-site are considered to be low.

848 Low lying parts of the single access road to the Berkeley site are susceptible to occasional flooding (typically once or twice a year for a few hours) but to date this has not been to sufficient depth to prevent vehicle access.

849 If the site were to be flooded up to the design basis level the entire surrounding area would also be flooded and for a few hours access to the site would only be possible by boat. Those persons present on-site would easily be able to take refuge in buildings with a floor above ground level. As such an event is foreseeable it is likely that only a limited staff would be on-site.

850 There are no short-term operator actions necessary to control or limit radiological releases as the facilities are essentially in a passively safe state.

*Bradwell*

851 The principal design and construction provisions in place to protect the plant from DBF are the sea wall and the gulley. However, the level of the site should prevent inundation due to flood up to a $10^{-4}$ pa exceedance frequency event.

852 The site flooding plan assumes that the site would receive at least nine hours' warning of an exceptional tide. Actions to be taken include forming flood defences around any vulnerable plant and placing sandbags around reactor basement hatches and ensuring they are closed.

853 Though prevention of access to the site has not been assessed in the safety case, personnel and equipment from off-site will not be required to prevent compromise of nuclear safety as all fuel has been removed from the site.

*Hinkley Point A*

854 The site ground level at Hinkley Point A site is a nominal 11.0m AOD. There is a concrete sea wall with a top level of approximately 8.5m AOD and a gabion wave spoiling wall between the sea wall and the site which extends to approximately 12.0m AOD, which is 0.57m above the maximum predicted flood height. All buildings containing ILW have thresholds at a minimum of 11.2m AOD, except for the active effluent treatment plant lower vault, which is at 11.1m AOD.

855 The active effluent treatment plant lower vault contains 3.0m$^3$ of ILW sludge in small sealed containers which are not anticipated to fail in the event of a flood. Therefore, the consequences of flooding this facility are considered to be minimal.

856 Note that within these facilities, the ponds and the bulk of ILW on-site are located in containments with thresholds for flooding of the order of 5m above the maximum predicted flood height.

857 The site has previously suffered external flooding by wave water near the cooling water pumphouse, which was at approximately 8.2m AOD. The cooling water pumphouse has now been demolished as part of the sites decommissioning programme, however it was this event which led to the construction of the gabion wave spoiling wall. Further floods in 1990 led to extension of the east end of the gabion wave spoiling wall and removal of an access gate to the sea frontage.

858 The entire site is drained by a comprehensive surface and stormwater drains system. All roads fall to the sea and accordingly would tend to act as open gullies if the site were to be flooded.

*Hunterston A*

859 The key structures that provide protection against a DBF are the containment structures of the facilities that contain radioactive waste. Components that could provide paths for floodwater to enter the facilities are either at a height where they are not affected by the DBF or are engineered to preclude water ingress.

860 It is therefore concluded that although the site may become inundated to a greater depth than the DBF, the key structures will remain watertight and any openings either impervious to ingress or above the water level. The key structures are obviously able to withstand the increased

hydrostatic loading and failure from hydrostatic or hydrodynamic loading is considered not credible.

861 The main protection of the facilities against flooding is provided by their height above sea-level and significant openings into the facilities being at high level on the facilities.

862 ONR notes that the ILW store at Hunterston A, which was constructed during the decommissioning phase, has been designed to withstand the flooding hazard.

863 There are currently no provisions to prevent the flood impact identified. Many hours notice of extreme tides and surges would be expected. Precautionary actions could, therefore, be taken to mitigate the risk of flooding.

864 There are no immediate consequences of delayed access to site as all operations can be safety terminated locally. As the DBF is the result of high tides and storm surge there would be forewarning of the event. In addition the height of flooding would reduce with the receding tide.

*Trawsfynydd*

865 The key structures that provide protection against a DBF are the containment structures of the facilities that contain radioactive waste. Components that could provide paths for flood water to enter the facilities are either at a height where they are not affected by the DBF or are engineered to preclude water ingress.

866 The main protection of the facilities against flooding is provided by the topography of the surrounding land which would route the water away from the nuclear safety-related structures.

867 Another reservoir in close proximity to the site is Llyn Celyn that is both a large body of water and at a ground level higher than the site. However, the topography of the area would result in water resulting from dam failure flowing in a direction well away from the site.

868 The site's height above sea-level (195m) prevents any impact from a tsunami or sea flood event.

869 There are currently no provisions to prevent the flood impact identified.

870 Complete failure of the dam would disable the site grid supplies but would not render inoperable the back-up plant required under Plant Operating Instruction for Minimum Safety-related Plant for ILW storage facilities.

871 There are no immediate consequences of delayed access to site as all operations can be safety terminated locally. Equipment and personnel from off-site are not required to prevent a compromise to nuclear safety as all irradiated fuel has been removed from site.

NNB GenCo – Hinkley Point C

872 NNB GenCo has reported in its stress tests submissions that the main flooding protection of Hinkley Point C site (nuclear-island and conventional island) is to be provided by:

- The height of the platform level at 14.0m AOD.
- The site drainage, which is being designed to accommodate the extreme intensity rainfall (design in progress).
- The top of ground floor slabs being 100mm higher than the platform level. This measure prevents minor water ingress into buildings (e.g. at doorways) by any water on the platform which is not directly collected by the site drainage.
- The sea wall that will limit the overtopping effect of the waves and provide protection against coastal erosion. A rigid concrete sea wall with a crest height of 13.5m AOD is

being designed. Residual water will be drawn away to the sea by a dedicated drainage system behind the sea wall.

873 The buildings of the nuclear-island and emergency generators are located on the platform at 14m AOD. This level provides a margin of 4.48m with respect to the extreme sea height level when adjusted for climate change. Within the design of the buildings and structures on-site there is little consideration of wave effect due to the site distance from the sea and the sea wall. The calculated wave height has primarily been used to set the design of the sea wall. Information on the proposed site flood defences is provided in Table 8 below.

**Table 8:** Hinkley Point C Site Flood Defences

| Defence type | Drainage | Height of flood defence (m AOD) | Site level (m AOD) |
|---|---|---|---|
| Sea Wall | Not yet finalised | 13.5 | 14.0 (1) |

Notes

*(1) Building thresholds to be 100mm higher than building floor slabs.*

874 NNB GenCo has also provided further information within its stress tests submission with regard to more detailed design considerations, including: volumetric protection, flood doors etc.

875 NNB GenCo has informed in its stress tests submission that the design of the site drainage system is ongoing; however, it is further reported that this system will be designed to protect the plant against the extreme intensity rainfall. This is expected to be presented by NNB GenCo in the Hinkley Point C PCSR.

876 NNB GenCo has provided information on the key operating arrangements at the Hinkley Point C site during a flooding event. These are to secure lines of passive defence, guarantee the autonomy of the site and secure facilities. Further there are anticipated operating arrangements to cover for the possibility of external flooding on to any of the EDF Energy nuclear fleet sites; these can be adapted to the specifics of each site.

877 NNB GenCo has reported in its stress tests submissions that they consider the possible flooding hazards from external events that constitute a risk to the nuclear plant are:

- the isolation of the site; and / or
- the loss of external power sources; and / or
- the loss of the pumping station; and / or
- the flooding of the site platform.

878 It has concluded that studies conducted as part of the design assumptions have not revealed any vulnerability at Hinkley Point C.

#### *3.1.2.1 ONR's Assessment of Provisions to Protect the Plants Against the Design Basis Flood*

<u>Sellafield Ltd – Sellafield and Windscale</u>

879 ONR accepts that the flood threat to nuclear facilities on the Sellafield site is bounded by pluvial occurrences. The general topography of the site and the base mat levels of nuclear facilities are such that threat from seawater incursion can be discounted. Provisions for protection of plants from flood can be assessed in light of their effectiveness in countering incursion of surface water.

880 The work completed by Sellafield Ltd in building a full-site surface water drainage model including detailed modelling of catchment areas and outfalls enables flow patterns to be investigated and surcharging of systems to be ascertained. Flooding local to facilities from both ponding of water and discharge from surcharged manholes can be clearly identified.

881 A review of the flood maps provided by the Sellafield submission indicates that excess surface water follows the road and open service trench layout and that hard standing areas suffer from ponding of water to varying depth.

882 While the design of recent facilities has taken account of the potential for surface water flooding following extreme events, it is evident that existing plants could be at risk in the event of a 1 in 10,000 storm. Although allowances for climate change increase the risk of flooding this effect does not threaten the site immediately and will take time to develop.

883 Sellafield Ltd's response to the threat of flood is a combination of temporary measures (bunding) and more permanent design solutions including redirection of flows around the separation area. This approach is reasonable bearing in mind the difficulties inherent in changing the capacity of the existing surface water drainage system and arrangements in place to give early warning of high intensity rainfall.

884 The information detailed on the flood maps can be investigated to identify potential interaction of flood water, service infrastructure and important safety systems needed to ensure resilience of facilities and this will be taken forward by ONR as a continuing intervention both in the short and medium terms.

Urenco UK Ltd

885 ONR considers the licensee's response to flooding to be proportionate and comprehensive. ONR supports the arguments presented by UUK on flooding.

Dounreay Site Restoration Ltd

886 ONR is satisfied with the licensee's assertion that concrete containment structures provide a suitable design basis for ILW material.

887 The approach taken by DSRL to test the extent of off-site release to sea, for the most onerous floodwater inundation, provides ONR with confidence that the licensee has sufficiently stressed the design basis for seawater flooding. The inherent conservatism in the licensee's approach goes beyond what would be reasonably expected for a best-estimate approach to severe accident analysis. ONR is satisfied from the stress tests that the Floc settling tank constitutes the bounding case vulnerability for a floodwater inundation.

888 While seawater inundation of higher category facilities has been discounted by DSRL (and subject to a test for cliff-edge impact of coincident storm surge), the licensee does not explicitly dismiss heavy rainfall occurring coincident with a seismic induced collapse of facilities on the site, leading to an off-site release. ONR is nonetheless satisfied that the proposed improvements to rainwater run-off and diversion provide a suitable basis for managing this very low frequency domino-effect.

889 DSRL has provided additional information that details the existing facility inspection and maintenance programme undertaken by external contractors; this programme specifically includes review of building structures, gully and drain maintenance to reduce the potential for water pooling.

890 ONR is satisfied that the proposed modifications to rainwater diversion systems constitute an appropriate mechanism for risk reduction on the site, commensurate with the remaining time to interim end state.

Springfields Fuels Ltd

891 ONR is satisfied that the licensee's safety cases demonstrate appropriate evidence that reasonably practicable improvements have been sought; ONR examines SFL's safety case LC15 periodic reviews to secure confidence that ALARP reviews take due cognisance of remaining facility lifetime and the impact of changes to plant since previous periodic reviews.

Atomic Weapons Establishment

892 AWE reports that the site drainage systems provide two engineered systems to mitigate flood risk. However, insufficient information has been presented as part of the stress tests submission that the site drainage systems provide the claimed function and that they are appropriately maintained and inspected.

**STF-41: AWE should consider reassessing the site flood model to determine the potential erosion of safety margins resulting from loss of the drainage networks.**

Rolls-Royce Marine Power Operations Ltd

893 RRMPOL has identified shortfalls in its current flooding resilience to a 10,000-year flooding event, which is ONR's standard regulatory expectation for plant which has a significant radiological risk. ONR was aware of this prior to the stress tests submission and acknowledges that these are significant shortfalls. ONR is currently actively engaging with RRMPOL on future improvements to flooding resilience.

BAE Systems Marine Ltd

894 ONR supports BAESM's conclusion that the elevation of nuclear facilities at the Barrow Licensed site makes it invulnerable to the 10,000-year extreme seaward flooding event. There are no other sources of external flooding other than extreme rainfall. However, the seaward flood hazard bounds this.

895 ONR acknowledges BAESM's conclusions that none of the buildings identified for use in a site emergency has any specific capability to withstand a severe flood hazard beyond that inherent in standard building codes. Although BAESM explains that no immediate response is required to assist the submarine crew to maintain the safety of the NRP following a severe flood event, it recognises that longer term support may be impeded by the potential failure of site facilities or associated infrastructure.

896 BAESM has identified a number of *Considerations* for improvement works to be undertaken to address potential shortfalls in providing an appropriate emergency response. ONR supports these *Considerations* and is currently actively engaging with BAESM in this area and will continue to do so as part of normal interactions with the site.

Devonport Royal Dockyard Ltd

897 ONR supports DRDL's assessment that the water retaining boundaries around the non-tidal docks and the LLRF are designed to protect all related operations from the effects of a DBF. Furthermore, the docking facilities also provide a seismically justified boundary which has a significant safety margin against an extreme flooding event.

898 Prevention of floodwater ingress through the submarine hatches, by their very nature, relies on administrative arrangements. This is a reasonably practicable arrangement for slowly rising water

levels and forecastable events such as storms. ONR notes that for events such as rapid flooding of the dock, this single line of protection may not prevent water ingress to the boat. While the risk of such events is low, DRDL has recognised that there is scope for improvement and has identified an appropriate resilience opportunity.

899 ONR supports DRDL's view that the dockyard is sited lower than all other parts of the surrounding area and that flooding at the extreme DBF should neither prevent nor delay access of personnel, equipment or the emergency services to the site.

Rosyth Royal Dockyard Ltd

900 ONR supports the RRDL claim that the radioactive waste store is adequately protected against the DBF by virtue of its position and the robustness of the seismically qualified structures.

Magnox Ltd – Defuelled reactors

901 All plants have adequate measures in place to protect against the effects of the DBF; however the robustness of these to greater floods is unclear. This should be addressed during the reassessment of the design basis suggested by ONR in STF-47 (see Section 4.1).

NNB GenCo – Hinkley Point C

902 ONR considers that the provisions to protect the plant from extreme sea height, including waves, appear to be appropriate and in line with ONR guidance on such events. ONR believes that the main line of defence against extreme sea-level is the setting of the nuclear-island at a height of 14m AOD. This appears to provide a healthy margin above the DB extreme sea-level event.

903 ONR notes that the design of the Hinkley Point C site is not yet sufficiently mature that information can be provided on the design and performance of the site drainage system. ONR recognises that this information is not currently available and will consider the design of the site drainage system with respect to extreme rainfall, and extreme snowfall, when this becomes available.

904 ONR notes that the operational arrangements described in the NNB GenCo submissions primarily relate to securing the site; little information is provided on actions to be taken with regard to the plant itself. ONR assumes this is due to the lack of maturity of the site-specific design and will seek further information on this as the design progresses.

905 The flood hazards from external events which NNB GenCO considers could constitute a risk to the NPP are considered reasonable by ONR.

### 3.1.3 Plants' Compliance with Their Current Licensing Basis

Sellafield Ltd – Sellafield and Windscale

906 No further discussion of Sellafield Ltd's arrangement to ensure compliance with the site License is included in this section, instead reference is made earlier text (see Section 2.1.3).

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

907 UUK, DSRL and SFL each have a number of processes in place to ensure that safety-critical SSCs remain available in accordance with licence condition requirements. These processes include the site and facility maintenance arrangements, the procedures for the control of modifications and the use of PSRs. These licensees do not provide a detailed summary of these arrangements in their respective stress tests reports; however the ongoing licence condition inspection regime on

each site aims to secure continued regulatory assurance that SSCs on those sites are maintained to an appropriate level commensurate with their required safety functions.

Atomic Weapons Establishment

908 DBFs have been defined for both of the AWE sites and a number of facilities have been assessed against these events. The assessment of the consequences of individual facilities is reported in individual safety cases.

909 A generic approach to hazard identification and analysis is applied to assessing flood hazards and a standard hierarchy of control is applied to reduce and mitigate risks. New facilities are being designed and constructed to modern standards with respect to extreme flood events.

Rolls-Royce Marine Power Operations Ltd

910 RRMPOL has not identified in its submission, its processes for ensuring that SSCs needed for achieving and maintaining the safe shut-down state in the case of flooding, as well as systems and structures design for flood protection, remain capable of delivering their safety functions.

911 Equipment and supplies required for use in an emergency are vulnerable to severe flood events.

BAE Systems Marine Ltd

912 BAESM has not identified in its submission, specific processes for ensuring that SSCs needed for achieving and maintaining the safe shut-down state in the case of flooding, as well as systems and structures design for flood protection capable of delivering their safety functions. However, it does explain that site procedures ensure that the required EMIT is carried out at the specified periodicity, against defined acceptance criteria, where relevant, by Suitably Qualified and Experienced Personnel (SQEP). The intent of this EMIT is to ensure that the SSCs are available and fit for duty, when required.

913 Furthermore, BAESM has not submitted information about its arrangements for ensuring that mobile equipment and supplies that are planned for use in connection with flooding are in a state of continuous preparedness.

Devonport Royal Dockyard Ltd

914 DRDL has robust systems for ensuring that all SSCs are appropriately identified, managed and maintained to ensure they remain available for all demands for which they are specified to function. The process of functional identification, quality requirements through manufacture, setting to work, commissioning and life-cycle management are clearly identified within the business management system.

915 DRDL notes that SSCs are subject to formal EMIT programmes. SSCs are classified subject to their contribution to nuclear safety, which in turn supports definition of the EMIT tasks and the related periodicity. The EMIT activities are managed through formal maintenance management arrangements and undertaken by the licensee directly or under subcontract maintenance and support arrangements.

916 All safety-related mobile equipment and associated supplies are identified in the company's maintenance database and job plans are written and undertaken in accordance with the appropriate business management procedures.

Rosyth Royal Dockyard Ltd

917 RRDL notes that the radioactive waste store systems and equipments are maintained and kept continuously available but if they were to fail, the radioactive material would remain passively safe for an extended period of time.

Magnox Ltd – Defuelled reactors

*Berkeley*

918 There is no need to achieve and maintain the safe shut-down state as the reactors are defuelled. Procedures for confirming that all parts of the Active Waste Vaults flood barrier are present and serviceable are included in site maintenance schedules. There are no potential deviations from the licensing basis with regard to the DBF.

*Bradwell*

919 As both reactors are permanently shut down and defuelled, no SSCs are required to achieve a safe shut-down state after a flood.

920 In general, plant is subject to routine maintenance, inspection and testing as required by the nuclear maintenance schedule, which lists those ongoing activities that are necessary to support the site safety case. This is implemented in accordance with Management Control Procedure (MCP) 19 “Bradwell site, Management of Maintenance”. Specific procedures include S-268 “Inspection and Assessment of Nuclear Safety-related Civil Structures to Comply with site LC28”, whose scope specifically includes "sea and river flood defences that protect the licensed site from flooding”.

921 As necessary, the plant and safety case is modified or updated in accordance with MCP 99 “Bradwell site, Unified Arrangements for Regulatory Compliance in Projects during Defuelling and / or Decommissioning”.

922 There are no identified deviations from the licensing basis with respect to the flooding safety case.

*Hinkley Point A*

923 There are no systems, structures or components which are required to achieve a safe shut-down state following the design basis event. Therefore, there are no systems, structures or components which must be maintained in faultless condition.

924 However, the plant is subject to routine maintenance, inspection and testing as required by the maintenance schedules, which list those activities that are necessary to support the site safety case and other legal requirements. This is implemented in accordance with MCP 19 “Management of Maintenance Work” and MCP 13 “Surveillance and Routine Testing of Plant Items and Systems”. Specific procedures include S-268 "Inspection and Assessment of Nuclear Safety-related Civil Structures to Comply with site LC28", whose scope specifically includes "sea and river flood defences that protect the licensed site from flooding".

925 As necessary, the plant and safety case is modified or updated in accord with MCP-99 "Unified Arrangements for Regulatory Compliance in Projects During Defuelling and / or Decommissioning".

926 At ten-yearly intervals, and in response to significant operating events, the safety of the plant is reviewed in a PSR. This reviews the safety of the plant against modern standards and operating experience. The most recent PSR was completed in 2005.

927 There are no identified deviations from the licensing basis with respect to the flooding safety case.

*Hunterston A*

928 The plant is subject to routine maintenance, inspection and testing as required by the nuclear maintenance schedule, which lists those activities that are necessary to support the ongoing site safety case. This is implemented in accordance with MCP 19 “Management of Maintenance Work” and MCP 13 “Surveillance and Routine Testing of Plant Items and Systems”. Any changes to the plant or the safety case are controlled via MCP 99.

929 At 10-yearly intervals, and in response to significant operating events, the safety of the plant is reviewed in a PSR. This reviews the plant against modern standards, operating experience and the effect of ageing. Such a review has recently been completed for Hunterston A site. In addition, when applicable, enhancements identified in response to operating experience from other sites have been implemented.

930 There are no potential deviations from the licensing basis with regard to the DBF.

*Trawsfynydd*

931 The plant is subject to routine maintenance, inspection and testing as required by the nuclear maintenance schedule, which lists those activities that are necessary to support the ongoing site safety case. This is implemented in accordance with MCP 19 “Management of Maintenance Work” and MCP 13 “Surveillance and Routine Testing of Plant Items and Systems”. Any changes to the plant or the safety case are controlled via MCP 99.

932 No deviations from the current licensing basis have been identified.

<u>NNB GenCo – Hinkley Point C</u>

933 The response provided in NNB GenCo’s stress tests submission simply reports that this information is “Not available at this time. The details of the site organisation have yet to be finalised.” This is a reasonable response at this stage in pre-licensing.

#### ***3.1.3.1 ONR’s Assessment of Plants’ Compliance with Their Current Licensing Basis***

<u>Sellafield Ltd – Sellafield and Windscale</u>

934 In response to the question on compliance with the current licensing basis, Sellafield Ltd has referred to information noted in Section 2.1.3 of this report. Although the information is detailed in the Earthquake section of this report it is relevant as the arrangements discussed are implemented in relation to all external hazards and as such encompass flooding considerations.

935 As noted in Section 2.1.3, ONR considers that the facilities on the Sellafield site are essentially compliant with the requirements of the safety case. There are clearly some areas where the full implementation of the case is subject to change as modifications and standards advance. This is recognised by ONR and is tracked through routine regulatory business, particularly the PSR process.

936 The Sellafield Ltd arrangements for control of plant modification proposals will enable planning, design and implementation of reasonably practicable measures to maintain defence against flooding and ONR will monitor progress of such works as part of normal business.

Atomic Weapons Establishment, Rolls-Royce Marine Power Operations Ltd, BAE Systems Marine Ltd and Devonport Royal Dockyard Ltd

937 AWE, RRMPOL, BAESM and DRDL have a number of processes in place to ensure that safety-critical SSCs remain available in accordance with licence condition requirements. These processes include the site and facility maintenance arrangements, the procedures for the control of modifications and the use of PSRs. The licensees did not provide a detailed summary of these arrangements in their stress tests submission. However, ONR's ongoing licence condition inspection regime aims to maintain continued regulatory assurance that SSCs on these sites are maintained to an appropriate level commensurate with their required safety functions.

938 ONR accepts that AWE has defined a DBF event for both sites and that there are generic hazard identification and analysis arrangements in place. ONR, through normal regulatory business, will gather evidence of EMIT activities associated with the site drainage system.

939 As RRMPOL's submission has not provided details of its arrangements for ensuring that SSCs required for achieving and maintaining a safe shut-down state are maintained to achieve their safety function, in the event of flooding.

940 RRMPOL has identified C*onsiderations* for ensuring that mobile equipment and supplies that are planned for use in connection with flooding are continuously available.

941 While BAESM has provided general information on its EMIT arrangements for key SSCs, no specific information has been submitted by BAESM to demonstrate how the safety functions are maintained.

942 There is no description of the implementation of EMIT arrangements in the DRDL stress tests submission.

Rosyth Royal Dockyard Ltd

943 ONR supports RRDL's claim that there are no SSCs required to ensure nuclear safety and that if any of the electrical or mechanical services that are required to support operations were lost, the radioactive material would remain in a passively safe state for an extended period of time. ONR's ongoing licence condition inspection regime aims to maintain continued regulatory assurance that SSCs on these sites are maintained to an appropriate level commensurate with their required safety functions.

Magnox Ltd – Defuelled reactors

944 There is no need to achieve and maintain the safe shut-down state following an event as the reactors and ponds are fully defuelled. Therefore, there are no SSCs that must be maintained in faultless condition.

945 Procedures for confirming that all parts of the Active Waste Vaults flood barrier are present and serviceable are included in site maintenance schedules. In general, plants are subject to routine maintenance, inspection and testing as required by the nuclear maintenance schedule, which lists those ongoing activities that are necessary to support the site safety case.

946 At ten-year intervals, and in response to significant operating events, the safety of the plant is reviewed in a PSR. This reviews the safety of the plant against modern standards and operating experience.

947 There are no identified deviations from the licensing basis with respect to the flooding safety case for all Magnox defuelled sites.

NNB GenCo – Hinkley Point C

948 The response to the compliance with the current licensing basis is not directly applicable to NNB GenCo as the plant has not had any significant construction undertaken and no site licence has currently been issued.

## 3.2 Evaluation of Safety Margins

### 3.2.1 Estimation of Safety Margins Against Flooding

Sellafield Ltd – Sellafield and Windscale

949 In discussing safety margins, Sellafield Ltd has reiterated information in relation to extreme tides and datum levels of nuclear and support facilities to demonstrate that the existing margins are adequate. A maximum tide level of 7.39m AOD is quoted against a 1 in 10,000-year event with the lowest base level of a facility with radiological content stated as being 14.0m AOD.

950 The consideration of safety margins in relation to river flow and capacity notes that flooding of the upstream end of the Calder Hall site is possible but gives no indication of the extent of protection offered to Sellafield facilities.

951 Sellafield Ltd notes that there is no safety margin against surface water flood in relation to 1 in 10,000-year events as the existing drainage system is shown to be surcharged and unable to accept the overland flow of water in certain locations.

952 Although no safety margin is claimed in relation to both fluvial and pluvial threats, Sellafield Ltd draws a distinction between the damaging power of high dynamic events such as tsunami and the lesser dynamic inundation probable from surface water incursion and minor river flood. A lesser propensity for correlated mechanical damage is claimed for the relatively low dynamic flood threat.

Urenco UK Ltd

953 The assessment data provided by UUK in its stress tests report indicates there is a large margin between the maximum recorded flood height in the area and the site height AOD. Design basis flooding that could seriously challenge safety functions at the UUK site is not considered credible. Existing measures such as building and site drains are considered adequate. The licensee reports that likelihood and most likely consequences of credible flooding on the UUK Capenhurst site do not warrant any further significant measures. ONR shares this view.

Dounreay Site Restoration Ltd

954 While not stated explicitly in the licensee's submission, ONR is satisfied that DSRL has adequately sought evidence of a potential design basis cliff-edge effect by assuming coincident tsunami and storm surge (which also account for predicted sea-level rises due to global warming by 2100). ONR recognises that DSRL has not evaluated a cliff-edge effect of a beyond design basis storm surge, but is satisfied that the licensee has provided a sufficient bounding argument for the most vulnerable facility (the Floc settling tank) on the site.

955 The approach taken by DSRL to test the extent of off-site release to sea, for the most onerous floodwater inundation, provides ONR with confidence that the licensee has sufficiently stressed the design basis for seawater flooding. The inherent conservatism in the licensee's approach goes beyond what would be reasonably expected for a best-estimate approach to severe accident analysis. ONR is satisfied from the stress tests that the Floc settling tank constitutes the bounding case vulnerability for a floodwater inundation (there is no cliff-edge effect to consider here).

Springfields Fuels Ltd

956 It was discussed in Section 3.1 that SFL has not indicated the resilience of facilities to rainfall induced flooding to any design basis frequency, nor is a cliff-edge analysis reported. As previously indicated, ONR is satisfied that there exists sufficient deterministic evidence that rainfall induced flooding could not conceivably challenge nuclear safety; ONR is further satisfied that existing analysis of criticality incidents and radiological release sufficiently bound concurrent events, i.e. flooding that follows a seismically induced building collapse.

Atomic Weapons Establishment

957 Given that a severe accident cannot result from a 1 in 10,000-year severe flooding event, AWE does not consider it necessary to evaluate safety margins.

Rolls-Royce Marine Power Operations Ltd

958 RRMPOL reports it has a design basis performance against a 100-year flood event. Consequently, there is no estimate of safety margin against the expected 10,000-year flood event.

BAE Systems Marine Ltd

959 For radioactive component and reactor commissioning activities, BAESM concludes that flooding events, even at levels well above the site design basis (up to 1.5m above DBF), are very unlikely to lead to an accident.

Devonport Royal Dockyard Ltd

960 The stress testing conducted by DRDL confirmed that each of the major facilities on the licensed site is protected from the effects of uncontrolled flooding up to the extreme DBF. The nature of the waterfront environment however, means that the postulated effect of water levels in excess of the extreme DBF is widespread. These effects include the potential for uncontrolled flooding over the cope edge into 5 basin and the operational docks affecting docked vessels.

961 The general resilience of a nuclear submarine in the afloat condition stems from its prime function as a self-contained operational warship. Submarines in dock would be potentially more vulnerable to conditions in excess of the extreme DBF. For example, the design of fuel handling arrangements, optimised for safety with the design basis, would be challenged if the submarine they were servicing became buoyant in an uncontrolled manner by an event that was well beyond the design basis.

962 The precise nuclear consequences of such an interaction are very difficult to predict and are captured by the probabilistic assessment of the governing safety cases.

963 DRDL's stress testing considers incremental changes in water level in excess of the extreme DBF. At modest levels of 4.3m AOD, it is clear that power distribution and generation systems are further compromised with the effect of delaying recovery times. Since the loss of power is already assumed within the extreme DBF, then this is deemed not to present an increment in the potential consequences.

964 DRDL also predicts that the LLRF may flood at modest levels above the extreme DBF. Given the configuration of nuclear fuel in the stored condition, there is no nuclear consequence to such an event.

965 As the increment above extreme DBF is increased then the potentially debilitating effect on the overall Devonport site is apparent, most notably compromising communications, access / egress to nuclear facilities and constraining recovery operations.

966 ONR notes that the design of a NRP in a warship in terms of diversity of systems for DHR, provision of electrical power and the robustness of watertight integrity and containment provides the inherent resilience against the effect of increased water levels well in excess of the extreme DBF. The NRP design falls within the remit of the MoD which is carrying out its own post-Fukushima review of NRPs. A programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

967 RRDL notes that no safety systems or safety-related systems are essential to the continuing safety of radioactive material in storage. Failure of the safety systems will occur in the event of extreme flooding above 6.2m AOD, but would not prejudice the integrity of the waste containers.

968 RRDL has determined that the structural integrity of the building would survive flooding by standing water to any depth. If the structure of the building was to fall under the impact of a transient wave, that failure would be progressive, with the outer seaward walls failing first and (by absorbing wave energy) offering protection to the seismically qualified reinforced concrete internal walls and the radioactive material behind them.

Magnox Ltd – Defuelled reactors

969 The sites generally claim large indicative margins before flooding could significantly impair essential safety-related plant associated with containment of radioactive materials in the radioactive waste facilities or the acceptability of limited flooding. Evidence for this is presented by comparing DBF levels, sea wall levels / ponding levels and the heights of important safety-related plant.

970 Dependence is placed on engineered barriers, many of which utilise structures dating back to the original construction of the plant, waste packages and temporary barrier arrangements.

NNB GenCo – Hinkley Point C

971 The evaluation process undertaken by NNB GenCo has led to an additional safety review and four types of cliff-edge effects potentially induced by flooding were identified:

- Flooding causing loss of heat sink, initiated by a rise in water level leading to the loss of successive filtration of main cooling water, and then from the flooding of the main and safety-related cooling pumps.
- Flood situation causing a loss of off-site power, initiated by the presence of a significant depth of water on the platform of the main station and unit transformers.
- Flood situation causing a total loss of external and internal electrical sources associated with the loss of back-up systems to the reactor. This type of effect could be initiated by the presence of a significant depth of water on the nuclear-island.
- Flooding causing a loss of safety classified equipment located in the outfall structure initiated by a presence of a layer of water on the platform.

972 Figure 2 below shows at what flood level these cliff-edge effects will be initiated.

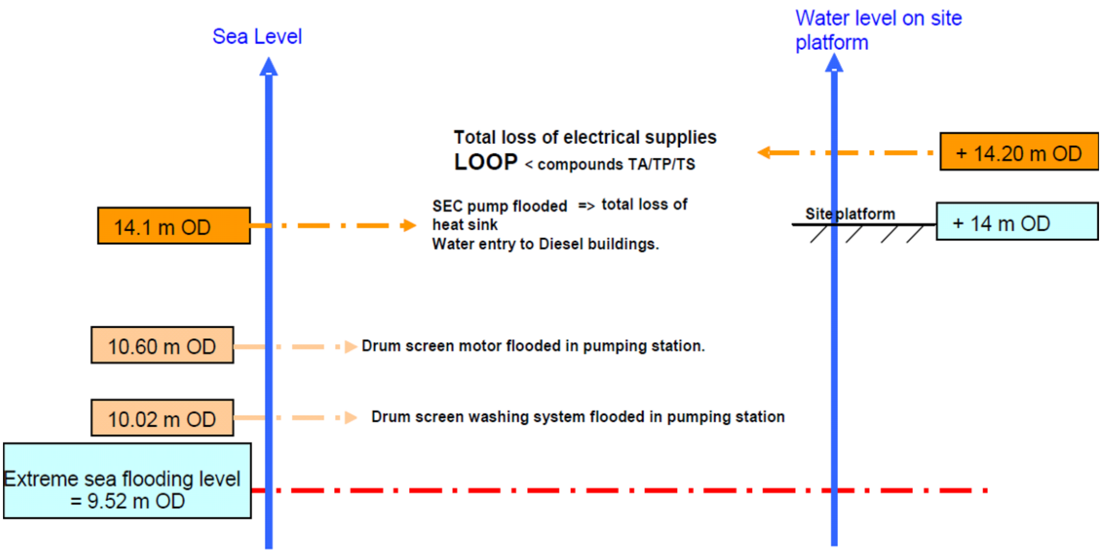


**Figure 2:** Hinkley Point C Flood Height Diagram (from HPC stress tests report Figure 1)

973 Figure 2 shows that the design of the Hinkley Point C site incorporates a safety margin of 4.68m above the DB extreme sea-level height without the effects of waves with regard to loss of electric power; these events are considered within Section 5.1 of this report. This margin falls to 2.68m if waves are considered; however, the nuclear site is a distance from the sea defences and therefore wave over-topping should not directly affect on-site electrical power. The planned height of the site sea wall is 13.5m AOD therefore there is a margin compared to that of the design basis of extreme sea-level, including wave effects of approximately 2m.

974 NNB GenCo has provided information on the limits and effects of groundwater, however, it has not provided any information about the margins in the design and whether it believes any cliff-edge effects are present.

975 NNB GenCo has reported within its stress tests reports that work is still ongoing with regard to flooding caused by extreme rainfall and that more information should be presented in Hinkley Point C PCSR.

### 3.2.2 Measures Which Can Be Envisaged to Increase Robustness of the Plants Against Flooding

<u>Sellafield Ltd – Sellafield and Windscale</u>

976 Having identified that surface water inundation forms the main flood threat to the site, Sellafield Ltd notes that closer investigation of the site surface water drainage model will inform judgement in relation to design of local protection works to electrical power distribution boards and mobile diesel generator connection points.

977 The use of pre-fabricated flood barriers has been considered and Sellafield Ltd concludes that procurement of such equipment should be reviewed.

<u>Urenco UK Ltd</u>

978 ONR shares the licensee's view that existing measures such as building and site drains are considered adequate.

Dounreay Site Restoration Ltd

979 As previously indicated the licensee notes it has already embarked upon an off-site water diversion project, designed to minimise the amount of rainwater running through the site. This will include widening of the Mill Lade run-off channel (planned for spring 2012) and re-engineering of associated pipework.

Springfields Fuels Ltd

980 SFL does not identify or propose in its stress tests report any measures that might increase the robustness of plants against flooding.

Atomic Weapons Establishment

981 Given that a severe accident cannot result from a 1 in 10,000-year severe flooding event, AWE does not consider it necessary to introduce additional safety margins.

Rolls-Royce Marine Power Operations Ltd

982 RRMPOL reports that the planned regeneration works on the manufacturing site will reconstruct the facilities to modern standards, including elevating them, such that the susceptibility to flood will be reduced. An appropriate DBF for these renewed facilities has been set. In addition to these improvements, RRMPOL has made four C*onsiderations* for improving the resilience of the sites to a severe flooding event.

BAE Systems Marine Ltd

983 BAESM’s stress tests have recognised that there are a number of opportunities to enhance the resilience of the site. These have been identified as *Considerations* for taking forward and will be subject to further review prior to commitment to implementation. Specifically, this would include taking account of any further UK studies into extreme seawater levels and extreme rainfall.

Devonport Royal Dockyard Ltd

984 A total of 22 potential resilience measures have been identified by DRDL covering all aspects of the stress tests considerations from definition of the design basis to protection of SSCs and increasing safety margins from an extreme flood event to the point at which a docked submarine is affected.

Rosyth Royal Dockyard Ltd

985 As there is no foreseeable event that could give rise to significant off-site radiological consequences, RRDL considers that there is no benefit in further increasing the robustness of the radioactive waste store against flooding.

Magnox Ltd – Defuelled reactors

*Berkeley*

986 The PSR 2009 and the Consolidated Safety Case for Berkeley site Radioactive Waste Facilities (2010) considered the effects of flooding and ALARP assessments were made for the potentially significantly affected facilities, i.e. the Reactor Safestores and the Active Waste Vaults. As a result of these assessments it was decided to implement flood protection of the Active Waste Vaults against a $10^{-4}$ pa site flood. The Reactor Safestores have been protected against a $10^{-2}$ pa flood as flooding of the Safestore basements and the void beneath the reactors has very low radiological consequences. Flood water would be of sufficiently low specific activity that it could be pumped into storm drains after the flood has passed. The only significant issue from having the Safestores

flooded is the potential for increased corrosion of vessel supports over the long period following contact with salt water.

*Bradwell*

987 The licensee considers that the only item of plant of safety significance which could be challenged by flood is the active waste vault ventilation system, to which electrical supplies could be lost. Given the low consequence and low probability of failure, it is considered that the site is sufficiently robust against flooding and that risks are ALARP.

*Hinkley Point A*

988 Following the completion of site defuelling, no additional measures are considered necessary to increase the robustness of the site against the flooding hazard.

*Hunterston A*

989 No need to increase the robustness of the plant against flooding was identified by the recently completed PSR.

*Trawsfynydd*

990 No need to increase the robustness of the plant against flooding has been identified.

NNB GenCo – Hinkley Point C

991 The NNB GenCo stress tests submission reports that additional safety studies will be carried out in order to provide confidence in the robustness of the plant with regard to sea-level change with or without the inclusion of the effects of waves. More detail will be presented in the Hinkley Point C PCSR.

992 Further, the NNB GenCo submission also provides information on additional design features which would contribute to improving the robustness of safety classified buildings and equipment against the presence of a layer of water on the platform level; these improvements have been reproduced below:

- Implementation of specific provisions to limit water ingress in to the pumphouse at the platform height.
- Implementation of specific provisions to limit water ingress to the buildings located on the outfall slab.
- Implementation of measures to protect the ultimate diesel generators and 12-hour batteries against flooding.
- Measurement of the leak-tightness performance of security doors of buildings containing safety-related plant when flood water is present on the platform of the nuclear-island.
- Furthermore, the current design basis for external flooding does not currently consider the seismic resistance of flood protection provisions (volumetric protection).
- As a result, assessments to confirm the seismic resistance of the sealing elements (i.e. volumetric protection) of structures that house safety-related plant will be carried out.

### 3.2.3 ONR's Assessment of Evaluation of Safety Margins

Sellafield Ltd – Sellafield and Windscale

993 As noted in previous paragraphs, the topography of the site is such that threats from seawater incursion can be discounted. Information collected to support preparation of HM Chief Inspector's final report (Ref. 2) in relation to the Fukushima event indicates that, even when allowance is made for storm surge in combination with a 1 in 10,000-year event and climate change effects, a maximum seawater level of 10.9m AOD is indicated. The base level for facilities with a radiological content is noted as 14.0m AOD and hence it is apparent that there is considerable margin against seawater incursion.

994 In recent years ONR has instigated a review of coastal erosion studies for the Sellafield site and these indicate that erosion and silt transport do not pose a threat in short and medium timeframes. Long-term effects, i.e. in excess of 100 years include silting of the River Calder estuary and erosion of the railway line embankment at the site boundary. The longer term effects quoted assume no intervention to provide sea defence works.

995 ONR considers that there is adequate margin against seawater incursion and supports Sellafield Ltd's focus on threats from surface water run-off and river flood.

996 The current assessment indicates that there is no margin against river flood although the area of the site at risk is limited to the lower lying regions of the Calder Hall zone. However the river channel capacity calculations were completed in 1974 when the course of the river through the site was straightened. ONR considers that the design flow capacity of the river channel should be reassessed in line with current methodologies taking account of changes in river bed level and that such work should inform a review of safety margin against river flood and the practicality of additional river defence works (see STF-38 in Section 3.1.1.1). ONR has raised this requirement with Sellafield Ltd and will take forward an intervention to review the adequacy of work completed and the possible need for river flood defence works.

997 Sellafield Ltd has completed a detailed assessment of surface water drainage arrangements for the site including construction of a computer model to investigate flow and discharge capacity. Output from the assessment indicates that existing drainage capacity is inadequate when subject to extreme (1 in 10,000-year) events and overland flow of excess surface water is expected.

998 Inspection of the flood maps produced using output from the surface water modelling confirms that excess water will follow road and open service trench systems with local ponding in areas of the site. In light of the work completed it is evident that margin against surface water flooding of facilities is variable and in some instances non-existent. However the work completed by Sellafield Ltd forms a good basis for further investigation with water depth projection possible on a square metre basis across the site.

999 Sellafield Ltd recognises that a more detailed assessment of the surface water flood threat to individual facilities and safety system connections and supplies can be completed and has undertaken to complete such a review. This work can assess the exposure to design basis and beyond design basis events and consider the practicality of providing additional flood protection measures. ONR will continue review of the Sellafield Ltd flood maps and the follow-up work proposed by Sellafield Ltd to assess the adequacy of protection to safety systems as part of normal business.

Urenco UK Ltd

1000 ONR considers UUK's justification of resilience to beyond design basis flooding events to be appropriate.

Dounreay Site Restoration Ltd

1001 As previously stated, ONR is satisfied that DSRL has adequately sought evidence of a potential design basis cliff-edge effect by assuming coincident tsunami and storm surge (which also accounts for predicted sea-level rises due to global warming by 2100). DSRL has not sought evidence of a cliff-edge (beyond design basis) storm surge, but is satisfied that the licensee has provided a sufficient bounding argument for the most vulnerable facility (the Floc settling tank) on the site. ONR acknowledges the difficulty faced in substantiating the Floc settling tank against any floodwater inundation.

1002 Nevertheless, ONR recognises that the Floc settling tank contains potentially mobile ILW inventory, in a structure which has limited secondary containment. ONR will secure assurance that the licensee gives due consideration of waste inventory mobility during the prioritisation of remediation activities.

**STF-42: DSRL should demonstrate to ONR the rationale with which it has considered the mobility of waste inventories in flooding events when prioritising the order with which hazard reduction activities are planned within its decommissioning strategy.**

Springfields Fuels Ltd

1003 As previously indicated, ONR is satisfied that there exists sufficient deterministic evidence that rainfall induced flooding could not conceivably challenge nuclear safety; ONR is further satisfied that existing analysis of criticality incidents and radiological release sufficiently bound concurrent events, i.e. flooding that follows a seismically induced building collapse.

Atomic Weapons Establishment

1004 ONR is unable to assess whether or not consideration of the safety margins is adequate, since AWE has not presented an evaluation of safety margins as part of its stress tests submission. AWE has considered increasing flood depths beyond the predicted design depths but does not elaborate beyond this.

1005 AWE has not presented an assessment of the progressive loss of SSCs beyond the design basis as part of its submission.

**STF-43: AWE should consider assessing the nuclear safety implications of consequential events including progressive loss of structures, systems and components following an extreme flooding event to establish whether further measures are needed to reduce the associated risks.**

Rolls-Royce Marine Power Operations Ltd

1006 RRMPOL recognises that the site is vulnerable to any flooding event with a frequency of exceedance less than $10^{-2}$. ONR's assessment is that the current safety margins do not meet modern standards. However, ONR recognises that RRMPOL is actively pursuing a regeneration programme to replace existing facilities on the manufacturing site with modern systems and structures that will comply with modern standards.

BAE Systems Marine Ltd

1007 BAESM's position on adequate protection against beyond DBF events is generally supported by ONR. A 1.5m margin about the 10,000-year reference flood event level is considered to be adequate protection against a beyond DBF event. However, the omission of a complete substantiation within its submission means that a full assessment cannot be made by ONR at this time. In particular, it is not clear if consideration has been given to the dynamic nature of a flood event or whether a static event has been considered.

**STF-44: BAESM should consider providing further substantiation of the claim that there is a 1.5m margin of safety beyond the design basis flood event.**

1008 However, ONR is encouraged that a number of *Considerations* have been identified by BAESM to improve the resilience of the site in implementing its emergency response plans.

1009 ONR will monitor progress against these minor stress tests submission shortfalls as part of the normal regulatory process.

Devonport Royal Dockyard Ltd

1010 DRDL has taken a staged approach to assessing the impact of increasing flood levels beyond the extreme design basis. In addition, DRDL has considered both static and dynamic flooding at each increment, and has recognised the subtle differences in the consequences caused by each type of event. The beyond design basis event extends to more than 6m above the extreme DBF level, which is a highly incredible event. This approach is considered by ONR to be appropriate.

1011 ONR considers the resilience measures identified by DRDL are well considered, well informed and comprehensive.

Rosyth Royal Dockyard Ltd

1012 ONR supports RRDL arguments that there is no foreseeable event that could give rise to significant off-site radiological consequences, and that therefore there is no benefit in further increasing the robustness of the radioactive waste store against flooding.

Magnox Ltd – Defuelled reactors

1013 The licensee considers that there is no requirement to evaluate margins since there is no longer a requirement for reactivity control or heat transfer. ONR considers that it is apparent that the principal requirement is to prevent release of radioactivity and to reduce radioactive waste.

1014 Water ingress could arise inter alia from flooding, rainfall, failure of engineered barriers or decommissioning activities. The response has been written on the basis of compliance with the current design basis and limited consideration of margins. In many cases the derivation of the design basis event is based on old analyses from the period of operation of the plant, and, while it is acknowledged that these have been reviewed under the PSR process, the licensee should carry out a review and update the analyses to modern standards as appropriate, this should be done in response to STF-47 (see Section 4.1).

1015 The radiological hazard is relatively low and, as it largely originates from the storage of radioactive waste, the requirements for active management required during an event is reduced. It cannot, however, be treated as if there is no hazard. Generally there is no requirement for electric power or cooling water and reliance is placed on passive engineered barriers. While this is true for materials contained in waste vaults, ponds and storage vessels, the act of decommissioning will lead to permanent or temporary changes in the plant configuration which could lead to the generation or release of nuclear waste which may not be so confined at the time of an event. Decommissioning activities may also compromise existing barriers or generate new water ingress / egress paths, ponding areas and threats to drainage systems (demolition materials, detritus, dust etc.). Although not explicitly stated, it could be assumed that these are covered fully in the safety cases presented with PMPs, but the Magnox responses could go further in covering this.

1016 The threat due to off-site release of radioactive material and area contamination is far less than would occur in a reactor incident but the licensee should ensure, so far as is reasonably practicable, that radioactive waste on the site is at all times adequately controlled or contained so that it cannot leak or otherwise escape from such control or containment.

1017 There is no consideration of the effects of water ingress on the stored waste forms or consequential hazards due to the generation of flammable gases.

NNB GenCo – Hinkley Point C

1018 ONR judges that NNB GenCo has used a structured and systematic approach for the determination of margins to determine the level at which water will enter buildings. The margins that NNB GenCo has determined seem reasonable and ONR supports NNB GenCo's statement that additional safety studies will be carried out in order to provide confidence in the robustness of the plant with regard to sea-level change.

1019 ONR notes that as the design of the drainage system is ongoing, the determination of a margin between the design basis extreme rainfall event and the operational capacity of the drainage system could not be presented in the NNB GenCo's stress tests submission. ONR will review this information when it becomes available as part of normal pre-licensing assessment.

## 3.3 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

1020 Review of the information provided by Sellafield Ltd indicates that the flood threat to the site has been considered in detail. Sellafield Ltd's application of the stress tests process has been thorough and well reported.

1021 ONR considers that the information provided in combination with work instigated by ONR in past years (i.e. coastal erosion study) indicates that the possibility of seawater incursion onto the site is almost non-existent and therefore the flood threat to nuclear facilities from this source can be discounted. In addition, the threat from seismic induced tsunami initially investigated following the Sumatra earthquake and Indian Ocean event in December 2004 has been revisited and confirmed not to be an issue.

1022 The work completed by Sellafield Ltd has revealed a low level of threat from river flood and potential for extensive overflow of the surface water drainage system following the occurrence of a 1 in 10,000-year rain storm. ONR has noted that an updated assessment of river channel capacity in line with current methodologies and taking account of erosion of the bed of the channel may confirm adequacy of flow and this is being followed up with Sellafield Ltd.

1023 ONR considers that the site surface water drainage model constructed by Sellafield Ltd can be investigated to determine the potential for surface water disruption of individual safety-critical services and installations. As noted, the investigation can consider both design and beyond design basis events and results can inform the selection of relevant flood protection measures as necessary. In coming months ONR will take forward this work and review output to confirm the adequacy of existing protection measures and the potential for further improvements.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1024 ONR considers that UUK, DSRL and SFL have provided sufficient demonstration that their respective sites are resilient to design basis flooding events, and that reasonably foreseeable flooding sources have been considered. ONR further welcomes licensee commitment to implement improvements to enhance confidence in facility resilience. ONR recognises that topology of Capenhurst and Springfields and location relative to coastal or river flooding plains means that floodwater inundation can be deterministically dismissed. ONR is satisfied that, despite the coastal location of Dounreay, existing safety cases provide adequate consideration of the most bounding off-site release occurring due to a beyond design basis storm surge.

Atomic Weapons Establishment

1025 AWE reports that its flood hazard assessment is robust and fit for purpose and that individual facility safety cases are also robust up to the design basis level. Although it has not been demonstrated in the stress tests report, AWE explains that there is margin beyond the design basis level.

1026 ONR's assessment generally supports these claims. However, a number of findings have been made where the case has not been adequately presented in the stress tests submission. ONR recognises that evidence for these findings may exist in supporting documentation. Where appropriate, clarification will be sought through the normal regulatory process.

1027 ONR recognises that AWE has recently undertaken a site-wide PSR and that a number of opportunities to improve resilience may have resulted from this. ONR is currently monitoring AWE's improvement programme in response to the site-wide PSR through normal regulatory business.

Rolls-Royce Marine Power Operations Ltd

1028 RRMPOL recognises that there is no DBF event defined for the sites, and that current facilities are not to modern standards. However, RRMPOL is actively pursuing a regeneration programme to replace existing facilities on the manufacturing site with modern systems and structures that will comply with modern standards. To assist that, a contemporary flood modelling study has been undertaken which is currently being peer reviewed.

1029 ONR agrees with RRMPOL's assessment that improvements to the emergency arrangements infrastructure should be made.

1030 ONR supports the findings of the RRMPOL submissions and will continue to monitor progress against its *Considerations* and the planned manufacturing site regeneration programme.

BAE Systems Marine Ltd

1031 BAESM has undertaken a flood hazard stress tests assessment of the Barrow nuclear licensed site. A flood hazard study was undertaken in 2001 and this is used to support its findings. However, no details have been presented as part of the stress tests submission and therefore no assessment has been made by ONR as to the adequacy of the study. There is also no indication that a revision of the study has been undertaken in the 11 years that have passed since that study was undertaken.

1032 The 10,000-year DBF event level has been set at 6.94m AOD, resulting from a combined high tide and storm surge; the study also took account of climate change. The effect of tsunami at the Barrow site is judged by BAESM to be minimal.

1033 Town flood defences protect against tide levels of 5.0m AOD. The site is protected by facilities being elevated to 8.5m AOD at floor level. There is therefore a margin of safety of 1.5m beyond the DBF event.

1034 ONR in general supports BAESM's claims that the flood hazard assessment is robust and fit for purpose. ONR has made a number of recommendations that will be taken up with BAESM through the normal regulatory process.

Devonport Royal Dockyard Ltd

1035 DRDL has demonstrated that its flood hazard assessment up to the extreme DBF is comprehensive and that SSCs installed to protect against the effects of an extreme flood are adequate. In many cases there is a significant safety margin. Where there is an erosion of safety margin for a design basis event, DRDL has indentified potential resilience measures to increase the margin.

1036 Definition of the design basis event takes account of climate change and uses site-specific data. The methods and techniques applied by DRDL to assess the flood hazard employ contemporary models and modern statistical tools. An independent technical assessment has been undertaken to review the DRDL approach. ONR considers this approach to be relevant good practice.

1037 ONR supports the claim that DRDL's flood hazard stress tests assessment is robust and fit for purpose.

1038 A number of resilience *Considerations* have been identified by DRDL and ONR will monitor the sentencing of these considerations as part of normal business.

Rosyth Royal Dockyard Ltd

1039 The nuclear plant comprises a single radioactive waste store housing a limited quantity of radioactive material. ONR considers that the safety justification for the facility demonstrates that it is robust against extreme hazard events up to those with a return frequency of $10^{-4}$ per year, and that it has substantial margins of safety considerably beyond that level due to the non-consequential progressive manner in which the building may eventually fail and the manner in which the radioactive material is stored. All modes of failure escalate progressively with the increasing scale of hazard, and there are no cliff-edge consequences.

1040 As the radioactive material is passive and not dependent for its safety upon the provision of electrical or mechanical services, RRDL's stress tests examined the implications of an external extreme hazard affecting its containment and the arrangements provided for its recovery following an accident beyond the design basis event. ONR is content with the assessment made by RRDL.

1041 Emergency arrangements were considered sufficient by RRDL up to the point where widespread devastation of the entire area might be caused by the hazard, with commensurate threat to both life and the civil infrastructure.

1042 ONR supports the claim that the flood hazard stress tests assessment for the RRDL site is robust and fit for purpose.

