Civil Nuclear Reactor Build – Generic Design Assessment

Step 2 Assessment of the Probabilistic Safety Analysis (PSA) and Severe Accident Analysis (SAA) of Hitachi-GE's UK Advanced Boiling Water Reactor (UK ABWR)

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EXECUTIVE SUMMARY

This report presents the results of my assessment of the probabilistic safety analysis (PSA) and severe accident analysis (SAA) of Hitachi General Electric Nuclear Energy Ltd's (Hitachi-GE) UK Advanced Boiling Water Reactor (UK ABWR) undertaken as part of step 2 of the Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA).

The GDA process calls for a step-wise assessment of the requesting party's (RP) safety submission with the assessments getting increasingly detailed as the project progresses. Step 2 is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including review of key nuclear safety and nuclear security claims with the aim of identifying any fundamental safety or security shortfalls that could prevent the issue of a Design Acceptance Confirmation (DAC). Therefore during step 2 my work has focused on the assessment of the key claims in the area of PSA and SAA to judge whether they are complete and reasonable in the light of ONR's current understanding of the reactor technology.

For PSA and SAA, safety claims are interpreted as being:

- specific and supportable statements of the PSA results (or surrogates or qualitative information in the absence of detailed analyses) that represent the risk of the UK ABWR;
- specific and measurable statements that show that the ABWR PSA meets relevant good practice in terms of its validity, scope, adequacy and usage to support design and future operation;
- specific statements, properly referenced, about the severe accident phenomena that are (or are not) relevant for the UK ABWR, and the progressive challenges to, and failures of, the multiple barriers;
- specific verifiable statements about engineered features, strategies and procedures to deal with severe accident sequences in the UK ABWR, and specific statements of why these reduce the level of risk as low as reasonably practicable (ALARP); and
- specific statements about the progression of the severe accident sequences and the behaviour of fission products in such events.

The standards I have used to judge the adequacy of the claims in this area have been primarily ONR's Safety Assessment Principles (SAP), in particular those related to PSA and SAA, and ONR's Technical Assessment Guides (TAG) on PSA and human reliability analysis (HRA).

My assessment work has involved regular engagement with the RP in the form of technical exchange workshops and progress meetings. In addition, my understanding of the ABWR technology, and, therefore, my assessment, has significantly benefited from a visit to the ABWR units at the Kashiwazaki-Kariwa nuclear power plant.

My assessment has been based on the RP's preliminary safety report (PSR) and some additional, more detailed reports relevant to PSA and SAA. The RP's preliminary safety case aspects related to PSA and SAA, as presented in those documents, can be summarised as follows:

- The UK ABWR PSA is under development and has not been submitted to ONR in step 2. The RP has provided a preliminary bounding estimate for the core damage

frequency (CDF) for internal events, and internal fire and flooding. The RP has also provided the strategy and high level programme to develop a modern-standards, full-scope level 1, level 2 and level 3 PSA during GDA. This PSA will inform the demonstration that the level of risk is ALARP and will support the design change decision-making process.

- The RP has provided high level descriptions of the severe accident phenomena relevant to ABWRs and the expected severe accident progression for the UK ABWR, has proposed severe accident management measures, and presented analyses of selected scenarios. The RP will develop further SAA to confirm the capability of the engineered features and measures to deal with severe accident sequences and to support the level 2 PSA. Source term analysis will also be developed and will provide input into the level 3 PSA.

My assessment has identified the following areas of strength:

- The RP has started to set up the basis to develop a full scope PSA that will reflect the UK ABWR design. In addition, UK specific parameters and data relevant to the evaluation of accident consequences will be incorporated into the level 3 PSA by using a state of the art computer code. The RP will review the PSA to reflect design modifications during GDA. The RP has provided a strategy to use this PSA to inform the design process and to inform the demonstration that the level of risk associated with the UK ABWR is ALARP.

- The high level description of the severe accident phenomena provided by the RP covers key phenomena which are expected to be relevant for boiling water reactors in general. The severe accident progression analyses for the UK ABWR are being developed using an internationally established computer code.