Magnox Ltd – Defuelled reactors

1043 Due to the removal of fuel from the defuelled reactor sites, the potential hazard is greatly reduced from that of an operational reactor, although there remains some hazard from flooding of stored waste forms. With the removal of fuel from these sites, there is no longer a requirement for reactivity control or heat removal systems. ONR notes that, because these sites are in the process of decommissioning, the safeguard provisions against flooding may be subject to disruption. In general the licensee has concluded that, due to the absence of fuel on-site, the nuclear consequences are low or insignificant. However ONR notes that there still remains a requirement to prevent radiological release or accidents as far as reasonably practicable and therefore provide design basis provisions commensurate with the remaining hazard potential. ONR has therefore raised a finding under Section 4.1 (STF-47) that Magnox Ltd should carry out a review of the design basis and margins available against external hazards (including flooding) at each decommissioning site to ensure adequate provisions are in place throughout the decommissioning process, commensurate with the remaining radiological hazard potential, to determine whether there is a need to improve protection requirements.

NNB GenCo – Hinkley Point C

1044 ONR believes that NNB GenCo has provided a good and well structured submission against the stress tests criteria with regard to flooding. NNB GenCo has employed an appropriate methodology in determining the DBF events. The stress tests submission has demonstrated healthy margins beyond the design basis for external sea flooding events. Currently the design is not sufficiently mature to allow for the determination of a margin against rainfall; further there are currently a number of issues that cannot be resolved due to the stage in the plant life-cycle.

# 4 EXTREME WEATHER CONDITIONS

## 4.1 Design Basis

### 4.1.1 Reassessment of Weather Conditions Used as Design Basis

Sellafield Ltd – Sellafield and Windscale

1045 In response to questions in relation to weather conditions prevalent on the Sellafield site, Sellafield Ltd has provided a background description of the main influences on weather patterns as a result of the site location close to the foot of the Cumbrian mountains and the coastal exposure to the Irish Sea.

1046 Local data is recorded by a Sellafield weather station located just outside the site fence at National Grid reference NY02150455. The Sellafield weather station records wind speed and direction, daily maximum and minimum temperatures, rainfall amount and sunshine duration.

1047 The design basis for extreme wind effects is noted as being based on British Standard guidance with early plants being designed or assessed against a three-second gust wind speed as given by CP3 Chapter V Part 2 and later PSRs considering guidance in BS 6399 Part 2. Both normal operational winds loading calculated on a 1 in 50-year return period and extreme wind loading corresponding to a 1 in 10,000-year return are considered. Sellafield Ltd notes that the design procedures detailed in British Standard guidance enable assessment of extreme events from a starting basis of a basic wind speed map drawn up for the British Isles.

1048 In addition site records are available for the past 50-year period and these have been interrogated to determine actual wind speed extremes. The maximum wind gust speed recorded at the weather station is noted as 46.1m/s, which corresponds well with the basic design speed of 47m/s for 1 in 50-year occurrences as specified in British Standard CP3 Chapter V Part 2.

1049 The possibility of exposure to tornado wind speeds has been noted with discussion of the occurrence of such events throughout the United Kingdom. Sellafield Ltd notes that tornado activity is very localised, affecting small areas with a predominance in the south of England. Sellafield Ltd considers that the probability of tornado wind speeds similar to a wind speed indicated by a 1 in 10,000-year assessment is $5 \times 10^{-6}$ per year. More intense wind speeds have a probability level less than $5 \times 10^{-6}$ and as such are discounted.

1050 In relation to potential loading from snow, Sellafield Ltd confirms that as with wind load assessment, British Standard guidance is used with detailed information taken from BS 6399 Part 3 for both 1 in 50-year and 1 in 10,000-year return periods.

1051 The methodology used to establish an extreme temperature range for use in design basis assessment is discussed with reference to Meteorological Office analysis. Temperatures ranging from +43°C to -24°C have been recommended for the 1 in 10,000-year assessment, although Sellafield Ltd notes that more recent studies completed to inform new build NPPs have indicated that for Sellafield the range could be limited to +34°C and -16.2°C. Measured maxima and minima recorded between 1950 and 1999 are stated as +30°C and -12°C with tabular data provided for low temperature between 2000 and 2010 indicating a worst case of -7.6°C.

1052 The consideration of design basis extreme weather effects extends to the combination of such events with the design process requiring assessment of combined wind, snow and temperature loading as detailed in relevant British Standards.

1053 The requirement for lightning protection is noted with reference to British Standard guidance and use of engineered protection measures. The validity of engineered protection measures is considered within the long-term periodic review process completed on a ten-year cycle.

Urenco UK Ltd

1054 The design basis for extreme weather considered credible for the UUK site is essentially the same as that for a seismic event being based on an assessment of the unmitigated dose consequence to the public (from all pathways) following a DBA with a frequency of 1 in 10,000 years. The UUK extreme weather design bases for existing safety cases vary in the approach applied, although they are generally considered adequate pending a more consistent approach in future. As part of its ongoing PSR process, UUK has reported in its report that a more consistent approach will evolve as safety cases are updated against its latest safety assessment methods. The design basis and beyond design basis consequences of extreme weather events are bounded by the consideration of seismic events at the UUK site. ONR supports this continual improvement approach to extreme weather assessment.

Dounreay Site Restoration Ltd

1055 Data for wind, temperature and snow for various exceedance frequencies from 2 x $10^{-2}$ pa to $10^{-4}$ pa are given in the licensee's stress tests report. The actual design basis conditions however are not stated explicitly. ONR understands that although no design basis assessments informed the original design of DFR or PFR, completed in the 1950s and 1960s respectively, design basis conditions for rain, snowfall, temperature, wind and flooding were determined for the Dounreay site during the site licensing process in the early 1990s. During licensing of the Dounreay site, and latterly during the course of LC15 PSRs, safety systems, structures and components have been subject to comparison against these standards.

1056 The licensee acknowledges that the recent publication of additional data, particularly relating to extreme ambient temperature, rainfall and the effect of climate change, will necessitate a review of the Dounreay design basis data in these areas. ONR understands that these were reviewed before 31 March 2012.

Springfields Fuels Ltd

1057 SFL identifies the potential for extreme temperatures on process operations on the site, particularly through freezing chemical feed pipework, thus necessitating process shutdown. The licensee further acknowledges the potential for severe snow accumulations to provide disruption to the site's business operations. High winds have the potential to cause structural damage and loss of building cladding that has occurred in the past; SFL nonetheless concludes that there are no credible extreme temperature or wind scenarios conditions that could challenge nuclear safety given that all nuclear material is contained within substantial steel vessels and pipework.

Atomic Weapons Establishment

1058 AWE has identified weather conditions that could affect the facilities on the sites including high winds and extreme snowfall. The safety cases for the major radiological facilities demonstrate that these events place less loading on building structures than a seismic event of the same return frequency and thus the seismic events provide the bounding damage scenarios.

Rolls-Royce Marine Power Operations Ltd

1059 RRMPOL submissions identify wind / snow loading and earthquake and snow in combination as a loading.

1060 No reassessment of the design basis for either the manufacturing or Neptune sites has been undertaken for the stress tests by RRMPOL.

1061 The earthquake and snow loading in combination is bounded by earthquake and flooding in combination, assessment of which is considered separately by ONR (see Section 2).

BAE Systems Marine Ltd

1062 Any extreme weather hazards that can result in worker or public dose are included in the fault schedule to derive safety functional requirements for safety assessment and consideration of ALARP.

1063 The extreme weather conditions that have been quantified by BAESM along with its design basis values for events with a return frequency of $10^{-4}$ per year are:

- Extreme ambient temperature: 36°C / –16°C
- Rainfall: 248mm over a 24-hour period
- Snow loading: 0.91kPa
- Wind: 64.4m/s

1064 The potential effect of these hazards, either alone or in combination, including seismic or flooding has been considered by BAESM as part of the stress tests. Particular focus has been put on exploring the mechanisms which could expose fuel coupled with coincident extreme weather that could provide a source of moderation, e.g. seismic collapse with extreme rainfall.

Devonport Royal Dockyard Ltd

1065 DRDL describes that the derivation and provenance of selected design bases for all naturally occurring hazards was reassessed in 2008 and tested against relevant industrial standards.

1066 DRDL is confident that all reasonably foreseeable extreme weather conditions have been included in the design basis, that the magnitudes selected have the appropriate provenance, and that they are relevant to the Devonport area.

1067 Contemporary data for the Plymouth / Devonport area have been captured by DRDL with the purpose of illustrating the margin to design basis levels.

Rosyth Royal Dockyard Ltd

1068 RRDL reports that the radioactive waste store was assessed for its ability to withstand extreme weather conditions of wind, high and low temperatures, rain and snow fall, and lightning to events with a $10^{-4}$ per year return period insofar as historical data, or its extrapolation, could provide.

1069 Damage to the architectural elements of the structure was permitted within RRDL’s safety justification on the grounds that they would not fail in such a way as to create an unacceptable risk to safety-related equipment, plant or services, or to the radioactive content of the building.

1070 RRDL explains that a change in the definition of extreme weather events is progressive over long time periods. No reassessment of the weather conditions used as a basis for the design has since been conducted by RRDL as the building is planned to be vacated of all significant material within four years.

Magnox Ltd – Defuelled reactors

*Trawsfynydd*

1071 The recent (2011) PSR concluded that wind loading might cause some damage to the superstructure of buildings but time would be available to effect repairs before any potential existed for a release of radioactivity. Temperature effects were of little concern since there were no temperature sensitive items of plant remaining.

1072 The safety cases for the proposed reactor building Safestores the new ILW store and the north and south Main Sludge Vaults all concede that extreme weather could damage the external containment but a radiological hazard was extremely unlikely. In the case of the reactor buildings the vulnerability to wind damage is currently high pending the completion of repair work but the risk is assessed as ALARP.

1073 Flooding of the ILW facilities could lead to hydrogen evolution but any subsequent explosion would not initiate a fire of fuel element debris and a best estimate of the consequences indicates that the highest public dose which would occur would be extremely low.

1074 Climate change studies predict higher temperatures and more extreme weather events over the next 70 years but the increases are not judged to have a significant impact.

1075 It has recently been found that the reactor building structures do not meet the current wind code requirements for a 1 in 50-year return frequency. The radiological risks have been shown to be between the BSO and BSL and a programme of remedial strengthening works has been instigated.

1076 Weather combinations corresponding to a $10^{-4}$ annual probability of exceedance have not been considered.

*Hunterston A*

1077 Safety cases have been produced against meteorological conditions. The recent PSR has concluded that an adequate safety case exists for each of the radioactive waste facilities. With regard to: extreme wind, snow, ice, temperature and lightning strike, no radiological consequences have been identified. Humidity and precipitation presents a potential threat to the containment and shielding of radioactive waste through the effects of corrosion or through transport of activity by water movement. Heavy rainfall could lead to local flooding, particularly of basement areas. Rainwater entry would be within the capacity of secondary containment systems and on a scale limited enough to allow for remedial action to be taken.

1078 Weather combinations corresponding to a $10^{-4}$ annual probability of exceedance have not been considered.

*Hinkley Point A*

1079 With regard to: snow, ice, lightning, extreme temperature and humidity, no potential radiological consequences have been identified. Extreme weather conditions were assessed against an annual probability of $10^{-4}$. With regard to wind loading, all assessed structures performed satisfactorily but localised failure of external cladding may occur.

*Berkeley*

1080 The original design of the plant would have been in accordance with construction standards of the mid-1950s corresponding to 1 in 50 to 1 in 100-year events but the licensee has provided consideration of the impact of more severe weather.

1081 The threat from extreme winds arises from the possibility of damage to roofing sheets or wall cladding and could result in wind blown missiles and / or compromise weather tightness. It is judged however that there will be no radiological consequences of missiles because ILW activity is within relatively massive structures. With regard to weather tightness, any resulting from extreme weather would be repaired. Heavy rainfall could lead to flooding of basement areas but would be on a scale limited enough to allow for remedial action to be taken. No significant temperature dependencies have been identified and lightning protection is now adequate following upgrading work completed in March 2011.

1082 Weather combinations at the $10^{-4}$ per year level have not been considered.

*Bradwell*

1083 The original design of the plant would have been in accordance with construction standards of the mid-1950s corresponding to 1 in 50- to 1 in 100-year events but the licensee has provided consideration of the impact of more severe weather.

1084 Due to the absence of fuel on-site, no nuclear significant consequences arising from extreme weather conditions have been identified.

NNB GenCo – Hinkley Point C

1085 NNB GenCo's stress tests analysis is based on the safety arguments presented within the GDA PCSR. However, since extreme values of weather conditions tend to be site dependent, confirmation that the GDA values bound the site-specific challenge will be carried out as part of the development of the HPC site-specific PCSR.

*Drought*

1086 Drought is not covered by NNB GenCo's stress tests submission.

*Lightning*

1087 NNB GenCo reports that lightning has been taken into account in the design of the UK EPR™ for Level 1 protection defined by BS EN 62305-1. However this is not related to return period. Buildings and structures will be protected against the direct effect of lightning strikes up to 200kA and operational experience from the EDF fleet suggests that equipment protected by a meshed cage within buildings may be protected against higher currents. Also safety-related equipment installed outside will be adequately protected against direct effects of lightning.

*Wind*

1088 Buildings and structures related to nuclear safety are designed according to Eurocodes1 Part 1-4. This code is not related to exceedance frequencies. With regard to equipment outside buildings that may be exposed to wind-generated missiles, NNB GenCo as part of the stress tests process has identified relevant safety-related equipment. NNB GenCo reports that if the analysis being carried out shows the need for protective provisions these will be implemented within the design of the UK EPR™.

*Extreme Ambient Temperature*

1089 The extreme low air temperatures for the HPC site have been evaluated using "Extreme Value Analysis" which uses the observed minimum air temperatures and provides a prediction of the 10,000-year extreme minimum. The stress tests report compared these values with those used within the design of the UK EPR™ showing that the site-specific values are well bounded by the design values.

1090 With regard to high temperatures, NNB GenCo reports that extreme value analysis has also been used to predict site-specific values corresponding to a 10,000-year period including the effects of climate change. This is 44°C or 40°C for a 12-hour sustained period and, to accommodate this, the equipment operating temperature will be specified at 50°C. However, the discussion on the relationship between ambient or local operating temperature, external temperature and HVAC is not entirely clear.

*Sea*

1091 The design basis is not specified but there is a discussion on Frazil Ice stating that if the intakes were to become blocked this would lead to loss of ultimate heat sink. Greater clarity is required to define the design basis including the likelihood and acceptability of loss of ultimate heat sink within the design basis.

*Snow*

1092 Snow has not been addressed by NNB GenCo's stress tests submission.

*Hail*

1093 NNB GenCo reports that hailstorms can cause on-site flooding but this is bounded by heavy rainfall events. However the combined effect of melting hail / snow and rain are not clear. NNB GenCo also reports that the majority of safety-related plant is inside buildings and so is protected and the equipment outside buildings is mainly those already mentioned for the effects of wind.

*Combinations*

1094 Combinations of extreme weather have not been addressed by NNB GenCo's stress tests submission.

#### *4.1.1.1 ONR's Assessment of the Licensees Stress Tests Analysis of the Design Basis*

<u>Sellafield Ltd – Sellafield and Windscale</u>

1095 The process for consideration of extreme weather effects on safety systems and components including civil engineering structures has been agreed with ONR and is subject to detailed memoranda of understanding. The UK design basis criteria for natural hazards, including extreme weather, is defined in the ONR SAPs as conservatively having a frequency of exceedence of less than 1 in 10,000 years.

1096 Both design of new plant and assessment of existing plant on the Sellafield site follow guidance detailed in relevant British Standards with extreme events corresponding to 1 in 10,000-year return period. It is noted that, although reference has been made to use of wind load at 1 x $10^{-3}$ level for existing plant, the actual assessment process is completed on the basis of a 1 x $10^{-4}$ (I in 10,000-year) level of challenge.

1097 Prediction of future climate change is relevant to the extreme wind hazard. Major studies considering a range of emission scenarios predict an increase in the average winter wind speed and a possible increase in average summer wind speed over the UK. UK Climate Impacts Programme reports have found little evidence that the risk from extreme wind will change significantly in the 21st century. Sellafield Ltd has concluded that, apart from keeping under review the projections for climate change, no specific actions were required relating to wind. ONR considers that the effects of climate change can continue to be managed through the existing PSR process.

1098 Assessment of snow loading is completed in accordance with BS 6399 Part 3 and as such includes consideration of wind disposition and build-up of snow as a result of roof configuration. It is noted that the coastal location of Sellafield results in adoption of a low basic site snow load intensity and the general roof live load of 1.5kN/$m^2$ adopted for many facilities bounds snow load considerations.

1099 In light of recent studies completed to inform design of new NPP, it appears that the extreme temperature range of +43°C to -24°C adopted by Sellafield Ltd following use of Meteorological Office analysis is conservative.

1100 ONR considers that the design basis requirements for extreme weather events applied to nuclear safety structures and systems on the Sellafield site provide an appropriate level of challenge and subject to review to account for possible climate change effects are proportionate in light of the site hazard potential.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1101 ONR considers that UUK, DSRL and SFL have adequately considered resilience of existing safety measures against foreseeable extreme weather scenarios; for older facilities that were not designed to withstand design basis weather scenarios, ONR is satisfied that these licensees have either demonstrated adequately through existing safety cases the resilience of those facilities, or by demonstration of containment integrity to complete structural failure.

Atomic Weapons Establishment

1102 AWE has not provided sufficient information within its submission on extreme weather events. This is covered by STF-49.

Rolls-Royce Marine Power Operations Ltd

1103 RRMPOL has only reported on wind and snow as forms of extreme weather in its stress tests submission.

**STF-45: RRMPOL should consider assessing aspects of extreme weather other than snow and wind, such as high and low temperature and humidity, rainfall and lightning.**

1104 RRMPOL has not conducted a reassessment of the extreme weather hazard design basis and as such ONR is not able to make a judgement as to its adequacy for either the manufacturing or Neptune nuclear licensed sites.

**STF-46: RRMPOL should consider reassessing the design basis for extreme weather events.**

BAE Systems Marine Ltd

1105 BAESM has not undertaken a reassessment of weather conditions as required by the stress tests specification. The data used is taken from an assessment of the Barrow site against external hazards undertaken in 2001. It has therefore not been possible to assess the adequacy of the design basis and BAESM has not been able to postulate if a more contemporary design basis is appropriate.

1106 Consideration has been given to combinations of events, including combinations of extreme weather with earthquake and flooding. The identified weather combinations are considered by ONR to be appropriate.

Devonport Royal Dockyard Ltd

1107 DRDL’s use of contemporary local data is important as many of the parameters have significant geographic dependencies.

1108 DRDL has used relevant British Standards for extrapolating site-specific data to the design basis weather event with a probability of occurrence of $10^{-4}$ per year.

1109 DRDL has consulted the Tornado and Storm Research Organisation (TORRO) report, which identifies the tornado magnitudes and frequencies for the UK. The Devonport site is located on the border of two areas identified by the TORRO report. The southern region has been used as the frequencies have more conservatism.

1110 The storm surge and stillwater information for the Devonport site have been updated as part of the PSR process.

1111 DRDL has made a comparison of historical data from the Met Office and Plymouth University. The design basis for normal and extreme weather events both bound all of the data considered in this comparison.

1112 DRDL has recognised that, when extreme weather events occur, there can be correlation between two or more events. In such cases the severity of the event is combined when assessing the design basis. ONR supports DRDL's assertion that all reasonably foreseeable extreme weather conditions (and their combinations) have been included in the design basis, that they have been adequately defined, and that the data used to inform the design basis is of sound provenance.

Rosyth Royal Dockyard Ltd

1113 RRDL has not presented the extreme weather conditions for which the radioactive waste store was designed. However, an appropriate return frequency has been specified and a broad range of weather events and their combinations have been considered.

1114 It is reasonable to accept RRDL's argument that, as weather patterns evolve slowly, there is little benefit in reconsidering the design basis extreme weather events given that there are no nuclear safety implications related to the waste storage under these conditions.

Magnox Ltd – Defuelled reactors

1115 It is apparent that the principal effects of extreme weather would be water ingress caused either by extreme rainfall or as a result of wind damage to buildings. In general the licensee has concluded that, due to the absence of fuel on-site, the nuclear consequences are low or insignificant but the design basis requirements do not appear to have been explicitly defined to reflect the low-hazard facilities.

1116 ONR considers that, while the radiological hazard is greatly reduced due to the removal of fuel from the site, a clear design basis criterion should be specified to ensure that appropriate safeguards are in place. ONR would expect the design basis criteria and safeguard provisions to be commensurate with the radiological hazard potential at each site.

1117 ONR also notes that, because these sites are in the process of decommissioning, the safeguard provisions may be subject to disruption. Consequently it is important to define the design basis provisions in order to control the radiological hazard during the decommissioning process.

**STF-47: Magnox Ltd should carry out a review of the design basis and margins available against external hazards at each decommissioning site to ensure adequate provisions are in place throughout the decommissioning process commensurate with the remaining radiological hazard potential.**

NNB GenCo – Hinkley Point C

1118 NNB GenCo's stress tests analysis is based on the safety arguments presented within the GDA PCSR. However, since extreme values of weather conditions tend to be site dependent, confirmation that the GDA values bound the site-specific challenge will be carried out as part of the development of the HPC site-specific PCSR. ONR is currently engaged with NNB GenCo on discussions as to how the GDA values bound the site-specific external hazards challenges corresponding to the UK design basis criteria for external hazards, i.e. $10^{-4}$ pa exceedance frequency for natural hazards.

1119 The stress tests report discusses lightning, wind, extreme ambient air temperature, frazil ice and hail. ONR has raised a query as to why drought and snow are not discussed and the approach to hazard combinations. ONR has also raised specific technical queries relating to lightning, air temperature, sea temperatures and hail. However, ONR does not believe that there is likely to be any difficulty in demonstrating that the UK EPR™ design basis and site-specific equipment will meet the UK design basis criterion of $10^{-4}$ exceedance frequency for all site-specific natural external hazards.

1120 NNB GenCo has informed ONR that the full spectrum of applicable extreme weather phenomena will be included in the external hazards sub-chapter of the site-specific Hinkley Point C pre-construction safety report. This will also include the provision of answers to the queries raised by ONR assessors as part of their assessment of the UK EPR™ stress tests report.

## 4.2 Evaluation of Safety Margins

### 4.2.1 Estimation of Safety Margin above Design Basis Events Against Extreme Weather Conditions

Sellafield Ltd – Sellafield and Windscale

1121 The discussion of safety margin does not consider the relevance of design criteria or the extent of conservatism inherent in the chosen values. The possible effects of beyond design basis weather events is considered in light of the need to maintain services and access, although some discussion of cold temperature effects on structural materials is noted.

1122 Possible disruption of water supplies is noted, both in winter as a result of freezing temperatures and in summer in the event of drought conditions. Sellafield Ltd notes that adequacy of water supply in drought conditions has been considered in past studies with supply sources identified including water abstraction from multiple local sources in the Calder valley. Although back-up water supply has been identified, Sellafield Ltd considers that Wastwater Lake forms an almost infinite supply and threat from weather disruption is very low.

1123 Temperature effects on process materials and the need to maintain cooling is noted but no detail of plants at risk or mitigation measures is provided. Existing provision of insulation and HVAC services is deemed to reduce the impact of external temperature variation and effects are considered to be relatively slow acting and as such countered by operational safeguards.

Urenco UK Ltd

1124 UUK has not identified any scenarios that would result in significantly worse consequences for more extreme weather conditions than would occur at the design basis and bounded by seismic events. Given the general building and equipment design standards and relatively low radiological risk posed by the UUK site from extreme events, the current site structures and equipment are judged to be adequate to give sufficient design resilience against extreme weather events. ONR shares this judgement.

Dounreay Site Restoration Ltd

1125 DSRL reports that high wind speeds or excessive snow loading may result in damage to external cladding or roof panels but does not consider these to present a credible threat to nuclear safety (although the risk to personnel is recognised). Furthermore, measures are in place to restrict operations in the event of adverse weather conditions. The licensee also maintains site-specific equipment to assist with snow clearing of emergency access and egress routes.

1126 ONR welcomes DSRL's commitment to extend further its consideration of the site windspeed data, but only insofar as is reasonably practicable recognising the site's ambition to achieve interim end state before 2030.

Springfields Fuels Ltd

1127 SFL dose not specifically refer to any extension of analysis to test resilience of facilities to beyond design basis extreme weather scenarios. ONR is satisfied that the licensee's extant safety case arrangements provide a suitable basis for consideration of facility resilience to extreme weather scenarios. Further consideration is given to the site's resilience to an extreme weather event in Section 6.

Atomic Weapons Establishment

1128 AWE has not made an estimation of the safety margin above the design basis events for extreme weather. This is covered by STF-49.

Rolls-Royce Marine Power Operations Ltd

1129 RRMPOL reports that resistance to snow and wind loadings have not been formally evaluated for buildings on the Neptune site and, as such, remain an aspect that requires assessment. However, the robust seismic performance of the reactor buildings subjectively implies that there will be reasonable performance. RRMPOL does not expect other buildings to have robust withstand against very extreme events, however the radiological consequence of failures will be low.

1130 Key buildings on the manufacturing site have been subjected to structural analysis by RRMPOL to determine the effect of snow and wind loadings. Loadings at the 1 in 10,000-year level were selected for analysis. No formal margins analysis or analysis of less onerous scenarios have been undertaken.

1131 RRMPOL has identified that two of the manufacturing facilities, an extension and most masonry buildings are not able to withstand severe wind or snow loadings. One of the manufacturing facilities has a roof structure that is particularly susceptible to snow loadings, with very high levels of overloading shown by the extreme events assessments. Given the recent roof replacement (and associated slight improvement in withstand), the additional insulation now incorporated could increase the probability that extreme snow loads would be able to build up on the roof.

1132 The other buildings assessed as part of the stress tests submission have been shown by RRMPOL to withstand extreme wind and snow loadings.

1133 Part of one of the manufacturing facilities is likely to withstand extreme snow loads, but failure in high winds would be expected. The particular manufacturing facility airlock has not been assessed for its performance against snow loads, but will withstand extreme winds.

1134 Sufficient loading of any building could however cause eventual collapse of the structures.

1135 The integrity of Bronze Commands under snow and wind conditions is not known, but site accessibility would be compromised, especially in snow. The emergency control centre is designed to withstand 1 in 10,000-year wind and snow loads.

BAE Systems Marine Ltd

1136 For radioactive component and reactor commissioning facilities, it is concluded by BAESM that extreme weather events, even at levels well above the site design basis, established by a study conducted in 2001, are very unlikely to lead to an accident.

Devonport Royal Dockyard Ltd

1137 Despite the availability of back-up diesel generator supplies, the complete loss of the onshore power distribution system to the submarine is contemplated by DRDL within the design basis and compensated for by the strict control of on-board systems for power generation and decay heat removal. DRDL explains that the inherent resilience of a submarine to the complete loss of external power supplies, even when compromised by its isolation in a dry dock from the ultimate heat sink, is sufficient to ensure margins of safety by virtue of the combination of management controls and cooling water systems that do not rely upon electrical power.

1138 DRDL has identified that these and other systems that provide water supplies to a submarine in dock are potentially vulnerable to protracted periods of below freezing temperatures and may require positive intervention to maintain flow. This is already identified in operating procedures and is routinely exercised at more moderate temperatures.

1139 DRDL recognises that emergency arrangements, where dependent upon diverse buildings, power supplies, telephone communications and IT systems, do not have the benefit of a well defined design basis for extreme weather and are more likely to be compromised. This is addressed separately under accident management (see Section 6).

1140 In considering the adequacy of protection beyond design basis, DRDL considers it necessary to take account of the unique characteristics of a submarine as a warship. These characteristics effectively negate many of the threats presented by extreme weather conditions. This element of the stress tests submission will be assessed by the MoD.

Rosyth Royal Dockyard Ltd

1141 RRDL has identified that the elements of the radioactive waste store that are most vulnerable to extreme weather conditions are the roof cladding, windows and doors. The failure of any of these presents no direct threat to the safety of radioactive materials present. For the radioactive material to be placed at risk from extreme weather, there would need to be a combination of two or more extreme weather events such as high winds and extreme snowfall (beyond the $10^{-4}$ per year return period) followed by sustained low temperatures over a protracted period of time. Were that to happen, a release of radioactive material from the purpose-built robust waste containers could occur but only as a minor leak.

Magnox Ltd – Defuelled reactors

1142 Due to the removal of fuel from site there is no longer a requirement for reactivity control, reactor shutdown or heat transfer capabilities to be maintained. Further, due to the absence of fuel on-site, the licensee considers that there is no requirement for heat transfer from the reactor ponds. Structural damage to buildings and waste management facilities has been assessed to present negligible nuclear safety consequence.

NNB GenCo – Hinkley Point C

*Drought*

1143 Drought is not discussed within the NNB GenCo's stress tests submission.

*Lightning*

1144 Buildings are only protected to 200kA but equipment within buildings within meshed cage has been observed to survive 454kA. Equipment located outside is protected to 200kA. NNB GenCo reports that a study will be conducted to assess the consequences of a lightning strike greater than 200kA for equipment located outside the mesh cage.

*Wind*

1145 The NNB GenCo's stress tests submission cites operational experience in France which suggests facilities are robust against both wind and missiles. A wind speed of 216km/h is mentioned for the design of the UK EPR™ and this is compared with a figure of 198km/h in October 1989 at Rhoose airport.

1146 NNB GenCo reports that for the UK EPR™ there is a margin factor of greater than two between the case load for external explosion and the case load for extreme wind for equipment relevant to power loss, loss of heat sink and severe accidents.

1147 With regard to wind generated projectiles, due to the design of the UK EPR™ the energy of projectiles likely to be generated by storms with maximum gusts of the order of 216km/h is not enough to damage civil structures and buildings containing cooling or safety-related equipment. Thus only plant and equipment outside buildings will be susceptible to missile damage. Potential targets have been identified and analysis is currently ongoing to determine the potential for damage.

*Extreme Ambient Temperature*

1148 For the nuclear-island the components that are sensitive to an increase in air temperature are mainly chillers and diesel engines. Concerning chillers, a cliff-edge effect occurs at 47°C which is 3°C above the predicted maximum external temperature. Concerning diesels, NNB GenCo considers that potential cliff-edge effects could occur at temperatures just beyond the maximum predicted site-specific temperature. NNB GenCo reports that this cliff-edge will be investigated when diesel engines are selected. For the balance of plant an equipment qualification temperature of 50°C has been specified, compared to the maximum site-specific outside temperature of 44°C.

1149 With regard to sea temperatures, the formation of frazil ice leading to a loss of heat sink can only occur if all four cooling water intakes and the discharge outfall pipe are completely blocked. Analysis for the UK EPR™ PCSR shows that the HPC design is robust to the effects of frazil ice and even under the worst predicted conditions this would not lead to the loss of the ultimate heat sink.

*Snow*

1150 Snow has not been addressed within the NNB GenCo's stress tests submission.

*Hail*

1151 The maximum impact has been calculated to be denting of the cladding without penetration. A review of operational experience across the EDF fleet shows that no incidents related to a hailstorm causing a safety hazard have been identified. The identified targets with regard to hail are mainly those identified for wind hazard.

*Combinations*

1152 Combinations of extreme weather are not addressed explicitly within the NNB GenCo's stress tests submission.

#### *4.2.1.1 ONR's Assessment of Estimation of Safety Margin Against Extreme Weather Conditions*

<u>Sellafield Ltd – Sellafield and Windscale</u>

1153 Consideration of extreme weather threats to facilities on the Sellafield site follows an agreed process taking account of input criteria detailed in agreed memorandum of understanding. Input design criteria have been established with desired levels of conservatism to ensure that facilities have a measure of robustness commensurate with hazard potential. As many of the high-hazard facilities on the site are formed from thick reinforced concrete cell type structures, the threat from extreme weather external hazards is limited. Estimates of safety margin against extreme weather effects on such structures are of limited value as the margins indicated would be large.

1154 For steel framed structures, the assessment of extreme wind and low temperature effects can identify limitations in protection and consideration of safety margin can be appropriate. However the design and assessment process adopted by Sellafield Ltd includes demonstration of “usage” factors and for main frame elements the extent of spare capacity is presented. Review of PSR submissions in past years has indicated that extreme wind load can threaten local cladding support but such loss is associated with a reduction in decontamination factor as opposed to threat to main containment. Low temperature effects are taken into account and the potential for brittle fracture of steelwork is considered. The assessment of susceptibility to brittle fracture identifies a trigger temperature for the effect to be realised and as this value is greater than that adopted for extreme low temperature further consideration of margin is unnecessary, i.e. the possibility of brittle fracture is treated as real.

1155 ONR considers that the threat posed by extreme weather effects on the structure of major hazard facilities is small and that a focus on safety systems and required service supplies is justified.

1156 The information provided by Sellafield Ltd is general and although few facilities require cooling and ventilation to ensure nuclear safety and maintenance of containment a more detailed review of such, including its susceptibility to extreme weather is needed. (see Section 4.3)

1157 The availability of water supply to the site has been demonstrated as being unaffected by extreme weather but as with other essential services local arrangements for connection to plants are not detailed.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1158 The conclusion derived in 4.1.1.1 applies here.

Atomic Weapons Establishment

1159 AWE, in its submission, has not considered beyond design basis extreme weather events and therefore has not been able to identify any potential cliff-edge effects or to determine safety margins. While it is claimed that a seismic event is bounding, potential cliff-edge effects beyond the design basis could change this. In addition the wide variety of structures on the AWE sites should prompt separate reviews rather than an overarching statement that a seismic event is bounding. This is covered by STF-49.

Rolls-Royce Marine Power Operations Ltd

1160 RRMPOL has considered wind and snow loadings up to the 1 in 10,000-year extreme weather event. As the purpose of the stress tests is to look beyond the design basis, ONR concludes that the objective has not been met. RRMPOL does however recognise that any structure will eventually collapse under sufficient loading, but does not identify what this loading is for each structure and therefore no safety margin is identified.

1161 RRMPOL has determined whether or not a structure will ”pass”, “fail” or “pass / fail marginally” by considering utilisation factors. However, the criterion set by RRMPOL has not been justified.

**STF-48: RRMPOL should consider reviewing the utilisation factors and criteria used for assessing structural performance in extreme weather.**

BAE Systems Marine Ltd

1162 BAESM reports that the radioactive component facility has safety measures to ensure control of criticality. The only mechanism by which weather conditions can contribute to causing a criticality event is severe rainfall in combination with either a seismic or extreme wind event. However, this would require rainfall many times greater than the 250mm 10,000-year return period DBF.

1163 BAESM explains that DDH has safety measures to ensure control of criticality and control of reactivity. A seismic or severe wind event in combination with addition of moderator (severe precipitation) could overcome these safety measures. However, the arguments presented by BAESM for the radioactive component facility also apply to the DDH.

1164 The shiplift and transfer system have safety measures to ensure control of reactivity. BAESM has identified that the transfer system is vulnerable to wind events with severity greater than that expected for a 1,000-year return period event. However, the control rod restraints will withstand the shock loading imparted as a result of the transfer system collapsing in a severe wind event.

1165 The WDQ has safety measures to ensure control of reactivity. BAESM explains that none of these safety measures is vulnerable to extreme weather events, other than those that give rise to a flooding hazard.

1166 Given the above, ONR supports BAESM's case that extreme weather events beyond design basis are highly unlikely to affect radioactive component or reactor commissioning activities.

Devonport Royal Dockyard Ltd

1167 ONR supports DRDL's claims that there is a margin of safety beyond the design basis. The key factors in this judgement are the submarine structure and its operating characteristics. The submarine has significant inherent resilience within its self-contained electrical power generation and DHR systems, including passive modes of DHR. Submarines afloat are not considered to be threatened by extreme natural events.

Rosyth Royal Dockyard Ltd

1168 RRDL has considered the potential impact of different extreme weather conditions, and their combinations, to the reliable operation of safety structures. The combination of a beyond design basis wind or snowfall event with a prolonged period of low temperatures is highly incredible. Given that cold weather would need to persist, ONR supports RRDL's assertion that interventions could be made before the waste storage containers could be affected to the extent that radioactive material would begin to leak.

Magnox Ltd – Defuelled reactors

1169 The licensees consider that there is no requirement to evaluate margins since there is no longer a requirement for reactivity control or heat transfer. ONR considers that it is apparent that the principal requirement is to prevent release of radioactivity and to control radioactive waste. ONR has raised a finding in Section 4.1 to review the radiological hazard to confirm the design basis and margins for the decommissioning sites in the light of the reduced hazard potential. The evaluation of margins beyond the design basis is therefore within the scope of STF-47.

NNB GenCo – Hinkley Point C

1170 The licensee has identified potential cliff-edge effects relating to extreme high external air temperatures affecting diesel engines and chillers. ONR has requested clarification with respect to the evaluation of margins with respect to air temperatures. As noted in Section 4.1.2, NNB GenCo has discussed the robustness of the UK EPR™ design but has not compared margins (except for extreme temperature) in terms of the UK criteria for design basis conditions (i.e. $10^{-4}$ exceedance frequency). ONR expects this to be covered in the site-specific PCSR. Nevertheless, ONR has raised a number of technical queries relating to the discussion on margins in the stress tests report.

### 4.2.2 Measures Which Can Be Envisaged to Increase Robustness of the Plants Against Extreme Weather Conditions

Sellafield Ltd – Sellafield and Windscale

1171 The discussion of increased robustness is very limited, consisting of a reaffirmation that a number of plants will have issues as a result of extreme weather effects on supply and instrumentation lines with added problems arising from cold weather effects on local diesel stocks.

Urenco UK Ltd

1172 Given the general building and equipment design standards and relatively low radiological risk posed by the UUK site from extreme events, the current site structures and equipment are judged to be adequate to give sufficient design resilience against extreme weather events. ONR shares this judgement.

Dounreay Site Restoration Ltd

1173 DSRL has reported that a review of its nuclear safety cases for higher hazard facilities provides confidence that extreme external events (such as extreme weather) do not pose a credible threat to nuclear safety. During the production of those safety cases, possible improvements to increase robustness were subject to review and implemented where reasonably practicable. DSRL has further noted its continuing confidence derived from its LC15 PSR process as a mechanism to consider ongoing adequacy of safety protection systems. ONR is satisfied that the analysis undertaken by DSRL for extreme external events is fit-for-purpose.

Springfields Fuels Ltd

1174 SFL has not identified any additional improvements to facility resilience to extreme weather events. However, ONR welcomes the licensee's commitment (referred to in Section 6.1.5) to undertake a resilience review of the site's capability to respond to emergencies in the event that the emergency control centre is compromised.

Atomic Weapons Establishment

1175 AWE has not identified in its submission any further measures required to increase the robustness of plants against extreme weather events.

Rolls-Royce Marine Power Operations Ltd

1176 RRMPOL has not identified any measures in its submissions that could increase the robustness of the current plants against extreme weather conditions. However, RRMPOL is actively pursuing a regeneration programme to replace existing facilities on the manufacturing site with modern systems and structures that will comply with modern standards.

BAE Systems Marine Ltd

1177 BAESM's submission has recognised that there are a number of opportunities that might enhance the resilience of the site. These have been identified as *Considerations* for taking forward and will be subject to further review prior to commitment to implementation.

Devonport Royal Dockyard Ltd

1178 DRDL has identified two potential areas for improvement. These are:

- Consideration should be given to assessing buildings that have the potential to collapse onto overside / cross site services or affect access / egress as a result of natural external hazards and any reasonably practicable modifications undertaken.

- Consideration should be given to assessing the effects of low temperatures (below the current design basis of -15°C) on the electrical supply system.

Rosyth Royal Dockyard Ltd

1179 Given the safety margins available, RRDL does not consider it necessary to identify measures to improve the resilience of the stores to withstand extreme weather events beyond the design basis.

Magnox Ltd – Defuelled reactors

1180 Magnox Ltd has a programme of remedial strengthening work to ensure that the reactor building structures at Trawsfynydd have sufficient capability to withstand an extreme wind event. Other than this Magnox Ltd has not identified any further requirement to increase robustness of the defuelled Magnox plants against extreme weather conditions.

NNB GenCo – Hinkley Point C

1181 No specific measures have been deemed necessary to improve the robustness of the plant to extreme weather.

#### 4.2.2.1 *ONR's Assessment of Measures Which Can Be Envisaged to Increase Robustness of the Plants Against Extreme Weather Conditions*

Sellafield Ltd – Sellafield and Windscale

1182 As a result of the focus of extreme weather effects on support services, and the lack of a detailed review of plants affected, Sellafield Ltd is unable to identify local measures that could increase robustness of susceptible plants.

1183 Further assessment will be completed following interaction with Sellafield Ltd to identify plants at risk and the local effects of extreme weather.

Urenco UK Ltd and Dounreay Site Restoration Ltd

1184 ONR shares the judgements made by UUK and DSRL that the safety cases, and their periodic reviews, are appropriate avenues for securing a review of resilience to severe weather events and provide ample opportunity for seeking improvements.

Atomic Weapons Establishment

1185 In its submission, AWE has not identified any measures to increase the robustness of plants against extreme weather events, it has not been possible for ONR to make an assessment at this time.

**STF-49: AWE should consider assessing the nuclear safety implications of consequential events including progressive loss of structures, systems and components following an extreme weather event to establish whether further measures are needed to reduce the associated risks.**

Rolls-Royce Marine Power Operations Ltd

1186 Despite identifying a number of shortfalls, RRMPOL has not made any additional considerations for improvement to the robustness of facilities on either the Neptune or manufacturing sites, although RRMPOL is actively pursuing a regeneration programme to replace existing manufacturing facilities on the manufacturing site with modern systems and structures that will comply with modern standards.

1187 ONR recognises that there are currently programmes of improvements on both sites, which will address most of the shortfalls; ONR is actively engaging with RRMPOL on this matter as part of normal regulatory business. Furthermore, ONR expects that measures aimed at improving the availability of Bronze Commands during a severe flooding event will also consider resilience to extreme wind and snow loading.

BAE Systems Marine Ltd

1188 ONR supports BAESM's identification of *Considerations* to enhance the resilience of nuclear facilities on the Barrow nuclear licensed site. These considerations for improvements will be followed up by ONR as part of normal business.

Devonport Royal Dockyard Ltd

1189 DRDL has made appropriate *Considerations* for reviewing improvements to the assessment of severe weather events at the Devonport site. ONR will monitor progress of the DRDL *Considerations* as part of normal business.

Rosyth Royal Dockyard Ltd

1190 Examining a beyond design basis wind or snowfall event combined with a prolonged period of low temperature, RRDL judges the need for additional protective measures to improve the robustness of the radioactive waste store to be unnecessary. The RRDL assessment is supported by ONR.

Magnox Ltd – Defuelled reactors

1191 A programme to increase the robustness of the reactor building is underway at Trawsfynydd but the remaining sites do not consider that any resilience enhancement is appropriate. ONR has raised STF-47 to define the design basis requirements for all sites. ONR considers that pending completion of this work, and the evaluation of margins, it is not possible to conclude whether any enhancement is appropriate. The consideration of potential enhancements should therefore be included within the scope of STF-47.

NNB GenCo – Hinkley Point C

1192 ONR notes that the UK EPR™ has been designed to modern standards taking due consideration of meteorological conditions. The fact that no specific additional measures have been identified should therefore be the expected outcome. However, ONR notes the potential for cliff-edge effects relating to diesels and chillers and this should inform the selection process of such items and whether any enhancement is appropriate.

## 4.3 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

1193 The extreme weather stress tests assessment completed by Sellafield Ltd has reviewed the impact of extreme environmental threats and demonstrated that the impact on major structures is minor.

1194 Extreme weather criteria input into design basis analysis have been reviewed and found to comply with ONR expectations and British Standard guidance. The use of extreme events corresponding to a 1 in 10,000-year occurrence is considered to be justified. A relatively recent review of extreme temperature range in support of new NPP design indicates that the criteria adopted by Sellafield Ltd are conservative. Consideration of beyond design basis events, i.e.

extreme weather events corresponding to a return period less than 1 in 10,000 years, would have little value in relation to potential effects on primary structure.

1195 Environmental conditions resulting from extreme weather events are often predictable and develop over an extended timescale, allowing operator intervention and consequent mitigation of potential consequences.

1196 Although overarching criteria have been demonstrated as being robust, the work reported is high level and a more detailed review of possible effects on support services at plants requiring continued cooling and / or ventilation is necessary:

**STF-50: Sellafield Ltd should complete a review of the possible impact of extreme weather conditions on service networks and temporary service connection points to ensure security of supply and confirm functionality of connection points.**

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1197 ONR considers that UUK, DSRL and SFL have evaluated to an adequate extent the resilience of facilities to severe weather scenarios, insofar as is practicable for the range of facility ages. The detrimental impact of a severe weather event on containment system is effectively bounded by the licensees' cases made for earthquakes.

Atomic Weapons Establishment

1198 AWE has not adequately considered extreme weather events in the stress tests analysis for its sites. A number of findings have been made by ONR that encourage AWE to reassess the current extreme weather design basis, to identify facilities that are vulnerable to such events and to consider possible measures to improve the resilience of those facilities.

Rolls-Royce Marine Power Operations Ltd

1199 RRMPOL has not made a reassessment of the severe weather event design basis. Snow and wind loadings have been considered on the manufacturing site and an assessment has highlighted a number of structures, including Bronze Commands which will fail at the design basis level. No integrity analysis of the Neptune site against severe snow or wind loading has been presented. Other severe weather events, such as extreme temperatures, humidity and lightning, have not been considered in RRMPOL's submissions.

1200 Stress tests findings that address the shortfalls highlighted above are described in Section 6.

BAE Systems Marine Ltd

1201 ONR generally supports BAESM's claim that the Barrow nuclear licensed site has justified site safety to the extent that it will accept environmental challenges within the current design basis envelope. Furthermore, ONR supports BAESM's view that challenges from extreme weather are highly unlikely to cause significant off-site consequences and that there are no identifiable cliff-edge effects beyond the design basis.

Devonport Royal Dockyard Ltd

1202 DRDL has undertaken a thorough analysis of the existing design basis for extreme weather events on the Devonport licensed site, which takes account of contemporary local data. Appropriate standards have been employed for extrapolating this data to a 10,000-year return period event, consistent with ONR's expectations. The design basis data were compared with historical data gathered by independent sources and were found to be bounding.

1203 DRDL has considered the margins of safety available during design basis and beyond design basis events. The margins of safety stem from the independent power and cooling sources available dock side and aboard the submarine. The structural robustness and preoccupation with maintaining watertight integrity of the vessel also contribute to the safety margins available for ensuring nuclear safety. Defence-in-depth is provided from a number of sources.

1204 ONR supports DRDL's assertion that the stress tests process has demonstrated the inherent robustness of the facility and plant performance in extreme environmental events.

Rosyth Royal Dockyard Ltd

1205 ONR supports RRDL's assessment of the robustness of the radioactive waste stores to resist extreme weather events, either singularly or in combination. While a vulnerability to a combination of beyond design basis events has been identified, it is judged by RRDL that the incredibility of such a combination warrants no further action to improve the resilience of the store structure; this judgement is supported by ONR.

Magnox Ltd – Defuelled reactors

1206 Due to the removal of fuel from site these the potential hazard is greatly reduced from that of an operational reactor. While the UK design basis criterion against natural external hazards for high-hazard facilities is $10^{-4}$ pa exceedance frequency, ONR's SAPs do facilitate a reduced design basis severity requirement commensurate with reduced hazard potentials. Magnox Ltd has recognised that with the removal of fuel from site, there is no longer a requirement for reactivity control or heat removal systems. However, ONR considers that there still remains a requirement to prevent radiological release / accidents and therefore provide design basis provisions commensurate with the remaining hazard potential. ONR has therefore raised a finding that Magnox Ltd should define an appropriate design basis and associated protection requirements for the decommissioning sites commensurate with the reduced hazard potential.

NNB GenCo – Hinkley Point C

1207 The stress tests report is primarily based upon the UK EPR™ design envelope and does not contain an evaluation against the UK design basis criteria for natural external events. Since weather conditions are generally site specific, the justification against extreme weather conditions is to be provided within the HPC site-specific PCSR. ONR is currently engaged with NNB GenCo regarding definition of the site-specific design basis and considers that due to the robust modern standard design of the UK EPR™, there is likely to be significant margin above the UK design basis criterion for natural external hazards.

1208 With regard to balance of plant not included in the GDA envelope, ONR expects this plant to be covered within the site-specific PCSR according to similar modern design standards.

# 5 LOSS OF ELECTRICAL POWER AND LOSS OF ULTIMATE HEAT SINK

## 5.1 Loss of Electrical Power

1209 Earthquakes, floodings and extreme weather conditions are rare events for nuclear plants. In contrast, nuclear licensed sites experience the loss of electrical power quite frequently.

### 5.1.1 Loss of Off-site Power

Sellafield Ltd – Sellafield and Windscale

1210 The various plants and facilities on the Sellafield site are connected to a common electrical distribution system which is in turn supplied by Electricity North West (the local distribution network operator) from the regional public network via multiple, normally energised, 132kV circuits. Any one 132kV circuit has the capacity to supply the whole of the site's electrical power requirement. The electrical configuration of the on-site 132kV substation provides redundancy to maintain supply in the event of a 132kV busbar fault or planned outage. There are multiple 132/11kV step-down grid transformers which provide supplies to the site 11kV electrical distribution network. The grid transformers are physically and electrically arranged to supply independent 11kV substations. Any one of the grid transformers has the capacity to supply all essential site electrical loads.

1211 A LOOP will result in the interruption of electrical loads categorised as not essential to ensuring the safety of the plants. This would result in the shutdown of plant processes, for which safety systems are designed to fail-safe.

1212 The essential electrical loads identified in the plant safety cases are provided with a means of back-up power. Those that need to be continuously operated are provided with a local battery Uninterruptible Power System (UPS) system and those that can be interrupted, but need to be restored, are supplied from the centralised, permanently installed, back-up generators. These generators provide the ordinary back-up AC power source. The UPS systems are designed to have sufficient capacity to operate until the centralised permanently installed back-up generators restore power.

1213 There are several 11kV centralised permanently installed back-up generators, comprising diesel alternators and a number of diesel fuelled Gas Turbine Generators (GTG). The diesel alternators have black start capability and therefore are started in sequence following LOOP. The GTGs do not have black start capability and therefore are started once at least one diesel alternator (or a mobile diesel alternator) has energised the GTG auxiliary supplies. Once started, the GTGs are designed to remain running even if all of the diesel alternators fail. In 2006, the licensee reviewed the overall essential electrical load to meet the safety case requirements and demonstrated adequate redundancy, showing that essential power requirements could still be met even with the failure of any two centralised permanently installed generators.

1214 Following a LOOP, operators in the continuously manned Utilities Control Room ensure the interruptible essential plant loads are brought online promptly. The overall sequence of events involves a prioritised restoration of loads within plants while ensuring the aggregate output from the back-up generators matches the load so that no generator is overloaded. The operators use computer-based remote control facilities to open and close circuit breakers within the distribution system and a further computer-based system to manage the generator co-ordination. These computer systems in the Utilities Control Room have redundant servers. The back-up to the computer systems involves manual operation of hardwired local control panels associated with the generators and main circuit breakers.

1215 The Fellside CHPP, located immediately adjacent to the Sellafield site, is connected via the site 132kV substation and provides the site with steam. Loss of site supplies caused by interruptions of the whole off-site 132kV system would initiate shutdown of Fellside CHPP and loss of steam from this source (alternative steam sources are provided). It is not designed to operate in "island" mode disconnected from the wider regional public network, and cannot provide back-up generation in the event of a LOOP.

1216 Sellafield Ltd has estimated how long the diesel fuel supplies for back-up supply generation would last before refuelling from off-site would be necessary. The assessment assumes the diesel tanks and local pipework remain functional and is based on supplying all of the essential loads identified in individual facilities' safety cases. Sellafield Ltd's assessment has identified that the site would not quite meet the 72 hours off-site refuelling requirement implied by the NPP stress tests scenario if no measures are taken to manage fuel usage. However, there are significant additional supplies of fuel on the site which could be made available in an emergency and Sellafield Ltd is considering how this fuel could be transferred to extend the time for off-site refuelling to well beyond seven days.

1217 The electricity distribution system, centralised permanently installed generators, uninterruptable supply systems and associated equipment are examined, inspected, tested and maintained in accordance with Sellafield Ltd extant arrangements for ensuring these systems are ready for operation.

Urenco UK Ltd

1218 There are no NPPs and no spent reactor fuel on the site. Decay heat removal systems are not relevant to UUK operations. The electrical distribution system provides no support to nuclear safety functions as all processes on-site are designed to shut down in a safe manner following loss of power. The centrifuge cascades are designed to shut down safely and discharge their inventories into geometrically safe containment.

1219 The licensee has identified a specific shortfall in its design basis analysis in that if the electrical supplies are switched off or lost for any length of time, they must be stopped from re-energising in order to allow a controlled return to power operations, as there is the potential for trace heating to reheat solidified $UF_6$ throughout the plant with the potential for minor containment rupture. Operating instructions are in place to prevent this. This issue has been identified as requiring consideration in the periodic reviews of safety and any learning will be extended to across the plants. ONR considers this response to be adequate and proportionate. ONR has sought assurance that the licensee will consider the feasibility of implementing any required operating instructions (or considers alternative measures) in the event of significant damage / outage (short term and prolonged) to the electrical system, or where concurrent events (e.g. criticality, restricted access) may impair the required actions.

1220 Loss of electrical power is not considered any further in this section of the report for the UUK site.

Dounreay Site Restoration Ltd

1221 DSRL has identified two types of disruption to electrical supply as being reasonably foreseeable:

- Disruptions due to loss of grid supply.
- Disruptions due to a fault or failure on the site's electrical supply system.

1222 DSRL describes its philosophy on loss of off-site power to require the cessation of normal operations, and safe shutdown of plant. Where necessary, personnel are required to evacuate affected plants and the emergency control centre would be manned for the purpose of surveillance and emergency response management; this therefore requires continuity of power supply. Guaranteed non-interruptible power would continue to support battery-backed supply loads to selected instrumentation and stack discharge monitors. DSRL explains that this continued supply purely facilitates ongoing monitoring and surveillance for a finite time period, but that continuity of power supply is not required to prevent or mitigate nuclear consequences.

Springfields Fuels Ltd

1223 The Springfields site is supplied with a natural gas supply primarily used to fuel a CHPP that provides a source of power to the site (90% of the site's needs). In the event of a loss of gas supply, SFL explains that the site maintains stocks of back-up fuel oil which would allow the CHPP to continue operation for approximately ten days without replenishment.

1224 Loss of on-site electricity supply through any mechanism would result in the shutdown of plant processes, for which safety systems are designed to fail-safe. SFL notes it is confident that plant safety cases adequately demonstrate that there would be no nuclear safety issue in the event of a total loss of electricity supply.

Atomic Weapons Establishment

1225 Both AWE nuclear licensed sites have electrical systems comprising the following aspects:

- Multiple available feeders from the UK National Grid supplying AC power systems with associated electrical power transformers, switchboards, switchgear and distribution cables to the individual facilities.
- Emergency power systems for supplying those AC and direct current (DC) loads required to fulfil essential safety functions. These systems include local on-site generation capability, mobile generators, electrical batteries, associated charging systems and infrastructure.

1226 AWE has identified that loss of off-site power does not challenge or affect any safety function claimed to prevent or mitigate a severe accident at either AWE nuclear site. In fault scenarios, multiple electrical power sources are available.

1227 AWE has identified loss of power cannot result in a severe accident. For operational facilities at both sites, power would be provided by local battery UPS to facilitate placing the facilities into a quiescent state. Local fixed and mobile generators would be used to re-establish systems to monitor the plant.

1228 AWE has assessed the impact arising from the loss of power as insignificant and has identified that the current provisions are suitable and sufficient and no additional arrangements are required to increase the robustness of the electrical supply systems.

Rolls-Royce Marine Power Operations Ltd

1229 RRMPOL has examined the operations at the Manufacturing and Neptune sites, and considered the effect of prolonged loss of off-site power on its operations. The effect of in-scope events on the electrical power system was examined by RRMPOL.

BAE Systems Marine Ltd

1230 BAESM's submission indicates that, apart from the risk of inadvertent criticality of the nuclear fuel, there is no risk from fission products until the reactor has been taken critical. The reactor is operated in a critical state only with the submarine afloat at WDQ and with all necessary ancillary systems available. Therefore the safety of the reactor during and after criticality is not dependent on-site electrical supplies or services.

1231 Once the submarine is afloat it has the benefit of the redundant and diverse internal electrical power sources which are designed to meet the arduous requirements of its service duty. The capabilities of these systems are the responsibility of the MoD.

1232 On site there is a site electrical distribution system and a shore battery. The site is not dependent on electrical supplies to maintain nuclear safety. Information relating to the resilience and capability of the site's back-up power is not presented in the submission.

1233 BAESM indicates that in the radioactive component facility and DDH, the identified risk is associated with inadvertent criticality which would require a combination of failure to retain control rods with addition of moderator. A return to DDH after commencement of critical activities is not permitted under the scope of the safety case. No initiating events on loss of electrical supplies or demands on back-up electrical supplies for mitigation have been identified by the stress tests.

1234 During ship lift and transfer, the submarine is not connected to shore electrical supplies and is therefore not affected by a loss of off-site power. At this point the reactor has not been operated and there is no requirement for core cooling.

1235 In the event that the submarine is using the onshore electrical supplies at the WDQ, there is the option to use the on-board diverse and redundant electrical supplies.

Devonport Royal Dockyard Ltd

1236 DRDL reports that loss of site-wide electrical supplies has been considered in the safety cases within the DBE and DBF. Within the DBE, facility electrical distribution is considered to be largely recoverable, following the operation of trips. Owing to the redundancies in place, the performance of off-site grid supplies is comparable with this. In a more severe seismic event complete loss of grid derived supplies is predicted. Also for on-site infrastructure, the cable subways are located only a small margin above the DBF, and are therefore expected to suffer from overtopping in extreme weather and tidal conditions. A package of work is underway in order to address this through the PSR process.

1237 The site-wide electrical distribution system was upgraded when 9 Dock was rebuilt. The stress tests have shown that the system is high integrity, reliable, diverse and has redundancy.

1238 Loss of electrical supplies is not an issue for the LLRF since the used fuel stored here is already at a low decay heat and fuel integrity is maintained without the need for electrical supplies. As a consequence of the low decay heat, the loss of electrical supplies is only an inconvenience since natural heat losses are sufficient even under dry conditions.

Rosyth Royal Dockyard Ltd

1239 The electrical supplies to the radioactive waste store are: mains AC electrical power for operations within the building and passive monitoring of stored material and battery backed DC power to support passive monitoring.

1240 Both electrical supplies are susceptible to failure from elevated levels of flooding. However, the safety of the radioactive material in storage is not dependent upon electrical services. RRDL indicates that there is no requirement for electrical power or instrumentation to protect containment integrity.

Magnox Ltd – Defuelled reactors

1241 All Magnox defuelled reactor sites have been shut down for at least nine years. LOOP alone could not result in a radiological release at these sites. Where fuel ponds remain, these are to provide shielding of waste material and do not perform a cooling function as there is minimal heat generated from the remaining waste material and therefore no active cooling is required. At some sites, prolonged loss of electrical supplies could result in the build-up of hydrogen, potentially leading to an explosion. If ventilation were lost to the vaults, then operators must restore ventilation or remove the vault plugs to prevent the hydrogen concentration reaching the LFL. The vaults are passively safe with the vault plugs removed.

1242 While diesel generators and battery-fed systems provide support at some sites, loss of these would not result in significant radiological consequences.

1243 Considering the consequences of the loss of electrical supplies at these sites, they will not be considered further.

NNB GenCo – Hinkley Point C

1244 Generally most active safety provisions for nuclear power reactors require electrical power to operate, unless they are activated by loss of power. Therefore to ensure safety at nuclear installations electrical supplies have redundant and diverse provisions. This provides high confidence that electrical power supplies will be available in a range of fault conditions. NNB GenCo's intended design of the electrical systems for the Hinkley Point C site comprises the following aspects:

- AC power systems with associated electrical power transformers, switchboards, switchgear and cables.
- Emergency power system for supplying those AC and DC loads required to fulfil essential safety functions. This system includes on-site generation capability, electrical batteries, associated charging systems and infrastructure.

1245 LOOP is recognised within the developing Hinkley Point C safety case as a frequent initiating event and, therefore, it is intended that redundant and diverse systems will be provided within the design to detect the initiating event and trip the reactors. Furthermore, it is intended that reactor shut down will not be reliant on off-site power.

1246 It is intended that a UK EPR™ at Hinkley Point C will be connected to the National Grid network and will be designed to ensure transmission of the electrical power generated by the turbo alternator to the grid and supply the power plant's auxiliaries in all normal and fault situations.

1247 The nuclear-island's power supply is intended to be arranged into four independent systems to include:

- a normal power supply for all the non-safety related loads located in the nuclear-island's buildings;
- a power supply to the control rod mechanisms;
- an emergency power supply for all safety-related loads of the unit;
- a uninterruptible power supply for the instrumentation and control system, switching supplies for electrical switchboards and all other loads that must remain energised during start-up of the EDGs; and

- a dedicated severe accident uninterruptible power supply provided to mitigate against faults that may result in the loss of both off-site supplies and the on-site main emergency supplies.

1248 In the event of LOOP each of the four diesel-driven generators is proposed to automatically start and connect to its emergency switchboard. The four diesel-driven generators are to be housed in two buildings (i.e. two independent generators each located in their own compartment per building) situated on opposite sides of the reactor containment building.

1249 Each EDG is to be a self-contained unit which includes its required auxiliary systems.

1250 The UK EPR™ is to be designed to cope with LOOP for at least three days via operation of the EDGs.

### 5.1.2 Loss of Off-site Power and Loss of the Ordinary Back-up AC Power Source

Sellafield Ltd – Sellafield and Windscale

1251 The essential electrical loads within individual plants and facilities are typically connected via an essential power distribution (EPD) switchboard fed via cables from the site distribution system. The physical integrity of the EPD switchboard needs to be retained for local generation to be able to supply the individual plant essential loads. The EPD has a connection point for a mobile diesel alternator (MDA) which would allow the restoration of essential loads should the supply to the plant via the distribution system be lost. A number of essential loads are operated from a local battery uninterruptible power supply system and the connection of an MDA to an EPD would ensure the continuous operation of these loads.

1252 On some higher-hazard plants, permanently installed diverse AC power sources (in the form of 415V diesel generators), are connected to the EPD switchboard. These generators can be started locally and have local fuel tanks to support operation for at least 24 hours.

1253 Sellafield Ltd has identified a limited number of vital loads associated with ventilation and cooling that would need to be met to avoid an off-site dose greater than 10mSv to the critical group. This vital electricity load is approximately one-eighth of that needed to meet the current safety case design basis essential load requirements.

1254 If sufficient electrical distribution system and diesel infrastructure were operational, this lower vital electricity load could be met by a single centralised permanently installed generator.

1255 Sellafield Ltd has estimated that its diesel fuel supplies could be extended out to beyond 72 hours from LOOP if usage is reduced to meet only vital electrical loads. However, Sellafield Ltd has identified through its review it would still face some potential logistical difficulties in distributing diesel fuel around the site to where it is needed, especially following beyond design basis initiating events affecting multiple plants.

1256 As part of its response to the events in Fukushima and in order to improve plant resilience to a range of external factors, Sellafield Ltd is examining the need for increased diversity, redundancy and capacity with regard to back-up power sources and associated fuel supplies.

Dounreay Site Restoration Ltd

1257 The licensee's safety cases address the viability of site facilities having no power whatsoever for a sustained period of time; DSRL's response refers to the provision of 415V diesel generators to supply power to the emergency control centre and specific facilities for the purpose of incident response, surveillance and monitoring.

Springfields Fuels Ltd

1258 As previously indicated, loss of on-site electricity supply through any mechanism would result in the shutdown of plant processes, for which safety systems are designed to fail-safe. Facility specific back-up power sources are available but SFL is confident that these would not be relied upon in the event of a loss of on-site distribution.

Atomic Weapons Establishment

1259 AWE has identified that the main requirement for electrical power would arise from maintaining the appropriate command and control functions required in the emergency plans. Upon loss of off-site power and back-up power, the emergency plans for both AWE sites would be co-ordinated from the mobile forward control vehicles, which have their own power generation capability.

Rolls-Royce Marine Power Operations Ltd

1260 RRMPOL reports that site facilities are not susceptible to prolonged loss of power, and that there is no engineered withstand for the off-site supplies from earthquake or flooding. The site power networks are neither seismically qualified nor flood protected. In a seismic event of relatively low level, or at an early stage of site flooding. RRMPOL assumes that the distribution network would be damaged or lost.

1261 RRMPOL considered the effect of the loss of services for the manufacturing site and concluded that there is no impact on safety from loss of power. Some plant services rely on electrical power and these would fail e.g. ventilation extract systems and pumping for closed circuit cooling systems. Diesel generators with auto start-up are available; however their location may become inundated under flood conditions.

1262 The Neptune reactor is designed to continue to be in a safe condition on loss of power. The control rods will drop into the core on loss of power and the dump valves will open, causing the moderator to drain from the core. The site possesses back-up power supply capabilities; there are no claims on these back-ups to prevent radiological consequences. For the Neptune site, a portable diesel generator is available, however its present location is vulnerable to inundation and its functionality cannot be assured under flood conditions.

1263 The 'Bronze Command' centres have no power back-up. The site Emergency Control Centre ('Silver Command') has a dedicated diesel back-up power supply. Both the Bronze Commands power supplies and local diesel generators may be impaired by flooding or seismic events.

1264 RRMPOL has raised its own *Considerations* of improving the resilience of the manufacturing site's power distribution networks, site UPS and site diesel generators to improve availability post-flood. The reconstruction project on the manufacturing site will provide improved resilience to flood events. RRMPOL has raised a *Consideration* to review the storage of Neptune site's portable generator at a location less susceptible to flood.

BAE Systems Marine Ltd

1265 BAESM considers that for all activities prior to initial criticality there is no generation of nuclear heat and no dependency on the site infrastructure for electrical power. For activities following initial criticality the submarine is in its seagoing state; the NRP is designed to be entirely independent of shore services.

Devonport Royal Dockyard Ltd

1266 The standby supply is provided by diesel generators located at key positions on the site and is capable of meeting the nuclear safety load for the submarines. In addition, the standby generators also provide power to the pumped flood main used to support decay heat removal. In a beyond DBE, DRDL anticipate that a complete loss of grid derived supplies is conceivable and the ability for reinstatement may be removed. DRDL's submission shows that, when subjected to a beyond DBF and seismic challenge, availability of on-site back-up supplies may be challenged.

Rosyth Royal Dockyard Ltd

1267 RRDL submits that the safety of the radioactive material in storage is not dependent upon electrical services. In the event of failure of the off-site electrical supply, passive monitoring could be carried out using the battery backed DC supply.

NNB GenCo – Hinkley Point C

1268 In situations where the EDGs are unavailable, for events at power or during hot shutdown, the following systems are intended to be used to provide safe shutdown:

- Two redundant Ultimate Diesel Generators (UDG) supporting the low-voltage systems
- Battery derived low-voltage electrical systems

1269 The low-voltage electrical systems consist of six redundant battery-fed systems to provide power as well as Control and Instrumentation (C&I) functions. Four of these systems provide two-hour support to functions, while the remaining two provide 12-hour support.

1270 The two UDGs are intended to provide supplies to the emergency feed water systems and C&I systems as well as recharging the station batteries. Only one is required to support the load. Both UDGs are intended to be started manually, either remotely from the Control Room or locally at the units. Fuel supplies enable the UDGs to operate for a minimum of 24 hours.

1271 Cooling of the fuel pond is intended to be provided by the third train of the Fuel Pond Cooling System, which is to be supplied by one of the UDGs. Water makeup is provided by the Fighting Water Supply System pump, again fed from the UDG. Sufficient water is intended to be held for supplying this system for over nine days. Fuel would, however, need to be transferred from the main fuel tanks to the UDG tanks for which no procedure currently exists.

### 5.1.3 Loss of Off-site Power and Loss of the Ordinary Back-up AC Power Sources, and Loss of Permanently Installed Diverse Back-up AC Power Sources

Sellafield Ltd – Sellafield and Windscale

1272 In the absence of centrally provided power for a prolonged period of time (extended out to seven days), Sellafield Ltd's stress tests review has identified a number of safety functions on a small number of specific facilities which need to be prioritised to ensure that there are no severe radiological consequences:

- Prevention of a flammable atmosphere (hydrogen deflagration) in the Magnox swarf storage silo.
- Removal of liquor collected in vessels in the ventilation system supporting the HASTs again for the prevention of flammable atmospheres.
- Cooling of highly active liquor in the HALES tanks and in the Waste Vitrification plant.
- Prevention of potential dry-out of insoluble fission products at one specific step of the THORP process.
- Lowering any suspended fuel in the Fuel Handling Plant back into the water.

1273 In addition, the function provided by the pumphouses providing bulk water to the site needs to be restored or replaced.

1274 A loss of power across the site will inevitably impact the infrastructure required to deal with an emergency across the site (as was the case at Fukushima). This is discussed further in Section 6.

Dounreay Site Restoration Ltd

1275 DSRL reports that loss of electrical supplies will be operationally inconvenient and will likely lead to the evacuation of facilities due to the loss of ventilation. Once ventilation systems are shut down, there are no fault conditions that could energetically force material out of containment.

Springfields Fuels Ltd

1276 SFL does not discuss in its report the adequacy of existing on-site diesel generation capability; ONR recognises that process plant is specifically designed to "fail-safe" upon loss of power. However sustained power supply would be a prerequisite to maintain emergency control centre availability and to sustain monitoring and surveillance of shut-down plant. The ten-day supply of fuel to CHPP provides a significant basis on which the licensee can be assured of site resilience in the short to medium term.

Atomic Weapons Establishment

1277 AWE indicates that all facilities that have an identified need for local back-up power generation will have mobile generator connection points. Should an installed back-up generator be unavailable there is provision for a mobile generator to be connected.

Rolls-Royce Marine Power Operations Ltd

1278 RRMPOL reports that, while its facilities are not susceptible to prolonged loss of on-site power, both the manufacturing and Neptune sites possess limited UPS supplies for key items of radiometric equipment and emergency lighting. There is no dependence on these systems to prevent radiological consequences. Some of this equipment utilises UPS backed-up power supplies, however, in the case of loss of power the duration of availability of these systems will vary depending on the facility and the operational conditions in place at the time. The sites' radiometric equipment is not subject to formal seismic qualification, and therefore may not be available under some incident scenarios.

BAE Systems Marine Ltd

1279 BAESM's submission reports that for all activities prior to initial criticality there is no generation of nuclear heat and no dependency of the site infrastructure on electrical power. For activities following initial criticality the submarine is in its seagoing state, the NRP is designed to be entirely independent of shore services.

1280 For activities after initial criticality, there is the option to use the internal diverse and redundant electrical power sources to supply any on-board safety requirements. The capability of these power sources is dictated by submarine safety while on operational duty and is a matter for MoD consideration.

Devonport Royal Dockyard Ltd

1281 In the event of loss of off-site grid / distribution and on-site back-up generators, DRDL consider that additional mobile diesel generators can be connected to directly supply the pumped flood main and submarines.

1282 A submarine has its own sources of electrical supply independent of the shore supplies. In the event that electrical supplies are being derived from shore, there is the alternative of using the submarines' diverse supplies for on-board loads, including reactor instrumentation. The release of on-board electrical supplies is strictly controlled in line with decay heat load. The capacity of the on-board electrical power sources is significant and based on submarine operational requirements.

<u>Rosyth Royal Dockyard Ltd</u>

1283 RRDL's submission asserts that the safety of the radioactive material in storage is not dependent upon electrical services. In the event of failure of the off-site electrical supply, and the battery backed DC supply, the electrical power requirements would be within the capacity of standard vehicles and portable equipment. A satisfactory emergency response could be implemented using hand-held portable instrumentation.

<u>NNB GenCo – Hinkley Point C</u>

1284 LOOP and loss of all on-site diesel generators would result in the start of deterioration of fuel in the reactor after a few hours.

1285 For a de-loaded reactor, boiling of the spent fuel pool water is expected to occur after about four hours. No indication of the spent fuel pool temperature or level would be available after two hours following the discharge of the batteries. Uncovering of the fuel would occur after one day.

### 5.1.4 Licensee Conclusion on the Adequacy of Protection Against Loss of Electrical Power

<u>Sellafield Ltd – Sellafield and Windscale</u>

1286 Sellafield Ltd concludes in its report that there is a high degree of diversity and redundancy amongst both on- and off-site electricity supplies, such that a total loss of electrical power is unlikely. There are sufficient fuel stocks on the Sellafield site for it to be self-sufficient during a seven-day blackout, although Sellafield Ltd has identified through its review potential logistical difficulties of distributing diesel fuel around the site for a protracted loss of electrical power and hence the timely restoration of off-site power would significantly reduce the challenge across the site. It is also exploring a more flexible configuration at the site 132kV electrical power connection point that would offer the potential for faster supply restoration.

1287 The NPP stress tests scenario assumes heavy off-site equipment arriving will not arrive within 72 hours whereas Sellafield Ltd estimates that its existing diesel fuel supplies would last for some days before off-site refuelling would be necessary. The review has identified that a large quantity of fuel is usually available at Fellside CHPP and therefore Sellafield Ltd is considering the procurement of a suitable means of transferring fuel across the site.

1288 Sellafield Ltd is considering a number of measures to improve robustness of individual plants and the site as whole. This includes reviewing the existing back-up systems to provided increased energy storage capacity such as larger fuel tanks and / or batteries, providing additional defence-in-depth safety features and considering if staff associated with particular plants could be provided with additional skills and equipment to increase their self-reliance. The licensee considers that diesel stocks are potentially vulnerable to flow issues during protracted extremely low temperatures and identified a *Consideration* to address this.

1289 Sellafield Ltd has identified alternative means to deliver the safety functions identified in Section 5.1.3 as being challenged by a loss of electrical power. However, these means are often either untried or previously undeclared and undocumented. As a result, the licensee has identified a number of *Considerations* to review the resilience of stand-by power generation.

1290 A recurring strategy proposed by Sellafield Ltd is the deployment, installation and running of the fleet of trailer-mounted MDAs to key locations across the site. A significant portion of its submission concentrates on the lessons and areas of improvement are associated with the deployment and use of MDAs. For a site-wide major event, Sellafield Ltd has identified that specialist staff might be overwhelmed both by the number of decisions that need to be made and the physical actions that they need to undertake. This has the potential to delay activities such as deployment and connection of the whole fleet of MDAs. In addition, Sellafield Ltd has recognised that its MDAs fleet may have limited flexibility, compatibility and capability to meet the needs of a site-wide major event.

Dounreay Site Restoration Ltd

1291 DSRL is confident that the site can adequately withstand a complete loss of electrical power.

Springfields Fuels Ltd

1292 It is inferred from SFL's stress tests report that the licensee is confident in the adequacy of existing protections systems against a loss of power scenario.

Atomic Weapons Establishment

1293 AWE has concluded that the existing provisions, together with enhancements being implemented under current projects as part of the AWE (A) site PSR, provide adequate protection against the loss of electrical power.

Rolls-Royce Marine Power Operations Ltd

1294 RRMPOL has concluded that the manufacturing and Neptune sites' facilities are not sensitive to prolonged loss of off-site power. The sites possess limited UPS capability with diesel generator back-up supplies for longer periods of outage, although the availability of power from these sources under flood or seismic event conditions cannot be ensured.

1295 Loss of all sources of on- and off-site power is not regarded as contributing to radiological consequences for the manufacturing site. For the Neptune site, power supplies are not required to prevent any radiological consequences.

1296 RRMPOL has identified that site radiometric instrumentation could be vulnerable to external events, including loss of power. RRMPOL is considering the need for a holding of portable health physics instrumentation in a location protected against external events.

BAE Systems Marine Ltd

1297 BAESM's submission reports nuclear safety prior to criticality is not reliant on off-site (or on-site) electrical power supplies. For all activities prior to initial criticality there is no generation of nuclear heat and no dependency of the site infrastructure on electrical power for cooling.

1298 For activities following initial criticality the submarine is in its seagoing state and effectively isolated from extreme seismic events and water levels. The NRP is designed to be entirely independent of shore services.

1299 For conditions where electrical power is required to support decay heat removal, these electrical requirements are within the capabilities of the on-board diverse and redundant electrical supplies. Claims made against the submarine's systems are a matter for MoD consideration.

Devonport Royal Dockyard Ltd

1300 DRDL's submission has identified some vulnerabilities of the on- and off-site electrical supplies. A number of fixed and mobile diesel generators are provided around the site and their availability is controlled in line with potential load demand from shore-based and boat-based electrical loads. Facility safety cases ensure there is sufficient mitigation in place to fulfil the critical safety functions for loss of power supply from natural hazards within the design basis.

1301 Beyond the design basis, there is the potential for complete site power loss that can only be mitigated in the short term by the inherent resilience of the submarine systems. The submarine has its own redundant and diverse methods of power generation which are protected from external events by the robustness of the submarine hull. Claims made against the submarine's systems are a matter for MoD consideration.

1302 These on-board electrical supplies are available in the situation that onshore supplies fail, and their availability is strictly controlled for all decay heat states.

1303 DRDL has concluded that the restoration of AC electrical supplies is not considered as an immediate demand as fuel damage will not occur, since if needed internal electrical supplies are available with sufficient capacity and longevity.

Rosyth Royal Dockyard Ltd

1304 RRDL has not identified inadequacies in the protection against loss of electrical power. The radioactive materials at Rosyth are non-fissile and there is no requirement to control reactivity. They do not produce significant heat and there is no requirement for an ultimate heat sink. They are not dependent upon electrical services for their safety. Also, all significant radioactive material is planned to be removed from site.

Magnox Ltd – Defuelled reactors

1305 Magnox has concluded that no significant radiological release could occur following a loss of all electrical power. Therefore, it considers that its current arrangements are appropriate.

NNB GenCo – Hinkley Point C

1306 NNB GenCo has noted that it is still developing the generic EPR™ design into the UK context. It has recognised that, following the events at Fukushima, further improvements should be considered to the design.

### 5.1.5 Measures Which Can Be Envisaged to Increase Robustness of the Plants in Case of Loss of Electrical Power

Sellafield Ltd – Sellafield and Windscale

1307 The measures identified by Sellafield Ltd are inextricably linked to its conclusions on the adequacy of the site, and are given in the preceding section.

Dounreay Site Restoration Ltd

1308 DSRL refers in its stress tests to a resilience review of the site's electrical distribution to coincidental flooding, which has concluded there are no immediate shortfalls. However, DSRL proposes a number of improvements to enhance surface groundwater pumping arrangements for substation basements, and for improvements to groundwater run-off and flow paths. ONR notes the licensee states the licensee's intention to consider and implement reasonably practicable improvements.

Springfields Fuels Ltd

1309 SFL has not identified in its report any additional measures by which to increase robustness of plants to a loss of electrical power; this is sufficiently justified on the basis that the site's extant safety cases demonstrate fail-safe shutdown of existing processes following loss of power.

Atomic Weapons Establishment

1310 AWE has identified that there are no cliff-edge effects associated with loss of electrical power. No further provisions to increase plant robustness have been identified during the stress tests over and above the current projects underway.

Rolls-Royce Marine Power Operations Ltd

1311 RRMPOL's *Considerations* include investigation of the capability of on-site fuel supplies for the diesel generator to provide back-up to the ECC (Silver Command) for extended periods. Its *Considerations* also include a review of the means of improving the flood resilience of the manufacturing site's power distribution networks, site UPS and site diesel generators. RRMPOL has also raised a *Consideration* for storing the Neptune site's portable generator at a location less vulnerable to flood.

BAE Systems Marine Ltd

1312 BAESM's stress tests submission has not identified additional measures envisaged to increase robustness of the plants in the case of the loss of site electrical power.

Devonport Royal Dockyard Ltd

1313 DRDL is currently undertaking a PSR. As part of this work DRDL has identified sources of potential ingress to the dockside electrical distribution and communication system and how this can be addressed. Also, improvements to the bunding of electrical plant houses are being reviewed.

1314 DRDL is also considering of the options and the benefits of providing portable generators and tools within and / or remote from the site, in parallel with considering alternative provision of electrical supply routes.

Rosyth Royal Dockyard Ltd

1315 RRDL's submission does not identify measures which can be envisaged to increase robustness of the plants in case of loss of electrical power. The safety of the radioactive material in storage is not dependent upon electrical services. Portable hand-held instrumentation is available on-site and generally available from other nuclear sites and companies within the Babcock International Group.

NNB GenCo – Hinkley Point C

1316 NNB GenCo has indicated in its report to ONR a number of areas that it is proposing to consider further as part of the evolution of the EPR™ design in a UK context. These include :

- Provision of a means repowering the Severe Accident Instrumentation and Control (I&C) equipment following a loss of batteries.
- Improvement to the autonomy time of the UDGs through the ability to transfer diesel fuel from the EDG tanks to the UDG tanks.
- Provision of a high powered mobile generator with fixed connection points on the power plant to provide a third source of electrical supplies.

- Provision of a diverse means of providing emergency feed water to the steam generators.
- Integration of the fuel building essential instrumentation in to the Severe Accident I&C system.

1317 NNB GenCo also recognises that its organisational procedures to severe events are still being developed and will incorporate learning from Fukushima.

### 5.1.6 ONR's Assessment of Loss of Electrical Supplies

Sellafield Ltd – Sellafield and Windscale

1318 ONR's review of the information provided by Sellafield Ltd relating to the assessment of loss of electrical supplies has concluded that what has been provided is accurate.

1319 With regard to the work completed by Sellafield Ltd to identify the loads that would need to be met to avoid off-site does greater than 10mSv to the critical group, ONR considers this to be comprehensive and provides some new insights that will impact the emergency arrangements for the site.

1320 ONR accepts the licensee's assessment that there is sufficient permanent centralised generation capacity to meet the estimated essential site loads in the event of loss of off-site supply. However, the licensee last undertook a formal review of essential loads in 2006 and ONR would expect this to be updated in light of the learning from its resilience review to identify the normal site loading, the essential loads that need to be provided to meet the existing safety case requirements, and also to identify clearly those loads that are vital to avoid significant off-site consequences during a site-wide extreme event (i.e. beyond the current design basis of the site). In addition, considering the long lead times for delivering major site infrastructure projects, ONR expects appropriate load forecasting to be undertaken to highlight likely shortfalls in the ability to supply the different types of safety significant loads. As a result, the following two findings have been raised by ONR:

**STF-51: Sellafield Ltd should undertake regular load forecasting in order to identify likely shortfalls in the provisions for normal and back-up electrical supply in good time to plan and deliver effective remedial actions and hence avoid material shortfalls occurring.**

**STF-52: Sellafield Ltd should ensure that the learning from its resilience review regarding vital site loads is embedded into future periodic reviews of site electrical requirements and taken into consideration in the management of change process whenever site electrical loads are to be modified.**

1321 ONR considers that the 132kV site supplies provide a good level of redundancy against multiple circuit outages due to planned maintenance combined with unexpected faults as only one circuit is required to provide the site load. They also follow diverse off-site routes providing protection from localised impacts. The vast majority of each 132kV circuit route length is overhead and, although subject to weather-induced interruptions, this does have the advantage of typical repair times being shorter than underground cables. ONR supports Sellafield Ltd work to explore a method of alternative supply restoration following 132kV failures.

1322 The 132/11kV grid transformers provide a good level of redundancy against multiple circuit outages due to planned maintenance combined with unexpected faults as only one transformer is required to meet the essential site loads. ONR understands from the flooding assessment undertaken that the grid transformers are not vulnerable to flood water and has sought clarification of this from the licensee.

1323 Although the judgement is that there is sufficient permanent centralised generation capacity to meet the estimated essential site loads in the event of loss of off-site supply, there is a complex set of inter-dependencies regarding the deployment of this generation. ONR will monitor Sellafield Ltd's progress in implementing any reasonably practicable improvements to these arrangements through targeted inspections planned during the forthcoming months.

1324 The on-site 11kV and 415V distribution system has been designed to accommodate a single failure. ONR accepts that the "backbone" of the 11kV system additionally has interconnection capability to accommodate all essential loads should two failures of critical circuits occur or a main substation is lost. Sellafield Ltd's statements regarding the resilience to flood risk and earthquake of the key substations forming the backbone system meet ONR's expectations. The peripheral sections of the system including supplies to individual plants might be expected to fail owing to limited redundancy and resilience against particular major events.

1325 Should the distribution system fail, back-up power for essential loads within individual plants can be provided by local generation connected to their individual EPD switchboard. Some plants have their own uninterruptible battery backed supplies with capacity to provide supplies for a limited time. The local generation is either permanently installed or MDAs but must connect to the EPD. ONR agrees with the licensee's general approach, as improving the robustness of a number of individual plants and facilities should enable the available specialist staff in an emergency situation to focus more effectively on the highest priorities. ONR welcomes the licensee's review of the resilience of these arrangements and the development of appropriate engineering solutions to shortfalls where appropriate. However Sellafield Ltd's plans in this area are not well developed at this stage and therefore the following finding has been raised:

**STF-53: Sellafield Ltd should complete its review of resilience, including the need for suitable event-qualified mobile diesel alternator connection points, and should undertake improvements where these would facilitate the reconnection of supplies to identified essential equipment.**

1326 This finding is of similar scope and intent to finding STF-8 raised in ONR's National Stress Tests Final Report for UK NPPs (Ref. 10) for licensees to investigate the provision of suitable event-qualified connection points to facilitate the reconnection of supplies to essential equipment.

1327 ONR acknowledges that the licensee has identified weaknesses in the site communications arrangements that could undermine emergency arrangements. These are discussed further in Section 6. However, it is appropriate to state in this section that more work is required to understand how electrical system vulnerabilities could impact on the availability of equipment that would be vital for handling a severe site-wide event, e.g. pumping stations, emergency lighting or site communications. Therefore, a finding has been raised:

**STF-54: Sellafield Ltd should continue to identify and address potential vulnerabilities in the provision of electrical supplies to systems that may not have an explicit nuclear safety claim in facility safety cases but whose loss could severely hinder site emergency arrangement following a severe event.**

1328 ONR acknowledges that the licensee has identified important potential shortfalls with the effective deployment and refuelling of mobile diesel alternators and those remedial actions are being undertaken. The review has identified that a large quantity of diesel fuel is usually available at Fellside CHPP and ONR supports Sellafield Ltd plan to procure a suitable means of transferring fuel across the site.

1329 The electrical back-up provisions rely heavily on diesel fuel and so the stocks of diesel fuel which need to be managed to ensure that there is sufficient quantity and quality available when required. ONR agrees with the licensee's assessment that current arrangements have potential vulnerabilities which need to be addressed.

1330 ONR will continue to engage with, monitor and challenge Sellafield Ltd's actions in response to the identified shortfalls and proposed improvements, in addition to assessing the adequacy of Sellafield Ltd's response to Recommendation IR-18 in HM Chief Inspector's report (Ref. 2) on the provision of robust, long-term independent electrical supplies under severe conditions.

Dounreay Site Restoration Ltd

1331 ONR agrees with the rationale offered by DSRL in that the inventories that remain do not require active electrically powered safety systems to maintain the basis of safety. ONR notes DSRL's recent improvement to facility ventilation systems and its efforts to align its operations that rely on ventilation systems with industry good practice. ONR's confidence is further supported by targeted assessment of facility decommissioning safety cases and compliance inspection programmes.

1332 Similar to the finding raised for Sellafield, more work is required to understand how electrical system vulnerabilities could impact on the availability of equipment that would be vital for handling a severe site-wide event e.g. pumping stations, emergency lighting or site communications. Therefore, a finding has been raised for DSRL to address:

**STF-55: DSRL should identify and address potential vulnerabilities in the provision of electrical supplies to systems that may not have an explicit nuclear safety claim in facility safety cases but whose loss could severely hinder site emergency arrangement following a severe event.**

Springfields Fuels Ltd

1333 Since submission of the stress tests report, ONR has acquired assurance that extant safety cases demonstrate that processes can be shutdown in a fail-safe manner following a loss of distribution. ONR agrees that the ten-day supply of fuel to CHPP provides a significant basis on which the licensee can be assured of site resilience in the short to medium term; in particular its capability to sustain on-site surveillance and to affect personnel recovery where necessary.

Atomic Weapons Establishment

1334 ONR has carried out assessments of the AWE periodic safety reports for AWE (B) (2007) and AWE (A) (2010). These reports reviewed the provisions on-site against the expectations of modern standards and reported on the situation regarding loss of site services including electrical power. The reports were accepted by ONR on the basis of a forward action plan that identified further safety justifications or improvements.

1335 In the case of AWE (B), while there were no immediate issues for nuclear safety, AWE had identified a number of shortfalls as measured against modern standards. The conditions for continued operation, that include the need to design and construct a new facility, were presented along with the key improvements that have been implemented as a result of ONR's decision on the adequacy of the PSR that had been produced and the regulatory approach that was adopted.

1336 ONR has not identified any further requirements for improvements to electrical supply integrity for either site as a result of its assessment of AWE stress tests submission. ONR supports AWE's current initiative to improve electrical supply integrity as part of the AWE (A) site PSR.

Rolls-Royce Marine Power Operations Ltd

1337 ONR notes that in the RRMPOL submission, no operations have been identified on-site that are susceptible to a loss of power incident. However, ONR is of the opinion that the availability of power to key emergency response locations and equipment may have an impact on the ability to respond under some circumstances.

1338 ONR supports RRMPOL's *Considerations* relating to the means of improving the flood resilience of the site's electrical power supplies, and the capability of on-site fuel supplies for the diesel generator to provide back-up to the ECC for extended periods.

1339 ONR supports RRMPOL's further *Consideration* of the need for a holding of health physics instrumentation in a location protected from external events.

**STF-56: RRMPOL should consider reviewing its strategy for demonstrating the continuing safety of the plant post incident, including a consideration of power requirements for instrumentation (e.g. criticality detection systems).**

BAE Systems Marine Ltd

1340 ONR notes that the NRP is significantly different from civil power reactors. In particular, it has its own redundant and diverse methods of power generation which are protected from external events by the robustness of the submarine hull.

1341 ONR accepts the BAESM case that nuclear safety prior to criticality is not reliant on off-site (or on-site) electrical power supplies. Following criticality, the submarine has significant capability of on-board electrical supplies to provide decay heat removal should onshore supplies fail.

1342 ONR notes that BAESM has mentioned the availability of back-up onshore supplies and shore battery; however, it is not clear what is the resilience of these supplies, and whether these would be available to support carrying out the emergency arrangements and plan on-site.

1343 The submission considers a limited range of scenarios and does not give information on the resilience of the site power supplies under a full range of incident conditions. The submission does not consider options that may improve the resilience or availability of electrical power supplies on-site.

**STF-57: BAESM should consider whether further measures are necessary that may improve the availability of electrical power supplies on-site under a full range of fault scenarios. This should include a review of the adequacy of back-up electrical supplies on-site that would support the management and operation of an emergency incident.**

Devonport Royal Dockyard Ltd

1344 ONR supports the work being carried out as part of the PSR; however, it is recognised that this work largely addresses the design basis events. ONR recognises that the provision of electrical services that are immune to flooding will always present a challenge in a dockyard environment. DRDL's submission has identified the robust extent of onshore supplies and the management controls exercised to achieve high availability proportionate to potential power and nuclear safety demands.

1345 ONR considers that the nature of the NRP is significantly different compared to civil power reactors. The significant difference between a civil power reactor and a submarine reactor based hazard is the security of supplies available from on-board the submarine and the level of protection afforded by the hull. DRDL has identified the management controls over personnel and equipment to ensure availability of on-board supplies, commensurate with the needs of the submarine for decay heat removal.

1346 ONR accepts DRDL's conclusion that beyond the design basis, there is the potential for complete site power loss that can only be mitigated in the short term by the submarine electrical and DHR systems. The passive nature of on-board DHR systems limits the requirements to recover loss of shore supplies in the short term. The design of the submarine's systems, including back-up power supplies is a matter for the MoD, which is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

1347 ONR notes that there is no requirement for electrical power or instrumentation to protect containment integrity. ONR agrees that no safety concerns have been identified in the stress tests that would benefit from additional electrical power generation.

1348 RRDL has identified that portable instrumentation could be vulnerable to a common cause external event that could affect the operability of installed monitoring. RRDL has noted that this instrumentation is common across other nuclear sites and other parts of the Babcock International Group.

Magnox Ltd – Defuelled reactors

1349 It is considered that Magnox has in general provided adequate descriptions of its systems. ONR is of the view that Magnox has robust provisions against the design basis to support essential safety functions on:

- Loss of off-site supplies.
- Loss of ordinary back-up AC power sources.

NNB GenCo – Hinkley Point C

1350 It is considered that NNB GenCo has in general provided adequate descriptions of its proposed systems. During the course of this assessment a number of queries have been raised to clarify arrangements and the scope of its assessments. Any responses to these queries, in conjunction with each site's stress tests report, have been taken into account when coming to the following conclusions.

1351 The generic reactor design has not yet received a final Design Acceptance Certificate from ONR, due to outstanding GDA Issues. Furthermore, NNB GenCo is still working with its architect engineer to develop the GDA design into a site-specific context and as such system designs and capacities are still being developed.

1352 ONR considers that, as the site-specific design and safety case is still being developed, it is difficult to consider it compliant with a design basis. However, ONR does consider that the areas identified by NNB GenCo for consideration to further improve the resilience of its design are appropriate. In addition, ONR considers the following issues warrant further consideration:

- Ensure that the ability of nuclear safety functions to perform is not limited to a single EDG, UDG or battery.
- Ensure that the autonomy time of any battery fed system or diesel generator is appropriate in relation to the ability of the site to respond to any event.

**STF-58: NNB GenCo should consider further the ability of the site to respond to the partial or complete loss of electrical supplies and the autonomy times of systems without off-site support.**

## 5.2 Loss of the Decay Heat Removal Capability / Ultimate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1353 As discussed in Section 1.1.2, Sellafield Ltd has demonstrated through calculation that a prolonged loss of active cooling (in the order of seven days) from the fuel ponds would not result in fuel uncovery and unacceptable consequences, assuming no loss of initial inventory via e.g. seismic induced cracks. Therefore, Sellafield Ltd has chosen not discuss the active cooling requirements of the fuel ponds further.

1354 The cooling of self-heating highly active liquor is the most significant duty for circulating water supplies. Both the cooling systems of the HASTs and the highly active liquor vessels in WVP give up their heat to atmosphere via cooling towers. While the ultimate heat sink of the atmosphere cannot be lost, the ability to reject heat to it could be lost, through e.g. damage to cooling circuits / towers or through the loss of pumping capability to maintain the circulation (most likely through a loss of power).

1355 Other self-heating inventories and products around the site can be cooled sufficiently by just keeping them wet or topped up with water, without the need for more active heat removal / ejection. On facilities dealing with Magnox fuel, it should be possible in most cases to move any flasks / skips / magazines isolated from the main body of pond cooling water by hand winding back into the pond or moved to a location where top-up water / spray can be added manually. On the FHP facility, there are gravity fed water supplies capable of providing the necessary spray for several hours to Magnox fuel in the decanning cell before alternative sources of water are required.

### 5.2.1 Design Provisions to Prevent the Loss of the Primary Ultimate Heat Sink, such as Alternative Inlets for Seawater or Systems to Protect Main Water Inlet from Blocking

Sellafield Ltd – Sellafield and Windscale

1356 Sellafield is a complex site, with many facilities making different claims on different heat sinks. This section is effectively addressed above.

Urenco UK Ltd

1357 ONR is confident that there are no holdings of nuclear material on the UUK site that require active cooling systems to sustain an ultimate heat sink. No further consideration is given for UUK in this report in the context of ultimate heat sink.

Dounreay Site Restoration Ltd

1358 As a decommissioning site with defuelled reactors and long-term cooled nuclear material, the nuclear safety of facilities located at Dounreay is not dependent upon the availability of an ultimate heat sink. ONR is satisfied there is adequate evidence provided within DSRL’s safety case to underpin this claim. No further consideration is given for DSRL in this report in the context of ultimate heat sink.

Springfields Fuels Ltd

1359 While not explicitly stated in SFL's stress tests report, ONR is confident that there are no holdings of nuclear material on the Springfields site that require active cooling systems to sustain an ultimate heat sink. No further consideration is given for SFL in this report in the context of ultimate heat sink.

Atomic Weapons Establishment

1360 AWE does not have any NPP or stored nuclear fuel requiring decay heat removal on its sites. Therefore, AWE's stress tests submission does not address design provisions to prevent the loss of ultimate heat sink for operations at either of AWE's sites.

Rolls-Royce Marine Power Operations Ltd

1361 RRMPOL reports that there are no operations on the Neptune and manufacturing sites with a decay heat removal requirement. No safety implications of loss of cooling of reactor fuel have been identified so has not been considered further in the submission.

1362 On the manufacturing site, some equipment has closed circuit cooling, and mains water-fed back-up cooling systems can be used under certain fault conditions. However, RRMPOL explains that no nuclear safety claim is made on the operation of the cooling systems. Equipment potentially having significant residual heat incorporates pressure relief features that will avoid radiological consequences under conditions of loss of cooling by preventing damage to the equipment.

BAE Systems Marine Ltd

1363 BAESM has described that the requirement for decay heat removal can only occur once the reactor has been taken critical. Since this and all subsequent post critical operations will only occur at WDQ, decay heat removal is within the capability of the on-board systems.

1364 BAESM's submission also reports that the operation of the reactor at power is intentionally limited, to limit the quantity of fission products that can accumulate in the fuel. Therefore, the maximum fission product inventory and decay heat in a reactor at Barrow are much less than those of an in-service submarine.

Devonport Royal Dockyard Ltd

1365 DRDL's submission indicates that for defuelling and fuel transfer, the decay heat levels are such that the natural heat losses are sufficient even with the fuel under dry conditions.

1366 During activities in dock, the ultimate heat sink of a submarine reactor can be either seawater, fresh water from an external supply, or at low decay heat levels natural convection / conduction to atmosphere / structure.

1367 When the submarine is afloat in dock, seawater can be drawn from outside the submarine hull through heat exchangers and discharged back into the dock.

1368 The emergency cooling / high pressure decay heat removal system is normally supplied from the freshwater main. This main has a low withstand to hazards, but improvements are not deemed necessary, as its loss is not significant to nuclear safety.

1369 The submarine can be docked down once a certain level of decay heat is reached. At this point cooling water supplies are obtained from the facility. For the SRC this is achieved using the free flood main (passive) or the saltwater cooling system (pumped). In 9 Dock, the saltwater supply system is designed to be the normal supply of cooling water to the docked down submarine.

1370 As the decay heat levels fall, natural heat losses provide an increasing proportion of the required core cooling, eventually meeting all core cooling demands.

1371 DRDL explains that the design of the on-board decay heat removal systems is addressed by the safety case for the submarine which is a matter for the MoD. Engineered on-board systems are available to clear blockages of seawater inlets.

1372 In the case of blockage of sea intakes on the dock facilities, screens are provided on pumps and / or intakes with redundancy of intakes / pumps. Claims made against the submarine's systems are substantiated by MoD.

Rosyth Royal Dockyard Ltd

1373 RRDL's submission reports that the radioactive materials at Rosyth are non-fissile and there is no requirement to control reactivity. They do not produce significant heat and there is no requirement for an ultimate heat sink. Therefore design provisions to prevent the loss of primary ultimate heat sink are not presented in the submission as they are not applicable to the site.

Magnox Ltd – Defuelled reactors

1374 The defuelled reactors have not operated for many years and nuclear fuel has been removed from the sites, the remaining material on-site does not produce substantial amounts of heat, which can be readily dissipated by natural processes to the surrounding environment and therefore does not need to be considered in this context. Consequently, these sites will not be discussed further in Section 5.2.

NNB GenCo – Hinkley Point C

1375 In normal operation, heat is to be removed from the reactor by the seawater cooling through the main condensers. Component and fuel pond cooling is to be provided by redundant trains of component cooling water systems, rejecting heat to the essential services water system, which is also cooled using seawater. These systems are to be supplemented by a diverse system of seawater cooling termed the UCWS.

1376 Four redundant seawater inlets are to be provided with diverse filtering means: two trains of chain filters and two rotating drum screens in accordance with established practice. These trains can be interconnected down-stream of the filters to bypass any screen that becomes unavailable.

1377 The seawater inlet is designed to take water from a sufficiently deep channel to minimise likely causes of interruption. The seawater inlet for the UCWS is a diverse design and can take water from the seawater discharge channel. In the event of blockage of the seawater inlet it is intended that automatic systems will trip non-essential loads to preserve the safety functions.

### 5.2.2 Loss of the Primary Ultimate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1378 Sellafield is a complex site, with many facilities making different claims on different heat sinks. This section is effectively addressed above.

Atomic Weapons Establishment

1379 AWE's submission shows that no operations on-site have been identified that require heat removal of the form normally associated in the nuclear power industry with decay heat removal / ultimate heat sink requirements. AWE has identified operations where controlled cooling on loss of heating could impact on equipment serviceability; however there are no direct nuclear safety implications.

1380 These cooling systems are closed loop water systems which reject heat to the ambient environment. Upon loss of cooling systems, the furnaces turn off, and begin to cool passively. In some facilities shutdown cooling is provided to help prevent potential equipment damage in case of normal cooling system failure. The shutdown cooling systems, where provided, are of a passive once through gravity fed system design.

Rolls-Royce Marine Power Operations Ltd

1381 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites. Therefore a consideration of loss of primary ultimate heat sink is not presented in the submission.

BAE Systems Marine Ltd

1382 At WDQ, seawater acts as the ultimate heat sink. For submarines with low decay heat levels (i.e. passive decay heat removal achieved), the loss of ultimate heat sink is not considered as a fault sequence, since passive cooling mechanisms are adequate and there will be no consequent challenge to the integrity of the fuel.

1383 Should an event at WDQ occur that results in the dock system going tidal, on-board water supplies can be configured to provide decay heat cooling when tide height is below the seawater cooling inlets. Returning tides periodically re-establish the ultimate heat sink. At low levels of decay heat the natural losses through convection and conduction are sufficient to prevent fuel damage.

Devonport Royal Dockyard Ltd

1384 For submarines with low decay heat levels (i.e. passive convection / conduction decay heat removal achieved), the loss of ultimate heat sink is not considered as a fault sequence, since passive cooling mechanisms are adequate and there will be no consequent challenge to the integrity of the fuel.

1385 For boats with higher decay heats, under all hazards assessed there would be the ability to reinstate cooling. For boats with lower decay heats, passive decay heat removal would be sufficient to maintain the integrity of the fuel.

1386 If the submarine is using onshore heat removal systems then the on-board systems can be realigned to restore heat removal via the on-board systems.

1387 If the submarine is docked down then on-board water supplies can be used to continue core cooling. In the case that these supplies are not available the decay heat levels should be such that the losses through available passive means of DHR will meet cooling requirements.

Rosyth Royal Dockyard Ltd

1388 RRDL's submission reports that the radioactive materials at Rosyth are non-fissile and there is no requirement to control reactivity. They do not produce significant heat and there is no requirement for an ultimate heat sink. Therefore loss of the primary heat sink is not applicable to the site.

NNB GenCo – Hinkley Point C

1389 Assuming loss of the ability to reject heat from the reactor via the main condensers an automatic reactor trip is intended to occur. After reactor trip, heat can be rejected to atmosphere by the atmospheric steam dump system and feed water can be supplied to the steam generators using auxiliary feed pumps. Feed water reserves are to be stored in the emergency feed water reserve tank and within the feed system as a whole.

1390 Once tripped, the plant is manually taken to cold shutdown conditions. Once depressurised and cooled, the primary cooling system can be realigned to reject heat to the RHRS. This can be cooled via the UCWS which has a degree of diversity from the main seawater systems.

1391 If the reactor is shut down and the primary circuit open, cooling is normally via the RHRS; discharging heat to the ESWS. If this is not available, the RHRS can also discharge heat to the UCWS. The UK EPR™ fuel pond also uses the ESWS as an ultimate heat sink and can use the UCWS as an alternative.

1392 Primary-circuit inventory and reactivity control are to be maintained using the coolant volume control system or one of a number of safety injection systems. However, the UK EPR™ design has an automatic static seal system, which minimises the need to replenish the primary coolant.

### 5.2.3 Loss of the Primary Ultimate Heat Sink and the Alternate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1393 Sellafield is a complex site, with many facilities making different claims on different heat sinks. This section is effectively addressed above.

Atomic Weapons Establishment, Rolls-Royce Marine Power Operations Ltd and Rosyth Royal Dockyard Ltd

1394 AWE, RRMPOL and RRDL does not have stored nuclear fuel requiring a ultimate heat sink. Therefore, loss of the primary heat sink and alternate heat sink has not been considered as it is not applicable to the sites.

BAE Systems Marine Ltd

1395 BAESM reports that following initial criticality, at WDQ, seawater acts as the ultimate heat sink. Should an event occur that results in loss of the ultimate heat sink, the submarine has internal water storage that can be configured to provide decay heat cooling when tide height is below the seawater cooling inlets. Returning tides periodically re-establish the ultimate heat sink if WDQ becomes tidal. At low levels of decay heat the natural losses through convection and conduction are sufficient to prevent fuel damage.

Devonport Royal Dockyard Ltd

1396 For submarines with low decay heat levels (i.e. passive decay heat removal achieved), the loss of ultimate heat sink is not considered as a fault sequence, since passive cooling mechanisms are adequate.

1397 For boats with higher decay heats, under all hazards assessed there would be the ability to reinstate cooling.

1398 When the submarine is afloat in dock, the on-board equipment is available for primary and alternate decay heat removal. While the submarine is docked down and the shore system is supporting decay heat removal the on-board systems can be configured to provide an alternate heat removal. The submarine is designed to be self sufficient and capable of operation in challenging environments. The on-board systems are the subject of the submarine safety case which is a matter for MoD consideration.

NNB GenCo – Hinkley Point C

1399 In the event of loss of all seawater systems, the reactor steam generators can continue to be supplied with water from the emergency feed system for as long as feed water and power is available. This can be several days and can be extended by the use of water in the fire-fighting system.

1400 In the event that the primary circuit is not intact and residual heat removal is lost, water can be injected into the primary circuit from the IRWST using (for example) the low-head safety injection pump – with steam vented to containment. The containment cooling system would be required to maintain subcooling in the IRWST and hence the ability of the containment sprays to control the containment pressure. This would require reestablishment of a seawater heat sink.

1401 In the absence of an operable containment cooling system, establishment of containment venting would be required to prevent overpressure, NNB GenCo is currently reviewing the possibility of installed control containment venting at Hinkley Point C. Also, NNB GenCo argues that the timescale for the progression of such an accident would be sufficient to allow additional mitigation measures to be taken.

1402 In the event of loss of diverse means of fuel pond cooling, the inventory can be replenished as it evaporates using the fire-fighting system. This system requires electrical power, but can be supplied via installed diesel generators. Stocks are intended to last several days, but can be replenished via the raw water system, should this be available.

### 5.2.4 Conclusion on the Adequacy of Protection Against Loss of Ultimate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1403 As with loss of power, Sellafield Ltd has concluded that the site has robust arrangements to deal with a loss ultimate heat sink, which, in the Sellafield context, relate principally to cooling highly active liquor stocks and keeping Magnox and oxide fuels wetted.

1404 There are diverse means of providing cooling to the highly active liquor in the HASTs and WVP vessels, but they all require supplies of water and the means to deliver it. In addition to the issues discussed above in Section 5.1 on the availability of power supplies for e.g. pumping stations, Sellafield Ltd has recognised the need to review resilience, flexibility and capability of fixed and emergency pumps and pipelines.

Atomic Weapons Establishment

1405 AWE concludes that there are no requirements for a primary ultimate heat sink for the operations at either of the AWE nuclear sites. Therefore, for the event of loss of cooling, AWE has assessed that there are no challenges to any safety function required to prevent or mitigate a severe accident at either of the AWE nuclear sites.

Rolls-Royce Marine Power Operations Ltd

1406 RRMPOL concludes that there are no decay heat removal requirements for the operations at its sites.

BAE Systems Marine Ltd

1407 BAESM's submission indicates that the on-board supplies and system provide adequate protection against the loss of the ultimate heat sink. At the levels of decay heat expected from operations at Barrow these on-board resources will allow cooling to the point at which natural convection / conduction losses will be sufficient to prevent fuel damage.