During step 2 I have identified the following areas that require follow-up:

- The bounding CDF estimate could result in risk figures that would not meet ONR's expectations for new reactors when compared against the numerical targets in the SAPs. Although the RP has indicated that this evaluation is conservative, the analyses provided are simplified and appear to be incomplete. At this point I do not have sufficient information to properly understand the risk profile for the UK ABWR, as this requires a full scope, modern standards PSA.

  ONR considers this shortfall in the RP's safety case important, and will issue a Regulatory Observation (RO) to request the RP to develop a detailed PSA programme and submit the PSA models, data, supporting analysis and accompanying documentation in a staggered (but logical) manner to enable assessment throughout steps 3 and 4.

  The RP has committed to submit additional information regarding the internal events PSA at the beginning of step 3, and the level 1 and level 2 PSA for internal events during operation at power by the end of 2014; however this will not provide the complete picture of the UK ABWR risk. The remaining parts of the PSA will follow later in GDA, including delivery of the hazards PSA well into step 4.

  The timely delivery by the RP of the level 1 and level 2 PSA for internal initiating events during operation at power (proposed for December 2014), and the quality of this part of the PSA, will be key to providing me with confidence of the RP's ability to deliver a full scope PSA which:

- Meets ONR's expectations.
- Provides a clear understanding of the UK ABWR risk.
- Supports the demonstration that the level of risk is ALARP.

Should the RP not deliver the analyses as per the programme, or the quality be lacking, ONR has additional regulatory options.

- The SAA information provided by the RP during step 2 is preliminary in nature and more information will be required to provide the basis for a meaningful assessment during steps 3 and 4. For example, the description of the severe accident phenomena is generic. More detail will be necessary about the proposed engineered features, strategies and procedures for the UK ABWR severe accident management. The scope of the events covered by the analyses will need to be expanded and documented thoroughly. In addition, fission product behaviour has not been considered at this stage. Additional information and analysis that the RP plans to provide in step 3 should address some of the identified limitations and I will follow-up these matters in step 3. I will also consider the need for technical support contractors to undertake independent confirmatory severe accident analyses later in GDA.

Through my interactions with RP subject matter experts (SME) in PSA and SAA, I have found the RP to be knowledgeable, responsive and open. The RP has also demonstrated to be working closely with other disciplines in a proactive manner.

Although the shortcomings identified indicate that work will be required to complete the PSA and SAA in order to meet regulatory expectations, I believe the RP is adequately setting up the basis for the development of this work during GDA. Therefore, based on this, I see no reason, on PSA and SAA grounds, why the UK ABWR should not proceed to step 3.

LIST OF ABBREVIATIONS

ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
ALARP	As Low As Reasonably Practicable
BMS	Business Management System
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
BWR	Boiling Water Reactor
CCFP	Conditional Containment Failure Probability
CDF	Core Damage Frequency
CHRS	Containment Heat Removal System
C&I	Control and Instrumentation
COL	Combined Operating Licence
COPS	Containment Overpressure Protection System
CVS	Containment Venting System
DAC	Design Acceptance Confirmation
DCD	Design Control Document
DCH	Direct Containment Heating
EPRI	Electric Power Research Institute
FMEA	Failure Mode Effect Analysis
GDA	Generic Design Assessment
HFE	Human Failure Event
Hitachi-GE	Hitachi General Electric Nuclear Energy Ltd
IAEA	International Atomic Energy Agency
INSAG	International Nuclear Safety Group
JNES	Japan Nuclear Energy Safety Organisation
JPO	(Regulators') Joint Programme Office

LIST OF ABBREVIATIONS

LDF	Lower Drywell Flooder System
LOOP	Loss Of Off-site Power
MCCI	Molten Core-Concrete Interaction
MDEP	Multinational Design Evaluation Programme
MSIV	Main Steam Isolation Valve
NPP	Nuclear Power Plant
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PDS	Plant Damage States
PRA	Probabilistic Risk Assessment
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety Report
RHWG	Reactor Harmonisation Working Group (of WENRA)
RO	Regulatory Observation
RP	Requesting Party
RQ	Regulatory Query
RPV	Reactor Pressure Vessel
SAA	Severe Accident Analysis
SAMG(s)	Severe Accident Management Guideline(s)
SAP(s)	Safety Assessment Principle(s)
SFP	Spent Fuel Pool
SGTS	Stand-by Gas Treatment System
SME	Subject Matter Expert
SSAR	Standard Safety Analysis Report
SSC	Structure, System and Component
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor

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1 INTRODUCTION

1.1 Background

1. The Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA) process calls for a step-wise assessment of the Requesting Party's (RP) safety submission with the assessments getting increasingly detailed as the project progresses. Hitachi General Electric Nuclear Energy Ltd (Hitachi-GE) is the RP for the GDA of the UK Advanced Boiling Water Reactor (UK ABWR).

2. During step 1 of GDA, which is the preparatory part of the design assessment process, the RP established its project management and technical teams and made arrangements for the GDA of its ABWR design. Also, during step 1 the RP prepared submissions to be evaluated by ONR and the Environment Agency during step 2.

3. Step 2 is an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including review of key nuclear safety and nuclear security claims with the aim of identifying any fundamental safety or security shortfalls that could prevent the issue of a Design Acceptance Confirmation (DAC).

4. This report presents the results of my assessment of the probabilistic safety analysis (PSA) and severe accident analysis (SAA) aspects of the UK ABWR as presented in the RP's Preliminary Safety Report (PSR) (Ref. 1) and supplementary documentation relevant to PSA and SAA (Refs. 2, 3, 4, 5, 6, 7, 8, 9, 10)

1.2 Methodology

5. My assessment has been undertaken in accordance with the requirements of ONR's How2 business management system (BMS) procedure PI/FWD (Ref. 11). The ONR Safety Assessment Principles (SAP) (Ref. 12), together with supporting Technical Assessment Guides (TAG) (Ref. 13) have been used as the basis for this assessment.

6. My assessment followed my step 2 assessment plan for PSA and SAA (Ref. 14) prepared in December 2013 and shared with the RP to maximise the efficiency of our subsequent interactions. Occasionally, during step 2, there have been reasons why my assessment work had to depart from the plan established in Ref. 14; the main discrepancies are explained in Ref. 15.

2 ASSESSMENT STRATEGY

7. This section presents my strategy for the step 2 assessment of the PSA and SAA of the UK ABWR (Ref. 14). It also includes the scope of the assessment and the standards and criteria that I have applied.

2.1 Scope of the Step 2 PSA and SAA Assessment

8. The objective of my step 2 PSA and SAA assessment for the UK ABWR was to review and judge whether the claims made by the RP related to PSA and SAA that underpin the safety, security and environmental aspects of the UK ABWR are complete and reasonable in the light of ONR's current understanding of the reactor technology.

9. For PSA, 'safety claims' are interpreted as being specific and supportable statements to show:

- the PSA results (or surrogates / qualitative information in the absence of detailed analyses) that represent the level of risk of the UK ABWR; and
- that the UK ABWR PSA meets relevant good practice as follows:
    - The PSA reflects the UK ABWR design submitted for GDA and the features of the UK ABWR GDA 'generic site'.
    - The scope of the ABWR PSA covers all significant sources of radioactivity, all relevant initiating events, and all modes of operation. In the absence of a full scope PSA, ONR expects the RP to provide a commitment and a detailed programme to develop such a PSA within the timeframes of GDA, allowing ONR sufficient time for assessment.
    - The UK ABWR PSA model, data and underlying analyses meet modern standards and international good practices, are comprehensive, traceable, and technically sound.
    - A formal process of communications between the RP's different technical departments and the PSA team has been established to ensure high quality of the inputs from other teams into the UK ABWR PSA, and adequacy of the substantiation of relevant aspects of the PSA from other technical areas.
    - The UK ABWR PSA is and will be used to inform the design process and to help ensure the safe operation of any ABWR that might be built in the future in the UK.
    - There is a process in place to revise the PSA to reflect any design modification during GDA and to use the PSA to inform the proposed modifications.
    - There is a process in place to capture, track and review PSA assumptions to enable those assumptions to be captured in future stages of the UK ABWR development.