Devonport Royal Dockyard Ltd

1408 DRDL has considered the extreme event of the submarine being disconnected from the ultimate heat sink, and the options that the on-board water sources provide

1409 When in dock and where shore support is provided for DHR, DRDL asserts that sufficient systems are maintained operational on the boat to revert back to on-board provisions and this is controlled commensurately with the decay heat level. At decay heat levels (when passive heat removal is achieved), there is no safety requirement for decay heat removal via cooling water since losses through convection / conduction would be sufficient to prevent fuel damage.

1410 DRDL has described the on-board DHR systems; however assessment of the adequacy of these is a matter for MoD.

Rosyth Royal Dockyard Ltd

1411 The radioactive materials on-site do not produce significant heat and there is no requirement for, or provision of, an ultimate heat sink. Therefore RRDL has not provided a specific conclusion regarding the adequacy of protection against loss of the ultimate heat sink as it is not applicable to the site.

NNB GenCo – Hinkley Point C

1412 Loss of heat sink is considered as a potential fault within the design basis and significant levels of redundancy and diversity are provided within the design of the UK EPR™. The general approach is to provide cooling using water from on-site reserves until off-site supplies can be re-established. On-site stocks of water are considered to be sufficient to meet the assumptions of the stress tests.

1413 The design allows for the potential that off-site power is likely to be lost coincident with loss of heat sink. Mitigation systems are generally dependent on operation of the installed diesel generators.

### 5.2.5 Measures Which Can Be Envisaged to Increase Robustness of the Plants in Case of Loss of Ultimate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1414 There are multiple water sources of varying quality available to the site. However, all of them require power to get the water either directly to site or via a reservoir from where it can be gravity-fed to the site. Given its location on the coast, it would also be possible to pump water from the sea and make a connection into the ring mains or feed into other water stocks. However, Sellafield Ltd has reported that this would only be a last resort due to the impact of saline water on nuclear plant and has not considered it in detail.

1415 Sellafield Ltd has identified in its submission a number of significant areas of focus to the water supplies to and around the site. These include the need to review the resilience of pipelines and power supplies to the off-site pumphouses, increasing the flexibility in local reservoirs, and reviewing the size, number and location of emergency pumps.

1416 While not considering in any detail the requirements to actively cool fuel ponds, Sellafield Ltd has considered the consequences of a loss of inventory from the ponds (a potential loss of both cooling and containment). The identified response to a breach of a pond wall would be to attempt to contain the breach and use tarpaulin / sandbags to create a temporary bunded area. Mobile pumps would then be used to return collected water and / or supplement it with additional water supplies. Despite proposing this as a strategy, the licensee has identified the need to review the emergency response further, consider the purchase and deployment of portable bunds, and to test the techniques and equipment at a suitable deep water facility.

Atomic Weapons Establishment

1417 AWE concludes that there are no requirements for a primary ultimate heat sink for the operations at either of the AWE nuclear sites. AWE has identified that there are no cliff-edge effects associated with the event of loss of cooling and, given the insignificance of the event, has identified, from the stress tests, that no further provisions to increase the plant robustness are required.

Rolls-Royce Marine Power Operations Ltd

1418 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites. Therefore measures which can be envisaged to increase robustness of the plants in case of loss of ultimate heat sink are not presented in the submission.

BAE Systems Marine Ltd

1419 The provisions to deal with loss of the ultimate heat sink are associated with the submarine internal systems and resources. These are outside the scope of the BAESM stress tests. Claims made against the submarine's systems are substantiated by MoD.

Devonport Royal Dockyard Ltd

1420 DRDL reports that even in the most severe fault conditions, i.e. a tsunami in excess of the submarine's draught, adequate cooling facilities will be available. The autonomous nature of the submarine means that it is largely independent of the external event, and a credible tsunami was not considered to challenge this.

1421 DRDL has nonetheless identified that further considerations should be made relating to measures which can be envisaged to increase robustness of the plants in case of loss of ultimate heat sink.

Rosyth Royal Dockyard Ltd

1422 Since an ultimate heat sink is not required, its robustness is not applicable.

NNB GenCo – Hinkley Point C

1423 In the event of loss of off-site power, the design is reliant on diesel generators to provide power for safety systems. NNB GenCo has therefore identified measures to increase the robustness of the diesel buildings against flooding as a potential enhancement to the design of the UK EPR™. They are also considering whether certain pumps can be powered by diverse means, such as turbine-driven pumps.

1424 In the event of loss of the main feed system, the EFWS has water supplies for about two days. Feed can potentially be supplied from the fire-fighting system for several days with water taken from the raw water storage system. Permanently installed systems to facilitate this are under consideration by NNB GenCo.

### 5.2.6 ONR's Assessment of Loss of the Decay Heat Removal Capability / Ultimate Heat Sink

Sellafield Ltd – Sellafield and Windscale

1425 ONR is satisfied that Sellafield Ltd has reviewed the implications of a loss of decay heat cooling / ultimate heat sink across the Sellafield site, and considers the process adopted to identify weaknesses robust. The conclusions reached in Sellafield Ltd's submission appear both significant and appropriate, and therefore ONR will be monitoring the development and implementation over the coming months and years.

1426 In an emergency situation, the challenge is to have sufficient quantities of water available and the means to deliver it. For the identified priority facilities, sufficient cooling can be provided by water on a once-through basis and cooling towers / heat exchangers are not necessarily required to still be functional.

1427 While ONR recognises that there are multiple sources of fresh water available to the site, and that Sellafield Ltd intends to do further work to increase the resilience of these supplies, the review of the response provided in the Sellafield Ltd submission did not find much in the way specific details of how the seawater could be used as a last resort. A suggestion is made in one part of the submission that a Godiva pump connected to a ring main could be utilised but it is suggested further engineering would be required and the time to implement is unknown. As result, ONR has raised the following finding:

**STF-59: Sellafield Ltd should explore the practicality and requirements of pumping water from the sea and other water sources such as local rivers to where it might be utilised, and establish if this could indeed be done in extremis with the systems currently available on-site.**

Atomic Weapons Establishment

1428 ONR's assessment of AWE's submission is that no operations on-site have been identified that require heat removal of the form normally associated in the nuclear power industry with decay heat removal / ultimate heat sink. Operations have been identified by AWE where controlled cooling on loss of heating could impact on equipment serviceability; however, there are no direct nuclear safety implications.

Rolls-Royce Marine Power Operations Ltd

1429 ONR has not identified any operations on-site that require heat removal of the form associated in the nuclear power industry with decay heat removal and ultimate heat sink. Therefore aspects of RRMPOL's submission relevant to decay heat removal and provision of ultimate heat sink are judged to be appropriate by ONR.

BAE Systems Marine Ltd

1430 ONR accepts that BAESM has made the case that at the decay heat provisions for the range of reactor operations carried out at WDQ are adequate to prevent fuel damage. Detailed assessment for on-board reactor systems is a matter for MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1431 Limited information was presented in the stress tests submission relating to the adequacy of site support services.

**STF-60: BAESM should consider reviewing the arrangements that ensure suitable systems are always available commensurate with expected levels of decay heat, and that resources (fuel and water) are available on-board and onshore for replenishment where necessary.**

Devonport Royal Dockyard Ltd

1432 While DRDL has described the on-board decay heat removal systems, assessment of the adequacy of these is a matter for MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions

1433 ONR agrees with DRDL that when in dock and where shore support is provided for DHR, sufficient systems must also be maintained operational on the boat, commensurate with the decay heat level. ONR agrees that this provides sufficient defence-in-depth.

1434 At low decay heat levels (i.e. passive decay heat removal achieved), ONR accepts DRDL's assertion that there is no safety requirement for decay heat removal via cooling water since losses through convection / conduction would be sufficient to prevent fuel damage.

1435 ONR notes that DRDL has considered the extreme event of the submarine being disconnected from the ultimate heat sink, and the options that the on-board water sources provide. ONR considers that it is difficult to see how DRDL could provide additional engineered systems to support the consequences of such an extreme event. Considerations of possible additional on-board enhancements are a matter for MoD. ONR supports DRDL's further consideration of measures which can be envisaged to increase the robustness of the plants in case of loss of ultimate heat sink.

1436 Claims made against the submarine's systems are substantiated by MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of MoD's conclusions.

Rosyth Royal Dockyard Ltd

1437 ONR agrees with RRDL's assertions that these current activities do not involve fissile or significant heat generating materials. There is therefore no safety demand for decay heat removal or an ultimate heat sink.

NNB GenCo – Hinkley Point C

1438 The design of the seawater systems is based on established practice and contains the expected level of redundancy and diversity. ONR judges that an adequate level of robustness has been demonstrated for faults within the design basis.

1439 In more severe events, the cooling of the reactor core is intended to be achieved by a variety of means comprising of: feeding water to the steam generators on a once-through basis; or injecting water directly into the reactor core and venting steam into the containment building – where it is condensed by sprays. These measures can be sustained for as long as supplies of subcooled water and power are available.

1440 Consideration of additional diversity of auxiliary feed systems is welcome by ONR if this is shown to be reasonably practical. ONR is continuing its assessment of some details of the design via the GDA process, in particular, the measures envisaged to mitigate severe accidents. This is discussed further in Section 6.

## 5.3 Loss of the Primary Ultimate Heat Sink, Combined with Station Blackout

Sellafield Ltd – Sellafield and Windscale

1441 The nature of the Sellafield site is such that station / site blackout is one of the more likely reasons for a challenge to cooling functions in facilities, or an external hazard such as a large earthquake or flood is likely to cause the loss of both essential functions. Therefore, these combinations of events have already effectively been considered above.

1442 The challenge is, as stated above, having sufficient quantities of water available and the means to deliver it. Magnox fuel not submerged in storage ponds could dry out and reach self-ignition temperatures in less than a day's time after the loss of water supplies. The product within the THORP centrifuge bowl could dry out approximately within a day time. However, the most significant issue in terms of off-site radiological consequences would be highly active liquor in its various holding tanks, which would start boiling after approximately 30 hours without cooling.

1443 Steam is required across the site to deliver a number of essential functions in normal operation. This is typically provided by the Fellside CHPP. However if the connection to the grid is lost and there are problems with water supply, the provision of steam will be compromised. Most demands for steam will stop following a site blackout as all normal operations will cease. However, there is a requirement on steam-driven ejectors on HALES to remove of liquor collected in "seal pots" to prevent hydrogen build-up. Both power and water are required to deliver this safety function. There are oil-fired emergency boilers with their own water supplies, but both the diesel stocks and water supplies are limited. As a result, Sellafield Ltd has identified a *Consideration* to review the resilience of both power and steam supply to HALES.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuel Ltd

1444 Section 5.2.1 has stated that there were no requirements of any ultimate heat sink at UUK, DSRL and SFL site.

Atomic Weapons Establishment

1445 AWE does not have any NPP requiring primary ultimate heat sink. Therefore, AWE's stress tests submission does not address loss of primary ultimate heat sink combined with loss of electrical supplies for the operations at either of AWE's sites.

1446 For processes involved with heating of nuclear material, loss of power to the electrical furnace heating will be accompanied by loss of power to the cooling systems. Where shutdown cooling systems have been provided to reduce possible equipment damage, then these are of a passive design such that no external power is required for operation.

1447 For the event of loss of cooling with loss of on-site power, AWE assesses that there are no challenges to any safety function required to prevent or mitigate a severe accident at the AWE nuclear sites.

Rolls-Royce Marine Power Operations Ltd

1448 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites. Therefore a consideration of loss of ultimate heat sink combined with loss of electrical supplies is not presented in the submission.

BAE Systems Marine Ltd

1449 At WDQ, the claimed provisions to deal with loss of the ultimate heat sink are associated with the submarine internal systems and resources. Considerations of the loss of the on-board systems are a matter for MoD.

Devonport Royal Dockyard Ltd

1450 DRDL reports that for all decay heat states permitted on the site, at least one passive decay heat removal mechanism is maintained available that is independent of facility supplies. The core parameters can be monitored for the full period that the heat sink is not available.

1451 For the submarine afloat in dock, in order to lose the ultimate heat sink and become reliant upon active systems, the submarine would need to be grounded such that water is lost at all states of the tide. Also the grounding height would need to be such that the on-board tanks could not be replenished.

Rosyth Royal Dockyard Ltd

1452 In the absence of a need for an ultimate heat sink, loss of electrical power has no impact on an ultimate heat sink. RRDL has not provided a specific conclusion regarding the adequacy of protection against loss of the ultimate heat sink and loss of electrical supplies since it is not applicable to the site.

Magnox Ltd – Defuelled reactors

1453 The defuelled reactors have not operated for many years and nuclear fuel has been removed from the sites, the remaining material on-site does not produce substantial amounts of heat, which can be readily dissipated by natural processes to the surrounding environment and therefore does not need to be considered in this context. Consequently, the effect of a combination of loss of ultimate heat sink and SBO will be bounded by SBO alone which is discussed in Section 5.1, hence these sites will not be discussed further in Section 5.3.

NNB GenCo – Hinkley Point C

1454 The current design of the UK EPR™ relies on either the main diesels or the ultimate back-up diesels to provide power to the post-trip cooling systems in the event of loss of the main grid. These systems are significantly diverse within the plant and therefore NNB GenCo does not consider common-mode failure likely.

### 5.3.1 Time of Autonomy of the Site Before Loss of Normal Cooling Condition of the Nuclear Matters

Sellafield Ltd – Sellafield and Windscale

1455 Sellafield is a complex site, with each facility having its own timelines. Key issues have already been discussed as appropriate in the sub-section above.

Atomic Weapons Establishment

1456 AWE has identified that there are no time constraints associated with safety issues on loss of cooling.

Rolls-Royce Marine Power Operations Ltd

1457 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites. RRMPOL has not identified any time constraints associated with safety issues on loss of cooling for equipment on the sites.

BAE Systems Marine Ltd

1458 BAESM's submission identifies the timescale after which successful decay heat removal can be provided by natural heat loss through the RPV.

Devonport Royal Dockyard Ltd

1459 For a submarine afloat, there is no time dependent requirement, due to the infinite heat sink surrounding the submarine.

1460 For a docked down vessel the time period before tank replenishment is required is in the region of days. At lower decay heats, no supplies are required.

Rosyth Royal Dockyard Ltd

1461 RRDL reports that the radioactive materials on-site do not produce heat and therefore there is no time constraint related to cooling.

NNB GenCo – Hinkley Point C

1462 The supplies of water to cool the reactor and storage pond on a once-through basis are considered to be sufficient to achieve the assumed autonomy time of 72 hours without resupply by a significant margin. The diesel generators also have substantial storage capacity as discussed in Section 5.1 above. In the unlikely event of loss of all supplies, some fuel damage would occur in a matter of hours and possibly loss of containment within a few days.

### 5.3.2 External Actions Foreseen to Prevent Nuclear Containment Degradation

Sellafield Ltd – Sellafield and Windscale

1463 Sellafield is a complex site, with each facility having its own challenges. Key issues have already been discussed as appropriate in the sub-section above.

Atomic Weapons Establishment

1464 AWE has identified that there are no mechanisms whereby loss of power and loss of cooling systems would result in degradation of nuclear matter containment.

Rolls-Royce Marine Power Operations Ltd

1465 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites.

BAE Systems Marine Ltd

1466 For the operations at the Barrow site the fission product inventory is limited by the scope and duration of operations. The first boundary to the release of fission products from the fuel is the high integrity fuel clad. Should fission products escape from this encapsulation they would then be retained within the fully welded primary circuit. Potential degradation mechanisms are part of the submarine safety case. Claims made against the submarine's systems are a matter for the MoD.

Devonport Royal Dockyard Ltd

1467 The first boundary to the release of fission products from the fuel is the high integrity fuel clad. Potential degradation mechanisms are part of the submarine safety case. Claims made against the submarine's systems are a matter for the MoD.

Rosyth Royal Dockyard Ltd

1468 RRDL indicates that In the event of a spillage or loss of containment, a surplus of shielded containers exists and could be used, if accessible. In the event that they could not be used, any alternative storage tank could be utilised instead, although dose rates would require to be managed. In the event that the radioactive material is dispersed into the environment, the risk to remediation workers, to the public, and to the environment would be low.

NNB GenCo – Hinkley Point C

1469 NNB GenCo is proposing to enter into supply contracts to obtain emergency supplies of diesel fuel within one day from local suppliers or remote depots as appropriate. The EDGs can use domestic fuel oil if required.

### 5.3.3 Measures Which Can Be Envisaged to Increase Robustness of the Plants in Case of Loss of Primary Ultimate Heat Sink, Combined with Station Blackout

Sellafield Ltd – Sellafield and Windscale

1470 The nature of the Sellafield site is such that station / site blackout is one of the more likely reasons for a challenge to cooling functions in facilities, or an external hazard such as a large earthquake or flood is likely to cause the loss of both essential functions. Therefore, these combinations of events have already effectively been considered above.

Atomic Weapons Establishment

1471 AWE does not have any NPP requiring primary ultimate heat sink. Therefore, AWE's stress tests submission does not address loss of primary ultimate heat sink combined with loss of electrical supplies for the operations at either of AWE's sites.

1472 Therefore, AWE has identified that there are no cliff-edge effects associated with loss of primary ultimate sink combined with loss of power. AWE's stress tests process has shown that no further provisions are necessary to increase the plant robustness in this case.

Rolls-Royce Marine Power Operations Ltd

1473 RRMPOL reports that there are no decay heat removal requirements for the operations at its sites. Therefore measures that may be envisaged to increase robustness of the plants in the case of loss of primary heat sink combined with loss of electrical supplies are not identified in the submission.

BAE Systems Marine Ltd

1474 The robustness of the plant claimed against loss of primary ultimate heat sink and loss of electrical supplies are associated with the submarine provisions. These are designed against the safety requirements and operational duties of the vessel, and are addressed in the submarine safety case. Claims made against the submarine's systems are a matter for the MoD.

Devonport Royal Dockyard Ltd

1475 DRDL indicates that even in the most severe fault conditions considered, an alternative heat sink will be available. DRDL's further consideration of measures which can be envisaged to increase robustness of the plants in case of loss of ultimate heat sink is also relevant to the situation of loss of power and ultimate heat sink.

Rosyth Royal Dockyard Ltd

1476 There is no requirement for an ultimate heat sink, so loss of electrical power has no impact. The robustness of the plant is not an applicable criterion.

NNB GenCo – Hinkley Point C

1477 NNB GenCo is considering the use of portable pumps to optimise the use of diesel fuel on-site in the event of limited plant availability. It is also considering the provision of diverse means of boiler feed.

### 5.3.4 ONR's Assessment of Loss of Primary Ultimate Heat Sink Combined with Station Blackout

Sellafield Ltd – Sellafield and Windscale

1478 ONR is content with Sellafield Ltd's approach of not saying anything additional for loss of primary ultimate heat sink combined with SBO because it is effectively already covered by what the licensee considered for loss of heat sink and SBO when discussed individually.

1479 ONR agrees with the inference within Sellafield Ltd's *Considerations* on the need for the resilience of both power and steam supplies needs to be examined further in particular in relation to HALES. ONR will be monitoring and challenging Sellafield Ltd's actions in response to this *Consideration* in the months ahead.

Atomic Weapons Establishment

1480 ONR's assessment of AWE's stress tests submission is that no operations have been identified where loss of cooling together with loss of electrical power would challenge nuclear safety.

Rolls-Royce Marine Power Operations Ltd

1481 ONR has not identified operations on-site that require heat removal of the form associated in the nuclear power industry with decay heat removal and ultimate heat sink. Therefore, RRMPOL's submission relevant to decay heat removal and provision of ultimate heat sink are judged to be appropriate by ONR.

BAE Systems Marine Ltd

1482 ONR accepts BAESM's case that the submarine internals systems provide the defence against loss of ultimate heat sink and site blackout. The design of the submarine's services is outside the scope of this assessment. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of MoD's conclusions.

Devonport Royal Dockyard Ltd

1483 ONR agrees that for the decay heat levels for which active cooling is required, the submarine systems provide a significant capability to maintain such cooling independent of site cooling water and electrical services.

1484 ONR accepts that at low decay heats, a case has been made that passive cooling by convection / conduction will prevent core damage. This passive cooling does not place demands on electrical supplies. Assessment of this argument is a matter for the MoD.

1485 ONR supports DRDL's further consideration of the measures which can be envisaged to increase robustness of the plant in case of the loss of ultimate heat sink combined with power loss.

1486 Claims made against the submarine's systems are substantiated by MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of MoD's conclusions.

Rosyth Royal Dockyard Ltd

1487 ONR agrees with the RRDL's report that in the absence of a need for a primary ultimate heat sink, loss of electrical power is not relevant with respect to loss of cooling.

NNB GenCo – Hinkley Point C

1488 Since the systems required to provide a heat sink rely on station power supplies, SBO with Loss of heat sink has the same consequences as SBO alone and is addressed in Section 5.1 above.

## 5.4 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

1489 ONR is satisfied with extent and scope of Sellafield Ltd's review of the consequences of and the requirements in the event of loss of cooling and loss of electrical power. Areas where the resilience of site needs to be improved have been clearly identified, and it is self-evident where the priority areas are.

1490 In addition to the *Considerations* identified by Sellafield Ltd, a number of other items have been identified by ONR which will be pursued further with the licensee.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1491 ONR considers that UUK, DSRL and SFL have provided sufficient demonstration that sites are resilient to sustained loss of off-site or on-site generated power without detriment to safe containment of nuclear material. The absence of any requirement for an ultimate heat sink further strengthens this judgement.

Atomic Weapons Establishment

1492 ONR notes that AWE is already pursuing a number of projects to enhance electrical supply integrity for current facilities at AWE (A).

1493 ONR has not identified further requirements for improvements to electrical supply integrity as a result of its assessment of AWE stress tests submission, for either site. ONR supports AWE's current initiative to improve electrical supply integrity as part of the AWE (A) site PSR.

1494 ONR's assessment of AWE's submission is that no operations on-site have been identified that require heat removal of the form normally associated in the nuclear power industry with decay heat removal / ultimate heat sink. Operations have been identified by AWE where controlled cooling on loss of heating could impact on equipment serviceability; however, there are no direct nuclear safety implications.

Rolls-Royce Marine Power Operations Ltd

1495 ONR notes that, in the RRMPOL submission, no operations have been identified on-site that are susceptible to a loss of power incident. However, ONR is of the opinion that the availability of power to key emergency response locations and equipment may have an impact on the ability to respond under some circumstances.

1496 ONR supports RRMPOL's *Considerations* relating to the means of improving the flood resilience of the site's electrical power supplies, and the capability of on-site fuel supplies for the diesel generator to provide back-up to the ECC for extended periods.

1497 ONR supports RRMPOL's further consideration of the need for a holding of health physics instrumentation in a location protected from external events.

1498 ONR recommends that RRMPOL should consider reviewing its strategy for demonstrating the continuing safety of the plant post-incident, including a consideration of power requirements for instrumentation (e.g. criticality detection systems). This item is covered by STF-56.

1499 ONR acknowledges that no operations on the RRMPOL sites require decay heat removal or ultimate heat sink provision.

BAE Systems Marine Ltd

1500 ONR notes that only certain operations on-site can result in generation of fission products and the need for decay heat cooling. The submarine internal systems are designed to meet these demands.

1501 ONR recommends that in claiming the submarine systems and resources, BAESM should consider whether additional measures are required to ensure that suitable submarine systems are always available commensurate with the levels of decay heat, and that resources (including fuel and water) are available on-board and onshore, for replenishment. This item is covered by STF-60.

1502 ONR recommends that BAESM should consider whether further measures are necessary that may improve the availability of electrical power supplies on-site under a full range of fault scenarios. This should include a review of the adequacy of back-up electrical supplies on-site that would support the management and operation of an emergency incident. This item is covered by STF-57.

Devonport Royal Dockyard Ltd

1503 ONR notes that the submission has examined the current DBA, the adequacy of the protection within design basis, and the resilience to beyond design basis events.

1504 ONR notes that, for the events of loss of power and loss of decay heat removal, the robust submarine internal systems remove the need for high availability demands on the shore-based systems. The management systems ensure that the appropriate levels of redundancy and diversity of submarine systems are maintained for the relevant decay heat loadings.

1505 An event that results in relocation of the submarine has been considered, but this could only occur as a result of a very large tsunami and this event is not credible within the English Channel. Even so, DRDL has indicated that the submarine has a variety of resources that could be used to maintain core safety in the short term.

1506 ONR notes that by their very nature, the operations at the docks are vulnerable to changes in sea-levels / conditions. ONR supports the improvements that DRDL has identified to eliminate sources of potential ingress to services; these are proceeding in the current PSR programme, and will be monitored by ONR.

Rosyth Royal Dockyard Ltd

1507 ONR agrees that no safety concerns have been identified in the stress tests that would benefit from additional electrical power generation, and that there is no safety requirement for decay heat removal or an ultimate heat sink. ONR agrees with the RRDL's report that in the absence of a need for a primary ultimate heat sink, loss of electrical power is not relevant with respect to loss of cooling.

1508 RRDL has identified that instrumentation could be vulnerable to common cause external events. RRDL has noted that this instrumentation is common across other nuclear sites and other parts of the Babcock International Group..

Magnox Ltd – Defuelled reactors

1509 At the Magnox defuelled sites there is no requirement for active systems to maintain nuclear safety. At the Hunterston A site, where there is still two fuel element fragments, this situation is unchanged as the thermal output from these fragments is be minimal and no active cooling is required; the storage of these items is covered by the current safety case. ONR agrees with the licensee's position that loss of electrical power and / or loss of heat sink would not present a significant issue on the defuelled Magnox sites.

NNB GenCo – Hinkley Point C

1510 The UK EPR™ design has been informed by existing practice, particularly in the French fleet of reactors, and the design of reactor cooling systems utilises good practice, providing redundant and diverse means of cooling the reactor, the fuel pond and associated equipment.

1511 The design has been demonstrated to be robust against anticipated loss-of-heat-sink faults within the design basis, but the assessment of more severe faults is still continuing within the GDA process. This may result in some modest changes to the design, but is not expected to result in fundamental changes.

1512 Total loss of reactor and containment cooling systems could lead to fuel damage within hours and possibly loss of containment within a few days in the absence of venting. Hence ONR has required NNB GenCo to consider whether any further mitigation measures are reasonably practicable. The process needs to consider the balance of risk associated with any change. An example is containment venting, which potentially reduces the risk of containment failure, but introduces a potential route for fission products to leak from containment. This is the subject of discussion with ONR as part of the licensing process.

# 6 SEVERE ACCIDENT MANAGEMENT

1513 All UK NPGNF carry out DBA and PSA proportionate to the level of hazard associated with each site. The principle of defence-in-depth requires that fault sequences with the potential to lead to a severe accident are analysed and, among other things, provision made to address their consequences. Analysis of severe accident events is generally performed on a best-estimate basis to give realistic guidance on the actions which should be taken in the unlikely event of such an accident occurring. Severe accident analysis may also identify that provision of further plant or equipment for accident management is reasonably practicable. Because of the greater variation in the processes and technologies that may be employed in operation of some of the NPGNF (e.g. fuel cycle facilities), the range of fault scenarios that could potentially lead to severe accident conditions are also likely to be greater than those traditionally considered in NPPs. Therefore, the approach taken by nuclear operators to analysis of severe accidents is varied and is at different levels of maturity.

## 6.1 Organisation and Arrangements of the Licensee to Manage Accidents

### 6.1.1 Organisation of the Licensee to Manage the Accident

Sellafield Ltd – Sellafield and Windscale

1514 Sellafield Ltd has reported that severe accident management is defined in the Sellafield and Windscale sites emergency arrangements – emergency plan and considers this to be compatible with the off-site emergency plan for Sellafield produced by the Cumbria County Council Resilience Unit. Sellafield has also reported that “Command and Control” for all site emergencies and severe accidents is managed at strategic, tactical and operational levels.

1515 Posts and roles essential to the continued safe operation and response to emergencies within each facility on-site, as well as at the Sellafield Emergency Control Centre (SECC), are identified and are staffed by suitably qualified and experienced personnel throughout every 24-hour period. The SECC is permanently manned by the Safety and Site Shift Manager (S&SSM) who has the responsibility for setting up the SECC and notifying the shift team and / or duty Sellafield Emergency Controller (SEC). Local emergency control centres (i.e. incident control centre and ACP) are resourced by plant personnel from the affected facility, who are also trained against role profiles and assessed as SQEP before being appointed to their role. These centres are set up to control actions within the affected area(s) of the facility as well as controlling access / egress. In Sellafield’s current arrangements, a number of facilities share Incident Control Centres (ICC). Sellafield acknowledges that, although this is acceptable for a single facility accident, it may not be practicable in a site-wide event with multiple facilities involved. Sellafield Ltd is therefore reviewing its arrangements to ensure there is sufficient diversity in its command and control infrastructure for responding to an event involving multiple facilities.

1516 Sellafield Ltd has its own dedicated site Fire and Rescue Team (SF&R) who are equipped with breathing apparatus sets and are required to be in attendance for all entries where breathing apparatus is required. Sellafield Ltd has described that all SF&R team members are appropriately trained and their competence is assessed regularly. The SF&R is a rapid response unit, backed by Cumbria Fire and Rescue, and is tasked to respond to site emergencies. Cumbria Fire and Rescue local to the site is manned by “retained” fire crews. This means that there is not a full-time dedicated fire service guaranteed to be available to assist SF&R.

1517 The majority of key plants on Sellafield site rely on SF&R service either to assist them with re-entry into the building following an emergency or to deploy required equipment for provision of cooling or make-up water, cleaning chemical spills and attending to injured personnel and fires. Sellafield Ltd noted that the SF&R current resource profile indicates that the service has the capacity to attend to one incident only. Sellafield Ltd is therefore reviewing its arrangement for SF&R to enhance its capacity, enabling it to respond to events involving multiple plants.

*Use of Off-site Technical Support for Accident Management*

1518 Arrangements exist for operators of other nuclear sites to provide assistance in the event of a site incident or Sellafield emergency. Arrangements for support from both regional and national emergency services, e.g. fire tenders / pumping units, are in place, but require regional and local transport infrastructure to be intact and available for successful deployment. As part of enhancing its resilience to nuclear emergencies, Sellafield Ltd is reviewing staging of these arrangements and liaising with the relevant stakeholders and multi-agency response teams.

*Procedures, Training and Exercises*

1519 Sellafield Ltd has defined prolonged loss of cooling to the HASTs (see Sections 1 and 5) as its “reference accident”. Identification of reference accidents is an approach that some of the multi-facility UK nuclear operators have adopted to define the extent of their detailed off-site emergency planning zone. Sellafield Ltd is currently reviewing the technical basis for emergency planning as part of a drive to enhance its capability to respond to nuclear emergencies.

1520 The site’s emergency arrangements are routinely practised at shift exercises (assessed by the licensee) and annual demonstration exercises (assessed by the regulator, ONR). These exercises include all aspects of the emergency scheme and therefore test both the site’s on- and off-site response, but not necessarily at the same time. Similarly, the site demonstrates its preparedness for responding to security events, transport of radioactive material and (non-nuclear) chemical events to ONR and other regulators. Furthermore, each plant carries out a programme of emergency exercises against a schedule endorsed by the appropriate management safety committee.

*Plans for Strengthening the Site Organisation for Accident Management*

1521 Each of the key posts in Strategic Management Centre (SMC) and the SECC will be manned by nominated day staff who are available throughout the 24-hour period according to a duty roster and who will be called by telephone or pager.

1522 The response time for key decision makers, part of the SECC on-call duty team is one hour. The technical support and back-up staff are expected to respond within three hours. There is no back-up for the duty team other than team members on the duty roster whose availability could not be guaranteed at all times.

Urenco UK Ltd

1523 UUK has acknowledged since publication of its stress tests report the potential for unmitigated criticality exceeding 100mSv beyond the site boundary, hence meeting the criteria for a severe accident defined in SAPs. Criticality is currently considered in the context and subsumed within the on-site and off-site plans. UUK has indicated it is undertaking further analysis of severe accident management and whether its current emergency preparedness is sufficient for this scenario.

1524 UUK and Sellafield Ltd (Capenhurst) have a joint on-site emergency plan that has been approved by ONR, which ensures that suitably qualified and experienced people and suitable facilities and equipment are available at all times to respond to any abnormal events. An off-site emergency plan has also been developed in conjunction with Cheshire West and Chester Council area to deal with potential off-site consequences. Regular exercises are held to demonstrate the adequacy of the arrangements defined in the plan to the satisfaction of both UUK's own observers and ONR, who provide feedback to UUK on collective and individual performance as part of continual improvement. The SECC, and associated facilities and emergency equipment, is maintained, checked and tested on a regular basis. External agencies are involved when the off-site emergency plan is initiated and the Strategic Co-ordination Centre is established. Agencies include the Health Protection Agency, Emergency Services, the Food Standards Agency, the Environment Agency, ONR, the Cabinet Office, and the Department of Energy and Climate Change.

1525 Required emergency response roles are clearly defined within the UUK on- and off-site emergency plans and are allocated to appropriately trained and competent personnel.

1526 Much of the organisation and arrangements for emergencies at UUK have been in place for many years and are subject to periodic review, testing and improvement. The stress tests undertaken by UUK have further examined the resilience of the emergency organisation and arrangements when "stressed" against extreme external events. This has resulted in UUK identifying areas for further consideration to ensure adequate and resilient emergency response provisions are in place.

<u>Dounreay Site Restoration Ltd</u>

1527 DSRL reports that no severe accidents have been identified for the Dounreay site (as defined in the 2006 SAPs). Since 1996 the main focus of the site has been to safely and securely manage ex-reactor material and radioactive waste arisings. DSRL nonetheless notes its commitment to be fully engaged in emergency preparedness. The licensee refers to its emergency plan as the basis for compliance with its legislatory obligations under its nuclear site licence (LC11), IRR and REPPIR.

1528 The licensee has described the key components of its extant emergency plan. Emergency response arrangements are tailored for reasonably foreseeable on-site and off-site incidents implemented via three tiered levels of response:

- Operational – this level has direct control of the incident and the safety of personnel involved.
- Tactical – this level controls the on-site response beyond direct control of the incident.
- Strategic – this level coordinates off-site response.

1529 Each Dounreay facility is managed by an Authority to Operate holder who has responsibility to coordinate planned annual emergency exercises with relevant on-site services. The site has a number of on-site emergency response facilities that support each of the three levels of response, in addition to off-site resource.

- Criticality Evacuation Centres.
- Emergency Radiological Incident Centre.
- ICC.
- Dounreay Emergency Control Centre.
- Strategic Coordinating Centre (Inverness Police HQ).
- Local Authority Emergency Centre.

1530 DSRL reports that all emergency facilities are maintained in a state of readiness, and that each facility has the required equipment and documentation to allow postholders to carry out their duties.

Springfields Fuels Ltd

1531 While there is not the potential for a severe accident on the Springfields site, SFL nonetheless has evaluated the adequacy of existing on-site and off-site emergency plans in the context of REPPIR significant scenarios. SFL considers that its site arrangements, and by inference its organisational structure, are designed to cope with the most onerous accident scenario (site reference accident) that could lead to an off-site release. No specific information is provided by the licensee on how the organisation of operational, tactical and strategic response operates, that is otherwise considered to represent good practice. SFL nevertheless identifies salient aspects of its arrangements as the basis for why it has confidence in its emergency preparedness:

- The site emergency control centre is manned full-time with trained personnel to direct recovery operations and provide communication links.
- The site has a full-time fire and rescue capability with good links to Lancashire Fire and Rescue services enacted through joint site exercises.
- The site occupational health centre is staffed by full-time emergency medical technicians to provide life sustaining support if needed.
- A full-time on-site monitoring team.
- Emergency communications exist to all significant site facilities backed up by a site warning system.

Atomic Weapons Establishment

1532 AWE's assessment has confirmed that (for both licensed sites) the emergency arrangements in place to respond to extreme events that could challenge the containment safety function are well-developed.

1533 Prior to considering these arrangements, it is worth revisiting the claims that AWE makes concerning the nature of reasonably foreseeable severe accidents at its sites arising from extreme external events, including floods, earthquakes, extreme weather and loss of power.

1534 Based on the inland location of its sites, and the absence of large enough water bodies in the vicinity, AWE identifies that DBF events at AWE could only arise from inundation and runoff and that there would be advanced warning and time to respond. AWE explains that DBF events, and more extreme floods, would not lead to a severe accident at either site, even considering additional consequential events (e.g. loss of power). On this basis, AWE concludes that further margins for flood protection are not required.

1535 AWE has identified that there is no potential for a severe accident following a 1 in 10,000-year DBE for three of the four high-hazard facilities at A-site and for the fourth the severe accident criteria would only be exceeded marginally by a "small amount", should there be a consequential fire. For the facility at B-site, AWE estimates that the probability of a seismic event and consequential mechanical impact leading to a severe accident is very low. Beyond the design basis, AWE recognises that the potential damage to the facilities would increase with earthquake intensity but without a step change in radiological release. AWE recognises that coincident events might occur with a severe earthquake, but maintains that these would not cause any escalation of the damage to the facilities.

1536 From the safety cases for major radiological facilities, AWE has determined that extreme weather conditions place less loading on building structures than a seismic event of the same return frequency. In addition, AWE asserts that building collapse with a consequential fire is bounding in terms of dose consequence. AWE has also identified that there is no potential for a reasonably foreseeable severe accident due to extreme weather.

1537 AWE concludes there is no requirement to restore power to facilities to prevent a severe accident and that a failure to restore gas supplies would not lead to a severe accident.

1538 The stated objective of AWE's emergency arrangements is to provide the organisation and infrastructure to implement effective measures to protect persons (both on- and off-site), the environment and property from the consequences of any emergency that may occur. The arrangements provide for escalating categories of emergency to be declared, namely facility emergency, on-site emergency, off-site emergency and radiation emergency. Local response arrangements are set out in facility emergency response plans. The response to site emergencies is detailed in the unclassified SEPs for Aldermaston and Burghfield. The off-site plan is prepared by West Berkshire Council and is publicly available from its website.

1539 This following provides an overview of AWE's accident management measures, based on its stress tests submission, SEPs and the AWE off-site plan.

1540 The SEPs describe the command and control structure for designated SQEP staff to deal with an emergency, command posts for overall incident control, control centres for the site-based emergency services, arrangements to alert, inform and protect persons on-site and to make necessary interventions to restore the site to a safe and stable state, and arrangements to activate the AWE off-site emergency plan if necessary. At both sites, AWE maintains its own 24-hour emergency services, including Police, Fire Rescue and Ambulance services, Medical and Radiation Protection services and the site Safety Shift team.

1541 Operations within facilities at AWE are undertaken on a batch production basis, almost wholly during standard daytime working hours, with nuclear production materials securely stored overnight within the nuclear facilities. The response to accidents in individual facilities are set out in facility emergency response plans, which provide instructions for managing and stabilising design basis faults defined in the facility safety cases. The immediate facility-level response following a seismic event or loss of building services, during normal working hours, is to make safe and evacuate the building. The type and degree of make-safe will depend on the operation being undertaken at the time of the event and the facility services available.

1542 For extreme events, such as a DBE, facility personnel may not be able to carry out post-accident actions if the facility structure is damaged such that it needs to be evacuated to ensure personnel safety. In these situations, AWE reports that incident control would switch to the site-wide response team.

1543 In the event of a site-wide emergency at the AWE (A) site, the Emergency Manager (EM) assumes overall control of the site and manages the response from the Situations Co-ordination Centre (SCC). Within a facility, the facility emergency controller is responsible for managing the response to the incident and for briefing the emergency services and the EM on the situation.

1544 At AWE (A), the Safety Shift team provides 24-hour emergency response capability. The team is led by the shift manager, supported by a senior shift engineer, a watch keep, shift craftspeople and shift patrol staff. Extra staff may be called out in response to an emergency if considered necessary. Outside of normal working hours the shift manager would carry out the duties of the EM and of the facility manager until relieved.

1545 At AWE (B), the Burghfield emergency controller assumes overall control and manages the response to an emergency from the Burghfield Command Post (BCP). During silent hours, shift cover is provided by one senior shift engineer, who acts on behalf of the Burghfield emergency controller until relieved. This is considered adequate by AWE for the levels of operations and hazards at the AWE (B) site during silent hours. The emergency controller is on call to respond within 30 minutes and will be supported by a deputy and a team of scientific, technical and operation staff.

1546 At both sites, a number of support staff and specialist advisers will support the site emergency teams. Members of the team are mustered by a variety of methods and during silent hours by the use of call-out procedures.

1547 If an off-site emergency is declared, the Thames Valley Police will set up the Police Strategic Co-ordination Centre (PSCC), led by a senior police officer, at their HQ in Kiddlington. The PSCC will manage the off-site response, with advice provided by a strategic scientific adviser from AWE (who will attend at the centre). Other external organisations will be represented at the PSCC, as detailed in the SEP.

1548 AWE reports that its radiological protection and assessment resources would be deployed during an emergency to provide detection and measurement of radioactive materials and monitoring and assessment of the radiological consequences. The operational health physics service provides a 24-hour emergency capability to the AWE (A) site and the health physics control room is staffed 24 hours a day by at least one co-ordinator and health physics surveyors, which would provide an initial response, supported by further personnel on an emergency call-in rota. Health physics would also provide advice to the designated hospital concerning dealing with any contaminated casualties, if required. At AWE (B) a health physics team is available for emergency response during working hours, at other times health physics support is supplied from AWE (A). Concerning fire-fighting, the on-site fire service has appropriate dosimetry and respiratory protective equipment to be able to take the appropriate action and any actions taken by them, or other emergency responders, would be subject to health physics evaluation of the potential doses to personnel.

1549 Unlike the emergency arrangements for the UK NPPs, AWE's emergency arrangements do not include provision for additional off-site technical support. For emergencies at AWE (A) the necessary technical support will be provided on-site and co-ordinated from the SCC. For the AWE (B) site, whenever the BCP is activated the SCC at AWE (A) will also be activated and will provide various personnel to support the technical response at the AWE (B) site.

1550 The site response group co-ordinates a programme of emergency training and regular exercises in support of the validation of the facility emergency response plans and SEPs. Emergency response and training exercises are conducted regularly and formally reviewed. Facility emergency controllers are required to take part in at least one exercise per year to retain their role. ONR observes one exercise per year and provides formal feedback with regard to adequacy of the emergency arrangements (under LC11). The local authority is required under REPPIR to test its off-site emergency plan every three years.

Rolls-Royce Marine Power Operations Ltd

1551 RRMPOL reports that there is no defined off-site back-up emergency response coordination location, should its infrastructure be rendered inaccessible or ineffective. This is due to a lack of resilience of the ECC and Bronze Command to flooding, and a lack of resilience of Bronze Command to seismic events. RRMPOL has raised two *Considerations* on improving the resilience of these buildings to flooding.

1552 RRMPOL discusses the challenges associated with a coincident emergency response for both licensed sites and notes that the emergency arrangements are not explicitly set up to deal with this. The licensed sites form part of a wider Rolls-Royce site, and it notes that a seismic event across this wider area would present a significant challenge, because the office buildings on the two sites would be expected to fail for relatively low levels of seismic event. Casualties may include emergency responders. Priorities between nuclear and conventional safety may need to be made, including between the two sites.

BAE Systems Marine Ltd

1553 BAESM describes that it has a nuclear site emergency plan in place. The arrangements are designed to deal with events which, though very unlikely, are reasonably foreseeable. Detailed response plans are designed to be sufficiently scalable to provide the base from which an extended response to more serious events can be developed.

1554 They list the locations for the on-site Nuclear Accident Headquarters, the off-site ECC, the Emergency Monitoring Headquarters (mobile unit) and the on-site Exclusion Zone Reception Centre. BAESM reports that none of these buildings have any capability to withstand environmental hazards, such as a seismic event, beyond that inherent in standard building codes. This means that a significant external hazard is likely to render the buildings unusable for locating the teams responsible for the emergency response.

1555 BAESM has raised a *Consideration* to investigate the hardening of relevant buildings and communications against external hazards and a number of *Considerations* associated with its emergency plan.

1556 BAESM recognises the importance of the ability to communicate after a severe external hazard and has raised a consideration, which in addition to addressing the hardening of buildings, considers the provision of communications equipment that could operate after such events. BAESM has raised a number of *Considerations* which address the effectiveness of personnel intervention.

1557 BAESM also raised a number of *Considerations* which recognise that off-site BAESM personnel may be needed to manage the accident on-site, and that local authority and other specialist technical resources will be off-site and not available for some time.

1558 BAESM has further discussed the approach to the scope and content of future emergency exercises and raised a *Consideration* to review this.

Devonport Royal Dockyard Ltd

1559 DRDL explains it has adequate organisational and management arrangements to respond effectively to the unlikely event of a nuclear emergency. These arrangements are designed to deal with events which, though very unlikely, are reasonably foreseeable. Detailed response plans are designed to be sufficiently scalable to provide the base from which an extended response to more serious events can be developed.

1560 DRDL has described its staffing and shift management arrangements for normal operations in detail. It has joint working and management arrangements, for emergency response, with the naval base.

1561 DRDL recognises the importance of site-wide communications, and notes that they will be progressively compromised by seismic and flooding events and this would degrade the effectiveness of the arrangements. They are looking at enhancing the communication system such that, following postulated events and subsequent system failure, effective communication is maintained.

1562 DRDL reports that the emergency facilities, (Forward Command Post (FCP), Emergency Monitoring Headquarters (EMHQ), Devonport Accident Control Centre (DACC) and Evacuation Zone Reception Centre (EZRC)) enable effective response by emergency personnel.

1563 DRDL notes that there is potential for loss of building function due to a seismic event for the FCPs. DRDL has raised a *Consideration* to examine the advance identification of suitable locations for alternative FCP locations and the identification of alternative personnel.

1564 DRDL describes that the majority of its technical response is made by personnel on-site or on-call to return to site. Additional technical support may be provided by staff on other NNPP sites. This includes technical authority advice on the NRP from Rolls-Royce and MoD. These organisations are based in Derby and Bristol respectively, so may not be affected by the external event that requires the emergency response at Devonport.

1565 In the event of an off-site emergency the Strategic / Gold command centre will be based at Middlemoor in Exeter, and MoD Gold will be led by the Military Coordinating Authority.

1566 DRDL describes that its exercise policy ensures that each aspect of the emergency arrangements is tested against a rolling schedule to reflect the requirements of the LCs and REPPIR. However, DRDL point out that demonstration exercises do not routinely exercise power supply and communications failures or the need to relocate a control centre, nor do exercises contemplate how traumatic consequences would influence accident management – given the additional context of infrastructure and service disruption off-site. DRDL in conjunction with MoD conducts annual tests of site emergency arrangements. In addition, arrangements for the national response are tested on a much larger scale with triennial exercises.

Rosyth Royal Dockyard Ltd

1567 RRDL explains that its emergency arrangements are designed to deal with events which, though very unlikely, are reasonably foreseeable. Emergency plans are designed to be sufficiently scalable to provide the base from which an extended response to more serious events can be developed.

Magnox Ltd – Defuelled reactors

1568 The decommissioning Magnox sites have emergency schemes that are based on those at operating sites such as Wylfa. Each site has an emergency plan that is approved by the Regulator, ONR. Magnox Ltd reports that there will always be an emergency controller plus a small team of other emergency scheme trained people on-site and the remainder of the emergency team members will be available on an emergency call-out rota. The on-site command centres – Main Control Room (MCR), Emergency Control Centre (ECC), ACP and Gatehouse (security lodge) – and off-site support – SCC and Central Emergency Support Centre (CESC) are the same as for any operational power reactor in the UK. There is a demonstration exercise witnessed by ONR at each site annually so that the Regulator can remain confident in the emergency scheme coping with any unanticipated event.

NNB GenCo – Hinkley Point C

1569 NNB GenCo describes within its stress tests submission that they will be developing a robust organisation and emergency arrangements that will be maintained to respond effectively to the unlikely event of an emergency. These arrangements will be based upon those currently employed throughout the UK nuclear industry and in particular those of EDF Energy Nuclear Generation Ltd.

### 6.1.2 Possibility to Use Existing Equipment

Sellafield Ltd – Sellafield and Windscale

*Provisions to Use Mobile Devices*

1570 Sellafield Ltd has reviewed the capability of existing equipment as part of its review of site resilience undertaken following the events at Fukushima. Consistent with the NPP stress tests requirements, it has made no claims on the availability of off-site heavy equipment for 72 hours and light portable equipment for 24 hours.

1571 The emergency procedures for individual plants require that suitable and sufficient equipment (e.g. radiation protection instrumentation, respiratory equipment and protective clothing) are readily available for use in emergency situations. Additional supplies of such equipment are stored at strategic locations throughout the site. Mobile trailers containing emergency equipment are also available if required. The majority of this equipment is located in a designated building on-site. As a result, its availability could be affected if there is no or limited access to this location because of severe damage to site infrastructure. Sellafield Ltd is aware of this limitation and is developing alternative arrangements / locations for storage of central emergency equipment as part of its plan to enhance resilience on-site.

1572 Considerable engineering resource including lifting devices for positioning shielding plates, etc are also available on-site for deployment under the overall control of a centralised “Engineering Services” group on-site. Arrangements are also in place for supply of additional equipment, e.g. air compressors, from off-site suppliers. However, the time to deploy such external equipment will depend on the state of off-site infrastructure.

*Provisions for and Management of Supplies*

1573 The retention of emergency supplies (e.g. fuel for diesel generators and water for provision of emergency cooling etc.) is agreed by the S&SSM in consultation with the dedicated “utilities” operating group on-site. The refuelling service for diesel generators is provided by the utilities’ staff using on-site mobile facilities and bulk fuel supplies. ONR notes that Sellafield Ltd is currently reviewing the resource requirements for undertaking these activities in severe accident conditions.

*Management of Radioactive Releases: Provisions to Limit Them*

1574 There are robust arrangements in place at each of the facilities at Sellafield for managing the radioactive discharges during routine operations, in accordance with conditions attached to the various permits granted by the Environment Agency (England and Wales). These conditions remain applicable during abnormal situations.

1575 In addition to measures preventing / limiting the release of radioactive material resulting from normal operation of the facilities, each plant has systems such as filters and particulate washing mechanisms (part of the ventilation systems) to mitigate such releases in accident conditions.

1576 Sellafield is equipped with a site perimeter monitoring system which provides continuous measurements of radioactivity. The Site Emergency Monitoring Points (SEMP) relay the readings directly to the SECC. These readings, along with any information received from individual plants’ monitoring systems, would provide an initial indication of the scale of any radioactive release. Such initial indication would be confirmed by tactical deployment of the site district monitoring vehicles to facilitate monitoring of the local (off-site) environment. These diverse sources of information would be used by the SECC to decide on the appropriate measures to be taken to limit the impact of the release on the workforce and local population.

1577 The site perimeter monitoring system would be affected by a prolonged site-wide loss of power. UPS and small portable petrol generators would be used to maintain power to a selected number of monitoring points (determined by the SECC). Transmission of information from the site perimeter monitoring system would be secured through UPS back-up systems. The SEMP are powered by adjacent buildings and also reliant on the site data network to transmit information. The SEMP does not have back-up supplies and would be out of service following a prolonged loss of power. Sellafield Ltd has raised a *Consideration* to identify means of extending the availability of the site data network to prolong the period of transmission of data to the SECC.

1578 In the event of an SBO, local plant ventilation and activity monitoring systems will be affected adversely and therefore the reliance on district monitoring vehicles (DMV) would be increased for provision of crucial radioactivity data to enable critical decisions to be made. Because these vehicles are not equipped for significant off-road access or severe winter conditions, a balance would have to be made between the requirement and frequency of on- and off-site information and the supply of diesel and other equipment required to support these services. Guidance for such decisions would be provided through severe accident management strategies.

1579 Provision of continuous weather forecasts (i.e. temperature, wind direction, humidity etc) is crucial for determining the size and direction of an aerial radioactive plume. There is a site weather station, and information from the Met Office is available.

*Communication and Information Systems (Internal and External)*

1580 Sellafield site warning sirens are mounted on a number of masts located across the site and are sounded on declaration of a Sellafield emergency in order to warn the workforce and the general public off-site to take shelter. Sellafield Ltd reported that the site sirens are electrically powered and backed-up by individual UPSs which can provide power for continuous sounding for nearly one day and continued operation in a non-continuous mode for approximately a month. It is also reported that other information can be provided through microphones located in the base of each siren for transmitting additional information if required. No other back-up system is available for the sirens.

1581 A pager system is available for use by the S&SSM to inform members of the emergency teams of the actions they are required to undertake. The system is not currently backed up by UPS and therefore not resilient to an SBO. Other means of communication such as telephones, mobile phones and the alert cascade communication systems would be available but their use is time-constrained by the length of battery back-up time.

1582 There are a number of radio systems employed on-site that enable communication between SECC and various emergency response units. Radio-to-radio communication can be used within a plant but not between plants or with the SECC.

1583 The site telephone network comprises a number of switches but the majority of lines route through a single distribution frame. However, the site uses more than one off-site exchange to ensure maximum resilience. There are a number of telephone exchange switches on-site, all equipped with a battery back-up system which will last for a number of hours but shorter than a 24-hour period. One of these systems is on an EPD board and can be connected to an MDA. Any change to the configuration of the exchange system is reliant on contract resource.

1584 In addition to the above, SECC and the West Cumbria Emergency Control Centres are equipped with the national resilience extranet which is a Cabinet Office sponsored information sharing system. This system is suitably backed up.

1585 Following the events in Fukushima, Sellafield Ltd has identified the need for a review of the current arrangements with regards to the resilience of its communication infrastructure to a potential blackout.

Urenco UK Ltd

1586 The licensee has not offered an explicit conclusion as to the adequacy of on-site communication capability in the event of an emergency. ONR is nevertheless satisfied from recent LC11 compliance inspections that relevant equipment is well maintained and controlled.

Dounreay Site Restoration Ltd

1587 The licensee has not offered an explicit conclusion as to the adequacy of on-site and off-site communication capability in the event of an emergency. DSRL has nonetheless committed to review the effectiveness of on-site communication in an emergency situation. ONR welcomes this commitment and will seek oversight of any changes during the licensee's 2012 Level 1 demonstration exercise and / or LC11 compliance inspections. The following finding is relevant here:

**STF-61: DSRL should review the effectiveness of existing on-site communication arrangements which have not been subject to full evaluation during the stress tests process.**

1588 The licensee has provided sufficient demonstration that electrical supplies are not specifically required to sustain the basis of nuclear safety in the event of a complete power supply to the site or indeed the region; while the licensee indicates the availability of a 415V diesel generator to sustain power to the emergency control centre, its stress tests do not report a view on the capability to transport diesel to the generator in the event of a prolonged power outage.