10. For SAA, safety claims are interpreted as being:

- specific statements, properly referenced, about severe accident phenomena relevant for the UK ABWR, and the progressive challenges to, and failures of, the multiple barriers;
- specific verifiable statements about engineered features and strategies and procedures to deal with severe accident sequences in the UK ABWR;
- specific statements of how they reduce the level of risk as low as reasonable practicable (ALARP) and why it would not be reasonably practicable to reduce the risk further by incorporating changes to the design;

- specific statements about the progression of severe accident sequences in the UK ABWR, including information on the severe accident code(s), tools and sources of information used, and their applicability to the UK ABWR and confirmation that they represent current state of knowledge; and
- specific statements about the behaviour of fission products in ABWR severe accident sequences, including information on the source term analysis code used and confirmation that this represents current state of knowledge.

11. During step 2 I have also evaluated whether the safety claims related to PSA and SAA are supported by a body of technical documentation sufficient to allow me to proceed with GDA work beyond step 2.

12. Finally, during step 2 I have undertaken the following preparatory work for my step 3 assessment:

- I have identified what constitutes ‘arguments’ and ‘evidence’ in relation to PSA and SAA, and thus what will be included in the scope of ONR’s step 3 and step 4 assessment work. This has been informed by lessons learned from the AP1000© and EPR™ GDAs.
- I have prepared a detailed step 3 PSA assessment plan.
- I have agreed with the RP a programme of submission in the area of the PSA for step 3. I have used this information to prepare my step 3 PSA assessment plan.
- I have held early technical discussion with the RP on some of the areas of the PSA model that may be considered to be particularly challenging, for example: modelling of control and instrumentation (C&I) systems, internal hazards PSA and approach to modelling loss of off-site power (LOOP) and derivation of frequencies of loss of electrical grid events.
- I am planning to undertake, in cooperation with ONR’s fault studies team, a scoping exercise for independent severe accident confirmatory analyses to be undertaken by ONR’s chosen technical support contractor (TSC). I have commissioned work during step 2 with a TSC to provide advice to ONR on the information required to prepare input data files for the independent confirmatory analyses; I will use the outcome of this work to agree a programme with the RP for the provision of required information in due course.

2.2 Standards and Criteria

13. The goal of ONR’s step 2 assessment is to reach an independent and informed judgment on the adequacy of a nuclear safety and security case. For this purpose, ONR’s assessment is undertaken in line with the requirements of the How2 BMS document PI/FWD (Ref. 11). Appendix 1 of Ref. 11 sets down the process of assessment; Appendix 2 explains the process associated with sampling of safety case documentation.

14. In addition, the SAPs (Ref. 12) constitute the regulatory principles against which duty holders’ safety cases are judged. They are the basis for ONR’s nuclear safety assessment and have been used for step 2 assessment of the UK ABWR. The SAPs 2006 edition (Revision 1 January 2008) were benchmarked against the International Atomic Energy Agency (IAEA) standards (as they existed in 2004). They are currently being reviewed.

15. Furthermore, ONR is a member of the Western European Nuclear Regulators Association (WENRA). WENRA has developed reference levels, which represent good practices for existing nuclear power plants and safety objectives for new reactors.

16. The relevant SAPs, IAEA standards and WENRA reference levels are embodied and enlarged on in the TAGs on PSA (NS-TAST-GD-030 Revision 4) and human reliability analysis (HRA) (NS-TAST-GD-063 Revision 2) (Ref. 16). A TAG on SAA is currently in preparation and will be used during GDA as appropriate.

17. In addition to the above standards and guidance, ONR has always been well informed about the probabilistic risk assessment (PRA) standards issued in the United States by the American Nuclear Society (ANS) and the American Society of Mechanical Engineers (ASME) Ref. 17. The GDA PSA team will use the latest ANS / ASME PRA standards as a supplement to our own internal guides, as appropriate.

2.2.1 Safety Assessment Principles

18. The key SAPs (Ref. 12) applied within the assessment are the fault analysis – PSA SAPs: FA.10 (Need for PSA), FA.11 (Validity), FA.12 (Scope and extent), FA.13 (Adequate representation), FA.14 (Use of PSA); the fault analysis – SAA SAPs: FA.15 (Fault sequences) and FA.16 (Use of severe accident sequences); and the numerical targets NT.1, in particular target 7 (Individual risk to people off the site from accidents), target 8 (Frequency dose targets for accidents on an individual facility – any person off the site) and target 9 (Total risk of 100 or more fatalities) (see Table 1 for further details).