1589 DSRL has described the extant counter-measures, embedded in its emergency plan, for restricting radioactive releases in the event of an off-site emergency.

Springfields Fuels Ltd

1590 SFL's response indicates the licensee's confidence in emergency preparedness by virtue of existing on-site infrastructure. The licensee has provided sufficient demonstration that electrical supplies are not specifically required to sustain the basis of nuclear safety in the event of a complete power supply failure from its on-site CHPP.

Atomic Weapons Establishment

1591 Unlike some UK NPP sites, AWE does not have dedicated back-up provision of emergency equipment containers located off-site for use in a severe accident. However, AWE's arrangements allow for sharing of equipment and resources across the two sites. Furthermore, AWE has undertaken to consider diverse storage areas for emergency response equipment.

1592 AWE has a number of emergency response vehicles (fire appliances, ambulances and the Forward Control Vehicle) available for use on-site. AWE also has a wide range of emergency and health physics equipment available on-site, including radiological protection equipment, emergency lighting, lifting, shielding, communication equipment, etc.

1593 Containment systems at AWE feature HVAC systems with filters to mitigate the dose consequences of design basis faults. They require a depression to be maintained, which is dependent on electrical supplies. Some containment systems also require an inert atmosphere. High-hazard facilities at both sites use local battery UPS to supply emergency power to facilitate make-safe and evacuation, if required.

1594 For the AWE (B) site, AWE reports that there are standby generators with sufficient on-site fuel to provide local electrical power for emergency response for an extended period.

1595 AWE has provisions and equipment for on-site and off-site monitoring and a radiation protection service to liaise with the off-site PSCC and to provide technical support to inform of advice on countermeasures such as sheltering and evacuation.

1596 The AWE off-site plan states that there is no need and therefore no plans for the issuing for iodide tablets (stable iodine) as they are of no benefit given the nature of the radiological hazard at AWE.

Rolls-Royce Marine Power Operations Ltd

1597 RRMPOL does not present a discussion specifically focused towards describing the existing equipment available to respond to a severe accident. However, its submission does provide information on the back-up diesel generator, criticality and radiation monitoring equipment. The withstand of this equipment is not seen to be significant, therefore RRMPOL has raised a number of *Considerations* to investigate the capability of the diesel generator and the need for holding health physics equipment and PPE in a location not susceptible to external events.

BAE Systems Marine Ltd

1598 BAESM makes the high-level statement that equipment and facilities are permanently in place to enable an emergency to be managed.

Devonport Royal Dockyard Ltd

1599 DRDL reports that it has arrangements within its emergency response for the logistics and resources cell to consider the use and provision of mobile facilities and equipment. The logistics and resources cell is to advise on availability of resources and the relative timescales of supply. If necessary, national civilian and military support will be used. DRDL, in its submission, does not describe the timescales over which off-site resources may be needed.

1600 DRDL explains that the site has large reserves of fuel for generators and cooling water for appropriate systems across the site. Whilst the amounts of diesel fuel and demineralised water are stated (with sufficient stock to support operations for a minimum of 48 hours), its submission does not make an explicit link between quantities and required supplies post a severe accident. However, as an operational naval base, the site has access to huge reserves of diesel fuel coupled with diverse and independently powered means of delivery from boat afloat and land based assets.

1601 DRDL reports that the submarine containment will play a significant role in the management of radioactive releases. This subject is addressed further in Section 6.3 below which discusses maintaining containment integrity. Staff not involved in the emergency response are relocated to shelter stations to minimise their radiation dose. DRDL has detailed plans, shared with the naval base which covers these aspects.

1602 DRDL describes telecommunications equipment across the site and considers the equipment used by the Nuclear Accident Response Organisation to be diverse and to offer redundancy. Nevertheless, DRDL will consider enhancing the communication system to improve resilience.

Rosyth Royal Dockyard Ltd

1603 RRDL states that no special equipment or vehicles are required to respond to a radiological accident on the site.

Magnox Ltd – Defuelled reactors

*Emergency Response Equipment*

1604 Each Magnox site has emergency equipment available on-site. In addition, back-up equipment is stored in beyond design basis containers that are located at a central UK location. The containers are equipped with Command and Control, fire-fighting, reactor cooling and contamination control materials that would aid any site; however, it would take time to transport them to the required location. Following the Fukushima event, Magnox has held a number of workshops in order to optimise the contents of these containers and to review their location. The company has yet to draw final conclusions.

*Stocks*

1605 Magnox can see little requirement at its decommissioning sites for the provision of fuel or other supplies and therefore it has no special arrangements for its management.

*Communications*

1606 Communications are essential as most of the emergency response team is off-site on a call-out rota and there are necessary communications links across the site between command centres, between site and off-site support such as SCC, CESC and the emergency services. Magnox Ltd explains that its telephone systems (landline and mobile) are robust and their routing arrangements are resilient. The company is considering the purchase of satellite phones to support the current arrangements.

NNB GenCo – Hinkley Point C

*Emergency Response Equipment*

1607 NNB GenCo has reported within its stress tests submission that the proposal being considered for Hinkley Point C is to have all necessary equipment in a "hardened facility" which would be near the edge of the site but within the site boundary. Another option is to have emergency mobile devices which are lightweight enough to be brought to the site by air. This would mean that the emergency procedures would not be reliant on road transport facilities which could become unavailable in the event of an extreme incident.

*Stocks*

1608 It is a normal requirement to have sufficient resource by way of stocks of essential consumables on each power station site for it to be able to remain independent of the outside world for at least 24 hours following a reactor trip. This 24-hour time is defined with the assumption that following this period, adequate arrangements can be established for any required essential supplies to be brought to site.

1609 The judgement is that essential stocks can be procured within the 24-hour mission period to replenish the relevant essential systems. However, it is recognised that there would be uncertainties, for example the effect of a severe external hazard on transport and communications infrastructure as well as the detailed arrangements for delivering and offloading the quantities of consumables that may be required.

*Communications*

1610 The substantive design of the communication and information systems for the Hinkley Point C site is still in development. It has been described within the NNB GenCo stress tests submission that there will be three levels of emergency communications equipment with different priorities.

1611 NNB GenCo has reported that the Priority 1 systems (those most replied upon in an emergency) will meet the plant design basis, this will include electrical supply from emergency sources that can be maintained following a loss of grid supplies. They must also perform their function throughout any environmental conditions and be protected against all internal and external hazards.

1612 NNB GenCo has further committed to facilitate reliable contact between the control room and emergency personnel in situations of total loss of electrical power. Therefore a suitable communication system (e.g. sound-powered telephones) will be set up in the plant areas identified as necessary for management of these situations.

### 6.1.3 Evaluation of Factors That May Impede Accident Management and Respective Contingencies

Sellafield Ltd – Sellafield and Windscale

1613 Extensive destruction of the infrastructure caused by a seismic event or flooding would impede access to the site. Under Sellafield Ltd's current arrangements, the duty S&SSM would assume control of the emergency on-site while awaiting the relief teams. However, as discussed in Section 6.1.1, provision of an adequate emergency response to an external event involving more than one facility could quickly overwhelm the SECC and other emergency services on-site. Sellafield Ltd's current emergency arrangements improvement programme includes plans for enhancing its response capability (resource and equipment) for dealing with multiple events.

*Dose, Contamination and Loss of Facilities on-site*

1614 Emergency exposures, defined in REPPIR, are exposures to ionising radiation of individuals involved in responding to emergencies which may be necessary to put emergency plans into effect. In such circumstances, the decision to authorise the emergency exposures to licensee's personnel would be taken by the SEC. Remotely operating equipment for assessment and inspection of affected areas will be used prior to any entry. Ongoing health physics monitoring and use of electronic personal dosimeters will allow response teams to perform a dynamic risk assessment and determine appropriate work practices and levels of PPE required. These measures will ensure that any doses incurred by the intervention personnel are reduced ALARP.

*Habitability of Main and Secondary Control Rooms*

1615 The majority of plant control rooms within the Sellafield site are not specifically designed to be occupied during severe accident conditions and the usual plant response to these events would be to evacuate and then make subsequent re-entries when it is safe to do so through a designated ACP. In addition to the primary and secondary SECC / SMC on-site, a tertiary SECC / SMC is located off-site at Summergrove to provide a diverse emergency control centre should on-site locations become untenable. Both on-site SECC / SMCs are seismically qualified to DBE 0.25g and 0.125g respectively. Following an initial review of its current arrangements, Sellafield Ltd has put forward a *Consideration* regarding hardened and sustainable control structures including plant control rooms as well as on- and off-site emergency control centres. ONR has welcomed this *Consideration* and is engaged with the licensee to ensure a satisfactory outcome is achieved.

*Alternative Facilities for Use during an Emergency*

1616 See paragraph above.

*Accident Management under External Hazard Conditions (Earthquakes, Floods)*

1617 In light of events in Fukushima, the licensee has acknowledged that underpinning assumptions relating to support from off-site emergency services and the ability of local staff to attend the site are questionable. In addition, factors affecting human performance need to be taken into account in order to evaluate the site resilience to severe accident conditions. These aspects will be subject to further assessment by Sellafield Ltd as part of the wider review of the site's accident management strategies and will also need to be considered in responding to HM Chief Inspector's Recommendation IR-24 made in Ref. 2.

*Unavailability of Power Supply*

1618 The effect of prolonged SBO on the site central emergency and communication structure has been discussed in detail in Sections 6.1.2.4 and 5 (in addition to the effects on essential nuclear safety functions discussed in Section 5). Additional services to provide analytical, medical, decontamination and welfare support also are expected to be compromised by damage to on- and off-site infrastructure. Sellafield Ltd is considering a review of resilience of key support services likely to be necessary for ongoing plant control and / or emergency response.

*Potential Failure of Instrumentation*

1619 The availability of instrumentation for provision of information on plant status and control of plant systems is crucial to the successful management of the plant in normal and accident conditions. Sellafield Ltd reports that the current arrangements for provision of nuclear safety-significant data are adequate for design basis accident scenarios.

*Potential Effects from Other Neighbouring Installations at Site*

1620 As discussed in Section 1, Sellafield is a multi-facility site which means that individual plants are faced with potential challenges from the buildings and operations in their vicinity. The effect of design basis accident scenarios on neighbouring plants within the site is considered as part of individual facility safety cases.

1621 In order to deal with the multi-facility nature of Sellafield site, the SECC is responsible for the tactical management of emergencies on-site. The S&SSM and the duty SEC have delegated authority from Head of site to take actions necessary to respond to an incident. These actions include (but are not limited to) liaising with local authorities and invoking the off-site emergency plan. As discussed in Sections 6.1.1 and 6.1.3, there are also a number of ICCs across the site that control actions within the affected areas and support the SECC in the event of an emergency. Sellafield Ltd has embarked on a comprehensive programme of work to enhance the resilience of Sellafield site to accident conditions that are likely to affect multiple plants on-site. ONR is actively monitoring the licensee's progress on delivery of these accident management strategies and the underpinning analysis as part of an ongoing engagement with Sellafield Ltd.

Urenco UK Ltd

1622 UUK's stress tests have not identified any significant specific threats that might impede its accident management capability in the event of a severe accident.

Dounreay Site Restoration Ltd

1623 DSRL's stress tests have not identified any specific threats that might impede its accident management capability in the event of an emergency.

Springfields Fuels Ltd

1624 SFL's stress tests have not identified specific threats that might impede its accident management capability in the event of an emergency.

Atomic Weapons Establishment

1625 In its stress tests response, AWE has considered the potential for extreme external events to disrupt site and facility access and to affect site services, infrastructure, instrumentation and the site emergency response adversely.

1626 AWE's emergency plans describe a call-out system for staff to attend site in the event of a site emergency, or to relieve members of the emergency response team, if required.

1627 AWE reports that the SCC at the AWE (A) site is located away from the main radiological facilities within a hardened building that will withstand a 1 in 1,000-year seismic event. The SCC is on the first floor so its operation would not be affected by flooding. It features a positive pressure ventilation system to protect occupants following a radiological release. AWE has not discussed the seismic, flooding or loss-of-power resilience of the back-up facility should the SCC become inoperable.

1628 At AWE (B), the BCP is acknowledged to be vulnerable to flooding. AWE has not described its seismic resilience within its stress tests response. AWE reports that an alternative command post is available as a fallback to the BCP, but has not described its resilience to a range of hazards, including seismic and flooding.

1629 For both sites, an AWE forward control vehicle could be used as the site control point should the primary and back-up control centres become inoperable. AWE has not elaborated on possible detriments to the emergency response that may arise from this arrangement, or on the resilience of the forward control vehicle to the range of hazards that may compromise it fulfilling this function, following an extreme external event.

1630 An extreme external event has the potential adversely to affect instrumentation linked to plant alarms and monitoring systems within radiological facilities. These systems are monitored remotely by the safety shift during silent hours. AWE has not provided specific information on contingencies against loss of this instrumentation within its stress tests submission.

1631 AWE has indicated that the high-hazard facilities on the AWE (A) site are sufficiently far apart that they would not affect each other following a major external event. AWE considers there to be a low risk of disruption for radiological facilities from the other on-site facilities considered.

Rolls-Royce Marine Power Operations Ltd

1632 RRMPOL presents a high-level discussion. The main issue to arise is the lack of resilience of the ECC and Bronze Commands to flooding, and a lack of resilience of Bronze Commands to seismic event, discussed above (see Section 6.1.1).

1633 The manufacturing plant does not have a control room. Habitability is likely to be dominated by the physical effects of external events such as building failure and flood. Only for a criticality event would a radiological hazard make the relevant building uninhabitable.

1634 There is a separate control room for the Neptune reactor which is adjacent to the reactor hall. Loss of cooling is not a relevant hazard, therefore a reactor accident is not relevant and the habitability of the control room will not be challenged by the resulting radiation hazard.

BAE Systems Marine Ltd

1635 BAESM notes that buildings for use in a site emergency do not have an external hazards withstand capability in excess of that inherent within standard design codes. Should these buildings fail the particular emergency response centre(s) will need relocation. BAESM has raised a *Consideration* specifically to investigate the hardening of relevant buildings and their communications against external hazards.

Devonport Royal Dockyard Ltd

1636 DRDL discusses the implications arising from flooding and seismic events for the way in which they can influence on-site and off-site accident management.

1637 DRDL reports that, in the case of high local dose rates, radioactive contamination or destruction of some facilities, personnel will not be exposed to high levels of radiation, and that the site is fully equipped with trained personnel to deal with such an eventuality.

1638 DRDL explains that the manoeuvring rooms on-board the submarines are continually manned, and that their habitability will not be impaired for any seismic and flooding event.

1639 DRDL describes that at any tidal height greater than or equal to 4.7m (0.4m above cope edge and extreme design basis), water will enter the EMHQ, however the staff can relocate to the DACC or the mobile EMHQ can be deployed. Water is only expected to enter the DACC when levels rise above 10m (5.7m above the cope edge, a water height that DRDL considers inconceivable).

1640 For a seismic event, loss of wired communications systems will result in impaired function of the FCP, though the buildings are judged to remain available up to the DBE. However, DRDL identifies the DACC as potentially collapsing in a magnitude 8 event (this magnitude of seismic event is not related to the DBE in the discussion). DRDL states that the Nuclear Accident Response Organisation can operate from any location which has adequate communication provided, for example the Silver location at Crownhill police station or even the SCC at Middlemoor.

1641 DRDL specifically reports that the scope of its assessment does not address the access problems presented at the waterfront and the diversion of emergency services to a myriad of events off-site. It is then explained that this issue will have a significant bearing upon the management of extreme events.

Rosyth Royal Dockyard Ltd

1642 RRDL reports that there is little potential for extensive destruction of infrastructure, due to the robust design basis withstand of the waste store, the elevation of the site which safeguards against static flooding, and the wide roadway design. RRDL reports that major devastation would require a large tsunami, which is not feasible.

1643 The main topic raised by RRDL is the lack of withstand to external hazards of the ECC which may fail at lower hazard intensities than the radioactive waste store. It is explained by Rosyth Royal Dockyard Ltd that there are no unique facilities provided in the ECC and it could relocate to any other surviving building, including off-site.

1644 RRDL reports that installed radiation monitoring equipment may be rendered unavailable from an external event. In this case standard hand-held portable instrumentation would be sufficient. Stocks of portable instrumentation are held at two separate locations in the event of a major accident. Rosyth Royal Dockyard Ltd notes that the locations are subject to damage from the common cause effects of external events. However, Rosyth Royal Dockyard Ltd describes that replacement instrumentation can be obtained from other Babcock sites or other nuclear establishments.

Magnox Ltd – Defuelled reactors

*Extensive Destruction of Infrastructure or Flooding Around the Installation That Hinders Access to the Site*

1645 There are no operator actions necessary to control or limit radiological release as the facilities are essentially passive safe and therefore Magnox Ltd considers that it is not a significant issue should these sites be islanded by a natural event such as flooding. The greatest issue is removal of casualties should people have been injured in the event. A reduction of, or lack of, personnel on-site in the immediate aftermath of an incident will not result in a dramatic deterioration of the state of the plant.

*Loss of Communication Facilities / Systems*

1646 Magnox Ltd reports that it has robust communications systems that feature diversity and redundancy. They include resilient company-wide area networks, telephones that are wired via independent exchanges, hard-wired telephones and the Nuclear Industry Airwave Service. Access to mobile phones would be available and Magnox is currently considering the provision of some satellite phones.

*Impairment of Work Performance Due to High Local Dose Rates, Radioactive Contamination or Destruction of Facilities on-site*

1647 In all exposure conditions, including accident response, doses to personnel must be below IRR dose limits and must be ALARP. In the event of a major accident the higher REPPIR emergency exposures can be applied to informed volunteers. The role of the Health Physicist in the ECC is to ensure safety of people on-site. Any staff that are not part of the response will be subjected to controls based on dose rate, airborne contamination levels and other hazards, and may be evacuated from site.

1648 The ECC is positioned to minimise the likelihood that it would be damaged in an accident or affected by radiation. It will undergo constant tenability checks and, if necessary, the function of the ECC could be transferred to other locations on-site. Arrangements at the ACP are comparable and should it be necessary an alternative facility could be established. In some extreme instances high radiation levels could make access to the damage scene unachievable. If this were the case then remote access or the installation of the appropriate level of shielding would be required and working time limited. Under conditions of high local dose rates, contamination and destruction the company would rely on the site command and control managing the event with the available resource.

*Impact on the Accessibility and Habitability of the Main and Secondary Control Room; Measures to Be Taken to Avoid or Manage This Situation*

1649 Magnox Ltd reports that at its decommissioning sites there are no operator actions necessary to control or limit radiological releases as the facilities are essentially passive safe. Therefore the inability to access the control room for a period of time (e.g. 24 hours) would not be critical.

*Impact on the Different Premises Used by the Crisis Teams or for Which Access Would Be Necessary for Management of the Accident*

1650 The site emergency control centre depends on only basic materials (e.g. charts and maps) for its essential functions and can be relocated if necessary.

*Feasibility and Effectiveness of Accident Management Measures under the Conditions of External Hazards (Earthquakes, Floods)*

1651 The accident management measures provided at Magnox Ltd sites are intended to be flexible. Identified personnel have high levels of authority to utilise any resources available on and off-site; including technical support and back-up equipment that is located at off-site facilities.

*Unavailability of Power Supply*

1652 No power supplies are necessary to control or limit radiological release at decommissioning Magnox sites as the facilities are essentially passive safe.

*Potential Failure of Instrumentation*

1653 There is no installed instrumentation that is essential to the control of the plant. Portable radiometric instrumentation, which would be used for the assessment of radiological releases, is kept in emergency response vehicles. Replacement of failed instrumentation or alternative monitoring arrangements would be organised through the CESC.

*Potential Effects from the Other Neighbouring Installations at Site*

1654 The decommissioning Magnox sites at Berkeley, Bradwell and Trawsfynydd do not have neighbouring installations and therefore no hazard needs consideration. Decommission Magnox sites at Hinkley Point A and Hunterston A do have nuclear installations as neighbours and they both have arrangements in place to ensure a co-ordinated response to incidents that could affect both sites.

NNB GenCo – Hinkley Point C

*Extensive Destruction of Infrastructure or Flooding Around the Installation That Hinders Access to the Site*

1655 Access to the Hinkley Point sites is normally via a public, single carriageway from Cannington. The station approach road is a single carriageway which first feeds Hinkley Point C before continuing to Hinkley Point A and B.

1656 NNB GenCo has reported that with respect to getting stocks on to site following a seismic event it is evident that road condition may be an issue compounded by any effects of flooding. This could mean that any stocks would need to be flown or shipped in. The ultimate diesel generator stocks can last 24 hours. Beyond 24 hours there are more diesel stocks available on-site but the issue of movement between tanks would require further consideration.

1657 NNB GenCo goes on to say that, to deal with situations of widespread destruction of infrastructure around the facility, NNB GenCo is considering options for lightweight equipment which can be airlifted to the site if necessary.

*Loss of Communication Facilities / Systems*

1658 Communication is a vital component of emergency response. NNB GenCo has described there are various communication systems utilised by EDF Energy and key stakeholders both during normal operations and response to emergencies. It is envisaged that NNB GenCo will employ several methods of communication; these have been detailed in NNB GenCo's stress tests submission.

*Impairment of Work Performance Due to High Local Dose Rates, Radioactive Contamination or Destruction of Facilities on-site*

1659 It is explained within the stress tests submissions that the licensee will have access to robotic equipment which would allow the remote inspection of facilities and some work to be carried out. This would be held at a central location but could be brought to site in the short term following an incident. There will be other back-up emergency equipment, such as generators and pumps. Acceptable options would include keeping the equipment near the site boundary or making it available off-site for airlifting to Hinkley Point C in the short to medium term.

*Impact on the Accessibility and Habitability of the Main and Secondary Control Rooms, Measures to Be Taken to Avoid or Manage This Situation*

1660 In response to this section of the stress tests NNB GenCo has simply reported that in a severe accident situation every effort will be made to ensure that containment is maintained and core melt is prevented. This will limit the probability that a high dose rate would affect the control rooms. NNB GenCo will need to consider this issue during the site design process.

*Impact on the Different Premises Used by the Crisis Teams or for Which Access Would Be Necessary for Management of the Accident*

1661 NNB GenCo has informed ONR that there will be a reserve emergency control centre in the case that the main emergency control centre becomes uninhabitable despite the protection measures taken such as filtered ventilation. Further, the CESC has remote facilities and the ability to take over from the on-site ECC.

*Feasibility and Effectiveness of Accident Management Measures under the Conditions of External Hazards (Earthquakes, Floods)*

1662 NNB GenCo has concluded in its stress tests submission that its accident management procedures will not be impacted by external hazards (earthquake, flood) as the control room is robust to external events. Although it does note that for external events, optimisation of procedures may be necessary with the support of the national crisis organisation.

*Unavailability of Power Supply*

1663 NNB GenCo has reported that in the case of total loss of electrical power (loss of external sources and diesel generators), back-up lighting for the control room of the station and the provision of sufficient information in a severe accident is provided by batteries. A breathable atmosphere for the operating crew is ensured for a period of three days. One of the areas for consideration for further resilience is to extend this period by the provision of a high power mobile emergency generator.

*Potential Failure of Instrumentation*

1664 Within NNB GenCo's stress tests submission the failure of instrumentation has been considered. It is reported that the diagnosis and prognosis of the situation will be made by emergency teams on the basis of the observed parameters that remain available. The crisis team at the CESC will have available technical experts who can discuss and share the diagnosis and prognosis.

*Potential Effects from the Other Neighbouring Installations at Site*

1665 The NNB GenCo report has identified two neighbouring facilities in the locality of the Hinkley Point C site; these are the Hinkley Point A and B sites. There is minimal risk from the Hinkley Point A Magnox power station which is currently being decommissioned and all fuel has been taken off-site. The Hinkley Point B site contains the two operating AGRs. In the event of a severe external hazard it is likely that HPB will undergo the same stresses as Hinkley Point C. NNB GenCo reports that as the reactor designs are different competing demands for external equipment are minimised. Further, NNB GenCo reports that the likely possibility of combined demands on emergency services and the central emergency centre will be included in the exercises to ensure appropriate resources are available. Constant communication between the emergency control centres at each site will be maintained. This will ensure that the effects of any accident with cross site effects can be mitigated effectively (such as an airborne radiological release). The CESC will also monitor these cross-site effects, coordinate action and provide advice to the sites where necessary.

### 6.1.4 Conclusion on the Adequacy of Organisational Issues for Accident Management

<u>Sellafield Ltd – Sellafield and Windscale</u>

1666 Prior to the events at Fukushima, Sellafield Ltd developed a plan to enhance the resilience of Sellafield site to nuclear emergencies and severe accident conditions. The plan covers (but is not limited to) the following aspect of emergency management:

- Review of the nuclear baseline for emergency response teams (including SF&R) with the view to enhance the capability of these teams, enabling them to respond to multiple events and severe accident conditions.
- Review of training needs for all personnel responsible for responding to nuclear emergencies.

- Development of management strategies, guidance, procedures and instructions for responding to severe accident conditions / events affecting multiple facilities on-site and analysis of these accident conditions to underpin these guidance.
- Identification of additional reasonably practicable equipment required for responding to emergencies and development of appropriate procedures for the maintenance and testing of such equipment to ensure their availability and operability.
- Further integration of safety and security and implementation of arrangements to ensure the site can respond to all emergencies regardless of their initiating cause.

1667 Sellafield Ltd has reported these measures will enhance the site resilient to nuclear emergencies and severe accidents. Following the review of its resilience in light of the events in Japan, Sellafield has identified a number of *Considerations* to further improve its current arrangements. The licensee will review of these *Considerations* with the view to implement all reasonably practicable measures.

Urenco UK Ltd

1668 The licensee has not explicitly indicated that there are shortfalls in its organisation to manage a severe accident.

Dounreay Site Restoration Ltd

1669 The licensee has not explicitly indicated that there are shortfalls in their organisation to manage an emergency. Extensive on-site and off-site capabilities already exist to support accident management.

Springfields Fuels Ltd

1670 The licensee has not explicitly indicated that there are shortfalls in its organisation to manage an emergency.

Atomic Weapons Establishment

1671 AWE has identified that accident conditions at its sites do not naturally escalate after the initial event.

1672 AWE concludes that challenging / stretching the emergency response arrangements does not result in a sudden large step change in accident consequence.

1673 AWE concludes that it has well-developed emergency arrangement to respond to extreme external events.

Rolls-Royce Marine Power Operations Ltd

1674 RRMPOL presents overall conclusions which describe that the site's emergency response arrangements do not display high levels of resilience to severe external events. Some emergency response buildings are susceptible to flooding and damage by earthquakes. RRMPOL however is actively pursuing a regeneration programme to replace existing facilities on the manufacturing site with systems and structures that will comply with modern standards. The site power distribution networks are not seismically-qualified or flood-protected and RRMPOL makes no safety claims on their availability. RRMPOL identified *Considerations* for improvement in this area.

1675 RRMPOL's second main conclusion is that its emergency arrangements are not explicitly set up to deal with coincident events on both licensed sites.

BAE Systems Marine Ltd

1676 BAESM has not provided any conclusions specifically for this section of its submission. ONR therefore takes the following information from BAESM overall conclusions.

1677 The emergency arrangements as currently framed assume that an accident scenario will develop progressively, with time for gathering information, decision making and action. However, the scenarios developed by BAESM identify the potential for rapidly occurring accidents which could, in principle, occur before the emergency arrangements can come into effect. BAESM has raised a *Consideration* to study this issue further.

Devonport Royal Dockyard Ltd

1678 DRDL does not present a conclusion for this section of its submission but has described its emergency arrangements which would be implemented in conjunction with MoD who can draw on wider resources to support any accident management situations.

Rosyth Royal Dockyard Ltd

1679 RRDL concludes that the radioactive inventory at Rosyth is sufficiently low that it would not present an immediate significant hazard to the public or the environment, and there would be time to organise and mount an effective response using the designated teams and equipment or other staff and equipment co-opted in.

Magnox Ltd – Defuelled reactors

1680 Magnox Ltd is confident that it has robust arrangements for dealing with any event at any of its decommissioning sites; especially now that they are in a passive safe condition. It has confidence in the extendibility of its arrangements; however, following the Fukushima event they have carried out a detailed review and identified some enhancements. The most significant is a thorough review of the location and contents of the beyond design basis containers. They are working with EDF to optimise the back-up equipment response to a severe accident at a UK site.

NNB GenCo – Hinkley Point C

1681 NNB GenCo is confident that it will have robust arrangements for dealing with any event at a UK EPR™ site.

### 6.1.5 Measures Which Can Be Envisaged to Enhance Accident Management Capabilities

Sellafield Ltd – Sellafield and Windscale

1682 The measures identified by Sellafield Ltd are inextricably linked to its conclusions on the adequacy of measures summarised above, and are given in the preceding sections.

Urenco UK Ltd

1683 The on- and off-site emergency plans are currently being reviewed and updated to take account of the Capenhurst site integration project, which will result in UUK being the sole licensee at the Capenhurst site. UUK is also planning to undertake a further review of the site emergency arrangements to identify any further reasonably practicable enhancements and to identify any cliff-edge effects within the emergency arrangements. UUK reports that its review of its emergency arrangements is broader than the scope identified as part of the NPP stress tests. UUK has reported that any enhancements arising from this review will be considered for implementation on an ALARP basis.

Dounreay Site Restoration Ltd

1684 DSRL's stress tests have not identified any specific shortfall in resilience; ONR is satisfied that sufficient evidence has been provided that the existing Emergency Arrangements would be sufficient for any design basis accident on the site; this conclusion takes due cognisance of recent emergency exercise performance.

1685 DSRL has committed to review further its overall resilience to long-lived events for different scenarios, taking due cognisance of HM Chief Inspector's Final Report Recommendations FR-22 and FR-23. Initial indications are that DSRL is confident it can effectively relocate its contingency arrangements either on-site or off-site should the need arise.

1686 DSRL's interactions with Nuclear Emergency Arrangements Forum (NEAF) are the appropriate mechanism to derive advice and improvement to arrangements where reasonably practicable. The licensee further proposes to review evacuation arrangements and the suitability of existing reception centres in conjunction with Highland Council.

**STF-62: DSRL should coordinate with the Highland Council to review the adequacy of existing local reception centres detailed in its off-site plan.**

Springfields Fuels Ltd

1687 SFL has acknowledged the potential vulnerability of the emergency control centre and fire station to seismic events given that they are not qualified to withstand any particular DBE. The following finding is raised:

**STF-63: Springfields Fuels Ltd should evaluate reasonably practicable structural improvements to its designated emergency control centre, taking into account reasonably foreseeable accidents that may hinder its availability.**

Atomic Weapons Establishment

1688 As part of its response to the stress tests, AWE has identified a number of improvements to the resilience of the site emergency response for consideration; the five *Considerations* are listed in Annex 3.

1689 AWE will respond to its *Considerations* to ONR in a report in June 2012.

1690 ONR has carried out assessments of PSRs for the AWE (A) and AWE (B) sites, in 2010 and 2007, respectively, and is tracking AWE's progress with improvement projects as part of normal regulatory business.

Rolls-Royce Marine Power Operations Ltd

1691 RRMPOL raised eight *Considerations* for the manufacturing site to address in its main conclusions. Most of these are common to the Neptune facility and are directed towards improving the resilience of the site as a whole. Two are directly related to considering improvements to the manufacturing site. These are consideration of improvements to flooding resilience of power supplies and the integrity of gloveboxes, bunds and racking.

1692 RRMPOL raised eight *Considerations* for the Neptune site to address in its main conclusions. Most of these are common to the manufacturing site and are directed towards improving the resilience of the site as a whole. Two are directly related to considering improvements to the Neptune facility. These are consideration of improvements to the resilience of the Neptune portable power generator to flooding and performing further analysis of the Neptune buildings against snow and wind loadings.

BAE Systems Marine Ltd

1693 BAESM has raised a series of *Considerations* which are presented as follows:

- Further analysis to better define the potential size of the threat to the submarine or site. These may be needed to ensure that plans are based on pertinent information.
- Strengthen the link between safety case accident sequences and emergency planning.
- Recognise the potential on-site and off-site environment in which the emergency arrangements are to be used.
- Provide clearer and wider dissemination of the existence, location and use of safety provisions already available. Consider the need for additional provisions.

Devonport Royal Dockyard Ltd

1694 DRDL has raised two *Considerations* to review basic store holdings to ensure sufficient are in place, and to consider improvement of electrical, instrumentation and communications systems.

Rosyth Royal Dockyard Ltd

1695 RRDL has reviewed the following factors to determine whether any additional measures should be considered:

- The availability of sufficient competent resources.
- The availability of effective callout and on-site communications.
- The availability of radiation monitoring instrumentation.
- The ability to contain radioactive materials released from its secondary containment.

1696 RRDL does not identify the need for any enhancements to its accident management capabilities.

Magnox Ltd – Defuelled reactors

1697 Magnox Ltd has held a series of site-based staff workshops following the Fukushima event to consider the robustness of its sites with regard to internal and external hazards. Some possible improvements to accident management capabilities were identified and they are being assessed. If considered appropriate, some of the proposals will be implemented. It is clear that Magnox Ltd, in collaboration with EDF, will be enhancing the contents of beyond design basis containers and they will be relocating some of them to decrease the distance to site.

NNB GenCo – Hinkley Point C

1698 There are 30 potential resilience enhancements listed in NNB GenCo stress tests submission, of which 14 are associated with severe accident management (see Annex 6).

### 6.1.6 ONR's Assessment of the Organisation and Arrangements of the Licensee to Manage Accidents

Sellafield Ltd – Sellafield and Windscale

1699 ONR agrees with the statements provided by Sellafield Ltd on its organisational arrangements to manage nuclear emergencies. ONR notes that, prior to the Fukushima event, Sellafield Ltd had embarked on a programme of work to enhance its arrangements for managing severe accidents. As part of this, the licensee is revising its arrangements to ensure all key emergency response roles are covered as part of duties assigned to individual roles and that enhanced training is provided for those required to respond to nuclear emergencies.

1700 As part of a separate engagement, ONR has identified improvement areas related to SF&R capability to respond to nuclear emergencies. ONR is working with the licensee to ensure that Sellafield Ltd addresses identified shortfalls associated with its fire and rescue service.

1701 Responding to severe events is not currently included in the scope of Sellafield Ltd's training and emergency exercises. However, it is acknowledged that the licensee is accelerating the existing programme for developing severe accident management strategies and the underpinning severe accident analysis. It is also reviewing the site capability to resource response to multiple, domino or beyond design basis events as part of the wider review of the site resilience. ONR recommends that:

**STF-64: Sellafield Ltd should review the severe accident guidelines taking into account improvements to the understanding of severe accident progression, phenomena and the equipment available to mitigate severe accidents (in line with STF-16).**

**STF-65: Sellafield Ltd should develop and rehearse emergency exercise scenarios covering beyond design basis events and severe accident conditions.**

1702 The last finding is consistent with finding STF-16 made in ONR's National Stress Tests Final Report for UK NPPs (Ref. 10).

1703 ONR will continue to monitor the licensee's progress to ensure timely implementation of any reasonably practicable measures identified, either through specific stress tests *Considerations* or through pre-existing improvement programmes.

1704 ONR recognises that there are resources and capabilities across the Sellafield site that may be available during an extreme event to supplement the capability of individual facilities.

1705 ONR welcomes *Considerations* raised by Sellafield Ltd related to:

- review of the endurance of UPS systems;
- deployment of DMVs and whether current provisions are adequate; and
- reliance on external resources for reconfiguration of the telephone network.

1706 In relation to the communication system, ONR's assessment of the licensee's stress tests report shows that Sellafield Ltd has reviewed the resilience of this system to design basis events. In relation to the site sirens, it is ONR's view that further work is required by the licensee to improve availability of the system during design basis natural events. Furthermore, ONR concludes that there is insufficient information related to any manual intervention that may be required to connect and start up the back-up supplies. ONR notes that Sellafield Ltd's stress tests report does not provide information on the resilience of the communication system to beyond design basis events and severe accident conditions. ONR recommends that:

**STF-66: Sellafield Ltd should extend its review of the resilience of the back-up supplies in support of the site data network and assess the resilience of the site communication system to design basis natural events and severe accidents.**

1707 Following the events in Fukushima, Sellafield Ltd has identified the need for a review of the current arrangements with regards to reliance on external resource for re-configuration of the telephone network and in general, for enhancing the communication infrastructure to a potential blackout. ONR welcomes this *Consideration* and recommends that:

**STF-67: Sellafield Ltd should extend its review of availability of external resource and review its in-plant communication systems used by site fire and rescue teams (e.g. radios) to ensure there is compatibility with equipment used by external emergency services, especially at identified radio shielded areas.**

1708 Information on radioactive releases (plume size and direction) is vital to the management of a severe accident. Sellafield Ltd has identified the vulnerability of the SEMP to a prolonged loss of power and raised a *Consideration* to identify means of extending the availability of the site data network to prolong the period of transmission of data from the SEMP to the SECC. ONR acknowledges this *Consideration* and recommends that:

**STF-68: Sellafield Ltd should extend its programme for development of severe accident management strategies to its strategic non-nuclear support facilities to ensure adequate information and support can be provided to the Sellafield emergency control centre in the event of a severe accident.**

1709 Provision of continuous weather forecasts (i.e. temperature, wind direction, humidity etc) is also crucial for determining the size and direction of an aerial radioactive plume. While it is recognised that Met Office data should be available in a prolonged loss of power, transmission and receipt of such information requires power. No additional back-up is currently available for this system. While portable devices can be used to provide some indication of meteorological parameters, their accuracy would be limited and affected by buildings and structure on-site. ONR recommends that:

**STF-69: Given the extent of the Sellafield site and the need for countermeasures on the site in the event of an accident, Sellafield Ltd should employ all reasonably practicable means to ensure weather forecast information can be made available to its emergency control centre / strategic management centre so that timely advice can be provided on-site.**

1710 In addition to these findings, ONR recommends that:

**STF-70: Sellafield Ltd should take cognisance of STF-14 (Ref. 10), and confirm the extent to which resilience enhancements are to be made to existing equipment and systems that are currently installed across the site. Information should be provided on the equipment and systems that may be affected and the nature of the resilience enhancement, including the mobile back-up equipment.**

1711 ONR will continue to monitor progress towards implementation of any reasonably practicable measures identified prior to and following the licensee's resilience evaluation process as part of its ongoing engagement with Sellafield Ltd.

1712 ONR agrees with Sellafield Ltd's summary of its existing emergency and contingency arrangements and factors that may impede their implementation. The challenges to accident management as a result of a seismic event or flood have already been discussed in Sections 2 and 3 of this report. A finding has already been raised in Section 1.4 for Sellafield Ltd to consider further how emergency arrangements would anticipate and adapt to criticality events: STF-21.

1713 ONR agrees with Sellafield Ltd's statement that ongoing health physics monitoring and use of electronic personal dosimeters will allow response teams to perform a dynamic risk assessment and determine appropriate work practices and levels of PPE required. These measures will ensure that any doses incurred by the intervention personnel are reduced to ALARP.

**STF-71: Sellafield Ltd should further assess the availability and operability of electronic personal dosimeters in a prolonged station blackout, in conditions associated with design basis natural events and in severe accidents.**

1714 ONR is actively monitoring Sellafield Ltd's progress in delivering enhanced training for emergency teams including SF&R through regular monthly meetings and targeted inspections.

1715 The loss of instrumentation at Fukushima played a significant role in the sequence of events during the accident in March 2011. Sellafield Ltd has recognised the importance of accurate information in SECC and has identified a number of *Considerations* to improve the current situation. ONR notes that, as an interim measure, Sellafield Ltd is considering implementation of arrangements for provision and update of vital plant information in SECC. This topic is covered by a finding raised earlier in this report: STF-22.

1716 In response to Recommendation IR-22, made in HM Chief Inspector's Final Report (Ref. 2), ONR has requested that all licensees review the provision of on-site emergency control and instrumentation for severe accidents. Sellafield Ltd's response to this Recommendation will be examined by ONR.

1717 In relation to habitability of emergency control centres, ONR notes that while the resilience of these structures to design basis events has been assessed, no information is provided on habitability of these centres in beyond design basis events or whether there are alternative habitable emergency control centres. Prior to the Fukushima event and following the review of its current arrangements, Sellafield Ltd has identified the need to consider the provision of hardened and sustainable control structures, including plant control rooms as well as on- and off-site emergency control centres. ONR is monitoring the licensee's progress to ensure all reasonably practicable provisions are implemented in a timely manner.

1718 ONR concludes that, in view of information provided, Sellafield Ltd has undertaken an adequate review of its resilience to nuclear emergencies but further work may be required to determine the site's resilience to beyond design basis and severe accident events. The licensee's review has identified a number of areas for possible improvements and has raised a *Consideration* to further strengthen its existing arrangements to enable the site to respond to events affecting multiple facilities and severe accidents. These are summarised in the licensee's report. ONR welcomes these but has raised additional recommendations as a finding for further consideration by the licensee. ONR recommends that:

**STF-72: Sellafield Ltd should develop a strategy for incorporating all reasonably practicable measures identified as part of its resilience evaluation process in its programme for enhancing its emergency response capability.**

1719 In doing so, Sellafield Ltd should consider STF-94 raised in the conclusion of this report; it requires the licensee to report on the progress made in addressing the conclusions of the *Considerations* and the ONR findings to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.

1720 Over the past two years, ONR has engaged with Sellafield Ltd to ensure the licensee enhances its emergency arrangements and capabilities to respond to severe accident conditions. ONR will continue to work with the licensee in this area and ensure timely delivery of all reasonably practicable measures identified in licensee's resilience programme.

Urenco UK Ltd

1721 ONR considers that UUK has met the intent and expectations of the stress tests in regard to its review of organisational capability for emergency response and that the licensee's overall response to the stress tests is considered comprehensive and measured. ONR supports UUK as it strives for continual improvement in this area and will engage with UUK through normal regulatory processes to ensure that reasonably practicable measures that could enhance the site's resilience to emergencies are identified and implemented.

Dounreay Site Restoration Ltd

1722 ONR agrees that there is extensive on-site and off-site capability to support accident management. ONR assesses the adequacy of DSRL's organisational preparedness to emergencies during planned emergency exercises and through planned LC11 themed compliance inspections. ONR recognises the licensee's commitment to undertake further work to demonstrate resilience of its contingency arrangements to different scenarios.

1723 ONR welcomes the proactive interactions DSRL has undertaken with NEAF and external bodies, in particular the progress towards addressing HM Chief Inpector's Recommendations IR-22 and IR-23 insofar as is practicable for a site expected to achieve interim end-state before 2030.

**STF-73: DSRL should extend its proposed review of resilience to long-lived events taking due cognisance of the impact of widespread (off-site) disruption to local and national infrastructure, continuing to coordinate with Nuclear Emergency Arrangements Forum.**

1724 ONR is however aware that there is no specific arrangement to secure off-site technical support; this observation must be put into context against the geographically remote location of the site (relative to other UK licensed sites), approximately 120 miles from Inverness.

**STF-74: DSRL should further consider how the site might obtain technical support from the wider industry in the event of a severe accident.**

Springfields Fuels Ltd

1725 ONR agrees that extensive on-site and off-site capability already exists to support accident management at Springfields. ONR assesses the adequacy of SFL's organisational preparedness for emergencies during planned emergency exercises and through planned LC11 themed compliance inspections. ONR recognises the licensee's commitment to undertake further work to demonstrate resilience of its contingency arrangements to different scenarios. ONR welcomes SFL's commitment to review the site's capability to respond should these facilities be compromised.

1726 While not explicitly stated in the licensee's stress tests report, SFL has since demonstrated it has representation on external forums such as NEAF, National Emergency Planning Liaison Group and their subgroups.

Atomic Weapons Establishment

**STF-75: All defence licensees (AWE, RRMPOL, BAESM, DRDL and RRDL) should consider the approach taken by several civilian licensees of using beyond design basis containers that contain a range of equipment and materials that could be beneficial when responding to a beyond design basis accident. This finding is of a similar nature to that raised in ONR's National Stress Tests Final Report for UK NPPs (STF-15).**

1727 ONR notes that within its response to the stress tests, AWE did not provide detailed information concerning the sequential loss of containment barriers, or the expected timeline and sequencing of possible consequential aggravating events, such as building fires, within the bounding fault sequences, for a range of extreme external initiating events. ONR accepts that this type of information is presented within facility safety cases, which also provide estimates of unmitigated and mitigated dose consequences and any requirements placed on the site emergency response organisation, infrastructure and resources. However, a re-examination of individual facility safety cases is beyond the scope of this ONR assessment, which is focused mainly on the stress tests submissions.

1728 In general, ONR considers that AWE has provided an appropriate level of detail concerning its organisational arrangements for emergency response and notes that more detail is provided in the site emergency plans and the AWE off-site plan.

1729 ONR agrees with AWE that there is no benefit from distributing stable iodine as a countermeasure to mitigate off-site dose consequences, given the nature of the radiological hazards at AWE's sites.

1730 ONR concludes that AWE appears to have well-developed organisational arrangements to respond to emergencies at single facilities, arising from extreme external events. On the basis of AWE's stress tests submission, ONR is less confident in the capability of AWE's emergency arrangements to respond to site emergencies arising from extreme external events that affect several facilities simultaneously, and which may include factors that impede accident management, such as those identified by AWE in Section 6.1.3. For example, ONR notes that AWE has not discussed the seismic, flooding or loss-of-power resilience of back-up facilities should the SCC or BCP become inoperable, so it is not possible to assess the resilience of the back-up centres to extreme external events. ONR recommends that:

**STF-76: AWE should reconsider the provision of suitable contingencies in its emergency response to extreme external events if aggravating factors, which may impede accident management, are realised. These factors include impaired road access to both the sites themselves and to individual facilities on-site, loss of availability of co-ordination and control centres and loss of communication.**

1731 ONR notes that AWE is pursuing a number of projects to improve site-wide infrastructure in response to shortfalls identified in the recent site-wide PSR process at AWE (A). These include improvements to the fault tolerance of the site-wide communications network and enhancements to integrity of electrical supplies to high-hazard facilities, and facilities and infrastructure required for the emergency response. AWE has identified further *Considerations* from the stress tests work (see Section 6.1.5) and will present its response to ONR in June 2012. ONR recommends that, as part of its response to the stress tests:

**STF-77: AWE should consider collating requirements placed on the site-wide infrastructure and emergency arrangements by individual facility safety cases and consider the demands that may be placed on the organisation, infrastructure and resources should a response be required at two or more facilities simultaneously, or within the same incident. AWE should consider identifying other factors that may impair the emergency response and develop suitable contingencies to ensure that the logistics of the emergency response are robust.**

1732 AWE's operational strategy at the facility-level following a seismic event or loss of building services, is to make safe and evacuate the building. ONR considers that AWE has not elaborated the on-site and off-site consequences of being unable to "make safe and evacuate" high-hazard facilities in response to extreme external events. ONR recommends that, as part of its response to the stress tests:

**STF-78: AWE should consider reviewing the on-site and off-site dose consequences of being unable to follow its strategy of making safe and evacuating high-hazard facilities in response to extreme external events.**

Rolls-Royce Marine Power Operations Ltd

1733 The submission presented by RRMPOL addresses the existing facilities on the nuclear fuel production licensed site. It does not address in detail the replacement fuel production facilities under the manufacturing site regeneration programme, or the modifications to the Neptune reactor to use a different design of fuel. RRMPOL reports that its findings for the existing facilities will nevertheless be applicable to future developments. It is ONR's current judgement that the manufacturing site regeneration project and modifications to Neptune are unlikely to introduce significant differences into the current assessment. This is because ONR expects any new facilities and modifications to existing facilities would be undertaken to modern standards.

**STF-79: RRMPOL should consider reviewing the stress tests requirements when the manufacturing site regeneration project and modifications to the Neptune facility are sufficiently mature.**

1734 The main points arising from RRMPOL's stress tests submission are the lack of resilience of the ECC and Bronze Commands to flooding and / or seismic events, the lack of a defined off-site back-up emergency response coordination location, the lack of resilience of the site electrical supplies to flooding, and that the emergency arrangements currently apply for an event at a single facility.

1735 RRMPOL has raised eight *Considerations* for the NFPP and eight *Considerations* for the Neptune facility to address these main points. Most of these *Considerations* are directed towards site resilience which is common to both the fuel production plant and the Neptune facility. ONR supports these *Considerations*.

1736 The Bronze Command centres have no formal seismic withstand. However, ONR notes that a *Consideration* for improving the resilience of Bronze Commands to seismic events is not raised. It is recognised that the manufacturing site regeneration project will provide a new Bronze Command facility and that this facility is expected to have improved seismic and flooding resilience.

**STF-80: RRMPOL should consider reviewing the resilience of Bronze Commands to seismic events or propose alternative arrangements.**

1737 RRMPOL reports that it would be particularly challenged by a seismic event affecting the Raynesway site as a whole. The emergency arrangements are not currently set up to deal with coincident events on both licensed sites. ONR considers the variety of *Considerations* made by RRMPOL will assist overall site resilience. However, it should be noted that the two sites are close together and it is reasonable to expect that a seismic event or flooding would be likely to affect both sites at the same time.

**STF-81: RRMPOL should consider reviewing its emergency arrangements for coincident events.**

BAE Systems Marine Ltd

1738 BAESM has a nuclear site emergency plan in place which has been through regulator due process and is regularly exercised in accordance with appropriate regulations. BAESM has raised a number of *Considerations* to improve their arrangements or to investigate additional options. ONR supports the *Considerations* raised but cannot confirm that the list of *Considerations* is appropriately comprehensive. ONR notes that a comprehensive assessment against the NPP stress tests specification requires additional information from the MoD on the severe accident behaviour of the NRP. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1739 ONR noted in its National Stress Tests Final Report for UK NPPs (Ref. 10) that a severe external event could lead to coincident damage to both the nuclear facilities and the emergency response centres. ONR assessment considers that this topic applies for the Barrow site. BAESM reports that none of these buildings have any capability to withstand environmental hazards, such as a seismic event, beyond that inherent in standard building codes. This means that a significant external hazard is likely to render the buildings unusable for locating the teams responsible for the emergency response. BAESM has raised a *Consideration* specifically to investigate the hardening of relevant buildings and communications systems. ONR supports this *Consideration*.

1740 BAESM has discussed the approach to the scope and content of future emergency exercises. This has been addressed by raising a *Consideration* which considers recognising, in the emergency arrangements and emergency plans, the potential environment on-site and off-site in which the arrangements and plans are to be used. ONR supports this *Consideration*.

1741 ONR notes that only brief information is presented on the subject of factors that may impede accident management. This includes the effects of extensive flooding, building collapse, debris across the site, radiation hazards, the need to evacuate the submarine and the unavailability of power supplies. The ability of the site to respond to the level of threat described within the stress tests has not been clarified. A number of these topics depend upon NRP information which is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs. The licensee will subsequently consider any implications on the above factors and a programme of work is planned by ONR to review its position in light of the MoD’s conclusions.

1742 ONR notes that external events could in principle affect a submarine exiting Barrow in the Whalney Channel resulting in, for example, a grounding or collision. Although such events would be outside the licensed site and under the responsibility of the MoD, BAESM may be called upon to provide assistance to ensure nuclear safety is maintained. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD’s conclusions.

<u>Devonport Royal Dockyard Ltd</u>

1743 ONR noted in its National Stress Tests Final Report for UK NPPs (Ref. 10) that a severe external event could lead to coincident damage to both the nuclear facilities and the emergency response centres. These facilities should be capable of operating adequately under conditions appropriate to the accident, and for the duration that they will be required. ONR has assessed that this also applies to the DRDL site. However, DRDL has recognised potential vulnerabilities in this area, and has raised *Considerations* for enhancing communication systems and finding suitable alternative locations for FCPs and additional personnel. ONR supports DRDL's *Considerations*.

1744 ONR notes that DRDL has identified some vulnerability of the FCP to flooding and the potential collapse of the DACC from a seismic event, but has not raised any *Considerations* to address this.

**STF-82: DRDL should consider enhancing the withstand of the forward command posts to flooding and the Devonport accident control centre to seismic events or propose formalised alternative arrangements.**

1745 DRDL reports that personnel will not be exposed to high levels of radiation and that the site is fully equipped and has trained personnel. ONR concurs with DRDL’s view that personnel engaged in mitigation of an accident condition will be under tight control with respect to the accumulation of dose and that the legal requirements for emergency dose exposure will be met. Operations carried out on-board a submarine by Royal Navy personnel are a matter for MoD, which is conducting its own post-Fukushima review.

1746 ONR notes that following a site-wide disruptive event it may be difficult for the site staff to reach the site and provide the necessary support under potentially severe conditions and although DRDL has not provided detail of how these difficulties would be overcome in its submission, it emphasises that initial responses are conducted by 24/7 on-site duty personnel, who are trained to manage the initial stages of a major event.

1747 ONR notes that DRDL's emergency arrangements are shared with the adjacent naval base and therefore in some cases DRDL staff would be required to respond to an emergency where the MoD lead. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions. ONR has full visibility of the conduct of the joint arrangements and the means by which the complexities of the adjacent sites are addressed in the delivery of the emergency arrangements.

Rosyth Royal Dockyard Ltd

1748 ONR considers that the amount and nature of the radioactive materials at Rosyth is such that a severe accident is not possible. This is due to the robust design basis withstand of the radioactive materials store against external hazards and the low-hazard potential of the radioactive material it contains.

1749 ONR notes that the installed radiation monitoring equipment may be rendered unavailable from an external event. In this case standard hand-held portable instrumentation would be obtained from two separate locations on the site. ONR agrees that replacement instrumentation should be readily obtainable from other Babcock sites or other nuclear establishments. ONR considers that enhancements to the organisation and arrangements of RRDL are not required.

Magnox Ltd – Defuelled reactors

1750 Much of the organisation and arrangements to manage accidents has been in place for many years. ONR takes a close interest in every site's emergency scheme, and each site emergency plan is formally approved by the Regulator. Every Magnox Ltd site has an annual demonstration exercise that is witnessed by a team of ONR inspectors; this drives the continuous improvement process. Checks are carried out to ensure that, among other things; suitably qualified and experienced persons operate the facility and fill the emergency scheme roles; all persons are subject to regular training and assessment; on-site and off-site facilities are adequate to deal with an event; and all claimed emergency equipment is regularly tested and maintained.