2.2.2 Technical Assessment Guides

19. The following Technical Assessment Guides have been used as part of this assessment (Ref. 13):

- NS-TAST-GD-030 Revision 4 – PSA
- NS-TAST-GD-063 Revision 2 – HRA

2.2.3 National and International Standards and Guidance

20. My step 2 assessment has been principally undertaken against the SAPs. However, the following standards and guidance set expectations for the performance and use of PSA and SAA to demonstrate the robustness of designs and are directly applicable to my overall GDA assessment:

- Relevant IAEA standards and guidance (Ref. 18):
  - Safety Standard – Specific Safety Requirements SSR-2/1 Safety of Nuclear Power Plants: Design.
  - Safety Standard – Specific Safety Guide SSG-3 Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants.
  - Safety Standard – Specific Safety Guide SSG-4 Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants.
  - Safety Standard – Safety Guide NS-G-2.15 Severe Accident Management Programmes for Nuclear Power Plants.
  - Safety Report Series No 56 – Approaches and Tools for Severe Accident Analysis for Nuclear Power Plants.
- WENRA references (Ref. 16):
  - Reactor Safety Reference Levels (January 2008).

  - Safety Objectives for New Power Reactors (December 2009) and Statement on Safety Objectives for New Nuclear Power Plants (November 2010).
  - Statement on Safety Objectives for New Nuclear Power Plants (March 2013) and Safety of New NPP Designs (March 2013).

- For completeness, the latest PRA standards issued by ANS and ASME (Ref. 17) also need to be considered.

2.3 Use of Technical Support Contractors

21. During step 2 I have engaged a TSC to support the following specific aspects of my assessment of the SAA for the UK ABWR:

- A summary of international good practice and international requirements in SAA relevant to boiling water reactors (BWR) in general and the ABWR design in particular (Ref. 19) has been produced. This has included consideration of:

  - severe accident phenomena;
  - systems and strategies used for prevention or mitigation of severe accidents;
  - scope, extent and results of severe accident and source term analyses (results of relevant simulations for BWR designs considered similar to the ABWR have been used); and
  - lessons learnt from the Fukushima accident.

- A review of the RP's SAA safety claims against the information compiled in Ref. 19 has been carried out. This evaluation has been documented in Ref. 20.

22. The TSC has provided me with technical advice and supported my review. The TSC has worked under close direction and supervision from myself. It should be noted that the regulatory judgement on the adequacy of the SAA safety claims for the UK ABWR has been made exclusively by ONR.

2.4 Integration with Other Assessment Topics

23. Early in GDA I recognised that during the project there would be a need to consult with other assessors as part of the PSA and SAA assessment process. Similarly, other assessors will seek input from my assessment of the PSA and SAA. These interactions help to prevent assessment gaps and duplications, and, therefore, they are key to the success of the project. Thus, from the start of the project, I made every effort to identify as many potential interactions as possible between the PSA, SAA and other technical areas, with the understanding that this position would evolve throughout the UK ABWR GDA.

24. Also, it should be noted that the interactions between the PSA and some technical areas need to be formalised since aspects of the assessment in those areas constitute formal inputs to the PSA assessment, and vice versa. These are:

- Human factors: this provides input to the PSA's HRA. This formal interaction has commenced during step 2. This work is being led by the human factors inspector. In addition, the PSA provides input to the identification of the human-based safety claims, human failure events and evaluation of their importance to overall risk.

- Fault studies: this provides input to the assessment of the level 1 PSA success criteria. This formal interaction has not commenced during step 2. This work will be led by the PSA inspector in coordination with the fault studies team.
- Severe accident analysis: this will provide input to the assessment of the level 2 PSA. This formal interaction has commenced during step 2. In step 2, this work has been led by the ONR PSA inspector in coordination with the fault studies team and with input from the reactor chemistry assessment team (regarding for example composition of radioactive releases and behaviour of radioisotopes, aerosols).
- Structural integrity: this provides input to the assessment of the containment structural analysis (drywell head and flange) for the level 2 PSA. This formal interaction has not commenced during step 2. This piece of work will be led by the civil engineering inspector as part of the assessment of the integrity of the containment overall. Structural integrity will also provide input to the assessment of the external hazards PSA (regarding fragilities of metal components); this piece of work will be led by the external hazards assessment team with input from the structural integrity team and in coordination with the PSA team. Specific details on how this assessment work will be conducted will be delineated later in the GDA.
- Civil engineering / external hazards: this provides input to the assessment of the containment structural analysis for the level 2 PSA and to the external hazards PSA regarding definition of hazards' magnitudes and frequencies, and fragilities of structures. This formal interaction has not commenced during step 2. This assessment task will be led by the civil engineering and external hazards team in coordination with the PSA team; specific details on how this assessment work will be conducted will be delineated later in the GDA.
- Radiological protection: this provides input to the assessment of the level 3 PSA. This work is being led by the PSA team as the level 3 PSA inspector is integrated in the PSA assessment team.
- C&I: PSA plays a key role in the design of these complex systems and their central role in the safety of the UK ABWR. This formal interaction has commenced during step 2. This work has been and will be led by the PSA team.
- Other formal interactions will be identified as the project progresses.

25. In addition to the above, there have been interactions between PSA and SAA and the rest of the technical areas, that is for example mechanical, electrical engineering and internal hazards. Although these interactions, which are expected to continue through GDA, are mostly of an informal nature, they are essential to ensure consistency across the technical assessment areas.

3 REQUESTING PARTY'S SAFETY CASE

26. This section presents a summary of the RP's preliminary safety case in the areas of PSA and SAA. It also identifies the documents submitted by the RP which have formed the basis of my assessment during step 2.

3.1 Summary of the RP's Preliminary Safety Case in the Area of PSA and SAA

27. The aspects covered by the preliminary safety case in the areas of PSA and SAA can be broadly grouped under a number of headings which are summarised in the following paragraphs.

28. **Risk associated with the UK ABWR**: the UK ABWR PSA is under development and has not been submitted to ONR in step 2. The RP has provided a preliminary bounding estimate for the core damage frequency (CDF) for internal initiating events (Refs. 2 and 3), and internal fire and flooding (Ref. 4). The RP has also provided initial figures for the expected CDF (once the UK ABWR design and PSA are finalised) which are one to two orders of magnitude lower than the bounding estimate. The RP indicated that further information will be provided in a 'PSA strategy document'.

29. **Adequacy, validity and scope of the UK ABWR PSA**: the RP has provided a strategy and programme to develop the UK ABWR PSA (Refs. 5, 6, 7 and 8). Ref. 5 also establishes a link between the UK ABWR design reference and the PSA, and provides a commitment to develop a process to capture PSA assumptions. The RP indicated that information regarding the methodologies to be used beyond step 2 to extend the scope of the PSA to cover shutdown, fuel route and the spent fuel pool (SFP), and internal and external hazards would be provided in the PSA strategy document (see Section 3.2).

30. **Use of the PSA to support the UK ABWR design process**: in response to my regulatory query (RQ) RQ-ABWR-0159 (Ref. 21), the RP made a commitment to use the PSA to provide the basis for demonstrating that the UK ABWR level of risk is ALARP and to support the design change decision-making process and the derivation of severe accident mitigation measures. The RP indicated that the process to risk inform the design will be part of Hitachi-GE's quality assurance process.

31. **Severe accident phenomena considered in the UK ABWR SAA**: Ref. 9 contains the description of the key severe accident phenomena of both in-vessel and ex-vessel phases of reactor accidents.

32. **Specific engineered features, strategies and procedures to deal with severe accident sequences in the UK ABWR:** potential engineered features to be used for severe accident management are briefly presented in Ref. 9. The report places claims on the following engineered features: alternative water injection system (AWI), lower drywell flooder system (LDF), containment overpressure protection system (COPS) and containment venting system (CVS). In addition to these systems, the following measures are mentioned in the report: containment heat removal system (CHRS), nitrogen inerting of the containment, flooding of the reactor well above the drywell head, hydrogen management inside the reactor building (outside containment) by the stand-by gas treatment system (SGTS), blow out panel in the reactor building, alternative power source and backup building. System descriptions are not included in the document. The RP has indicated that more detailed information on the systems will be provided in step 3. Details of the severe accident management strategies and procedures have not been presented within the RP's documentation submitted in step 2.