1751 If a decommissioning Magnox site was subjected to an accident then the hazard is considerably reduced compared to an operational site as it is passively safe as there is no longer any irradiated fuel on the site; however, radioactive waste is still present in vaults. Further, no operator actions are necessary to control or limit radiological release as the facilities are essentially passively safe and therefore lack of site staffing post a serious external event will not result in a dramatic deterioration of the state of the plant. The licensee recognises that the SAGs do not give guidance on how to deal with hazards resulting from waste present in the vaults, nor do they deal with staff welfare issues. As back-up equipment in the beyond design basis containers is likely to be enhanced there will be an impact on the SAGs, consequently, Magnox Ltd will review, update and generally improve the SAGs. In support of these actions, ONR has raised the following finding:

**STF-83: Magnox Ltd should review, update and issue revised severe accident guidelines in the light of changing hazard at decommissioning sites; the guidelines should include human performance / welfare issues and availability of equipment located in beyond design basis containers.**

<u>NNB GenCo – Hinkley Point C</u>

1752 NNB GenCo has reported a number of times in its stress tests submission that emergency equipment, robotic equipment, debris moving equipment and stock would require air or sea transportation onto site if Hinkley Point is made inaccessible due to damage to the roads or flooding of the surrounding area. ONR would like to highlight that vehicles which are required to transport this type of equipment and resources are likely to be unavailable following an extreme event as their priorities will be to support the local population. The response of EDF NGL has been to make equipment airliftable but not to rely on this method of transportation; EDF NGL is considering specialist vehicles and the maintaining of equipment and stocks on-site.

1753 NNB GenCo has explained in its submission that, as the reactor designs at Hinkley Point are different, competing demands for external equipment are minimised in an emergency scenario. Further, NNB GenCo reports that the likely possibility of combined demands on emergency services and the central emergency centre will be included in the exercises to ensure appropriate resources are available. ONR believes that it is likely that following a serious external event both the Hinkley Point B and C sites will require similar equipment, supplies and recourses. As the design progresses ONR will monitor whether sufficient equipment, supplies and resources are available in the location of the Hinkley Point site to meet this demand.

1754 NNB GenCo's responses to the "Impact on the accessibility and habitability of the main and secondary control rooms, measures to be taken to avoid or manage this situation" section appears to be very limited and does not address the stress tests requirements. ONR will work with NNB GenCo to see that this issue is addressed appropriately during the design of the Hinkley Point C site.

1755 NNB GenCo has described within its stress tests submissions that there will have sufficient supplies on-site for at least 24 hours. All currently operating NNPs have supplies on-site for at least 24 hours. ONR has raised a stress tests finding (STF-9) as part of its National Stress Tests Final Report for UK NPPs (Ref. 10) that licensees should investigate the enhancement of essential stocks. As Hinkley Point C is still in the design and construction phase of its life-cycle this finding should be considered as the design progresses.

1756 NNB GenCo has concluded in its stress tests submission that its accident management procedures will not be impacted by external hazards. ONR would like to highlight that this was shown not to be the case post-Fukushima and would recommend that further thought is given to this as the plans for the activities following a severe accident develop.

1757 With regard to the potential failure of instrumentation, NNB GenCo seems to be heavily reliant on the diagnosis and prognosis of the situation made by emergency teams and off-site technical experts. Without further details it is difficult for ONR to comment; however, the availability of such personnel might be limited directly following a severe event.

## 6.2 Accident Management Measures in Place at the Various Stages of a Scenario of Loss of the Cooling Function

<u>Sellafield Ltd – Sellafield and Windscale</u>

1758 The loss of cooling affecting the processes on Sellafield site is discussed in Section 5.2 of this report. ONR's assessment and a recommendation for consideration by Sellafield Ltd is summarised in Section 5.2.2.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1759 There is no requirement for cooling to maintain the basis of nuclear safety at UUK, DSRL and SFL sites. No further consideration is given in this regard.

Magnox Ltd – Defuelled reactors

1760 Magnox Ltd reports in its decommissioning sites stress tests reports that this section is not relevant as the sites are now defuelled.

### 6.2.1 Before Occurrence of First Containment Barrier Damage

Sellafield Ltd – Sellafield and Windscale

1761 This section is not relevant to NPGNF. As noted previously, Sellafield has seven reactors of which the four Calder Hall reactors are out of the scope of this report and have been covered as part of a separate report submitted to ONR. The remaining three reactors are in advanced stages of decommissioning. In broader terms, as described in Section 1.1, all radiological hazards on-site are subject to containment. The nature and levels of containment barriers vary depending on the type of material stored. A summary of these containment barriers relevant to the processes on Sellafield site is provided in Section 1.1.

Atomic Weapons Establishment

1762 As indicated in Section 5, loss of cooling is not considered to present a significant hazard at AWE's licensed sites.

Rolls-Royce Marine Power Operations Ltd

1763 Loss of cooling safety function not applicable to both RRMPOL sites.

BAE Systems Marine Ltd

1764 BAESM notes that criticality accidents can occur quite rapidly after the initiating event. BAESM reports that its emergency arrangements are currently structured around accidents that escalate in severity slowly. Hence BAESM has raised a *Consideration* which states that accidents which present a radiological consequence quickly should be more closely studied and taken into account in its emergency arrangements.

1765 BAESM presents a timeline table which shows how long it could take for a severe accident to develop for a complete loss of all heat sinks on-board the submarine. BAESM has not presented any information on the practicality of the site providing assistance for this scenario with the intent of preventing the accident happening following a site-wide disruptive event. The timescales for the development of a severe accident are the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1766 DRDL reports that the first barrier to fission product release is the high integrity cladding of the fuel itself. In its discussion of decay heat removal systems, which protect the fuel from damage, it does describe a range of engineered duty and standby decay heat removal systems.

Rosyth Royal Dockyard Ltd

1767 The Rosyth site does not use or store irradiated nuclear fuel. There is no decay heat removal requirement at the site. ONR agrees that the loss of cooling function is not a relevant element of the stress tests. Sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4 of the NPP stress tests are therefore not relevant.

NNB GenCo – Hinkley Point C

1768 In the event of loss of normal cooling function, a number of back-up systems are available to maintain cooling. The initial objective is to maintain feed of water to the steam generators and hence to control primary circuit pressure and inventory.

1769 NNB GenCo is considering additional diverse means of doing this using portable fire-fighting equipment.

1770 In the pond area, loss of cooling function will lead to closure of dampers in the ventilation system to limit the spread of vapour and preserve access to adjacent areas where operator action may be necessary to implement back-up cooling arrangements. The thickness of the concrete walls of the fuel storage building is sufficient to maintain adequate radiation shielding in the event of loss of pond water.

### 6.2.2 After Occurrence of First Containment Barrier Damage

Sellafield Ltd – Sellafield and Windscale

1771 See Section 6.2.1.

Atomic Weapons Establishment

1772 As indicated in Section 5, loss of cooling is not considered to present a significant hazard at AWE's licensed sites.

Rolls-Royce Marine Power Operations Ltd

1773 Loss of cooling safety function is not applicable to either RRMPOL site.

BAE Systems Marine Ltd

1774 BAESM briefly describe the containment structures and systems available on the submarine that would apply after the failure of the first barrier. The site response and resilience to maintaining containment has not been presented. Maintaining the integrity of the NRP containment barriers is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1775 DRDL reports that the second barrier to fission product release is the high integrity reactor pressure vessel and fully welded primary circuit. In their discussion of decay heat removal systems and key features of the NRP they do highlight that there are engineered features such as isolation and pressure relief valves and decay heat removal systems which work to maintain the integrity of the primary circuit in faulted conditions. These systems do not rely on the licensee's emergency arrangements for their provision or operation.

Rosyth Royal Dockyard Ltd

1776 The Rosyth site does not use or store irradiated nuclear fuel. There is no decay heat removal requirement at the site. Sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4 do not apply to RRDL.

NNB GenCo – Hinkley Point C

1777 For the UK EPR™, damage to the reactor is prevented by the essential safety functions of reactor trip, shut down and hold down, adequate post-trip cooling and maintaining the containment for the fuel and fission products. The first barrier to fission product release likely to fail is the primary circuit. This can occur either as a result of a defect or deliberate venting of coolant to prevent excessive coolant pressure. In these events, the Emergency Core Cooling System (ECCS) is expected to mitigate the fault and prevent damage to other barriers such as the fuel cladding.

1778 The ECCS comprises equipment from various systems and is designed specifically to mitigate the consequences of the class of faults termed LOCA. The principal protection required following a LOCA is to ensure adequate shutdown margin and provision of adequate core cooling to limit fuel damage, minimise the release of fission products from the fuel cladding and prevent loss of coolable core geometry.

1779 Initially, the safety injection systems take water from the IRWST, although as this is depleted, the pumps are realigned to extract water that collects in the containment sump – effectively creating a closed loop system.

1780 The containment sump is designed with strainers, intended to capture debris entrained into the sump and to prevent this impeding cooling. This system is still the subject of qualification.

1781 In the event of boiling of the spent fuel pond, the active heating and ventilating system will have some capability to prevent pressurisation of the fuel pond building. The design of this system is still the subject of assessment for the UK design.

### 6.2.3 After Failure of the Second Containment Barrier

Sellafield Ltd – Sellafield and Windscale

1782 This section is not relevant to NPGNF. The notion of containment in respect of material and processes on Sellafield site has been discussed in Section 1.1 of this report.

Atomic Weapons Establishment

1783 As indicated in Section 5, loss of cooling is not considered to present a significant hazard at AWE's licensed sites.

Rolls-Royce Marine Power Operations Ltd

1784 Loss of cooling safety function is not applicable to either RRMPOL site.

BAE Systems Marine Ltd

1785 BAESM briefly describes the containment structures and systems available on the submarine that would apply after the failure of the second barrier. The site response and resilience to maintaining containment has not been presented. Maintaining the integrity of the NRP containment barriers is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1786 DRDL reports that after failure of the second containment boundary, the primary circuit, the third barrier to fission product release is submarine primary containment structure. DRDL describes the actions taken to ensure that this primary containment is maintained and made available during maintenance activities.

Rosyth Royal Dockyard Ltd

1787 The Rosyth site does not use or store irradiated nuclear fuel. There is no decay heat removal requirement at the site. ONR agrees that the loss of cooling function is not a relevant element of the stress tests. Sections 6.2.1, 6.2.2, 6.2.3 and 6.2.4 of the NPP stress tests are therefore not relevant.

NNB GenCo – Hinkley Point C

1788 In the event of the start of core uncovery, indications of adverse conditions become apparent in elevated core outlet temperatures. When these are detected, the operator stops attempts to maintain satisfactory core cooling by safety injection and starts to follow severe accident guidance.

1789 The UK EPR™ has passive design provisions to ensure that, in the event of a molten core breaching the reactor pressure vessel, the melt can be collected and spread into a suitable configuration for cooling by water originating in the IRWST.

### 6.2.4 ONR's Assessment of Accident Management Measures in Place at the Various Stages of a Scenario of Loss of the Cooling Function

Sellafield Ltd – Sellafield and Windscale

1790 This topic has been covered in Sections 1.2 and 5.2 of this report.

Atomic Weapons Establishment

1791 As indicated in Section 5, loss of cooling is not considered to present a significant hazard at AWE's licensed sites.

Rolls-Royce Marine Power Operations Ltd

1792 There is no decay heat removal requirement at the sites. ONR agrees that the loss of cooling function is not a relevant element of the stress tests.

BAE Systems Marine Ltd

1793 The loss of heat sink scenario shows that the submarine possesses a number of ways of removing decay heat which are independent of the site and its services. The main issue is managing the submarine systems accordingly under challenging conditions given that a site-wide disruptive event may have occurred. BAESM presents a timeline which shows how long the submarine can remain independent of site assistance prior to a severe accident developing given success (or failure) of on-board decay heat removal. However, the sites ability to meet these timescales given a site-wide disruptive event has not been fully described. A number of the areas of NRP behaviour to explore this further are the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1794 ONR notes that DRDL have given a high-level explanation of the containment barriers and the systems in place for decay heat removal. ONR notes that a complete assessment of the relevant factors requires additional information from the MoD, which is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

1795 The Rosyth site does not use or store irradiated nuclear fuel. There is no decay heat removal requirement at the site. ONR agrees that the loss of cooling function is not a relevant element of the stress tests.

Magnox Ltd – Defuelled reactors

1796 ONR agrees with the licensee that this is not applicable as there is no irradiated fuel on-site that requires cooling. There are small quantities of fissile material present within the waste stored in the vaults but Magnox Ltd calculations confirm that this is insufficient for criticality or heat generation.

NNB GenCo – Hinkley Point C

1797 The UK EPR™ design has explicitly addressed the possibility of a severe accident – leading to fuel damage – in the equipment design and operating documentation. The ECCS system has four-train redundancy and features of the design are intended to significantly reduce the likelihood of core damage compared to previous PWR.

1798 The design is generally acceptable, but there are some detailed issues that are still the subject of assessment. We welcome the review of requirements that NNB GenCo has recently carried out and believe that this has the potential to reduce the vulnerability to common mode failure.

## 6.3 Maintaining the Containment Integrity after Occurrence of Significant Nuclear Matter Damage (up to Nuclear Meltdown)

1799 This item is not relevant to NPGNF, except potential future PWRs operated by NNB GenCo. It has however been kept because it provides technical details allowing the comparison between NPGNF and reactors.

### 6.3.1 Elimination of Nuclear Meltdown in High Pressure

Sellafield Ltd – Sellafield and Windscale

1800 This section is not relevant to processes and operations on Sellafield site.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1801 There is no inventory on UUK, DSRL and SFL sites that could lead to nuclear meltdown.

Atomic Weapons Establishment

1802 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE’s sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1803 A nuclear meltdown is not a reasonably foreseeable fault sequence on either of the RRMPOL sites; therefore this section of the stress tests is not applicable. However, where non fuel melt scenarios are relevant, comments are made.

BAE Systems Marine Ltd

1804 BAESM does not present any information on this phenomenon. Further exploration of this issue would require additional information on the severe accident behaviour of the NRP from the MoD**.** MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1805 DRDL does not present any information on this phenomenon. Further exploration of this issue would require additional information on the severe accident behaviour of the NRP from the MoD**.** MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

1806 RRDL reports that there is no mechanism for producing significant nuclear matter damage that would present a challenge to containment integrity. Therefore this section of the stress tests does not apply.

Magnox Ltd – Defuelled reactors

1807 Not applicable as there is no irradiated fuel on-site.

NNB GenCo – Hinkley Point C

1808 In the event of the core-outlet thermocouples indicating fuel uncovery, the primary circuit is manually depressurised either via a dedicated set of blow-down valves or by manual operation of the normal relief valves. This ensures that the risk of high-pressure melt ejection is minimal. This does not preclude earlier depressurisation to permit injection of water from passive sources, but after indications of core uncovery, the emphasis changes from maintenance of fuel integrity to preservation of the containment.

### 6.3.2 Management of Explosive Risks Inside the Containment

Sellafield Ltd – Sellafield and Windscale

1809 Management of hydrogen risks inside containment in various plants on the Sellafield site is discussed in Sections 1.1 and 5.1 of this report. For the Magnox swarf storage silo, measures identified as safety systems provide additional ventilation capability for a number of hours. As a result, the availability of these safety measures (e.g. back-up generators along with sufficient fuel supplies) in a prolonged loss of power is key for control of a hydrogen-enriched, potentially explosive atmosphere. Other mitigating measures, such as natural ventilation and flushing the hydrogen-enriched atmosphere with inerting gases, can be employed but the effectiveness of these measures has not been trialled on the facility. Sellafield Ltd has identified the need for a review to determine the effectiveness of these measures through modelling.

1810 In relation to HALES, emergency measures to prevent creation of an explosive atmosphere rely on availability of steam generation capability and ultimately on power supplies. This has been discussed in Section 5.3.

Urenco UK Ltd

1811 There is no material at the UUK site that has the propensity to undergo significant explosion.

Dounreay Site Restoration Ltd

1812 The shaft and silo facilities at Dounreay have the potential to generate small amounts of hydrogen, but installed gas analysers provide DSRL with confidence that these quantities are insignificant. Inert gas supplies are installed and maintained to provide purge capability should it be needed. Residual sodium and NaK coolant within the PFR and DFR reactors do not pose an explosion hazard but must be retained in an inert atmosphere to prevent ignition given their respective volatilities when exposed to oxygen.

Springfields Fuels Ltd

1813 ONR is aware that certain facilities on the Springfields site require the use of hydrogen gas (stored external to the buildings in gas cylinders at high pressure) to facilitate various furnace type drying operations, but these are more appropriately considered as an external hazard rather than intrinsic to the containment itself. The external hydrogen hazard is considered further under Section 6.3.10 of this report.

Atomic Weapons Establishment

1814 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1815 ONR considers this accident phenomenon does not apply to the RRMPOL sites.

BAE Systems Marine Ltd

1816 BAESM is not in a position to provide detailed discussion on the consequences from a hydrogen detonation and deflagration. The primary containment is designed and constructed to meet the pressure demand from the maximum postulated hydrogen burn. Testing of the primary containment boundary is undertaken to provide confidence in containment performance. Further exploration of this issue would require additional information from the MoD on the severe accident behaviour of the NRP. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1817 DRDL reports that the primary containment is designed and constructed to meet the pressure demand from the maximum postulated hydrogen burn. Testing of the primary containment boundary is undertaken to provide confidence in containment performance. However, DRDL is not in a position to provide discussion on the consequences from a hydrogen detonation and deflagration. Further exploration of this issue would require additional information from the MoD on the severe accident behaviour of the NRP. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

1818 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1819 Hydrogen is produced in the Magnox vaults and could build up, potentially giving rise to an explosion, this is normally managed / removed via vault ventilation systems. If ventilation were lost to the vaults, then operators must restore ventilation or remove the vault plugs to prevent the hydrogen concentration reaching the LFL. The vaults are passively safe with the vault plugs removed.

NNB GenCo – Hinkley Point C

1820 The design of the pressure vessel compartment includes a dry well. This is intended to prevent direct contact between molten fuel and water in the event that material from a molten core caused vessel failure. This minimises the risk of explosive vapour generation.

1821 In the event of hydrogen being released into the containment building, passive hydrogen recombiners limit the global hydrogen concentration to levels well below those at which a deflagration could occur. Local levels can exceed combustible concentrations in severe accidents, but this is limited by measures promoting gas mixing within the containment building. These include a system of rupture foils and dampers, which are designed to passively open in the event of a severe accident. Analysis has indicated that hydrogen combustion is unlikely to threaten containment integrity.

1822 NNB GenCo is considering whether further mitigation is reasonably practical.

1823 NNB GenCo is considering the measures required to prevent unacceptable accumulation of hydrogen in the fuel ponds In the event of loss of forced ventilation.

### 6.3.3 Prevention of Overpressure of the Containment

Sellafield Ltd – Sellafield and Windscale

1824 This section is covered as part of the discussion presented in Section 6.3.2 on creation of an explosive atmosphere. Whilst Sellafield Ltd has not provided information on the full range of faults that could result in an overpressure, the consequences of these fault scenarios are bound by those it has reported in its stress tests report.

Urenco UK Ltd

1825 During the feed of uranium hexafluoride, heating is required to facilitate transfer in the gaseous state. In the event of over-temperature, fail-safe trips would initiate to shut heating off; those trips do not require sustained electrical power to deliver their safety functions.

Dounreay Site Restoration Ltd

1826 There is no inventory on the Dounreay site that could lead to containment overpressure. Containment systems that do exist on the site are provided to mitigate the effects of a release of liquid metal coolant; containment in this context is differentiated from that of a gas or water cooled reactor as there is no requirement for overpressure withstand. Glove box containment is achieved through depressions maintained by ventilation systems, but there are no inventories that could energetically drive a release of contamination.

Springfields Fuels Ltd

1827 As previously indicated in Section 6.3.2, the effect of external hydrogen storage on the potential to disperse uranic material is considered further in Section 6.3.10 of this report.

Atomic Weapons Establishment

1828 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered as relevant to loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1829 Although not discussed by RRMPOL a criticality could produce an overpressure in a glove box. The preventative measures for this are the criticality controls in place for the chemical plant on the manufacturing site. RRMPOL's research reactor is not a pressurised system, so this element of the stress does not apply to the Neptune reactor.

BAE Systems Marine Ltd

1830 This aspect of severe accident management is not discussed by BAESM. Containment is designed to withstand the pressures resulting from a severe accident. Operating rules and restrictions are in place to ensure containment integrity is appropriate to NRP state and for ensuring watertight integrity.

Devonport Royal Dockyard Ltd

1831 DRDL reports that the containment is designed to withstand the pressures resulting from a severe accident. Operating rules and restrictions are in place to ensure containment integrity is appropriate to NRP state and for ensuring watertight integrity.

Rosyth Royal Dockyard Ltd

1832 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1833 Not applicable as there is no irradiated fuel on-site and Magnox reactors do not have containment buildings.

NNB GenCo – Hinkley Point C

1834 The UK EPR™ is designed with sufficient containment strength to withstand design basis faults for up to 12 hours without the need for active containment cooling. However, the design includes containment sprays, which can be used to reduce the containment pressure in the event of a severe accident. The containment cooling system is designed with redundant trains of coolers and is intended to remove the need for containment venting in cases where power supplies are available.

1835 The use of a portable diesel fire pump to spray water through the containment spray system has the potential to extend the grace period to five days. In this time, alternative electrical supplies need to be established using a portable diesel generator, or the installed supplies re-established. See Section 5.1 above.

1836 ONR notes that NNB GenCo is currently considering the feasibility of installing containment venting capability; this capability could be provided by installing a filtered containment vent.

### 6.3.4 Prevention of Re-Criticality

Sellafield Ltd – Sellafield and Windscale

1837 Reactivity control and prevention of criticality is discussed in Section 1.1.2 of this report. In addition to the information reported in that section, Sellafield Ltd has identified the need to consider provision of neutron poison material for emergency deployment and storage, local to vessels containing fissile material to prevent criticality if these vessels fail.

Urenco UK Ltd

1838 Although UUK does not specifically report on the credibility of a recurring criticality incident on the site, UUK indicated a revisit to the means of retaining sub-criticality post-seismic events as part of the next PSRs for each plant; accordingly ONR has sought and received commitment from the licensee that this includes the credibility of recurring criticality.

**STF-84: Urenco UK Ltd should review its existing emergency plans to ensure that, in relation to the response to a criticality accident, the plans incorporate further details to support: the principle of extendibility for off-site response and control of reactivity through the use of neutron poisons.**

Dounreay Site Restoration Ltd

1839 DSRL indicates that repeating criticality events can occur with fissile material in liquid form. This type of event should not occur with fissile material in solid form. One facility at Dounreay has fissile material in uranyl nitrate liquid solution form. This liquor is presently safely stored in safe geometry slab tanks. At least one of these slab tanks contains enough fissile material for criticality if the liquor was in spherical geometry. There is theoretically therefore the potential for a repeating criticality event. DSRL emphasises that such an event is extremely unlikely. A repeating criticality event in that facility is the dominant scenario upon which the DSRL criticality evacuation plans are determined. DSRL has confirmed that it has in stock suitable neutron poisons, the deployment of which is considered in its emergency plans. This scenario was recently reviewed as part of the Dounreay modification report to relocate the site’s eastern Criticality Evacuation Centre.

Springfields Fuels Ltd

1840 SFL does not report on the credibility of a recurring criticality incident on the site; a recurring criticality cannot be deterministically dismissed altogether.

**STF-85: Springfields Fuels Ltd should consider whether the securing of neutron poisons is a reasonably practicable improvement to emergency preparedness following a repeating criticality incident.**

Atomic Weapons Establishment

1841 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE’s sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1842 RRMPOL reports that if a criticality occurred at the NFPP licensed site which did not disperse the fissile material, a pulsing mode could develop which gives rise to multiple criticality events.

RRMPOL has raised *Considerations* for holding a stock of neutron poisons and reviewing the means of safely accessing the site and deploying the material in the event of a severe accident.

1843 RRMPOL describes that at the Neptune Reactor licensed site, the accident phenomenon of re-criticality arising from melting of the fuel does not apply to the Neptune reactor.

BAE Systems Marine Ltd

1844 This aspect of severe accident management is not discussed by BAESM. Exploration of this issue would require additional information on the severe accident performance of the NRP from the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1845 DRDL reports that it would be difficult to achieve a re-criticality following a reactor accident and that there will not be a major uncontrolled release of energy. Any further exploration of this issue would require additional information on the severe accident performance of the NRP from the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

1846 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1847 Not applicable as there is no irradiated fuel on-site. There are small quantities of fissile material present within the waste stored in the vaults but Magnox Ltd calculations confirm that this is insufficient for criticality or heat generation.

NNB GenCo – Hinkley Point C

1848 In the event of a severe accident in containment, safety injection and corium cooling would utilise water from the IRWST. This water is heavily borated to a level where any configuration of intact fuel assemblies can be accommodated without risk of criticality. Damage to the fuel is expected to reduce the reactivity of the material by resulting in a higher fuel-to-moderator ratio. The extensive use of fresh water can be discounted.

1849 Accidents in the fuel pond may result in the injection of water from external sources. The design of the fuel storage racks is such that even in a freshwater environment, adequate safety margin is preserved.

1850 Studies have demonstrated that the loss of normal fuel geometry is likely to increase fuel-to-moderator ratio and hence to reduce the reactivity of the material so that the risk of recriticality in the event of a degraded core is minimal.

### 6.3.5 Prevention of Basemat Melt Through

Sellafield Ltd – Sellafield and Windscale

1851 This section is not relevant to operations and processes on Sellafield site.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1852 There is no inventory on UUK, DSRL and SFL sites that could lead to a basemat melt through.

Atomic Weapons Establishment

1853 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1854 This accident phenomenon does not apply to the RRMPOL sites.

BAE Systems Marine Ltd

1855 Maintaining the integrity of the NRP containment barriers is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1856 DRDL has not commented in this area, advising that this is an area of MoD responsibility.

Rosyth Royal Dockyard Ltd

1857 Not applicable for RRDL, see Section 6.3.1

Magnox Ltd – Defuelled reactors

1858 Not applicable as there is no irradiated fuel on-site.

NNB GenCo – Hinkley Point C

1859 The UK EPR™ is designed with an engineered corium spreading cavity. Should molten material escape the core, it will form a suitable configuration where it can be passively cooled by water falling from the IRWST. This will effectively prevent basemat attack for as long as the containment temperatures remain tolerable.

### 6.3.6 Need for and Supply of Electrical AC and DC Power and Compressed Air to Equipment Used for Protecting Containment Integrity

Sellafield Ltd – Sellafield and Windscale

1860 See Section 5 for further information.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1861 There is no inventory on UUK, DSRL and SFL sites that would require electrical power supply or compressed air for protecting containment integrity.

Atomic Weapons Establishment

1862 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1863 While RRMPOL describes its power supply systems, compressed air and ventilation systems in its submission, but it is apparent that it is not required for containment integrity.

<u>BAE Systems Marine Ltd</u>

1864 BAESM does not discuss the need for electrical power, compressed air and hydraulic system to maintain containment integrity for the NRP. Submarines are fitted with automatic containment systems that, once initiated require structural and mechanical integrity, but do not require electrical power or air to maintain their integrity. Individual containment valves are backed by small local accumulators which can be manually operated. Manual containment isolation valves are also available.

<u>Devonport Royal Dockyard Ltd</u>

1865 DRDL reports that the containment on the submarines is passive; once initiated, it requires no power supply (electricity or air) to maintain. Containment is initiated by use of hydraulic systems backed-up by small gas charged accumulators dedicated to the operation of individual containment valves. A maintained 24V supply initiates shutting of containment valves but this can also be accomplished by manual operation of hydraulic actuators (hydel operation). In addition, manual isolation valves are available. The complete loss of electrical supplies on an operational submarine will place the plant automatically into its passive emergency cooling mode and initiate containment without the need for any electrical or pneumatic charge.

<u>Rosyth Royal Dockyard Ltd</u>

1866 Not applicable for RRDL, see Section 6.3.1.

<u>Magnox Ltd – Defuelled reactors</u>

1867 Not applicable as there is no irradiated fuel and no containment building.

<u>NNB GenCo – Hinkley Point C</u>

1868 Long term, the containment cooling requires electrical power from the installed diesel generators to operate the containment sprays and to ensure adequate subcooling of water in the IRWST and the containment sump.

### 6.3.7 Measuring and Control Instrumentation Needed for Protecting Containment Integrity

<u>Sellafield Ltd – Sellafield and Windscale</u>

1869 Measurement devices and control instrumentation provide information on essential safety functions and therefore vary in the parameters they measure. Sellafield Ltd has provided a summary of plants and their safety functions and parameters being measured / controlled in the Sellafield Ltd's stress tests report.

<u>Urenco UK Ltd</u>

1870 During the feed of uranium hexafluoride, heating is required to facilitate transfer in the gaseous state. In the event of over-temperature, fail-safe trips would initiate to shut heating off; those trips do not require sustained electrical power to deliver their safety functions.

<u>Dounreay Site Restoration Ltd and Springfields Fuels Ltd</u>

1871 There is no inventory on the sites that specifically requires control instrumentation to protect containment integrity.

Atomic Weapons Establishment

1872 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1873 RRMPOL describes its measurement and control instrumentation systems and reports that they are not needed to maintain containment integrity in the facilities on both sites.

BAE Systems Marine Ltd

1874 The role of measurement and control instrumentation, if any, is not discussed by BAESM. There is no demand upon any measurement or control instrumentation for protecting containment. The response of the containment once initiated is entirely passive.

Devonport Royal Dockyard Ltd

1875 DRDL reports that there is no demand upon any measurement or control instrumentation for protecting containment. The response of the containment once initiated is entirely passive.

Rosyth Royal Dockyard Ltd

1876 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1877 Not applicable as there is no irradiated fuel and no containment building.

NNB GenCo – Hinkley Point C

1878 Battery-backed essential AC and DC systems have a minimum autonomy period of 12 hours. NNB GenCo indicates that consideration is to be given to providing additional means to repower electrical supplies for equipment needed in severe accidents.

### 6.3.8 Capability for Severe Accident Management in Case of Simultaneous Nuclear Meltdown Accidents at Different Units on the Same Site

Sellafield Ltd – Sellafield and Windscale

1879 Nuclear meltdown is a phrase used to describe severe damage caused to the core of a nuclear reactor caused by overheating of the core (e.g. resulting from LOCAs) and does not apply to operations and processes on Sellafield site or other NPGNF facilities. Irradiated fuel is stored in a number of ponds on Sellafield site. The ponds are water-retaining structures that provide coverage for the nuclear fuel, preventing the temperature increases that could in turn result in fuel fires. Pond water also provides a shielding function from direct exposure or from scattered radiation (radiation shine). However, this is only of relevance to workers on-site.

1880 As discussed earlier in this report, if the ponds retain their structural integrity following a severe event, they are not expected to pose a significant threat to safety, both on and off-site. Measures have been identified to deal with some level of damage and cracks to the various ponds around the site; however, it is recognised that simultaneous damage to the ponds caused by a severe accident would overwhelm the emergency response capability in Sellafield site. The effect of extreme events on multiple facilities on-site has been discussed in detail in Sections 5, 6.1 and 6.2 of this report.

Atomic Weapons Establishment

1881 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1882 Due to the nature of the hazards on-site, core meltdown is not a feasible fault sequence; therefore this section is not relevant to RRMPOL.

BAE Systems Marine Ltd

1883 BAESM reports there will only be one reactor capable of operating at power at any time on the site. Hence, multiple reactor accidents are not therefore possible at the BAESM site.

Devonport Royal Dockyard Ltd

1884 DRDL does not provide any information about simultaneous meltdowns in its submission.

Rosyth Royal Dockyard Ltd

1885 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1886 Not applicable as there is no irradiated fuel on these sites and therefore it is impossible to have a nuclear meltdown accident.

NNB GenCo – Hinkley Point C

1887 The proposal is to build two UK EPR™s on the Hinkley site. However, this is not formally justified as part of the generic safety submission currently under assessment as part of GDA and will be the subject of a site-specific assessment.

1888 The provision of emergency response for sites with multiple reactors is part of EDF arrangements at a number of sites. Similar arrangements are expected to apply.

### 6.3.9 Conclusion on the Adequacy of Severe Accident Management Systems for Protection of Containment Integrity

Sellafield Ltd – Sellafield and Windscale

1889 Accumulation of hydrogen can lead to creation of an explosive atmosphere, damage to the containment structure and a subsequent loss of containment through leakage as well as aerial release of radioactivity. This topic is covered in Section 6.3.2 of this report and therefore not considered further in this section. Sellafield Ltd has identified a number of *Considerations* related to containment integrity which are detailed in Sellafield Ltd's stress tests report.

1890 Assessment of containment damage caused by seismic events is covered in Section 2.2.1 and is not repeated here.

Atomic Weapons Establishment

1891 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by

AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1892 RRMPOL presents information on the "confinement challenge" and explains that only a very small release of radioactive material could arise even if complete collapse, flooding or an engulfing fire occurred.

BAE Systems Marine Ltd

1893 BAESM has not provided any conclusions specifically for this section of its submission.

Devonport Royal Dockyard Ltd

1894 DRDL does not present a conclusion specifically for this section of its submission.

Rosyth Royal Dockyard Ltd

1895 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1896 Not applicable as these decommissioning Magnox sites do not have containment buildings. Even if they did, the problem would not exist as there is no longer any irradiated fuel on the sites.

NNB GenCo – Hinkley Point C

1897 The design of the containment and the operation of the plant are intended to reduce the likelihood of containment failure and improve the cooling of fuel debris in the event of a severe accident.

1898 There are a number of specific issues which will continue to be addressed as part of the remainder of the design assessment and during detailed design. These issues may result in detailed changes to the design, but are not expected to substantially affect the design.

### 6.3.10 Measures Which Can Be Envisaged to Enhance Capability to Maintain Containment Integrity after Occurrence of Severe Nuclear Matters Damage

Sellafield Ltd – Sellafield and Windscale

1899 Section 1.2 of this report provides a summary of the main safety functions, including containment of nuclear material. Sellafield Ltd has reported that a number of legacy facilities and equipment supporting the critical safety functions in these facilities would not withstand an extreme seismic event or an SBO. In light of this, Sellafield Ltd has considered the need to review the robustness of alternative power supplies to ensure availability and operability of containment repair kits following a severe seismic event or an event that could lead to a significant damage to these legacy facilities. Sellafield Ltd has raised a further *Consideration* for identifying practical means for safe deployment of fixative agents following failure of containment in the event of such emergencies.

1900 ONR's assessment of the licensee's resilience to seismic events is summarised in Section 2 of this report.

Atomic Weapons Establishment

1901 Due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1902 RRMPOL presents information on the "shielding challenge" following a criticality event in the manufacturing plant. If a criticality accident occurred, RRMPOL reports that there is the potential for an off-site direct radiation hazard at the closest point of public access. As a result of the last PSR, RRMPOL introduced a polythene shield wall into the appropriate part of the facility which would reduce the direct radiation hazard off-site by approximately a factor of seven to a low value.

1903 This shield wall is most effective from a process fault in which the building structure is not challenged. This is because the shield wall is not seismically qualified. RRMPOL argues that after a seismic event the public are not likely to be walking in the affected area. The option of seismically qualifying the shield wall is not discussed by RRMPOL.

1904 For the Neptune site, RRMPOL reports that loss of shielding of the reactor would not occur as a result of flooding or design basis seismic event, including in combination. RRMPOL also argues that beyond design basis seismic events would not cause a cliff-edge effect but a progressive failure of the reactor hall walls as loadings increase. However, reactor shut down which reduces the dose rates should have been accomplished before the loss of shielding.

BAE Systems Marine Ltd

1905 BAESM has raised a number of *Considerations* to review its emergency response. Maintaining the integrity of the NRP containment barriers is the responsibility of the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1906 No information is presented by DRDL in its submission, which describes that this is a matter for the MoD. However, it is recognised that the existence of the secondary containment boundary (the submarines pressure hull) provides further protection against the release of radioactive material although no claims are made against this in the safety case.

Rosyth Royal Dockyard Ltd

1907 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1908 This is not applicable.

NNB GenCo – Hinkley Point C

1909 NNB GenCo will carry out a study and investigate the provision of further systems or equipment to control containment over-pressure in severe accident conditions. A large number of potential enhancements were identified. These include:

- The possibility of controlled venting of the containment.

- The provision of instrumentation and surveillance equipment hardened for severe accident conditions.
- The use of portable pumps for pumped injection of water into the containment and fuel pond.

1910 ONR will assess this submission as part of the licensing process.

### 6.3.11 ONR's Assessment of Maintaining the Containment Integrity after Occurrence of Significant Nuclear Matter Damage (up to Nuclear Meltdown)

Sellafield Ltd – Sellafield and Windscale

1911 ONR concurs with Sellafield Ltd views on management of nuclear containment and welcomes the licensee's *Consideration* to verify effectiveness of additional mitigating measures through modelling in the Magnox swarf storage silo. The requirement for power and steam supplies at HALES to manage the hydrogen risk has been discussed in earlier sections of this report. ONR will monitor Sellafield Ltd's progress in implementing any reasonably practicable measures through targeted inspections planned during the forthcoming months.

1912 ONR therefore notes that the Sellafield stress tests report has identified resilience of preventive measures to a beyond design basis event that could lead to an overpressure and a subsequent loss of containment. However, there is insufficient information on withstand of containment structures to a beyond design basis overpressure. ONR therefore recommends that:

**STF-86: Sellafield Ltd should undertake safety margin analysis in order to determine relative withstand of containment structures to a beyond design basis overpressure.**

1913 Such an analysis will provide realistic information, enabling the site to prioritise its efforts in response to multiple events.

1914 In relation to a criticality event, ONR concludes that further work may be required by Sellafield Ltd to determine how fire coincident with criticality in a severe accident condition can affect the dynamics of a release.

**STF-87: Sellafield Ltd should consider, in more detail, the consequences of fire coincident with criticality and the capability of Sellafield site to respond to these events.**

1915 STF-21 has been made in Section 1 for Sellafield Ltd to consider and provide further information on how its emergency arrangements would anticipate and adapt to challenging criticality event coincident with other site-wide emergencies such as a seismic event.

1916 Sellafield Ltd has demonstrated in its stress tests submission that it understands the essential safety functions, and the associated parameters to be measured and controlled using appropriate instruments. Through a *Consideration*, it has identified the need for maintaining an up-to-date list of key plant parameters in the SECC. While this *Consideration* is welcomed, ONR notes that there is insufficient evidence that in a prolonged SBO, the availability of necessary instrumentation can be guaranteed. However, some parameters can be measured by other means or calculated using previously known figures.

1917 In addition to monitoring the implementation of this *Consideration*, ONR will also be examining Sellafield Ltd's response to HM Chief Inspector's Final Report Recommendation IR-22 (Ref. 2) in reviewing the on-site emergency control, instrumentation and communications.

1918 In relation to identification of additional measures to enhance containment integrity, ONR agrees with Sellafield Ltd's *Consideration* and concludes that further work may be required to ensure availability and operability of containment repair kits following a severe accident.

Urenco UK Ltd

1919 ONR is satisfied that the potential for overheating $UF_6$ cylinders is sufficiently considered in the licensee's safety case and with appropriate engineered protection.

Dounreay Site Restoration Ltd

1920 ONR is satisfied that DSRL's emergency arrangements made under LC11 and REPPIR adequately consider the impact of a repeating criticality.

Springfields Fuels Ltd

1921 ONR recognises that facilities on Springfields contain limited quantities of uranic compounds that are heavy by nature and typically not conducive to dispersal off-site in the event of a hydrogen explosion. SFL has subsequently confirmed that should a hydrogen detonation occur, the extant plant safety cases models these scenarios and concludes that the off-site dose is of low consequence (less than 1mSv). ONR has sought further clarification from the licensee as to the on-site radiological significance of uranic material dispersal. The following finding is relevant here:

**STF-88: Springfields Fuels Ltd should demonstrate how its on-site and off-site plans cater for widespread dispersion of uranic material (in oxide form and uranium hexafluoride) predicated on concurrent seismic / hydrogen detonation events.**

1922 ONR has previously witnessed a Level 1 Emergency exercise in September 2011 that simulated a Criticality incident; ONR was satisfied that the response to the incident adequately anticipated a recurring criticality incident

Atomic Weapons Establishment

1923 ONR agrees that due to the nature of the hazards on-site and the operations conducted, significant nuclear matter damage, of the type usually considered in loss of cooling accidents for reactors, is not considered by AWE to be a risk at AWE's sites. Radioactive releases due to loss of containment integrity are considered in the next sub-section.

Rolls-Royce Marine Power Operations Ltd

1924 RRMPOL reports that a very small release of radioactive material could arise if complete collapse, flooding or an engulfing fire occurred. ONR considers that this conclusion may not be unreasonable given the type and amounts of materials used. The consequences of airborne radioactive releases following a building collapse would be unlikely to be considered to be a severe accident.

1925 ONR notes that a criticality presents the potential for a cliff-edge radiological consequence and can be considered as a severe accident. A seismic event causing building collapse combined with a flood could in principle give a rearrangement of materials from their criticality safe geometries in combination with a moderator. RRMPOL has raised *Considerations* to review the prevention of a criticality by improving the resilience of internal building structures and keeping a stock of neutron poisons available. ONR supports these *Considerations*.

1926 ONR considers that the seismic withstand of the Neptune reactor buildings is to a modern standard and likely to remain intact following a design basis event. This reduces the likelihood of a criticality event, and would provide containment and shielding in the event of a criticality due to disruption and flooding of the building internal structures.

BAE Systems Marine Ltd

1927 BAESM has presented four accident scenarios against which to assess the stress tests. Although this does not follow the NPP stress tests specification, the scenarios individually present a significant challenge to the fuel and / or the submarine. ONR notes that a comprehensive assessment against the NPP stress tests specification requires additional information from the MoD on the severe accident behaviour of the NRP. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1928 The main outcome from considering a NRP loss of reactivity control / criticality scenario is that these accidents can present a radiological consequence quickly. BAESM emergency arrangements currently assume that severe accidents will develop slowly. Therefore BAESM recommends that this topic should be more closely studied and taken into account in its emergency arrangements. ONR supports this *Consideration.*

1929 The discussion provided by BAESM concentrates on the provision of core cooling rather than discussing containment performance and the potential for fission product releases. ONR notes that the presentation on the potential for, and consequences of, various containment failure modes is therefore not comprehensive. ONR notes that the information about containment performance is stated to require further information from the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

1930 From the information presented by DRDL, the effectiveness of the submarine containment is seen to rely on its inherent structural strength and high integrity of construction, supplemented by regular testing. Also, once initiated, the performance of the containment is independent of electrical and air supplies. ONR considers that both these characteristics are beneficial to providing resilience to safety challenges.

1931 ONR notes that the submission from DRDL does not include information on a variety of NRP containment integrity areas relevant to the NPP stress tests specification stating that this is a matter for the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1932 DRDL does not provide any information regarding the capability for severe accident management in cases of coincident meltdown of multiple NRPs.

**STF-89: DRDL should consider reviewing its capability for severe accident management in cases of simultaneous core damage accidents.**

Rosyth Royal Dockyard Ltd

1933 Not applicable for RRDL, see Section 6.3.1.

Magnox Ltd – Defuelled reactors

1934 ONR fully supports the Magnox Ltd view that this is not applicable to the five decommissioning Magnox sites.

NNB GenCo – Hinkley Point C

1935 The adequacy of the proposed measures is still the subject of assessment and it is possible that the design will be the subject of change either before a site licence is granted, or during construction.

## 6.4 Accident Management Measures to Restrict the Radioactive Releases

### 6.4.1 Radioactive Releases after Loss of Containment Integrity

Sellafield Ltd – Sellafield and Windscale

1936 As summarised in Section 1 of this report, radioactive inventories at Sellafield are subject to at least one containment barrier (primary containment). In the case of more modern facilities, a secondary containment is in place to provide a further layer of protection against containment failure. Design provisions for restricting releases after loss of such containment barriers are primarily centred around sumps and associated pumps, and reconfiguration of the ventilation systems.

Urenco UK Ltd

1937 UUK has reported that various equipment, facilities and materials are available on the site to enable repairs to plants and cylinders if required. An emergency plan with associated arrangements exists to provide prompt and appropriate response to any emergency, including taking measures to restrict radioactive release. The licensee has identified areas for further consideration to improve the resilience of its accident management arrangements with respect to extreme external events.

Dounreay Site Restoration Ltd

1938 The stress tests for Dounreay identified countermeasures to restrict personnel radiation exposure in the event of a loss of containment. The licensee does not however identify any measures specifically to restrict radioactive releases in a severe accident. DSRL does not have any severe accidents that, strictly, would accord with the SAP definition. However, DSRL's capability to secure personnel recovery following a building collapse (or higher-level principles to arrest a loss of containment) in the aftermath of, say, an earthquake is not explicitly discussed. ONR has however subsequently examined the licensee's arrangements and infrastructure that would facilitate personnel recovery. ONR is assured that there is a robust rationale for undertaking the necessary risk assessments needed to enact personnel recovery plans and that these are adequately reflected in the on-site plans.

Springfields Fuels Ltd

1939 SFL's stress tests report does not identify countermeasures to restrict personnel radiation exposure in the event of a loss of containment.

Atomic Weapons Establishment

1940 The majority of primary containment systems at AWE are glove boxes, with associated HVAC, or gas supply, and filter arrangements (some have inert atmospheres). Some also feature containment vessels within the glove boxes, depending on the physical form of the radioactive material and process concerned. Some facilities also have additional and specific civil structures, which act as containment barriers. In the waste stores, waste drums act as the primary containment. The civil structure of the buildings, in conjunction with HVAC and filter arrangements, acts as secondary or tertiary containment systems (and may be claimed as such within facility safety cases).

1941 In its response to the stress tests, AWE has not presented a systematic study of the sequential loss of containment barriers following an extreme external event and the potential dose consequences, because it considers that this type of information is already covered within extant safety cases.

1942 AWE has outlined its operational emergency response provisions in the event of a radioactive release outside of the facility boundary. The on-site emergency response team is central to minimising on-site and off-site dose consequences.

Rolls-Royce Marine Power Operations Ltd

1943 RRMPOL reports that on the NFPP licensed site, in the event of a complete building collapse, flooding or an engulfing fire, only a very small release of radioactive material may result and have not discussed this further in its submissions for both sites.

BAE Systems Marine Ltd

1944 BAESM highlights that there are four boundaries to the release of fission products: the fuel clad, the primary circuit, the primary containment and the secondary containment. Two *Considerations* have been raised by BAESM to review its emergency response.

Devonport Royal Dockyard Ltd

1945 DRDL highlights that there are four boundaries to the release of fission products: the fuel clad, the primary circuit, the primary containment and the secondary containment. The operational provisions are briefly described and inform that containment is maintained appropriate to plant state and decay heat level.

Rosyth Royal Dockyard Ltd

1946 RRDL asserts that there is no inherent capacity for a continued release following an external event. However, if released from its containment the action of weather could disperse the waste to cover a greater area, but with the dose rate reducing commensurately.

1947 RRDL reports that prevention of continued transport of the waste lies well within its current contingency arrangements. Two techniques are very briefly described:

- covering the released resin with absorption material; and
- wetting the resin to prevent it drying out.

Magnox Ltd – Defuelled reactors

1948 Not applicable as there is no irradiated fuel and no containment building.

NNB GenCo – Hinkley Point C

1949 In the event of containment over-pressure leading to failure of the containment pressure boundary, the containment outer shell can accommodate a significant leakage and the active heating and ventilation system can extract and process the leakage flow.

1950 Much of the secondary containment would in turn leak into auxiliary buildings, which themselves have provision for treatment of activity found in the heating and ventilation system.

### 6.4.2 Accident Management after Uncovering of the Top of Nuclear Matters in the Storage Facility

Sellafield Ltd – Sellafield and Windscale

1951 The fuel ponds on-site, and the approach Sellafield Ltd has taken to consider the challenges of keeping sufficient water levels in the ponds, have been discussed in Sections 1, 2 and 5.

1952 Significant damage to the pond structure caused by a seismic event could result in doses on and off-site because of loss of pond water (on-site mainly because of direct / scattered radiation and off-site doses because of release of entrained activity in pond water). A number of legacy ponds in Sellafield may incur damage during severe external hazards leading to loss of pond water. Such an event would present significant challenges to the workforce involved in responding to the emergency. Sellafield Ltd's assessment of such events and ONR's conclusion is covered in the next section of this report: Conclusion on the adequacy of measures to restrict the radioactive releases.

1953 Sellafield Ltd has concluded that a number of legacy facilities on-site will be adversely affected by severe external hazards leading to release of radioactive material off-site. Sellafield Ltd is considering review of its current arrangements with a view to enhance its emergency arrangements and to improve its capability for mitigating the consequences of such severe events.

1954 A summary of Sellafield Ltd's *Considerations* for further improvements in this area are provided in Sections 6.3.10.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

1955 There are no scenarios on UUK, DSRL and SFL sites which could lead to a nuclear matters uncovering.

Atomic Weapons Establishment

1956 The containment function in AWE's storage facility is provided by the waste drums, which do not require active cooling. In its written response to the stress tests, AWE has not presented a systematic study of the loss of waste containment following an extreme external event. However, the challenges to the containment safety function in the event of an extreme flooding or seismic event have recently been analysed in the context of a recent PSR at the facility, which was reviewed by ONR. A number of shortfalls were identified and improvements are being actively pursued by AWE.

Rolls-Royce Marine Power Operations Ltd

1957 ONR considers this aspect of the stress tests is not relevant to RRMPOL.

BAE Systems Marine Ltd

1958 When BAESM receives new unirradiated fuel, the fuel remains unirradiated until a core is taken critical inside the NRP within the submarine during commissioning. Fuel damage due to loss of heat sink for radioactive components outside the NRP is not possible. Also unirradiated fuel does not present an external radiation hazard. Therefore the loss of radiation shielding is not relevant for radioactive components outside the submarine.

1959 BAESM presents relevant information for potential criticality / loss of reactivity control accidents for fuel on-site.

Devonport Royal Dockyard Ltd

1960 DRDL describes that the spent fuel area only receives fuel when it has reached a sufficiently low decay heat to assure fuel integrity should the nuclear matter become uncovered.

1961 The potential for mechanical damage to fuel due to impacts is credible and relevant for seismic events or other external events which may cause equipment above or adjacent to the fuel pits to fail / collapse. DRDL reports that fuel damage or a criticality from mechanical impacts is not anticipated to occur until significantly beyond the design basis and therefore has not considered this scenario further.

1962 DRDL explains that, should the fuel become uncovered in either a used fuel flask or in the fuel pits in the LLRF, the bulk material properties would continue to provide an element of shielding and installed monitors would alarm to advise of increased dose rates.

Rosyth Royal Dockyard Ltd

1963 This aspect of the stress tests does not apply to Rosyth.

Magnox Ltd – Defuelled reactors

1964 Magnox Ltd has reported that this is not directly applicable as there is no irradiated fuel on these sites. However, some of the decommission sites stress tests reports do raise the issue of corrosion of fuel element debris in the dedicated vaults. This results in the generation of small quantities of hydrogen that is managed / removed via vault ventilation systems. If ventilation were lost to the vaults, then operators must restore ventilation or remove the vault plugs to prevent the hydrogen concentration reaching the LFL. The vaults are passively safe with the vault plugs removed.

NNB GenCo – Hinkley Point C

1965 In the event of the pond boiling and the fuel becoming uncovered, the fuel building active ventilation system would be required to process the activity. This is still subject to assessment within the GDA process.

1966 In the case where there is boiling within the fuel pool, there is a possibility of build up of pressure within the spent fuel hall. However this can be mitigated by opening up the connection between the fuel building and the nuclear auxiliary building. This increases the volume and hence reduces the maximum pressure.

### 6.4.3 Conclusion on the Adequacy of Measures to Restrict the Radioactive Releases

Sellafield Ltd – Sellafield and Windscale

1967 Sellafield Ltd has concluded that there are measures in place to restrict radiological releases. These include preventive, mitigating and emergency measures as summarised in Sections 5 and 6.3 of this report.

Urenco UK Ltd

1968 ONR notes previously it was satisfied with UUK’s commitment to examine further its overall response to criticality accidents and combinations of extreme external events.

Dounreay Site Restoration Ltd

1969 DSRL has not explicitly considered in its stress tests the adequacy of measures to restrict radiological release following loss of containment. ONR does however recognise that containment for pressure withstand is not applicable to PFR or DFR.

Springfields Fuels Ltd

1970 SFL's stress tests report does not identify countermeasures to restrict personnel radiation exposure in the event of a loss of containment; SFL has since clarified that its off-site plan identifies sheltering and food bans as the primary countermeasures. ONR is further aware that effective links have been forged with West Lancashire emergency services and the NHS, exemplified through previous emergency exercises.

Atomic Weapons Establishment

1971 AWE has identified four "high-hazard" operational facilities and one storage facility that could lead to a severe accident as defined in Section 1.1.1.

1972 For its high-hazard operational facilities, AWE concludes that accident consequences do not naturally escalate after the initial extreme external event and hence that challenging / stretching the emergency arrangements does not result in a sudden large step change in the accident response.

1973 AWE also concludes that if its high-hazard facilities were to be damaged and a loss of containment occur, there is little potential for an escalation of the radioactive release, unless there were to be a fire. AWE concludes that reasonably foreseeable extreme external events are highly unlikely to lead to off-site dose consequences on the scale of the Fukushima event, in the vicinity of AWE's sites.

Rolls-Royce Marine Power Operations Ltd

1974 RRMPOL's general conclusion is that very small releases of radioactive material could arise if complete building collapse, flooding or an engulfing fire occurred. In principle, a criticality event could occur following a seismic event coincident with flooding of the site. With the exception of a criticality event which, although highly unlikely, could present significant off-site consequences, RRMPOL considers there is no dependency on post-event action.

1975 RRMPOL notes that for the fuel production plant new facilities are proposed which would be constructed to modern standards, including an elevation that will significantly reduce the susceptibility of the site to flooding.

1976 RRMPOL describes a number of *Considerations* for potential improvements to the site resilience for external hazards.

BAE Systems Marine Ltd

1977 BAESM does not present a conclusion for this section but provides an overall conclusion for its whole submission.

Devonport Royal Dockyard Ltd

1978 DRDL does not present a conclusion for this section but provides an overall conclusion for its whole submission.

Rosyth Royal Dockyard Ltd

1979 Rosyth Royal Dockyard Ltd concludes that the radioactive material on-site has no inherent capacity for a continued release following an external event. Also the prevention of continued transport of the resin by other means lies well within its current contingency arrangements.

Magnox Ltd – Defuelled reactors

1980 Magnox Ltd notes that the only waste on-site is now contained within vaults, it is passively safe, and any release of radioactivity is highly unlikely even in severe accident conditions. The only issue is hydrogen generated from the corrosion of fuel element debris. However, there is no active system the loss of which would lead directly to a fault condition. Even with ventilation lost and the hydrogen concentration above the LFL, radiological release will not occur unless there is an ignition source in the vault. This is held to be a low probability event. The dose consequences are also not high. Risks as a result of hydrogen ignition in the vault are therefore below the BSO for the site, ALARP and justified in the current site safety case.

NNB GenCo – Hinkley Point C

1981 The adequacy of the proposed measures is still the subject of assessment and it is possible that the design will be the subject of change either before a site licence is granted, or during construction.

### 6.4.4 ONR's Assessment of Accident Management Measures to Restrict the Radioactive Releases

Sellafield Ltd – Sellafield and Windscale

1982 ONR acknowledges that the licensee has identified weaknesses in its existing arrangements to restrict release of radioactive material off-site in the event of extreme external hazards. In addition, ONR recognises that some of the legacy facilities on Sellafield were not built according to modern standards and design codes and may be vulnerable to design basis accident scenarios (e.g. DBE). The licensee has undertaken a number of projects to enhance the resilience of these structures in line with modern design codes in order to reduce the risks arising from these facilities so far as it is reasonably practicable. Seismic strengthening of part of the Magnox swarf storage silo is an example of these projects. In line with HM Chief Nuclear Inspector's conclusion following the Fukushima event (Ref. 2, Conclusion FR-2), ONR and Sellafield's strategy in relation to legacy facilities remains as hazard reduction through retrieval of waste.

1983 In relation to events that could lead to radioactive releases, ONR notes that Sellafield Ltd has assessed the resilience of the relevant preventive measures in a beyond design basis event. However, the resilience and withstands of the containment barriers to such events has not been assessed. STF-86 is therefore relevant here.

1984 ONR agrees with Sellafield Ltd's conclusion that the work undertaken by it in relation to evaluation of its resilience has not identified any potential deviation from licensing basis. Sellafield Ltd's preliminary findings will evolve and prompt further consideration as Sellafield Ltd develops a deeper understanding of interactions and processes, related to accident management, across the site. ONR will monitor Sellafield's progress in this area to ensure all reasonably practicable measures are implemented as part of the wider resilience programme.

Urenco UK Ltd

1985 ONR supports the UUK's commitment to further review accident management arrangements and will secure assurance from UUK that appropriate and reasonably practicable improvements are made in these areas.

Dounreay Site Restoration Ltd

1986 DSRL's capability to secure personnel recovery following a building collapse (or higher-level principles to arrest a loss of containment) in the aftermath of, say, an earthquake is not specifically discussed by the licensee. The licensee has subsequently provided to ONR detail of extant arrangements adopted by rescue services for risk-informed decision making when responding to emergency situations; these arrangements are tested during emergency exercises. ONR recognises that the most practicable route to reduce risk is to achieve full POCO and decommissioning of these facilities. ONR also agrees that there is limited opportunity to develop practicable improvements given the identified timescales for achieving interim end-state (expected to be before 2030). The licensee's stress tests report does not identify countermeasures to restrict personnel radiation exposure in the event of a loss of containment. However, ONR is satisfied that the off-site emergency plan identifies sheltering, evacuation and restrictions on certain foodstuff as the means of dose management following a release of radioactive material.

Springfields Fuels Ltd

1987 SFL's stress tests report does not identify countermeasures to restrict personnel radiation exposure in the event of a loss of containment. However, ONR is satisfied that the off-site emergency plan identifies sheltering, evacuation and restrictions on certain foodstuff as the means of dose management following a release of radioactive material.

Atomic Weapons Establishment

1988 With regard to fire hazards, AWE has not elaborated within its response to the stress tests, on fault sequences initiated by fires that can lead to a loss of containment, or involving consequential fires caused by a loss of containment initiated by an extreme external event. ONR considers such sequences to be potentially significant because fire may provide a suitable energetic vector for dispersal of radioactive material. The design basis hazard assessment with respect to fire is presented within AWE's facility safety cases, which are assessed by ONR on a sampling basis during normal regulatory business.

1989 ONR notes that AWE is currently undertaking a programme of work to underwrite its approach to nuclear fire safety. As part of this review process, ONR recommends that:

**STF-90: AWE should consider reviewing the threat posed to containment systems from fire hazards and the potential dose consequences for on-site and off-site risk groups. AWE should consider, within its review, the potential dose consequences of an extreme event leading to a loss of containment and a consequential fire. In light of the assessed consequences for workers and the public, AWE should consider any further mitigation, in addition to those measures currently in place.**

1990 ONR is tracking AWE's progress with PSR improvements to its storage facility via normal regulatory business.

Rolls-Royce Marine Power Operations Ltd

1991 RRMPOL reports that a very small release of radioactive material could arise if complete building collapse, flooding or an engulfing fire occurred. ONR considers that this conclusion is reasonable, given the type and amounts of materials used. ONR agrees with RRMPOL's submission that a criticality accident with the potential for consequent radiation "shine" is extremely unlikely.

1992 In the event of a release or criticality RRMPOL considers there is little ability to undertake mitigation after the event, and there is no dependency for post-event action. ONR acknowledges that following building collapse and / or flooding, the options for mitigation of releases or a direct radiation hazard may be limited or difficult to implement.

BAE Systems Marine Ltd

1993 ONR considers this section of the stress tests was intended to postulate and explore ways in which the containment could fail, describe in general terms the resulting type of release of fission products that may arise, and investigate what the site could do to mitigate the release. However, the brief discussion presented by BAESM does not address this fully.

1994 BAESM reports that further information on this is required from the MoD. In the absence of this information, it is not possible for ONR to conclude that full consideration has been given to the site response and resilience to minimising radioactive releases. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1995 ONR notes that fuel movements within the site are not addressed within BAESM's submission. However, ONR considers loss of cooling faults are not relevant, and the criticality scenarios discussed by BAESM provide bounding information.

Devonport Royal Dockyard Ltd

1996 DRDL describes the four boundaries to the release of fission products and reports that containment is maintained appropriate to plant state and decay heat level. The response has not addressed the ways in which the containment could fail, the resulting consequences, nor investigated what the site could do to mitigate any releases. This is a matter for the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

1997 DRDL reports that the spent fuel area only receives fuel when it has reached a sufficiently low decay heat to assure fuel integrity should all cooling water be lost. ONR therefore agrees that fuel damage while in storage, due to loss of heat sink, is not a credible fault.

1998 DRDL does not address in adequate detail within its submission the potential radiological consequences and the recovery actions that may be needed following mechanical damage to fuel due to impacts, and loss of radiation shielding.

**STF-91: DRDL should consider reviewing its responses required in the event of a loss of shielding of stored fuel.**

1999 ONR notes that nuclear fuel and source movements on the site between the submarine and the LLRF, and between the LLRF and off-site are not addressed within DRDL's submission. In common with the fuel pits, ONR agrees that loss of cooling is not a relevant fault for fuel movements.

**STF-92: DRDL should consider reviewing the nuclear fuel and source movements on-site to demonstrate the comprehensiveness of the emergency response measures available.**

Rosyth Royal Dockyard Ltd

2000 ONR agrees that there is no inherent mechanism for energetic dispersion of the radioactive material stored at the site. However, if released from its containment the action of weather could disperse the resin to cover a greater area, but with the dose rate reducing commensurately. ONR considers that RRDL has adequate contingency measures in place that would prevent dispersion from taking place. ONR notes that conservatively assessed dose rates on-site from waste dispersion are small, and would allow stay times sufficient to provide an effective response. Off-site dose rates would not be significant.

Magnox Ltd – Defuelled reactors

2001 As there is no irradiated fuel on the decommissioning Magnox Ltd rector sites it is very difficult to see how there could be a significant radioactive release. The waste in the vaults is in a passive state. The only possible issue that could drive a radioactive release is the fact that corrosion of fuel element debris does release hydrogen and should forced venting be lost then this would eventually become a problem if ignition sources exist. However, Magnox Ltd has reported that there is no active system the loss of which would lead directly to a fault condition. Even with ventilation lost and the hydrogen concentration above the LFL, radiological release will not occur unless there is an ignition source in the vault. This is held to be a low probability event. The dose consequences are also not high. Risks as a result of hydrogen ignition in the vault are therefore below the BSO for the site, ALARP and justified in the current site safety case. ONR concurs with the licensee's view.

NNB GenCo – Hinkley Point C

2002 The adequacy of the proposed measures is still the subject of assessment and it is possible that the design will be the subject of change either before a site licence is granted, or during construction.

## 6.5 ONR's Conclusion

Sellafield Ltd – Sellafield and Windscale

2003 ONR agrees with Sellafield Ltd's conclusion that the work undertaken by it in relation to evaluation of its resilience has not identified any potential deviation from licensing basis. Sellafield Ltd's preliminary findings will evolve and prompt further consideration as Sellafield Ltd develops a deeper understanding of interactions and processes, related to accident management, across the site. ONR will monitor Sellafield's progress in this area to ensure all reasonably practicable measures are implemented as part of the wider resilience programme.

Urenco UK Ltd, Dounreay Site Restoration Ltd and Springfields Fuels Ltd

2004 ONR considers that UUK, DSRL and SFL have undertaken comprehensive reviews of resilience of severe accident management, in particular their organisational capabilities to address reasonably foreseeable accidents in the context of REPPIR; ONR acknowledges and welcomes UUK's commitment to undertake further work to explore areas to enhance resilience. ONR will seek to influence licensees to explore further concurrent faults (with coincidental or consequential) during emergency exercises undertaken pursuant to the requirements of LC11.

Atomic Weapons Establishment

2005 In general, ONR considers that AWE has provided an appropriate level of detail concerning its organisational arrangements for emergency response and notes that more detail is provided in the site emergency plans and the AWE off-site plan.

2006 ONR concludes that AWE appears to have well-developed organisational arrangements to respond to emergencies at single facilities, arising from extreme external events. On the basis of AWE's stress tests submission, ONR is less confident in the capability of AWE's emergency arrangements to respond to site emergencies arising from extreme external events that affect several facilities simultaneously, and which may include factors that impede accident management.

2007 ONR recommends that AWE should reconsider the provision of suitable contingencies in its emergency response to extreme external events, if aggravating factors, which may impede accident management, are realised. These factors include impaired road access to both the sites themselves and to individual facilities on-site, loss of availability of co-ordination and control centres and loss of communication. This item is covered by STF-76.

2008 ONR recommends that, as part of its response to the stress tests, AWE should consider collating requirements placed on the site-wide infrastructure and emergency arrangements by individual facility safety cases and consider the demands that may be placed on the organisation, infrastructure and resources should a response be required at two or more facilities simultaneously, or within the same incident. AWE should also consider factors that may impair the emergency response and develop suitable contingencies to ensure that the logistics of the emergency response are robust. This item is covered by STF-77.

2009 ONR recommends that, as part of its response to the stress tests, AWE reviews the on-site and off-site dose consequences of being unable to "make safe and evacuate" high-hazard facilities in response to extreme external events. This is covered by STF-78.

2010 ONR welcomes the review that AWE is currently undertaking to underwrite its approach to nuclear fire safety. As part of this review process, ONR recommends that AWE reviews the threat posed to containment systems from fire hazards and assesses the potential dose consequences for on-site and off-site risk groups. ONR also recommends that AWE reviews the dose consequences of an extreme event leading to a loss of containment and a consequential fire. In light of the assessed consequences for workers and the public, ONR recommends that AWE considers any further mitigation, in addition to those measures currently in place. These items are covered by STF-90.

<u>Rolls-Royce Marine Power Operations Ltd</u>

2011 ONR considers that the potential for a severe accident as a result of a severe external event is small. This is because building collapse, flooding or fire is likely to give rise to small airborne releases of radioactive material due to the amounts and nature of the nuclear materials used. In addition, ONR considers the potential for a criticality accident to be small due to the need for physical damage or rearrangement of nuclear material, coincident with water ingress due to flooding. ONR agrees with RRMPOL's submission that a criticality accident with the potential for consequent radiation "shine" is extremely unlikely.

2012 RRMPOL presents overall conclusions which describe that the site emergency response arrangements do not display high levels of resilience to severe external events. The emergency response buildings are susceptible to flooding and damage by earthquakes, and the site power distribution networks are not seismically qualified nor flood protected. ONR judges that the lack of resilience of the site infrastructure is more likely to complicate and delay recovery of the site, rather than compromise the mitigation of unlikely radiological consequences.

2013 RRMPOL has raised a number of *Considerations* to review improvements to the sites infrastructure and to minimise the likelihood of a criticality event. ONR supports these *Considerations*. It should be noted that the Bronze Command centres have no formal seismic withstand. This item is covered by STF-80.

2014 In the event of a release or criticality RRMPOL considers there is little ability to undertake mitigation after the event, and there is no dependency for post-event action. ONR acknowledges that following building collapse and / or flooding, the options for mitigation of releases or a direct radiation hazard may be limited or difficult to implement.

2015 RRMPOL reports that its emergency arrangements are not currently set up to deal with coincident events on both licensed sites. ONR notes that the fuel production plant and Neptune reactor are close together and it is reasonable to expect that a seismic event or a significant flood would affect both sites at the same time.

2016 The submission presented by RRMPOL addresses the existing facilities on the site. It does not address the replacement fuel production facilities under the manufacturing site regeneration programme, or the modifications to the Neptune reactor to use a different design of fuel. It is ONR's initial judgement that the manufacturing sire regeneration project and modifications to Neptune are unlikely to introduce significant differences into the current assessment. This item is covered by STF-79.

<u>BAE Systems Marine Ltd</u>

2017 For full consideration of the NPP stress tests specification, further information is needed from the MoD to fully characterise the severe accident threats and response of the site. BAESM has raised a number of *Considerations* to improve its arrangements or to investigate additional options. ONR supports these *Considerations* but cannot confirm that the list of *Considerations* is appropriately comprehensive to address severe accident management.

2018 ONR noted in its National Stress Tests Final Report for UK NPPs (Ref. 10) that a severe external event could lead to coincident damage to both the nuclear facilities and the emergency response centres. ONR's assessment considers this topic applies for the Barrow site. BAESM reports that none of these buildings have a withstand to environmental hazards beyond that inherent in standard building codes. BAESM has raised a *Consideration* to investigate the hardening of relevant buildings and communications systems.

2019 BAESM acknowledges that its emergency arrangements do not include the effects of site-wide disruptive events in emergency exercises. BAESM has raised a *Consideration* to investigate the potential environment on-site and off-site in which the arrangements and plans are to be used.

2020 ONR notes that summary information is presented on the subject of factors that may impede accident management. This includes the effects of extensive flooding, building collapse, debris across the site, radiation hazards, the need to evacuate the submarine and the unavailability of power supplies. The ability of the site to respond to the level of threat described within the stress tests has not been fully clarified. A more comprehensive assessment of this requires additional information from the MoD on the severe accident behaviour of the NRP. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

2021 BAESM recognises that its emergency arrangements assume a severe accident will develop progressively. However, the assessment presents accident scenarios that can develop quickly, before emergency arrangements can come into effect. BAESM has raised a *Consideration* to study this issue more closely.

2022 ONR considers that the severe accident management element of the stress tests is intended to take the plant beyond the design basis and postulate the potential for radiation exposures both on-site and off-site. This is an area where the implications for the site response have not been fully explored from the perspective of measures the site could take to restrict radioactive releases and minimise radiation exposures. Much of the required severe accident information is to be advised by the MoD. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position in light of the MoD's conclusions.

Devonport Royal Dockyard Ltd

2023 DRDL has raised a number of *Considerations* to investigate improvements in its response to severe accidents at Devonport. ONR supports these *Considerations*. However, the following areas are highlighted for additional discussion.

2024 ONR noted in its National Stress Tests Final Report for UK NPPs (Ref. 10) that a severe external event could lead to coincident damage to both the nuclear facilities and the emergency response centres. ONR has assessed that this also applies to the DRDL site. DRDL has recognised potential vulnerabilities in this area, and has raised *Considerations* to enhance communication systems and find suitable alternative locations for FCPs and additional personnel. ONR supports DRDL's *Considerations*. However, ONR notes that, although DRDL has identified some vulnerability of the FCP to flooding and the potential collapse of the DACC from a seismic event, it has not raised any *Considerations* to address this. This item is covered by STF-82.

2025 DRDL's demonstration exercises do not routinely exercise the wider effects of site-wide disruptive events and severe accidents. DRDL reports it does exercise its arrangements annually and include the regional / national response once every three years.

2026 ONR considers that the severe accident management element of the stress tests is intended to take the plant beyond the design basis and postulate the potential for radiation exposures both on-site and off-site. This is an area where the implications for the site response have not been fully explored within DRDL's stress tests submission. Full clarity is not given to the measures the site could take to restrict radioactive releases and minimise radiation exposures following a submarine reactor accident. However, ONR is aware that DRDL's emergency arrangements include responses to submarine accidents. Characterising the severe accident response, containment failure modes and fission product releases from the NRP is a MoD matter. MoD is carrying out its own post-Fukushima review of the NRPs and a programme of work is planned by ONR to review its position is light of the MoD's conclusions.

Rosyth Royal Dockyard Ltd

2027 ONR considers that the amount and nature of the radioactive materials at Rosyth is such that a severe accident is very unlikely, due primarily to the robust design basis withstand of the radioactive materials store, and the characteristics of the radioactive material.

2028 ONR agrees that there is no inherent mechanism for energetic dispersion of the radioactive material stored at the site. In the very unlikely event that a release did occur, RRDL has contingency measures in place that would prevent dispersion of radioactive material by other means, for example the action of the weather. Conservatively assessed on-site dose rates from resin dispersion are small, and would allow stay times sufficient to provide an effective response. Off-site dose rates would therefore be very small.

2029 ONR considers that enhancements to the severe accident arrangements of RRDL are not required.

Magnox Ltd – Defuelled reactors

2030 It has been successfully argued that the decommissioning Magnox reactors are passively cooled and that natural event-induced severe accidents will have negligible effect. The only issue raised at some of these sites is that corrosion of fuel element debris could result in hydrogen building up in fuel element debris vaults, to a point were it could have safety significance, if forced ventilation of the vaults was lost. However, if loss of ventilation to the vaults occurred, operators must then restore ventilation or remove the vault plugs to prevent the hydrogen concentration reaching the LFL. The vaults are passively safe with the vault plugs removed.

2031 Should a severe event occur, the sites still have regulatory approved emergency response plans and the members of the emergency scheme should cope with whatever situation they are faced with. For a severe accident additional back-up equipment is available off-site. This is being reviewed. Once details are finalised the Magnox Ltd SAGs will be updated to take into account the available back-up equipment and focus more on hazards associated with radioactive waste vaults. They will also give more attention to the welfare of staff and human performance in adverse conditions.

2032 ONR is satisfied that Magnox Ltd has seriously considered severe accidents and emergency arrangements at its decommissioning sites in the light of events at Fukushima. Work is still ongoing and identified enhancements will be assessed and, if appropriate, they will be implemented.

NNB GenCo – Hinkley Point C

2033 The adequacy of the proposed measures is still the subject of assessment and it is possible that the design will be the subject of change either before a site licence is granted, or during construction. ONR recognises that the basic UK EPR™ design has been produced to cope with beyond design basis events and to minimise release of fission products even in severe accidents. When Hinkley Point C is constructed it may contain enhancements that have been added in the light of the Fukushima event.

# 7 ONR ASSESSMENT OF LOWEST HAZARD SITES STRESS TESTS

2034 As described in Section 1.2 of this report, ONR has categorised the following nuclear licensed sites as "lowest hazard":

- Sellafield Ltd – Capenhurst.
- Imperial College of Science Technology and Medicine (Ascot Campus).
- Research Sites Restoration Ltd (Harwell and Winfrith).
- Low Level Waste Repository Ltd (Drigg).
- GE Healthcare Ltd (Amersham and Cardiff – the Harwell site is awaiting delicensing in 2012 so is excluded from further consideration here).
- Studsvik UK Ltd (Metal Recycling Facility, Cumbria).

2035 This approach recognises that their respective radioactive inventories are not capable of producing accident or severe accident scenarios capable of giving any significant off-site consequence[§]. These sites do not therefore meet the requirement under REPPIR to have an off-site emergency plan. Stress tests specifications were designed for NPP sites. ONR therefore accepts that a proportionate and tailored response to the stress tests is appropriate for the UK low-hazard NPGNF sites, which is what has been provided by those licensees who operate these sites. ONR's conclusion of the stress tests produced for the sites is also proportionately based and presented collectively in this section as opposed to explicit consideration under Sections 2–6.

2036 The assessment conclusions are presented in a manner that reflects commonalities associated with each of the sites, along with site-specific summaries. The SAPs, which represent ONR's view of relevant good practice for sites with significant off-site radiological consequences, have formed the benchmark for informing an assessment of the licensees' stress tests submissions. The principles of proportionality and ALARP are at the forefront of ONR's assessment and judgements when using the SAPs as the benchmark.

## 7.1 ONR General Assessment of Low-hazard NPGNF Sites

2037 The licensees have conducted their stress tests assessments using specialists in emergency planning, safety cases and engineering, with input from relevant site leadership. This has also including a degree of benchmarking via the nuclear industry Safety Directors Forum. They have reported the stress tests work and its findings to their respective Nuclear Safety Committees, or other independent site oversight arrangements, for review and consideration to ensure the adequacy of the reports.

2038 The licensees' stress tests reports considered in this section vary in the level of detail provided. ONR considers this to be result of the proportionate and tailored approach that has been taken, given the varying hazard potential of the different sites, different nature of operations and the

[§] The Harwell site, operated by RSRL, is an exception here because the current off-site plan under REPPIR is predicated on a 15mSv reference accident. However, ONR has considered in this section that the licensee's approach to calculating consequence is based on disproportionate conservatism as opposed to good practice approach of "best-estimate" analysis. ONR therefore considers that Harwell should be conveniently categorised as a "lowest hazard" site.

non-applicability of many of NPP stress tests specifications. ONR considers that, generally, the licensees have provided sufficient detail in their reports. Where ONR considered that further information was needed to verify the report conclusions, this was obtained via technical exchanges and further consultation with the licensee as appropriate. ONR has also seen other documents which give sufficient information of the assessment of the site against external hazards. ONR's view is therefore that, given the life-cycle stage of the sites and the low level of radiological hazard presented, the overall detail provided within the stress tests is sufficient.

2039 ONR considers that each licensee referred to in this section has given a clear account and description of the characteristics of their sites. This demonstrates their low-hazard nature, life-cycle stage and relatively straightforward operations. This is consistent with their extant safety cases and supports the proportionate and tailored responses provided to the stress tests.

Compliance with Current Licensing Basis

2040 Licensees' stress tests reports essentially demonstrate that the sites meet their licensing basis. This is ensured by having valid safety cases and conducting their operations in compliance with these, performance of PSRs, inspection and maintenance and by having appropriate modification arrangements, all sanctioned under licence conditions. However, the individual reports vary as to the quality of discussion on this issue.

2041 ONR considers that the licensees are essentially compliant with the requirements of their safety cases.

Methods Used to Evaluate Earthquake, Flooding and Extreme Weather Events

2042 ONR considers that the design basis (and beyond design basis) events derived for these sites are a reasonable representation of the likely (low) hazard level in the UK and are proportionate to the site radiological inventories. The reports from the licensees considered in this section are clear on the situation regarding earthquake, flood and extreme weather withstand capability of their facilities and considered to be adequate for the purpose of establishing the position of the sites with respect to challenges from these events. ONR considers that the licensees have provided sufficient detail in their reports that is proportionate to scale of the external hazard and associated risk.

2043 Each of the sites is considered to have applied an appropriate level of DBE, flood and extreme weather criteria and data that is proportionate to their hazards and, where relevant, an appropriate over-margin to consider any cliff-edge effects when moving (or "stressed") to beyond design basis. The methods used by these licensees are judged by ONR to be adequate and based on reasonably practicable nuclear industry practice for facilities with low radiological inventories.

2044 The design basis events are derived by all the licensees on a conservative basis to be events with an annual probability of exceedance in the range between $10^{-4}$ or $10^{-3}$ pa. Typically, where the unmitigated off-site dose, assessed conservatively, is assessed as greater than 1mSv but less than 5mSv, the plant should be engineered to withstand the event to the extent that the expected off-site dose is less than 1mSv following an event with an annual probability of exceedance of $10^{-3}$. Where the expected unmitigated off-site dose is greater than 5mSv, the plant should be engineered to withstand the event to the extent that the unmitigated off-site dose is <5mSv. The peak free horizontal ground acceleration relevant to each annual probability of exceedance varies depending on the local seismicity of the site.

2045 For the sites considered here, the stress tests generally report that the legacy facilities on the licensees' sites do not need to be not designed to meet this criterion based on ALARP considerations. The unmitigated off-site consequences are not capable of exceeding the dose limits when complete structural collapse is assessed. New facilities on these sites are nevertheless qualified against these criteria and subjected to commensurate regulatory expectations.

Earthquake, Flooding and Extreme Weather Conditions

2046 ONR is satisfied that the presentation of the external hazard assessments, while variable in detail, is generally sufficient to satisfy the requirements of the stress tests. The results of the licensees' stress tests commonly conclude that the UK lower hazard NPGNF sites appear to have adequate resilience and margins of safety against DBE, flooding, extreme weather and loss of power. The licensees have reported that due to the age of the facilities on their sites and low radiological inventories, the design of their facilities does not require seismic qualification beyond modern design standards. Structural collapse is assumed in the event of a DBE and each licensee has, on a conservative basis, assessed that no significant off-site consequences can occur as a result of this. ONR's view is that licensees have undertaken proportionate assessments and therefore supports the conclusions of licensees.

2047 The reviews have also qualitatively considered the effects of moving to beyond design basis. Based on judgements made by the licensees, regarding factors such as limited low radiological inventory, extant safety cases, site location / topography and conservative design basis consequence assessments, they report there is no cliff-edge that changes the conclusions of the stress tests or alters the scale of the consequences identified in the licensees' safety cases. Given the low radiological inventories of these sites, significant off-site consequences are not considered credible even when "stressed" to beyond design basis. As a result, not all the sites have considered it necessary to explicitly consider the consequences to the site of moving to beyond design basis events. ONR notes that Low Level Waste Repository, Sellafield Ltd Capenhurst and Research Sites Restoration Ltd have however provided this explicit demonstration.

2048 The stress tests identify that, while access to sites may be restricted in the event of a design basis or beyond design basis external event, there is no expectation that access on an urgent basis by off-site personnel or emergency services is necessary to prevent a significant radiological risk. Based on the inventories held at these sites, ONR is content with this position. The effects of a seismic or flooding event on the movement of staff on and around the site are not discussed to any detail in the reports. However, based on their respective inventories and claimed inability to give rise to significant off-site consequences, delayed on-site emergency response is not generally considered by licensees to result in an escalation of consequences. An exception here is Harwell (RSRL), whereby timely on-site response would be necessary to secure deployment of mobile diesel generators to sustain ventilation on one facility.

2049 Each site provides a site-specific flood assessment and most provide details of data sources. The case against seismically induced flooding is based on a mixture of demonstrating no credible threat, drainage paths away from plant, and on the protection afforded to plant by its design.

2050 Protection from severe rainfall is accommodated by site drains and site topography that naturally drains excess water away. The sites have also reviewed the risk from tsunami and tidal surge and conclude, based on the geologically passive nature of north west Europe, site location / topography, their low radiological inventories and, where appropriate, the existence of flood defences, that tsunami or tidal surge present no credible risk to these sites. ONR further acknowledges the broader evidence from the post-Fukushima industry reviews that UK earthquakes are too small to directly generate tsunamis which will give rise to any challenge to the lowest hazard sites. The licensee arguments presented in the stress tests are broadly accepted by ONR as being valid.

Loss of Electrical Power

2051 ONR is satisfied that the nature of the operations and inventory at each of these sites is such that no nuclear classified structures, systems and components are required to implement safe shutdown procedures and maintain site safety. In addition, none of the sites are dependent on off-site or on-site power, other services or resources to maintain safety in the short or medium term (several days), or to implement accident management arrangements. While loss of power would be operationally inconvenient and would likely result in an evacuation of any occupied facilities on the sites, e.g. as a result of loss of ventilation, main on- and off-site and standby electrical supplies are not required to ensure nuclear safety at any of these sites.

2052 Long-term disruption to services and access routes to the sites due to external events and loss of power is only likely to result in prolonged inoperability of these sites and delayed implementation of on-site recovery from an event. This will have implications for business continuity. ONR notes that inoperability of LLWR would have potential consequences for recovery operations at other nuclear sites. This would result in LLW arisings needing to be held at other sites until the LLWR became operable.

Organisation and Arrangements to Manage Accidents

2053 The licensees have organisations and emergency arrangements developed and maintained to respond effectively to the unlikely event of an emergency. These arrangements are designed to deal with events which, though very unlikely, are reasonably foreseeable. Detailed on-site emergency response plans are designed to be sufficiently scalable to provide the base from which an extended response to more serious events could be developed. The low-hazard nature of the sites considered in this section does not require them to have off-site emergency response plans. Much of the organisation and arrangements for emergencies has been in place for many years.

2054 ONR takes a close interest in every site's emergency arrangements, and each site emergency plan is formally approved by the Regulator. The accident management arrangements, organisation and plans are periodically inspected by ONR to gain confidence in their continued adequacy in light of operational experience and ability to respond to different accidents and minimise their effects. Every site has an annual demonstration exercise (based on a suitably challenging accident scenario) that is witnessed by a team of ONR inspectors; this drives continuous improvement. Checks are carried out to ensure that, among other things: suitably qualified and experienced persons operate the facility and fill the emergency scheme roles; all personnel are subject to regular training and assessment; on-site (and off-site as appropriate) facilities are examined to ensure they are adequate to deal with an event; and all claimed emergency equipment is regularly tested and maintained.

## 7.2 ONR Site-specific Assessments

GE Healthcare Ltd

2055 GE Healthcare has considered DBE and flooding in a qualitative manner, and provided a judgment of the resilience against this hazard with reference to its REPPIR assessments. Given the low radiological inventory, none of the buildings at the GE Healthcare sites have been designed and qualified against extensive seismic or flooding events. The buildings are of typical standard industry construction. ONR is satisfied that this is a proportionate design basis given that the consequences of building collapse fall below REPPIR criteria for an off-site emergency plan.

2056 GE Healthcare reports that its resilience and margins for safety against design basis and beyond DBE, flooding, extreme weather and also loss of power events are considered to be adequate and appropriate. This is based in the location / topography of its sites, the nature of its operations and types of safety systems employed and low radiological inventory. ONR supports this view.

2057 The licensee has stated in its report its commitment to continually scrutinise and improve its accident management arrangements and to remain fully engaged with the nuclear industry in focusing on emergency response resilience in light of the Fukushima accident. ONR will review GE Healthcare's progress in this matter through normal regulatory processes and will ensure that any reasonably practicable improvements are identified and implemented.

Sellafield Ltd – Capenhurst

2058 The Sellafield Ltd Capenhurst stress tests address those areas of the NPP specifications that the licensee has judged to be applicable to its site. ONR considers the scope of the report to be appropriate and applicable. Sellafield Ltd Capenhurst has been explicit in defining its design basis earthquake and flooding events.

2059 With respect to earthquake, Sellafield Ltd Capenhurst assumes complete building collapse and conservatively assesses the off-site consequences to be <1mSv, based on likely damage states and breach of transport cylinder containment and uranic storage drums. The licensee reports that moving to beyond design basis would only make this structural collapse more likely, hence would not escalate the off-site consequences due to the limited inventory at the site. ONR considers this assessment of the consequence of design basis and beyond basis earthquake to be a reasonable representation of the likely impact to the site.

2060 The stress tests conclude that extreme flooding (tidal / tsunami and extreme weather) at and beyond the design basis that could result in significant radiological risk to workers or the public is not considered credible. The licensee bases this on the location / topography of the site giving adequate protection in the event of tsunami / tidal surge, and a judgment that surface water entering or accumulating in the cylinder and drum storage areas would not provide sufficient force to dislodge these and cause significant damage. The licensee's safety case supports this conclusion.

2061 ONR shares the judgments and conclusions made over the impact of design basis and moving to beyond design basis events at Sellafield Ltd Capenhurst. ONR considers that the assessment and conclusions of the Sellafield Ltd Capenhurst stress tests adequately and proportionately demonstrate that the site has been "stressed" for resilience at the design basis and when moving to beyond design basis.

2062 ONR is aware that Sellafield Ltd as a company is undertaking a wider review of its emergency arrangements and a Resilience Evaluation Process (RESEP) in light of the Fukushima accident. This is a structured approach to identifying any reasonably practicable enhancements and any cliff-edge effects within the licensee's safety cases and emergency arrangements. ONR will monitor the licensee progress and outcomes of this process through normal regulatory processes and will ensure that any recommendations identified are implemented where they are reasonably practicable.

2063 ONR also supports Sellafield Ltd's view, expressed in its report, that the most significant measure to enhance the Capenhurst site robustness to the effects of extreme external events is completion of the de-conversion process to transform the uranium hexafluoride to $U_3O_8$, which removes the chemotoxic hazard.

Studsvik UK Ltd

2064 The Studsvik stress tests address those areas of the NPP specifications that the licensee has judged to be applicable to the site. ONR considers that the scope and depth of Studsvik's stress tests are proportionate and applicable. No design basis earthquake, flood or extreme weather event has been explicitly defined for the Studsvik site based on its low hazard; hence there is no requirement for the buildings on the site to have been designed for resilience against such events. Studsvik has however, qualitatively assessed the effects of such events on the site, the impact of long-term disruption and how its on-site emergency arrangements would be invoked to manage such events.

2065 The Studsvik stress tests conclusions are that its accident management arrangements are appropriate and resilient and that no changes to existing site arrangements or design have been identified as necessary to enhance these based on the stress tests. ONR is satisfied with this conclusion that extreme external events at and beyond the design basis will not result in significant consequences at Studsvik due to the very low limiting radiological inventory.

Low Level Waste Repository Ltd

2066 ONR considers the scope of LLWR stress tests to be appropriate and applicable given the characteristics of the site. LLWR has been explicit in defining its design basis and beyond design basis earthquake and flooding events. The licensee's stress tests have concluded that each of these events does not result in significant off-site consequences.

2067 Extreme flooding at and beyond the design basis is assessed as not producing consequences more severe than in an extreme seismic event. Given the low radiological inventory at LLWR, there is no requirement for seismic qualification of its facilities beyond industry standards. As such, complete collapse of the site facilities is assumed and the licensee's safety case conservatively shows that this does not result in significant off-site consequences for design basis events. Moving to beyond design basis has also been explicitly considered by the licensee as not likely to cause any cliff-edge that would detrimentally impact the site's design basis resilience. The licensee reports that this will make such damage and collapse more likely but would not result in greater consequences than would be experienced for a design basis event. ONR supports this view and considers this to be an appropriate and reasonable judgment of the effect of extreme external events at LLWR. Moving to beyond design basis is not likely to cause any cliff-edge that would detrimentally impact the site's design basis resilience.

2068 The LLWR stress tests consider that extreme external events could prevent or delay resources reaching the site and impair the effectiveness of implementation of on-site recovery from an event. This would result in unavailability of LLWR and would have potential consequences for recovery operations at other nuclear sites and for commercial low waste operations in general. LLW would therefore need to be held at other sites until such time as the LLWR became operable.

2069 LLWR's review has explicitly proposed further measures for consideration that will potentially enhance the on-site defence-in-depth measures and resilience to extreme external events. These include procurement of additional emergency equipment and a review of its communication and control interface with the Sellafield nuclear site to allow effective prioritisation / re-prioritisation of resources should both sites be simultaneously affected by the same external event. ONR welcomes this and through its regulatory processes will seek to ensure that the licensee considers the reasonable practicability of these measures and implements them in the interest of continual improvement.

Research Site Restoration Ltd

2070 The RSRL stress tests for Harwell and Winfrith licensed sites only address applicable areas of the specifications for NPPs which the licensee has judged appropriate. ONR considers the scope of RSRL stress tests to be appropriate and applicable given the characteristics of those two sites. RSRL refers to one external event at Harwell that could lead to excessive consequences off-site

(15mSv) in the event of a seismic event; the licensee's analysis assumes that the subsequent building collapse leads to release of the entire building inventory of solid ILW. This scenario constitutes the basis for meeting requirement for having an off-site plan in accordance with REPPIR. ONR considers the worst-case conservative approach taken by RSRL to give an unrealistically high off-site release estimate since no "best-estimate" account is taken for the capability of existing containment and building fabric to offer at least some physical barrier. ONR has engaged with the licensee to secure commitment for a review of this analysis, particularly against the context of diminishing inventory, and therefore hazard, posed by the site over the next ten years.

2071 RSRL's stress tests consider the hydrogen hazard that could deterministically provide a motive driving force for release:

- Cessation of operations in that particular facility would arrest the generation of hydrogen (a normal by-product of grouting operations) without the need for any safety protection systems being enacted.
- Potentially affected structures are reinforced concrete and the resultant encapsulated grout does not have the propensity for mobilisation. The structures are claimed to be resilient to DBEs, but no specific cliff-edge assessment has been attempted by the licensee.
- Hydrogen is known to continue to be generated once product drums containing a cement matrix are stored in a vault store. It is foreseeable that a total loss of ventilation capability might be a consequential result of a seismic incident. For this extreme scenario, RSRL refers to an automatic start-up of a battery backed air injector system that would sustain ventilation for 12 hour without an external power supply.

2072 RSRL indicates that subsequent failure to restore power to the Harwell site after 12 hours would necessitate the deployment of a mobile diesel generator to sustain ventilation capability. Essentially, RSRL has not been able to deterministically discredit the potential for passive hydrogen generation from the completed cement matrix without relying on sustained supply of diesel to facilitate ventilation operations. The licensee alludes to, but does not quantify, significant timescales to achieve a flammable hydrogen concentration. Fundamentally, the licensee in this scenario would be reliant on sustained emergency preparedness to prevent a hydrogen deflagration or detonation. ONR recognises that the accumulation rate would likely be extremely low, and is satisfied with RSRL's subsequent demonstration that continued hydrogen generation from cemented grout matrix would accumulate to the lower flammability limit only after five days sustained loss of power.

2073 ONR considers the licensee's description of existing organisational arrangements for accident management on both sites to be well structured, with clear definition of on-site responsibilities for SQEP personnel. The licensee does not, however, provide in its report any indication as to its resilience to long-term incidents that might inhibit the sustained supply of diesel to mobile generators, nor indeed the logistics of supply in the event of the site being isolated from external services. ONR has sought a commitment from the licensee to address this specific matter to secure assurance that sufficient diesel capacity would be available, and that the licensee has in place a strategy for deploying diesel to vulnerable areas of the site within its emergency arrangements. ONR recognises the very slow timescale for hydrogen generation, allied to the wider societal importance of hazard reduction on the site, would limit the extent to which the licensee could implement reasonably practicable improvements against an inordinately remote sequence of events. The following finding is relevant here:

**STF-93: RSRL should review the availability and capability to deploy diesel and generators in order to sustain ventilation of hydrogen generating intermediate and low level radioactive waste on the site; this may be adequately addressed through a suitable deterministic argument if one can be made regarding minimal generation rates when intermediate and low level radioactive waste is in matrix form.**

2074 The licensee provides sufficient demonstration that a severe accident involving coincidental external hazards cannot credibly lead to an off-site release at Winfrith.

2075 ONR is however encouraged by the comprehensive forward accident management improvement plan for both sites that includes a review of planned measures for recovery and mitigation of site-wide accidents under degraded conditions.

Imperial College of Science, Technology and Medicine

2076 The Imperial College stress tests only address applicable areas of the NPP specifications which the licensee has judged appropriate. ONR considers the scope of licensee's stress tests to be appropriate and applicable given the characteristics of the site. The licensee provides sufficient demonstration that a significant release of radioactive material to the environment is not possible because of the low fission product inventory remaining in the CONSORT reactor core. Recent assessments provide the licensee with confidence that prolonged loss of cooling will not result in:

- the rupture of fuel cladding;
- a release of fission products from the fuel; or
- a deflagration or detonation of hydrogen.

2077 The low level of decay heat means that the CONSORT reactor does not require an ultimate heat sink to remove residual heat from the core in an emergency. Loss of power would result in a trip to reactor operations.

2078 The CONSORT reactor was not designed in accordance with any DBE since its construction preceded modern seismic standards. The licensee's seismic safety case concludes that accelerations associated with a 1 in 10,000-year earthquake would not directly damage the reactor structure. The only opportunity for fuel damage by earthquake induced falling debris will be the very short period of time during fuel recovery as part of POCO planned before 2015. Accordingly the licensee has evaluated the off-site and worker consequences associated with structural failure leading to fuel exposure following loss of shielding cover. The potential consequences under this most extreme sequence of events would lead to on-site and off-site release less than 1mSv.

2079 The licensee does not indicate the impact of coincidental floodwater inundation as a potential energetic motive force to distribute fuel off-site. The licensee has nonetheless provided ample demonstration that the site's topography and distance from the nearest fixed water source is such that flooding has been discounted in its safety cases. Extreme rainfall occurring coincidental to a structural collapse has not been considered by the licensee in its report. Theoretically, for the very short period of time that fuel is being recovered, the fuel has greater propensity to become mobile in such an extreme sequence of circumstances. ONR nevertheless considers that the licensee's focus should be limited to the development of a robust design basis and reasonably practicable safety measures to facilitate safe defuelling in accordance with ONR's policy on LC35 and policy on "time at risk", as detailed in TAG T/AST/005. The above scenario cannot be deterministically excluded altogether, but ONR is satisfied that the inordinately remote possibility combined with the greater strategic benefit of inventory reduction and robust design basis are sufficient basis to exclude further consideration.

2080 Imperial College's stress tests have identified existing emergency response arrangements as detailed in its on-site plan. An off-site emergency control centre is available should the on-site facilities become compromised. Emergency battery power is available to support radiological monitoring. ONR welcomes the licensee's proposal to procure a suitable diesel generator which will facilitate continued surveillance capability that would be of value for reassurance monitoring of any reasonably foreseeable incident. ONR is further satisfied that the licensee has adequately reviewed on-site communication capability in the context of a prolonged severe accident. ONR is sufficiently satisfied that the licensee's review of resilience is fit-for-purpose and reasonably practicable in the context of a site that poses negligible off-site hazard.

## 7.3 ONR's Overall Conclusion of the Stress Tests for Low-hazard NPGNF Sites

2081 ONR concludes that the UK licensees that operate the lowest hazard NPGNF sites have generally completed adequate and proportionate stress tests reviews in line with the intent of the NPP specifications, insofar as they are relevant. The stress tests reviews undertaken by the licensees have not indicated any fundamental weaknesses related to the NPP stress tests specifications.

2082 ONR is content with the overall adequacy of the stress tests programmes that have been undertaken by the low-hazard UK NPGNF licensees and supports the claims made regarding resilience of the sites to seismic, flooding, extreme weather and loss of power. ONR is satisfied that should an extreme external event occur at or near these sites, then even if the emergency response system is impaired / delayed, the nature of the low radiological inventory held on these sites is such that would not result in significant off-site consequences. This conclusion is supported by assessment of the stress tests reports, technical exchanges with the licensees and ONR's knowledge and inspections of the licensees' sites, safety cases, their operations and the low radiological inventories on these sites.

2083 ONR is of the view that the operators of the lowest hazard sites have committed to proportionate continual improvement in their stress tests reports. This is either by explicit identification of further measures for consideration which could enhance the sites resilience, or by commitment to continual review and improvement through engagement with industry forums and ONR, to consider further lessons that can learnt from the accident at the Fukushima Dai-ichi NPP. ONR is continuing to engage with the UK licensees to ensure that the recommendations identified in this report, those from HM Chief Inspector's final report on the implications and lessons learnt from Fukushima, and any improvements identified in the licensees' own reports are timely addressed and implemented, so far as is reasonably practicable.

# 8 GENERAL CONCLUSION

2084 This report is the UK stress tests report presenting the results from the stress tests as applied to UK NPGNF. Overall, ONR is content with adequacy of the stress tests programme undertaken by all the NPGNF licensees, and with the licensee reports. ONR expects that the enhancements identified to strengthen resilience further will be implemented within an appropriate timescale and that these will provide a positive contribution to nuclear safety in the UK in the event of a significant beyond design basis event.

2085 ONR has followed the structure and contents of the stress tests report as defined for NPPs as far as possible, in order to keep consistency between NPP and NPGNF stress tests. It appeared that for most facilities considered in this report the original requirements structure needed to be amended slightly, in order to avoid focusing on scenarios which hardly, or do not, apply. Unsurprisingly, the NPP stress tests process is not always relevant for assessing NPGNF resilience, although the safety purpose is identical: restricting radioactive releases so far as reasonably practicable.

2086 It is noticeable that NPGNF facilities and associated licensees are very diverse in terms of physical features, activities, potential hazards and stages of plant life-cycle. A new section, dealing with lowest hazard sites has been created because these sites were not relevant to consider for each requirement most of the time.

## 8.1 Key Provisions Enhancing Robustness

2087 The continuous improvement culture is a fundamental building block of a responsible nuclear site licensee, and equally important to the development of knowledge and experience within the independent nuclear safety regulator, ONR. The events at Fukushima, while tragic, provide a unique opportunity to learn from a severe nuclear accident. The stress tests process is part of that learning opportunity.

2088 In the UK, the licensee of a nuclear installation is required by LC15 to periodically review its safety case for the plant. This PSR usually takes place every ten years and requires the licensee to demonstrate that the original design safety intent is still being met. The reassessment is performed against the latest safety standards and technical knowledge. The operating experience of the plant is also considered in the review. If the PSR identifies any reasonably practicable safety improvements, then it is a legal requirement that these should be made by the licensee. In addition, any life-limiting factors that would preclude operation for a further ten years should also be identified in the review. The PSR includes a review of the safety of the plant in response to events such as earthquakes, floods, fire and explosion. The PSRs take account of modern standards and recent research findings. ONR independently assesses licensees’ PSR reports using its SAPs and TAGs.

2089 The UK nuclear plants were designed and built to standards in use at the time; the design generally involved flooding studies but, for some, this did not include seismic design. As a result, it has long been known that some older structures may suffer damage at (or below) a DBE. The construction of new facilities – designed to modern standards – has been planned or considered to re-house some nuclear activities and enable the decommissioning phase of such older buildings.

## 8.2 Safety Issues

2090 Neither the reviews undertaken by the licensees for the stress tests, nor the earlier national reviews, have indicated any fundamental weaknesses in the definition of design basis events or the safety systems to withstand them for UK nuclear installations. This was also a conclusion of HM Chief Inspector's Final Report (Ref. 2).

2091 The stress tests process, as applied by licensees, has been robust and challenging for the design basis events. For beyond design basis hazards and events, the process has also been challenging due, in part, to the novel approach prescribed for NPP stress tests. Further work will be needed by some licensees to achieve a consistent standard for beyond design basis external hazards.

## 8.3 Potential Safety Improvements and Further Work Forecasted

2092 The licensees have derived a significant number of potential improvements to enhance resilience for emergency actions following events beyond the design basis, or not currently foreseen. There are also potential improvements to the type or number of barriers to some hazards, which should improve defence-in-depth. In examining these proposals for NPGNF, attention has to be paid to proportionality according to the hazard potential and the normal holistic requirements of the nuclear site licence conditions, such as operating rules, instruction, maintenance arrangements, emergency arrangements, etc.

2093 The list of further studies and potential resilience enhancements identified by Sellafield Ltd, the defence licensees, Magnox Ltd and NNB GenCo are provided in Annexes 2 to 5. Typical examples include:

- Flood resilience enhancements.
- Site power distribution network resilience enhancements.
- Provision of emergency back-up equipment. This equipment may include:
  - diesel generator to provide back-up to emergency centres;
  - means of safely accessing the site in the event of flooding;
  - means of moving emergency support equipment in accident conditions;
  - emergency command and control facilities including communications equipment; and
  - emergency response / recovery equipment.

2094 Further to the additional studies and potential improvements identified by the licensees, ONR has raised a number of findings (see the Executive Summary for a table of findings). Some of these reinforce or extend the *Considerations* identified by the licensees, while others are additional to the *Considerations*.

2095 ONR expects that the stress tests process will finish when the improved processes, plant and procedures move into the licensees' normal procedures for change and review of safety cases in line with relevant LCs. An Implementation Report, intended to be published by ONR in autumn 2012, will confirm this transition. To support this, and ensure appropriate progress is being made by the licensees, the following finding has been raised:

**STF-94: Reports on the progress made in addressing the conclusions of the licensees *Considerations* and the ONR findings should be made available to ONR on the same timescale as that for HM Chief Inspector's recommendations (June 2012). These should include the status of plans and details of improvements that have been implemented.**

2096 While ONR's expectation is that the licensees will address their *Considerations*, the stress tests findings and HM Chief Inspector's recommendations, it should also be noted, from a regulatory perspective, that the licensees' response to Fukushima is being addressed under LC15 (Periodic Review) and is, therefore, subject to normal regulatory legal requirements.

# ANNEX 1: CHIEF NUCLEAR INSPECTOR'S CONCLUSIONS AND RECOMMENDATIONS

This annex lists the conclusions and recommendations from the interim and final reports by HM Chief Inspector of Nuclear Installations (Refs 1 and 2).

**Conclusions**

***Conclusion FR-1[**]: Consideration of the accident at Fukushima-1 against the ONR Safety Assessment Principles for design basis fault analysis and internal and external hazards has shown that the UK approach to identifying the design basis for nuclear facilities is sound for such initiating events.***

***Conclusion FR-2: The Fukushima accident reinforces the need for the Government, the Nuclear Decommissioning Authority and the Sellafield licensee to continue to pursue the Legacy Ponds and Silos remediation and retrievals programme with utmost vigour and determination.***

***Conclusion FR-3: The mandatory requirement for UK nuclear site licensees to perform periodic reviews of their safety cases and submit them to ONR to permit continued operation provides a robust means of ensuring that operational facilities are adequately improved in line with advances in technology and standards, or otherwise shut down or decommissioned.***

***Conclusion FR-4: The circumstances of the Fukushima accident have heightened the importance of Level 2 Probabilistic Safety Analysis for all nuclear facilities that could have accidents with significant off-site consequences.***

***Conclusion FR-5: The additional information we have received since our Interim Report, and our more detailed analysis, has added further substantiation to, and reinforced, our initial conclusions and recommendations.***

***Conclusion FR-6: The industry and others have responded constructively and responsibly to the recommendations made in our interim report and instigated, where necessary, significant programmes of work. This shows an ongoing commitment to the principle of continuous improvement and the maintenance of a strong safety culture.***

[**] The prefix "FR" has been used to distinguish conclusions made in the final report from those made in the interim report.

**Conclusions from the Interim Report**

The conclusions from the interim report are listed in full below, noting that they continue to stand.

***Conclusion IR-1:*** [††] ***In considering the direct causes of the Fukushima accident we see no reason for curtailing the operation of nuclear power plants or other nuclear facilities in the UK. Once further work is completed any proposed improvements will be considered and implemented on a case by case basis, in line with our normal regulatory approach.***

***Conclusion IR-2: In response to the Fukushima accident, the UK nuclear power industry has reacted responsibly and appropriately displaying leadership for safety and a strong safety culture in its response to date.***

***Conclusion IR-3: The Government's intention to take forward proposals to create the Office for Nuclear Regulation, with the post and responsibilities of HM Chief Inspector in statute, should enhance confidence in the UK's nuclear regulatory regime to more effectively face the challenges of the future.***

***Conclusion IR-4: To date, the consideration of the known circumstances of the Fukushima accident has not revealed any gaps in scope or depth of the Safety Assessment Principles for nuclear facilities in the UK.***

***Conclusion IR-5: Our considerations of the events in Japan, and the possible lessons for the UK, have not revealed any significant weaknesses in the UK nuclear licensing regime.***

***Conclusion IR-6: Flooding risks are unlikely to prevent construction of new nuclear power stations at potential development sites in the UK over the next few years. For sites with a flooding risk, detailed consideration may require changes to plant layout and the provision of particular protection against flooding.***

***Conclusion IR-7: There is no need to change the present siting strategies for new nuclear power stations in the UK.***

[††] The prefix "IR" has been to identify clearly those conclusions from the interim rport. Conclusion IR-1 here is therefore the same as Conclusion 1 in the iterim report.

***Conclusion IR-8: There is no reason to depart from a multi-plant site concept given the design measures in new reactors being considered for deployment in the UK given adequate demonstration in design and operational safety cases.***

***Conclusion IR-9: The UK's gas-cooled reactors have lower power densities and larger thermal capacities than water cooled reactors which with natural cooling capabilities give longer timescales for remedial action. Additionally, they have a lesser need for venting on loss of cooling and do not produce concentrations of hydrogen from fuel cladding overheating.***

***Conclusion IR-10: There is no evidence to suggest that the presence of MOX fuel in Reactor Unit 3 significantly contributed to the health impact of the accident on or off the site.***

***Conclusion IR-11: With more information there is likely to be considerable scope for lessons to be learnt about human behaviour in severe accident conditions that will be useful in enhancing contingency arrangements and training in the UK for such events.***

**Recommendations**

The recommendations are listed in full below with the interim report and final report recommendations identified differently noting that the interim report ones continue to stand.[‡‡]

[‡‡] It should be noted that the final report recommendations identification in these lists are not sequential as they follow the sequence of where they are derived in the "Discussion" Section of that report. Furthermore, "IR" refers to "Interim Report" and not interim recommendations – they are all still valid. Italics identify where additional clarification is provided.

| General | |
|---|---|
| International Arrangements for Response | **Recommendation IR-1:** The Government should approach IAEA, in co-operation with others, to ensure that improved arrangements are in place for the dissemination of timely authoritative information relevant to a nuclear event anywhere in the world.<br>This information should include:<br>*a)* *basic data about the reactor design including reactor type, containment, thermal power, protection systems, operating history and condition of any nuclear materials such as spent fuel stored on the site should be held permanently in a central library maintained on behalf of the international community; and*<br>*b)* *data on accident progression and the prognosis for future accident development. The operator would provide such information as is available to its national authorities. International mechanisms for communicating this information between national governments should be strengthened. To ensure that priority is given to relevant information, international agreement should be sought on the type of information that needs to be provided.* |
| Global Nuclear Safety | **Recommendation FR-9:** The UK Government, nuclear industry and ONR should support international efforts to improve the process of review and implementation of IAEA and other relevant nuclear safety standards and initiatives in the light of the Fukushima-1 (Fukushima Dai-ichi) accident. |
| National Emergency Response Arrangements | **Recommendation IR-2:** The Government should consider carrying out a review of the Japanese response to the emergency to identify any lessons for UK public contingency planning for widespread emergencies, taking account of any social, cultural and organisational differences.<br><br>**Recommendation IR-3:** The Nuclear Emergency Planning Liaison Group should instigate a review of the UK's national nuclear emergency arrangements in light of the experience of dealing with the prolonged Japanese event.<br><br>*This information should include the practicability and effectiveness of the arrangements for extending countermeasures beyond the Detailed Emergency Planning Zone (DEPZ) in the event of more serious accidents.*<br>**Recommendation FR-6:** The nuclear industry with others should review available techniques for estimating radioactive source terms and undertake research to test the practicability of providing real-time information on the basic characteristics of radioactive releases to the environment to the responsible off-site authorities, taking account of the range of conditions that may exist on and off the site.<br>**Recommendation FR-7**: The Government should review the adequacy of arrangements for environmental dose measurements and for predicting dispersion and public doses and environmental impacts, and to ensure that adequate up-to-date information is available to support decisions on emergency countermeasures. |
| Planning Controls | **Recommendation FR-5**: The relevant government departments in England, Wales and Scotland should examine the adequacy of the existing system of planning controls for commercial and residential developments off the nuclear licensed site. |

| General | |
|---|---|
| Openness and Transparency | **Recommendation IR-4:** Both the UK nuclear industry and ONR should consider ways of enhancing the drive to ensure more open, transparent and trusted communications, and relationships, with the public and other stakeholders.<br><br>**Recommendation FR-8:** The Government should consider ensuring that the legislation for the new statutory body requires ONR to be open and transparent about its decision-making, so that it may clearly demonstrate to stakeholders its effective independence from bodies or organisations concerned with the promotion or utilisation of nuclear energy. |

| Relevant to the Regulator | |
|---|---|
| Safety Assessment Approach | **Recommendation IR-5:** Once further detailed information is available and studies are completed, ONR should undertake a formal review of the Safety Assessment Principles to determine whether any additional guidance is necessary in the light of the Fukushima accident, particularly for "cliff-edge" effects.<br><br>*The review of ONR's Safety Assessment Principles (SAP) should also cover ONR's Technical Assessment Guides (TAG), including external hazards.* |
| Emergency Response Arrangements and Exercises | **Recommendation IR-6:** ONR should consider to what extent long-term severe accidents can and should be covered by the programme of emergency exercises overseen by the Regulator.<br><br>*This should include:*<br><br>*a) evaluation of how changes to exercise scenarios supported by longer exercise duration will permit exercising in real time such matters as hand-over arrangements etc.;*<br><br>*b) how automatic decisions taken to protect the public can be confirmed and supported by plant damage control data; and*<br><br>*c) recommendations on what should be included in an appropriate UK exercise programme for testing nuclear emergency plans, with relevant guidance provided to Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) dutyholders.*<br><br>**Recommendation IR-7:** ONR should review the arrangements for regulatory response to potential severe accidents in the UK to see whether more should be done to prepare for such very remote events.<br><br>*This should include:*<br><br>*a) enhancing access during an accident to relevant, current plant data on the status of critical safety functions, i.e. the control of criticality, cooling and containment, and releases of radioactivity to the environment, as it would greatly improve ONR's capability to provide independent advice to the authorities in the event of a severe accident; and*<br><br>*b) review of the basic plant data needed by ONR – this has much in common with what we suggest should be held by an international organisation under Recommendation IR-1.* |

| Relevant to the Regulator | |
|---|---|
| Research | **Recommendation FR-10:** ONR should expand its oversight of nuclear safety-related research to provide a strategic oversight of its availability in the UK as well as the availability of national expertise, in particular that needed to take forward lessons from Fukushima. Part of this will be to ensure that ONR has access to sufficient relevant expertise to fulfil its duties in relation to a major incident anywhere in the world. |

| Relevant to the Nuclear Industry | |
|---|---|
| Off-site Infrastructure Resilience | **Recommendation IR-8:** The UK nuclear industry should review the dependency of nuclear safety on off-site infrastructure in extreme conditions, and consider whether enhancements are necessary to sites' self sufficiency given for the reliability of the grid under such extreme circumstances.<br>*This should include:*<br>*a) essential supplies such as food, water, conventional fuels, compressed gases and staff, as well as the safe off-site storage of any equipment that may be needed to support the site response to an accident; and*<br>*b) timescales required to transfer supplies or equipment to site.*<br>**Recommendation IR-9:** Once further relevant information becomes available, the UK nuclear industry should review what lessons can be learnt from the comparison of the events at the Fukushima-1 (Fukushima Dai-ichi) and Fukushima-2 (Fukushima Dai-ni) sites. |
| Impact of Natural Hazards | **Recommendation IR-10:** The UK nuclear industry should initiate a review of flooding studies, including from tsunamis, in light of the Japanese experience, to confirm the design basis and margins for flooding at UK nuclear sites, and whether there is a need to improve further site-specific flood risk assessments as part of the periodic safety review programme, and for any new reactors. This should include sea-level protection. |
| Multi–reactor Sites | **Recommendation IR-11:** The UK nuclear industry should ensure that safety cases for new sites for multiple reactors adequately demonstrate the capability for dealing with multiple serious concurrent events induced by extreme off-site hazards. |
| Spent Fuel Strategies | **Recommendation IR-12:** The UK nuclear industry should ensure the adequacy of any new spent fuel strategies compared with the expectations in the Safety Assessment Principles of passive safety and good engineering practice.<br>*Existing licensees are expected to review their current spent fuel strategies as part of their periodic review processes and make any reasonably practicable improvements, noting that any intended changes need to take account of wider strategic factors including the implications for the nuclear fuel cycle.* |

| Relevant to the Nuclear Industry | |
|---|---|
| Site and Plant Layout | **Recommendation IR-13:** The UK nuclear industry should review the plant and site layouts of existing plants and any proposed new designs to ensure that safety systems and their essential supplies and controls have adequate robustness against severe flooding and other extreme external events.<br><br>*This recommendation is related to Recommendation IR-25 and should be considered along with the provisions put in place under that recommendation. It should include, for example, the operator's capability to undertake repairs and the availability of spare parts and components.* |
| Fuel Pond Design | **Recommendation IR-14:** The UK nuclear industry should ensure that the design of new spent fuel ponds close to reactors minimises the need for bottom penetrations and lines that are prone to siphoning faults. Any that are necessary should be as robust to faults as are the ponds themselves. |
| Seismic Resilience | **Recommendation IR-15:** Once detailed information becomes available on the performance of concrete, other structures and equipment, the UK nuclear industry should consider any implications for improved understanding of the relevant design and analyses.<br><br>*The industry focus on this recommendation should be on future studies regarding the continuing validation of methodologies for analysing the seismic performance of structures, systems and components important to safety. This should include concrete structures and those fabricated from other materials.* |
| Extreme External Events | **Recommendation IR-16:** When considering the recommendations in this report the UK nuclear industry should consider them in the light of all extreme hazards, particularly for plant layout and design of safety-related plant.<br><br>**Recommendation FR-2**: The UK nuclear industry should ensure that structures, systems and components needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, are adequately protected against hazards that could affect several simultaneously.<br><br>**Recommendation FR-3**: Structures, systems and components needed for managing and controlling actions in response to an accident, including plant control rooms, on-site emergency control centres and off-site emergency centres, should be capable of operating adequately in the conditions, and for the duration, for which they could be needed, including possible severe accident conditions. |
| Off-site Electricity Supplies | **Recommendation IR-17:** The UK nuclear industry should undertake further work with the National Grid to establish the robustness and potential unavailability of off–site electrical supplies under severe hazard conditions. |
| On-site Electricity Supplies | **Recommendation IR-18:** The UK nuclear industry should review any need for the provision of additional, diverse means of providing robust sufficiently long-term independent electrical supplies on sites, reflecting the loss of availability of off-site electrical supplies under severe conditions.<br><br>*This should be considered along with Recommendation IR-8 within the wider context of "on-site resilience".* |

| Relevant to the Nuclear Industry | |
|---|---|
| Cooling Supplies | **Recommendation IR-19:** The UK nuclear industry should review the need for and, if required, the ability to provide longer term coolant supplies to nuclear sites in the UK in the event of a severe off-site disruption, considering whether further on-site supplies or greater off-site capability is needed. This relates to both $CO_2$ and freshwater supplies, and for existing and proposed new plants.<br><br>**Recommendation IR-20:** The UK nuclear industry should review the site contingency plans for pond water make-up under severe accident conditions to see whether they can and should be enhanced given the experience at Fukushima. |
| Combustible Gases | **Recommendation IR-21:** The UK nuclear industry should review the ventilation and venting routes for nuclear facilities where significant concentrations of combustible gases may be flowing or accumulating to determine whether more should be done to protect them. |
| Emergency Control Centres, Instrumentation and Communications | **Recommendation IR-22:** The UK nuclear industry should review the provision on site of emergency control, instrumentation and communications in light of the circumstances of the Fukushima accident including long timescales, widespread on and off-site disruption, and the environment on site associated with a severe accident.<br><br>*In particular, the review should consider that the Fukushima-1 site was equipped with a seismically robust building housing the site emergency response centre which had: adequate provisions to ensure its habitability in the event of a radiological release; and communication facilities with on-site plant control rooms and external agencies, such as TEPCO headquarters in Tokyo.*<br><br>**Recommendation IR-23:** The UK nuclear industry, in conjunction with other organisations as necessary, should review the robustness of necessary off-site communications for severe accidents involving widespread disruption.<br><br>*In addition to impacting communications, it is possible that external events could also affect off-site centres used to support at site in an emergency. Alternative locations should be available and they should be capable of being commissioned in an appropriate timescale.* |

| Relevant to the Nuclear Industry | |
|---|---|
| Human Capabilities and Capacities | **Recommendation IR-24:** The UK nuclear industry should review existing severe accident contingency arrangements and training, giving particular consideration to the physical, organisational, behavioural, emotional and cultural aspects for workers having to take actions on site, especially over long periods. This should take account of the impact of using contractors for some aspects on site, such as maintenance, and their possible response.<br><br>*This is a wide-ranging recommendation and there are a number of aspects that need to be included:*<br><br>*a) the reviews need to acknowledge design differences between individual nuclear facilities and consider whether corporate Severe Accident Guidelines need to be customised;*<br><br>*b) adequacy of trained personnel numbers for long-term emergencies, particularly for multi-unit sites, and taking into account the potential impact of infrastructure damage and societal issues on the ability to mobilise large numbers of personnel;*<br><br>*c) the time windows for availability of off-site support may be challenged, hence the role of on-site personnel may change, which has implications for procedures and training;*<br><br>*d) the review of Severe Accident Management Guidelines (SAMG) should consider not only critical safety functions' prioritisation, but also whether and how SAMGs support any dynamic reprioritisation based on emerging information;*<br><br>*e) consideration should also be given to operator support requirements relating to tactical and strategic decision-making; and*<br><br>*f) in addition to the acute phase of a severe accident, consideration also needs to be given to stabilisation, recovery and clean- up, and the personnel involved from the many organisations involved.*<br><br>**Recommendation FR-11**: The UK nuclear industry should continue to promote sustained high levels of safety culture amongst all its employees, making use of the National Skills Academy for Nuclear and other schemes that promote "nuclear professionalism". |

| Relevant to the Nuclear Industry | |
|---|---|
| Safety Case | **Recommendation IR-25:** The UK nuclear industry should review, and if necessary extend, analysis of accident sequences for long-term severe accidents. This should identify appropriate repair and recovery strategies to the point at which a stable state is achieved, identifying any enhanced requirements for central stocks of equipment and logistical support.<br><br>*Recommendation IR-25 is linked with Recommendation IR-13. Combining these two recommendations means that we would expect industry to:*<br><br>*a) identify potential strategies and contingency measures for dealing with situations in which the main lines of defence are lost. Considerations might include, for example, the operator's capability to undertake repairs and the availability of spares (capability includes the availability of personnel trained in the use of emergency equipment along with necessary supporting resources);*<br>*b) consider the optimum location for emergency equipment, so as to limit the likelihood of it being damaged by any external event or the effects of a severe nuclear accident;*<br>*c) consider the impact of potential initiating events on the utilisation of such equipment;*<br>*d) consider the need for remotely controlled equipment including valves; and*<br>*e) consider in the layout of the site effective segregation and bunding of areas where radioactive liquors from accident management may accumulate.*<br><br>*Regarding other aspects of Recommendation IR-25, the industry needs to:*<br><br>*f) ensure it has the capability to analyse severe accidents to properly inform and support on-site severe accident management actions and off-site emergency planning. Further research and modelling development may be required;*<br>*g) ensure that sufficient severe accident analysis has been performed for all facilities with the potential for accidents with significant off-site consequences, in order to identify severe accident management and contingency measures. Such measures must be implemented where reasonably practicable and staff trained in their use; and*<br>*h) examine how the continued availability of sufficient on-site personnel can be ensured in severe accident situations, as well as considering how account can be taken of acute and chronic stress at both an individual and team level (this is linked to Recommendation IR-24).*<br><br>**Recommendation FR-1:** All nuclear site licensees should give appropriate and consistent priority to completing Periodic Safety Reviews (PSR) to the required standards and timescales, and to implementing identified reasonably practicable plant improvements.<br><br>**Recommendation FR-4:** The nuclear industry should ensure that adequate Level 2 Probabilistic Safety Analyses (PSA) are provided for all nuclear facilities that could have accidents with significant off-site consequences and use the results to inform further consideration of severe accident management measures. The PSAs should consider a full range of external events including "beyond design basis" events and extended mission times. |

| **Way Forward** | |
|---|---|
| Way forward | **Recommendation IR-26:** A response to the various recommendations in the interim report should be made available within one month of it being published. These should include appropriate plans for addressing the recommendations. Any responses provided will be compiled on the ONR website.<br><br>***This recommendation was met in full by all of those on whom the recommendations fell, and is therefore discharged.***<br><br>**Recommendation FR-12:** Reports on the progress that has been made in responding to the recommendations in this report should be made available to ONR by June 2012. These should include the status of the plans, together with details of improvements that have been implemented by that time. |

# ANNEX 2: SELLAFIELD LTD CONSIDERATIONS

| No | Consideration |
|---|---|
| SL-1 | Provide local neutron inhibiting materials for emergency deployment to prevent / halt a potential criticality excursion. |
| SL-2 | Review the arrangements for providing alternative sources of cooling water to HASTs in extreme circumstances. |
| SL-3 | Review the arrangements for management of site fuel stocks. |
| SL-4 | Procure a bowser / road tanker capable of transferring fuel efficiently around the site. |
| SL-5 | Review the manning levels required to respond to prioritized site demands during a major event. |
| SL-6 | Develop a programme to deploy, connect and test MDAs to EPD connection points routinely on safety significant plants. |
| SL-7 | Enhance the robustness of the forced ventilation system for Magnox wastes to a severe seismic event. |
| SL-8 | Review the potential for trapped hydrogen with the Magnox waste matrix being liberated as a result of a severe seismic event. |
| SL-9 | Obtain skid-mounted diesel pumps for potential deployment in the later Magnox fuel storage pond following a severe seismic event. |
| SL-10 | Review the robustness of alternative power supplies sufficient to allow timely crack repair (using already available dedicated repair plates, water containment and various pumping systems) following a severe seismic event. |
| SL-11 | Seismically enhance existing bridges across the River Calder and develop the ability to deploy temporary structures. |
| SL-12 | Confirm realistic rates of self-heating within Magnox fuel undergoing reprocessing and the minimum quantity of water required to prevent self-ignition on potential loss of cooling. |
| SL-13 | Develop and substantiate specific contingency plans to extinguish a fire within solid waste facilities. |
| SL-14 | Consider the need to engineer additional flood defences alongside the River Calder. |
| SL-15 | Undertake more detailed modeling of surface run-off and drainage within built-up areas of the site. |
| SL-16 | Review the resilience of the current arrangements to pump out the central drainage water collection and discharge system. |

| No | Consideration |
|---|---|
| SL-17 | Utilise the design of any future changes to the site infrastructure to direct rainfall flood flows so as to minimise ponding. |
| SL-18 | Reengineer applicable flood defences to address very severe rainfall flooding. |
| SL-19 | Take local actions to address potential vulnerabilities to flooding of individual EPD boards and MDA connection points. |
| SL-20 | Consider the procurement of pre-fabricated flood barriers for local ad hoc deployment. |
| SL-21 | Take local actions to address the potential vulnerabilities of diesel stocks to protracted extremely low temperatures. |
| SL-22 | Examine the potential to connect MDAs to facilitate the lowering safely of suspended flasks, skips and magazines in the event of a prolonged loss of electrical power. |
| SL-23 | Examine the means by which product within the THORP centrifuge bowl can be kept wetted so as to avoid subsequent decomposition. |
| SL-24 | Review the resilience of the water supplies to site in extreme circumstances. |
| SL-25 | Increase the flexibility and use of the existing water supply cells. |
| SL-26 | Consider the reinstatement of the River Calder pumphouse. |
| SL-27 | Review the size, number and location of emergency pumps. |
| SL-28 | Review the emergency responses for all spent fuel storage ponds to identify commonality between systems and equipment. |
| SL-29 | Procure further portable bunds for potential deployment around spent fuel storage ponds. |
| SL-30 | Utilise the site deep water facility to test both techniques and equipment and to carry out training and emergency exercises. |
| SL-31 | Review the arrangements for personnel undertaking emergency roles. |
| SL-32 | Maintain a list of key plant parameters within the SECC. |
| SL-33 | Review ICC arrangements to ensure sufficient diversity to facilitate response to a multi-plant event. |
| SL-34 | Ensure that due cognisance is given to the need to retain appropriate access for emergency services during future changes to the site infrastructure. |

| No | Consideration |
|---|---|
| SL-35 | Review the arrangements for fire and rescue response to a severe event. |
| SL-36 | Consider the construction of hardened and sustainable physical control structures. |
| SL-37 | Procure temporary mobile units (and possibly off-site air-transported deployable containers) for provision of either welfare support or to augment the management of emergencies. |
| SL-38 | Enhance the resilience of the communications infrastructure. |
| SL-39 | Review the provision of support to the communications infrastructure during a severe event. |
| SL-40 | Review the resilience of the site data network and the need to extend the period of monitoring and data transmission to SECC. |
| SL-41 | Consider the balance to be struck between the deployment of DMVs on- and off-site and whether current provision is suitable and sufficient. |
| SL-42 | Consider the criticality implications of using water sprays and / or foams to bring to ground potential aerial releases. |
| SL-43 | Determine practical means for deploying safely widespread fixative agents to minimise potential spread of airborne contamination. |
| SL-44 | Review the resilience of key support services likely to be necessary for ongoing plant control and / or emergency response. |
| SL-45 | Engage with the Hydrogen Working Party to determine the minimum air displacement flows for the wet storage of Magnox wastes so as to remain below the lower flammable level. |
| SL-46 | Determine, via simple modeling, whether either or both “natural ventilation” and / or “lifting plugs” would be effective as a back-up means for managing hydrogen during wet storage of Magnox wastes. |
| SL-47 | Review the resilience of both power and steam supplies to HASTs in extreme circumstances. |

# ANNEX 3: DEFENCE LICENSEES STRESS TESTS CONSIDERATIONS

**Atomic Weapons Establishment**

| No. | Consideration |
|---|---|
| AWE-1 | Consider the provision of enhanced emergency response equipment and management. |
| AWE-2 | Consider diverse storage area locations for emergency response equipment to provide resilience from common mode failure. |
| AWE-3 | Consider enhancing preparation and planning for extreme events and long-term post-accident recovery. |
| AWE-4 | Consider the provision of additional supplies following extreme external events. |
| AWE-5 | Consider increasing defence-in-depth of emergency response staff. |

**Rolls-Royce Marine Power Operations Ltd – Nuclear Fuel Production Plant (Manufacturing) Licensed Site**

| No. | Consideration |
|---|---|
| RRM-1 | Investigate the capability of the diesel generator to provide back up to the Emergency Control Centre (ECC) for extended periods (up to 24 hours, preferably longer) without need for off-site fuel supplies. |
| RRM-2 | Consider improving the resilience of the site power distribution networks, site UPS and Chemical Plant and site diesel generators to improve availability post flood. |
| RRM-3 | Consider improving the resilience of the Bronze Command to site flooding, provision of an alternative back up location that is not susceptible to Derwent River flooding, or relocating part or all of the stock of Health Physics instrumentation and PPE to a location not susceptible to flooding. |
| RRM-4 | Consider improving the resilience of the ECC to site flooding, or provision of an alternative back up location that is not susceptible to Derwent River flooding and to which access from off-site locations can be assured. |
| RRM-5 | Consider how to improve the resilience against combinations of earthquake and flooding of selected aspects of the manufacturing facilities.<br>Attention should be focussed especially on the use and integrity of the racking, including whether to change the loading arrangements to make formation of unfavourable arrangements of fissile material less likely following topple. The benefits of moving material to this store when flooding is predicted should also be reviewed. |
| RRM-6 | Consider the need for a holding of Health Physics instrumentation and PPE in a location not susceptible to the same severe seismic events that could result in extensive production area damage. |
| RRM-7 | Consider if a stock of neutron poisons should be retained in a location not susceptible to inaccessibility due to severe seismic events and flooding at the site, what form these could take and if there are practicable means of deployment following severe events. |
| RRM-8 | Consider the provision, either as part of site infrastructure, or through arrangements with other sites or government providers, a means of safely accessing the site in the event of flooding at relatively short notice. |

**Rolls-Royce Marine Power Operations Ltd – Neptune Licensed Site**

| No. | Consideration |
|---|---|
| RRM-9 | Investigate the capability of the diesel generator to provide back up to the Emergency Control Centre for extended periods (up to 24 hours, preferably longer) without need for off-site fuel supplies. |
| RRM-10 | Consider storing the Neptune portable generator within the reactor building or other location not susceptible to flooding to improve its availability post flood. |
| RRM-11 | Consider improving the resilience of the Bronze Command to site flooding, provision of an alternative back up location that is not susceptible to Derwent River flooding, or relocating part or all of the stock of Health Physics instrumentation and PPE to a location not susceptible to flooding. |
| RRM-12 | Consider improving the resilience of the Emergency Control Centre (ECC) to site flooding, or provision of an alternative back up location that is not susceptible to Derwent River flooding, and to which access from off-site locations can be assured. |
| RRM-13 | Perform analyses of the Neptune buildings against snow and wind loadings. |
| RRM-14 | Consider the need for a holding of Health Physics instrumentation and PPE in a location not susceptible to the same severe earthquakes that could result in extensive reactor plant damage. |
| RRM-15 | Consider if a stock of neutron poisons should be retained in a location not susceptible to inaccessibility to severe earthquakes and flooding at the site, what form these could take, and if there are practicable means of deployment following severe events. |
| RRM-16 | Consider the provision, either as part of site infrastructure, or through arrangements with other sites or government providers, a means of safely accessing the site in the event of flooding at relatively short notice. |

**BAE Systems Marine Ltd**

| No. | Consideration |
|---|---|
| BAE-1 | Consideration might be given to using the crew as part of the wider site emergency response. |
| BAE-2 | The scenario with sea-levels beyond the design basis and / or a tsunami beyond the design basis, resulting in an energetic wave at the Wet Dock Quay, should be analysed more rigorously. This should include the implications for a submarine moored at the Wet Dock Quay. |
| BAE-3 | The linkage between safety case accident sequences and emergency planning could be strengthened. |
| BAE-4 | Multiple accidents involving nuclear fuel at the Barrow site cannot be ruled out. |
| BAE-5 | A scenario, in which a radiological consequence has already happened, should be more closely studied and taken into account in the Emergency Arrangements. |
| BAE-6 | Consider the need for a schedule, in a known, secure but accessible location, to inform personnel of the means by which installed water, electrical and gas services, etc, to the DDH can be isolated, and the locations of such means. |
| BAE-7 | Consider the means of establishing the status of the plant in a damaged and unsafe location, e.g. monitoring the plant from some distance to forewarn of an incipient criticality accident, if advances in technology can provide this. |
| BAE-8 | Consider the means of gaining access to a severely damaged building (e.g. the DDH), with concomitant requirements for lighting, shoring, etc. |
| BAE-9 | Consider the means of safeguarding against a slowly developing criticality accident, which is easily and quickly applied. |
| BAE-10 | Consider the availability, identification and training of personnel to carry out the above. |
| BAE-11 | A scenario at the Wet Dock Quay, involving drainage of the Dock system, should be more closely studied, within a broader accident management coverage. |
| BAE-12 | The existence, location and use of the ‘high and dry’ provisions, including portable diesel-powered pumps and hoses, to augment seawater services to a submarine at the Wet Dock Quay, need to be made known to all relevant personnel. |
| BAE-13 | The existence, location and use of any other existing or new emergency provisions for a submarine at the Wet Dock Quay need to be made known to all relevant personnel. |
| BAE-14 | Consider the need to store all this emergency equipment in a known, secure but accessible location. |

| No. | Consideration |
|---|---|
| BAE-15 | Consider means of moving emergency support equipment, post event. |
| BAE-16 | Consider the identification and training of personnel to carry out the above. |
| BAE-17 | The Wet Dock Quay itself may be damaged by the seismic event. This will prevent access to / egress from the submarine until an alternative route is set up. |
| BAE-18 | The implications of the above scenario include major damage to the Barrow Dock system and perhaps failure of the Michaelson Road Bridge: Thus, it may not be possible to move the submarine for some considerable time: Any specific procedures for dealing with this scenario should recognise this. |
| BAE-19 | The effect of loss of dock water on the Fast Leak Drill (following a Loss of Coolant Accident (LOCA), as currently specified, should be assessed. |
| BAE-20 | All the emergency provisions should be subject to EMIT by SQEP. |
| BAE-21 | Consider the possibility of hardening buildings required by the Emergency Arrangements against environmental hazards and the provision of communications equipment that could operate after such hazards. |
| BAE-22 | Consider recognising, in the Emergency Arrangements and emergency plans, the potential environment on and off-site, in which the arrangements and plans are to be used. |
| BAE-23 | Consider how non-essential personnel will know that they should evacuate the site and how they can evacuate the site, if local structures and facilities, including road bridges and street lighting, are damaged. |
| BAE-24 | Consider how the appropriate personnel on-site will know when not to expect guidance via the Emergency Arrangements and how they will be managed instead. |
| BAE-25 | Consider how site personnel will communicate with each other (and off-site) if telephone systems (including mobile phone networks) have been damaged: It is noted that the submarine at the Wet Dock Quay will have very effective communication systems, but these will have a limited possible audience, which will not include personnel on-site. |
| BAE-26 | Consider the skills that will be needed to respond to the particular situation developing on the site and whether such skills are readily available. |
| BAE-27 | Recognise that personnel who are suitably qualified and experienced in the activity being undertaken at the time of the hazard, and in the safety issues associated with the activity, may be injured by damage caused by the initiating event. |
| BAE-28 | Recognise that the seismic event may also damage office buildings on-site, so that other informed personnel may not be immediately available. |

| No. | Consideration |
|---|---|
| BAE-29 | The plan to prevent a criticality accident may require ingress into a damaged, unlit building (e.g. the Devonshire Dock Hall (DDH), collapsed, unlit but on fire), with significant personnel safety implications, exacerbated by the possibility of a seismic aftershock: what guidance will be available to make the best decision. |
| BAE-30 | Recognise that BAE personnel off-site, who may be needed on-site, will not be available or even in communication with the site for some time and may have other priorities. |
| BAE-31 | Recognise that Local Authority and specialist technical resources from off-site will not be available or even in communication with the site for some time. The Local Authority will anyway have other priorities. |
| BAE-32 | Recognise that the initiating hazard will complicate off-site emergency measures. |

**Devonport Royal Dockyard Ltd**

Note that DRDL have identified considerations that apply to both the licensed site, and to the authorised site where activities in the wider Devonport area are under control of the MoD. Those considerations which are not within the scope of ONR regulation are highlighted in grey below, and are included here for completeness.

| No. | Consideration |
|---|---|
| DRD-1 | Assess the hazard posed to the electrical systems by mechanical (e.g. freshwater) services within and the cryogenic storage tanks above the subways failing as a result of a seismic event and whether any reasonably practicable improvements can be made. |
| DRD-2 | Consideration should be given to investigating the availability of cables with crimped ends, instead of the bespoke connector arrangements, thus allowing greater flexibility of connection. |
| DRD-3 | Identify post seismic Shelter Stations, Forward Command Posts and alternative emergency response personnel. |
| DRD-4 | Consider the benefit of an alternative ‘clearway’ to the helipad, noting the likely collapse of the Weston Mill Bridge (alternative landing site may be available on surface platforms within the DPoP). |
| DRD-5 | Consideration may be given to the provision of alternative electrical generation equipment. |
| DRD-6 | Consideration should be given to determining the potential flow rates as submarine non-tidal berths. |
| DRD-7 | Ascertain the practicability of providing protection against ship collisions. |
| DRD-8 | Consider relocating portable emergency response equipment (e.g. the PECWPs) to a location less likely to suffer flood / seismic damage and how their release may be controlled to prevent failure due to secondary effects following a seismic event. |
| DRD-9 | Consideration could be given to providing alternative means of leak limitation to support freeze seals. |
| DRD-10 | Although it is recognised that there is a robust understanding of the design basis, consideration should be given to ensuring that there is a nation wide programme of works to ensure that the modelling of extreme water level at individual sites is consistent and reviewed on a regular basis. |

| No. | Consideration |
|---|---|
| DRD-11 | In addition to providing a means of preventing water ingress through the ducts, further alternatives, such as upgrading sump pumps, improving the water-tightness of equipment and connections, relocating potentially vulnerable equipment and the provision of additional / alternative Diesel Generators should be considered. |
| DRD-12 | To protect electrical systems in the subways, consideration should be given to bunding around the hatches and fitting waterproof covers which are closed during periods of high tide. |
| DRD-13 | To protect electrical systems in the subways, provision of engineered closures to transform the 9 Dock Crane Barrier into essentially a continuous perimeter bund for the Dock should be considered. This consideration should also be applied to 14 and 15 Docks. |
| DRD-14 | To aid access / egress and keeping non-essential personnel safe, consideration should be given to restricting movements to essential personnel only and the marking of safe routes. |
| DRD-15 | Consideration should be given to ensuring the volume of water ingress into the dock is minimised to increase the margins before a submarine in dock is affected. |
| DRD-16 | To reduce the effect of unplanned slueing of a submarine off the dock cradle, consideration should be given to the attachment of mooring lines within the dock. This also applies to a sinker submarine docked down and an afloat submarine during a fast dock flood. |
| DRD-17 | To protect the switchboards with the Electrical Plant Houses (EPHs), either the switchboards could be bunded or alternative supplies from existing or additional Diesel Generators s should be considered. |
| DRD-18 | To modify the diesel tank vents to prevent fuel contamination resulting from a flood. |
| DRD-19 | Should brows and / or pontoons be lost, then for the Non Tidal X Berths (NTXBs), a Flat Bottomed Boat (FBB) or Rigid Inflatable Boat (rib) could be permanently moored within 5 Basin to provide access as required, and for the Docks, mobile cranes could be used to replace the brows. |
| DRD-20 | In the highly unlikely event a submarine in Dock floats up under the Reactor Access House (RAH), increasing the sinker configuration of the submarine; redesigning the RAH to accept a rising submarine; and / or building a flood barrier around the dock / caisson should be considered. |
| DRD-21 | Investigate the use of the cryogenic stores on 5 Basin Arm and 9 Dock to supply liquid nitrogen for freeze seals. |

| No. | Consideration |
|---|---|
| DRD-22 | Either increase the bunding or install waterproof containers for the 9 Dock Diesel Generators (DGs) providing power to the submarine and also the salt water cooling, salt water trim and day dock drainage systems. Similarly for Pumped Flood Main DGs. |
| DRD-23 | Consider providing bunding to the Central Frequency Changing Station switchboards, and switching off supplies in good time to reduce damage. |
| DRD-24 | Consider installing wireless systems and UPS in Emergency Monitoring Headquarters (EMHQ). |
| DRD-25 | Access to a Tsunami warning system with suitable site-wide alarms should be investigated to allow time for personnel to take appropriate action. |
| DRD-26 | Emergency equipment, whether in containers or in unsecured areas, should be identified and moved to secure locations. |
| DRD-27 | Consider suitable mooring arrangements to restrain an afloat submarine fore and aft. |
| DRD-28 | Local isolation of the Oil Fuel Depot Thanckes fuel tanks on Yonderberry Jetty should be considered in case of fire. |
| DRD-29 | Consideration should be given to lengths of mooring lines employed. |
| DRD-30 | Consider installing protective barriers, or relocating submarines to locations with improved protection, to avoid vessel impact. |
| DRD-31 | Consider altering the lengths of hoses / cables employed so that their service is not affected by increasing pontoon height. |
| DRD-32 | Consideration should be given to assessing buildings that have the potential to collapse onto over-side / cross-site services or affect access / egress as a result of natural external hazards and any reasonably practicable modifications undertaken. |
| DRD-33 | Consideration should be given to assessing the effects of low temperatures (below the current design basis of -15$^{o}$C) on the 60Hz electrical supply system. |
| DRD-34 | Consideration for investigating options for the provision of alternative generators and associated equipment / tools. |
| DRD-35 | Consideration be given to formalising the use of Elevated Thermal Roll Over (ETRO) for decay heat removal in 9 Dock and enhanced training be given to the operators in its application. |
| DRD-36 | Consideration be given to moving the radioactive release monitors to a store which is resistant to large scale seismic and flooding events. |

| No. | Consideration |
|---|---|
| DRD-37 | Consideration should be given to enhancing the communication system such that following postulated events and subsequent system failure, effective communication is maintained. |
| DRD-38 | The stores holdings are to be reviewed and enhanced where appropriate to ensure sufficient basic stores (sandbags, light, etc) are in place to respond to large scale events. |
| DRD-39 | Consider altering the lengths of hoses / cables employed so that their service is not affected by increasing pontoon height. |

**Rosyth Royal Dockyard Ltd**

| No. | Consideration |
|---|---|
| RRD-1 | Due to the low nature of the site the licensee has not identified any further considerations over and above its existing emergency arrangements, which can be scaled for major events. |

# ANNEX 4: MAGNOX LTD STRESS TESTS CONSIDERATIONS

The *Considerations* below apply on all Magnox defuelled reactor sites. They are numbered to match the *Considerations* already presented in the National Final Report on Stress Tests for UK Nuclear Power Plants (Ref. 10), Annex 3.

| No. | Consideration |
|---|---|
| M-7 | Consideration will be given to enhancing the availability of beyond design basis equipment. |
| M-8 | Consideration will be given to providing further equipment to facilitate operator access around the Site. |
| M-10 | Consideration will be given to enhancing on-site arrangements for command, control and communications. |
| M-12 | Consideration will be given to updating and enhancing severe accident management guidance. |
| M-14 | Consideration will be given to the fire safety case for ILW storage facilities to identify any appropriate enhancements to the level of resilience. |

# ANNEX 5: NNB GENCO STRESS TESTS CONSIDERATIONS

| No. | Consideration |
|---|---|
| NNB-1 | Seismic qualification of the valves and pipelines from the raw water storage system. |
| NNB-2 | Carry out assessments of the seismic resistance of flood protection (volumetric protection). |
| NNB-3 | Implementation of specific provisions to limit water ingress in to the cooling water pump house at the platform height. |
| NNB-4 | Implementation of specific provisions to limit water ingress to buildings located on the outfall slab at the platform height. |
| NNB-5 | Implementation of measures to protect the ultimate diesel generators and 12-hour batteries against flooding. |
| NNB-6 | Measurement of the leak-tightness performance of security doors of buildings containing safety-related plant when flood water is present on the platform of the nuclear-island. |
| NNB-7 | Extension of ultimate diesel generator autonomy by using mobile pumping of the main emergency diesel generator fuel tanks to recharge the ultimate diesel generator fuel tanks. |
| NNB-8 | Extension of the duration of power supply of the essential functions by implementing additional stationary and / or mobile power sources (including any associated connection points). |
| NNB-9 | Provision of means for re-powering the dedicated Severe Accident Instrumentation and Control equipment. |
| NNB-10 | Provision of fixed connection points for the re-supply of electrical power to the reactor and fuel buildings. |
| NNB-11 | Provision of an extra water supply for containment heat removal from the raw water storage system. |
| NNB-12 | Provision of increased autonomy of the secondary circuit cooling through fresh water re-supply of the emergency feedwater system tanks by the raw water storage system. |
| NNB-13 | Provision of an external connection to the fuel building to allow re-supply of the spent fuel cooling pools via the raw water storage system. |
| NNB-14 | Establishment of passive or automatic opening of the spent fuel cooling pool hall to the nuclear auxiliary building to improve protection to over-pressurisation of the spent fuel pool hall. |
| NNB-15 | Carry out a study of the equipment and organizational arrangements needed to facilitate the safe positioning of a fuel assembly being handled during a loss of electrical power event. |

| No. | Consideration |
|---|---|
| NNB-16 | Integration of selected fuel building instrumentation in to the severe accident I&C scheme. |
| NNB-17 | Addition of a remote operation capability to valves for introduction of extra water in the reactor building through the containment heat removal system spray nozzles. |
| NNB-18 | Setting up a suitable communication system on the site in order to manage situations involving total loss of electrical power (i.e. sound-powered telephones). |
| NNB-19 | Carry out a study and investigate the provision of diverse means of providing emergency feed water to the steam generators. |
| NNB-20 | Carry out a study and investigate the provision of further systems or equipment to control containment over-pressure in severe accident conditions. |
| NNB-21 | Carry out studies to investigate impact and advantages / disadvantages of adding means of cross connection between individual trains of safety systems. Both electrical and fluid systems to be considered. |
| NNB-22 | Addition of diesel driven fire pumps. |
| NNB-23 | Check containment penetration leakage beyond the current qualification requirements for the reactor containment. |
| NNB-24 | Qualify the performance of instrumentation required for monitoring containment integrity for beyond design basis conditions. |
| NNB-25 | Qualify the performance of the available instrumentation in the spent fuel cooling pool for prolonged boiling conditions. |
| NNB-26 | Provision of a mobile pump for introduction of water in to the reactor building through the containment heat removal system spray nozzles. |
| NNB-27 | Provision of a high power mobile emergency generator. |
| NNB-28 | Carry out a study of the risk of hydrogen production due to radiolysis of water in the spent fuel cooling pool and if necessary identify and install additional equipment. |
| NNB-29 | Carry out a study into the prevention and mitigation of hydrogen gas accumulation in the fuel building. |
| NNB-30 | Ensure that severe accident management procedures provide contingencies for events which exceed both design basis and design extension conditions. |

# ANNEX 6: OVERALL SUMMARY TABLE OF RECOMMENDATIONS OR ACTIONS IN THE UK

| Technical area | Industry commitments, recommendations or *Considerations* (see Annexes 2 to 5) | Regulatory STF (see Table 0 in Executive Summary) | Recommendations from HM Chief Inspector's Report (see Annex 1) |
|---|---|---|---|
| **Within stress tests scope** | | | |
| Earthquakes | RRM-5, RRM-6, RRM-7, RRM-14, RRM-15, DRD-1, DRD-32, NNB-1, NNB-2 | STF-23 to STF-25, STF-27 to STF-33, STF-35 to STF-37, STF-70 | IR-10, IR-13, IR-16, FR-2, FR-3, FR-4 |
| Flooding | RRM-4, RRM-5, RRM-8, RRM-10, RRM-11, RRM-12, RRM-15, RRM-16, BAE-2, DRD-10, DRD-12, DRD-13, DRD-15, DRD-17, DRD-18, DRD-20, DRD-22, DRD-23, NNB-3 to NNB-6 | STF-35, STF-38 to STF-44, STF-70 | IR-10, IR-13, IR-16, FR-2, FR-3 |
| Extreme weather | RRM-13, DRD-32, DRD-33 | STF-45 to STF-50, STF-70 | IR-10, IR-13, IR-16, FR-2, FR-3 |
| Loss of electrical supplies and Loss of ultimate heat sink | RRM-1, RRM-2, RRM-9, RRM-10, RRM-11, BAE-6, BAE-12, BAE-19, DRD-2, DRD-5, DRD-11 to DRD-13, DRD-17, DRD-22, NNB-7 to NNB-15, NNB-21, NNB-22, NNB-26 | STF-51 to STF-60, STF-70, STF-93 | IR-17, IR-18, IR-19, IR-20 |
| Severe accident management | AWE-1 to AWE-5, RRM-3, RRM-4, RRM-7, RRM-15, BAE-1, BAE-3 to BAE-5, BAE-7 to BAE-11, BAE-13 to BAE-18, BAE-20 to BAE-32, DRD-2 to DRD-4, DRD-8, DRD-9, DRD-14, DRD-16, DRD-20 to DRD-31, DRD-34 to DRD-39, RRD-1, M-7, M-8, M-10, M-12, M-14, NNB-16 to NNB-20, NNB-22 to NNB-30 | STF-21, STF-22, STF-26, STF-34, STF-61 to STF-69, STF-71 to STF-92 | IR-6, IR-7, IR-21, IR-22, IR-24, IR-25, FR-4 |
| Process for implementing recommendations and findings | | STF-20, STF-94 | FR-12 |

| Technical area | Industry commitments, recommendations or *Considerations* (see Annexes 2 to 5) | Regulatory STF (see Table 0 in Executive Summary) | Recommendations from HM Chief Inspector's Report (see Annex 1) |
|---|---|---|---|
| **Out of stress tests scope** | | | |
| Emergency response information | | | IR-1 |
| Global nuclear safety | | | IR-2 |
| Safety assessment | | | IR-5 |
| National emergency response | | | IR-2, IR-3, FR-6, FR-7 |
| Planning control | | | FR-5 |
| Research | | | FR-10 |
| Off-site infrastructure | | | IR-8, IR-9 |
| Safety case | | | IR-25, FR-4 |

Notes

Some STF are allocated to several technical areas.

AWE-n: *Considerations* from Atomic Weapons Establishment

RRM-n: *Considerations* from Rolls-Royce Marine Power Operations Ltd

BAE-n: *Considerations* from BAE Systems Marine Ltd

DRD-n: *Considerations* from Devonport Royal Dockyard Ltd

RRD-n: *Considerations* from Rosyth Royal Dockyard Ltd

M-n: *Considerations* from Magnox Ltd

NNB-n: *Considerations* from EDF Energy NNB Generation Company Ltd

STF-n: Stress Tests Finding as a result of review of licensees' stress tests reports

IR-n, FR-n: Recommendations from HM Chief Inspector's reports (Refs 1 and 2)

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Due to their classification level, submissions 11 and 21 to 25 of the list above were returned to their authors (licensees) after ONR's assessment completion

While every effort has been made to ensure the accuracy of the public references listed in this report, their future availability cannot be guaranteed.

# 10 GLOSSARY AND ABBREVIATIONS

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| ABP | Associated British Ports |
| AC | Alternating Current |
| ACP | Access Control Point |
| AGR | Advanced Gas-cooled Reactor |
| ALARP | As low as reasonably practicable |
| AOD | Above Odnance Datum |
| AWE | Atomic Weapons Establishment |
| BAESM | BAE Systems Marine Ltd |
| BCP | Burghfield Command Post |
| Beyond design basis | In a beyond design basis event, the conditions are more severe than in a design basis event. (see Design basis) |
| BSL | Basic Safety Level |
| BSO | Basic Safety Objective |
| BUCS | Back-up Cooling System |
| C&I | Control and Instrumentation |
| CCP | Cartridge Cooling Pond |
| CCWS | Component Cooling Water System |
| CEDE | Committed Effective Dose Equivalents |
| CESC | Central Emergency Support Centre |
| CHPP | Combined Heat and Power Plant |
| CHRS | Containment Heat Removal System |
| Cliff-edge | A cliff-edge effect is a small change in a parameter that leads to a disproportionate increase in consequences. |
| $CO_2$ | Carbon dioxide |
| COBR | Cabinet Office Briefing Room |
| *Consideration* | A *Consideration* (in italic with a capital C) is an indication of how the licensees currently plan to take forward potential improvements into a decision-making process. Note that a *Consideration* is not a commitment to undertake a specific activity or purchase specific equipment. |
| Corium | The high-temperature mixture of fission products and liquefied components, once they have melt due to the decay heat and a loss of cooling; from a nuclear reactor core, the mixture contains oxides, notably $UO_2$, fuel structure metallic parts and diverse dissolved materials. It has a lava-similar behaviour. |
| CRD | Container Receipt and Despatch |
| DAC | Design Acceptance Confirmation |
| DBA | Design Basis Analysis |
| DBE | Design Basis Earthquake |
| DBF | Design Basis Flood |

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| DC | Direct Current |
| DDH | Devonshire Dock Hall |
| Defra | Department for Environment, Food and Rural Affairs |
| DEPZ | Detailed Emergency Planning Zone |
| Design basis | The range of conditions and events that should be explicitly taken into account in the design of the facility, according to established criteria, such that the facility can withstand them without exceeding authorised limits by the planned operation of safety system. |
| DFR | Dounreay Fast Reactor |
| DHR | Decay Heat Removal |
| DMTR | Dounreay Materials Test Reactor |
| DMV | District Monitoring Vehicle |
| DNSR | Defence Nuclear Safety Regulator |
| DPoP | Dockyard Port of Plymouth |
| DRDL | Devonport Royal Dockyard Ltd |
| DSRL | Dounreay Site Restoration Ltd |
| EARP | Enhanced Actinide Removal Plant |
| EBFS | Emergency Boiler Feed System |
| EBS | Emergency Boration System |
| EC | European Council |
| ECC | Emergency Control Centre |
| ECCS | Emergency Core Cooling System |
| EDF | Electricité de France |
| EDF NGL | EDF Energy Nuclear Generation Ltd |
| EDG | Emergency Diesel Generator |
| EFWS | Emergency Feed Water System |
| EM | Emergency Manager |
| EMHQ | Emergency Monitoring Headquarter |
| EMIT | Examination, Maintenance, Inspection and Testing |
| ENSREG | European Nuclear Safety Regulators Group |
| EOT | Electric Overhead Travelling (crane) |
| EPD | Essential Power Distribution |
| EPS | Encapsulated Product Stores |
| ESWS | Essential Sea-water System |
| EUR | European Utility Requirement |
| FGMSP | First Generation Magnox Storage Pond |
| FHP | Fuel Handling Plant |
| FPCS | Fuel Pond Cooling System |

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| FWS | Feed Water System |
| GDA | Generic Design Assessment |
| GOCO | Government Owned, Contractor Operated |
| GTG | Gas Turbine Generator |
| HALES | Highly Active Liquor Evaporation and Storage |
| HAST | Highly Active Liquor Storage Tank |
| HF | Hydrogen fluoride |
| HIRE | Hazard Identification and Risk Evaluation |
| HSE | Health and Safety Executive |
| HSWA74 | Health and Safety at Work etc. Act 1974 |
| HVAC | Heating, Ventilation and Air Conditioning |
| I&C | Instrumentation and Control |
| IAEA | International Atomic Energy Agency |
| ICC | Incident Control Centre |
| IDAC | Interim Design Acceptance Certificate |
| IFDF | Irradiated Fuel Dismantling Facility |
| ILW | Intermediate Level Radioactive Waste |
| INES | International Nuclear and Radiological Event Scale |
| IRWST | In-containment Refuelling Water Storage Tank |
| ISFS | Interim Spent Fuel Storage |
| LC | Licence Condition |
| LFL | Lower Flame Level |
| LHSI | Low Head Safety Injection |
| LLRF | Low Level Refuelling Facility |
| LLW | Low Level Radioactive Waste |
| LOCA | Loss of Coolant Accident |
| LOOP | Loss of Off-site Power |
| Magnox | Magnesium non-oxidising |
| MCP | Management Control Procedure |
| MDA | Mobile Diesel Alternator |
| MEP | Magnox Encapsulation Plant |
| MHSI | Medium Head Safety Injection |
| $M_L$ | The Richter local magnitude $M_L$ is defined to be used for local earthquakes, and is the magnitude scale used by British Geological Survey when locating UK earthquakes. |
| MoD | Ministry of Defence |
| MRF | Metal Recycling Facility |
| MWe | MegaWatt electric: unit of power relating to the power produced |

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| | downstream to the turbines and the alternator. |
| MWth | MegaWatt thermal: unit of power relating to the power produced by the reactor, upstream to the turbines and alternator. |
| NDA | Nuclear Decommissioning Authority |
| NEAF | Nuclear Emergency Arrangements Forum |
| NFPP | Nuclear Fuel Production Plant |
| NIA65 | Nuclear Installations Act 1965 |
| NNB GenCo | EDF Energy NNB Generation Company Ltd |
| NNPP | Naval Nuclear Propulsion Programme |
| NPGNF | Non-Power Generating Nuclear Facilities |
| NPP | Nuclear Power Plant |
| NRP | Naval reactor plant |
| ONR | Office for Nuclear Regulation (formerly the Nuclear Directorate of the HSE) |
| OPEX | Operational Experience |
| pa | per annum |
| PCM | Plutonium Contaminated Material |
| PCSR | Pre-construction Safety Report |
| PECWP | Portable Emergency Cooling Water Pumping system |
| PFR | Prototype Fast Reactor |
| PGA | Peak Ground Acceleration |
| PML | Principia Mechanica Ltd |
| POCO | Post Operational Clean Out |
| PPE | Personal Protective Equipment |
| PSA | Probabilistic Safety Analysis |
| PSCC | Police Strategic Co-ordination Centre |
| PSD | Primary Shutdown System |
| PSR | Periodic Safety Review |
| PSR2 | Second round of PSR |
| PWR | Pressurised Water Reactor |
| R1 | Reactor 1 |
| R2 | Reactor 2 |
| RAH | Reactor Access House |
| RCS | Reactor Coolant System |
| REF | Residue Export Facility |
| REIC | Remote Emergency Indication Centre |
| REPPIR | Radiation (Emergency Preparedness and Public Information) Regulations 2001 |
| RESEP | Resilience Evaluation Process |
| RHRS | Residual Heat Removal System |

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| RRDL | Rosyth Royal Dockyard Ltd |
| RRMPOL | Rolls-Royce Marine Power Operations Ltd |
| RSRL | Research Sites Restoration Ltd |
| RWMD | Radioactive Waste Management Directorate |
| S&SSM | Safety and Site Shift Manager |
| Safety margins | Safety margins identify the gap between a considered situation and the threshold situation beyond which the probability of accident is not tolerable. |
| SAG | Severe Accident Guidelines |
| SAGE | Scientific Advisory Group for Emergencies |
| SAP | Safety Assessment Principle(s) (HSE) |
| SAV | Separation Area Ventilation |
| SAWB | Solid Active Waste Building |
| SBERG | Symptom Based Emergency Response Guidelines |
| SBO | Station Blackout |
| SCC | Strategic Coordination Centre |
| SCE/SM | Shift Charge Engineer / Shift Manager |
| SEC | Sellafield Emergency Controller |
| SECC | Sellafield Emergency Control Centre |
| SEMP | Site Emergency Monitoring Point |
| SEP | Site Emergency Plan |
| SETP | Segregated Effluent Treatment Plant |
| Severe accident | A fault sequence which leads either to consequences exceeding highest radiological doses given in the basic safety level – on-site: 500mSv, off-site: 100mSv for initiating fault frequencies less than $10^{-4}$ per annum – or to a substantial unintended relocation of radioactive material within the facility which places a demand on the integrity of the remaining physical barriers. |
| SF&R | Site Fire and Rescue Team |
| SGHWR | Steam Generating Heavy Water Reactor |
| SHWP | Seismic Hazard Working Party |
| Single failure criterion | This criterion sets that, during any normally permissible state of plant availability, no single random failure, assumed to occur anywhere within the systems provided to secure a safety function, should prevent the performance of that safety function. |
| SIS | Safety Injection System |
| SIXEP | Site Ion Exchange Effluent Plant |
| SMC | Strategic Management Centre |
| SME | Seismic Margin Earthquake |
| SPP1 | Sludge Packaging Plant 1 |
| SPRS | Sellafield Product and Residue Store |
| SQEP | Suitably Qualified and Experienced Personnel |

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| SRC | Submarine Refit Complex |
| SRT | Sludge Retention Tank |
| SRV | Safety Relief Valve |
| SSBN | Ship Submersible Ballistic Nuclear |
| SSC | Structure, System and Component important for safety |
| SSN | Ship Submersible Nuclear |
| STF | Stress Tests Finding |
| STP | Solvent Treatment Plant |
| Stress tests | The stress tests are summarised as a targeted reassessment of the relevant safety margins of NPPs in the light of events which occurred at Fukushima: extreme natural events challenging the plant safety functions and leading to a severe accident. |
| TAG | Technical Assessment Guide(s) (ONR) |
| TAP | Technical Advisory Panel |
| THORP | Thermal Oxide Reprocessing Plant |
| TORRO | Tornado and Storm Research Organisation |
| UCWS | Ultimate Cooling Water System |
| UDG | Ultimate Diesel Generator |
| $UF_6$ | Natural uranium hexafluoride |
| UHS | Uniform Hazard Spectra |
| UKAEA | UK Atomic Energy Authority |
| $UO_2F_2$ | Uranyl fluoride |
| UPS | Uninterruptible power supply |
| URS | Uniform Risk Spectra |
| US NRC | United States Nuclear Regulatory Commission |
| UUK | Urenco UK Ltd |
| WAGR | Windscale AGR |
| Walkdown | An on-site systematic review of a structure, system or components (SSC) by a small team of suitable, qualified and experienced persons to review the SSC capability to withstand defined hazards. |
| WAMAC | Waste Monitoring and Compaction |
| WDQ | Wet Dock Quay |
| WENRA | Western European Nuclear Regulators' Association |
| WEP | Waste Encapsulation Plant |
| WPEP | Waste Packaging and Encapsulation Plant |
| WTC | Waste Treatment Complex |
| WVP | Waste Vitrification Plant |

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