33. **Analysis of the progression of severe accident sequences and the behaviour of the fission products in the UK ABWR**: Ref. 9 provides a high level description of several severe accident analyses performed with the computer code MAAP 4. Scenarios analysed cover four groups of accident sequences starting from internal initiating events during operation at power and considering different sets of multiple failures: total loss of feedwater (with several variations of multiple failures), station blackout, anticipated transient without scram (ATWS), and double-ended break of a feedwater line. In delineating these scenarios the RP has not taken into account the severe accident management measures mentioned above. The RP will develop further SAA to confirm the capability of the engineered features and measures to deal with severe accident sequences and to support the level 2 PSA. Source term analysis will also be developed to provide input to the level 3 PSA. The RP has provided a document that describes the SAA computer code, nodalisation and validation Ref.22 (however, this document was submitted to ONR at the beginning of June 2014, too late to be considered formally in my step 2 assessment).

34. **Considerations in the light of the Fukushima accident**: lessons learned by the RP from the Fukushima accident and general preventive and mitigative accident management measures of the UK ABWR are described in Ref. 10. The proposed accident management measures include: mobile equipment for accident management and connection points to enable the connection of that equipment. In addition, the RP indicates that the UK ABWR design will include a backup building providing alternative power supply and coolant injection function. Furthermore, the resilience of the UK ABWR design in case of external events (for example earthquakes and flooding) and the basic strategy for managing possible consequential scenarios (station blackout and loss of ultimate heat sink) are described in Ref. 10 on the basis of the Japanese stress test results.

35. **ALARP considerations**: no specific information was available in this area as the UK ABWR PSA is under development. As indicated previously, the RP has stated that the PSA will be used to inform the ALARP demonstration. The consideration of the adequacy of the input of the PSA into the ALARP demonstration against ONR's expectations in SAP FA.10 will be a key part of my assessment beyond step 2.

3.2 Basis of Assessment: RP's Documentation

36. The RP's documentation that has formed the basis for my step 2 assessment of the safety claims related to the PSA and SAA for the UK ABWR are:

- UK ABWR PSR chapter "Fault studies to discuss deterministic analysis, PSA and fault schedule development" (Ref. 1): in response to RQ-ABWR-095 (Ref. 21), the RP clarified that the objective of this report in the area of PSA and SAA was to provide an overview of the ABWR risk by using publicly available information. Because of this, the document provides a limited level of detail. Further information was subsequently provided in the 'PSA Support Document' (Ref. 23) and a number of additional PSA topic reports, discussed below. The PSA safety claims have been stated by the RP, at a high level, in response to RQ-ABWR 0159 (Ref. 21). The RP indicated that these claims would be also summarised in the 'PSA strategy document' Ref. 24 (submitted to ONR at the end of June 2014 and therefore not in time to be considered formally in my step 2 assessment).
- UK ABWR topic report "PSA support document" (Ref. 23): this document presents an overview of the approach, scope and results of a PSA that the RP has developed for a standard ABWR design (so called 'standard ABWR PSA') based on a Japanese ABWR PSA. This report expanded the information

presented in the PSR; its scope is limited to internal initiating events during operation at power.

- UK ABWR topic report “PSA sensitivity analysis report” (Ref. 2): this document presents the results of three sensitivity analyses that the RP has undertaken using the standard ABWR PSA mentioned above. These sensitivities were performed to understand the differences in the results between the standard ABWR PSA and the US ABWR PSA. According to Ref. 1 the main reason for this difference is the data used for the initiating event frequencies, the random component failure probabilities and claims on recovery actions by the operators. In the sensitivity analysis, the initiating event frequencies and component failure probabilities were substituted by generic data available in literature (which the RP considers to be conservative) and most of the recovery actions were assumed failed. The sensitivities resulted in a substantial increase in the CDF.
- UK ABWR topic report “Level 1 PSA methodology report” (Ref. 5): this document outlines the approach that the RP will adopt to develop the UK ABWR level 1 PSA. In addition, the report presents a preliminary list of initiating events, and includes initiating event frequencies, random component failure data, and high level information on the systems that will be modelled in the UK ABWR PSA. The document includes statements regarding the consistency of the approach proposed with ONR’s PSA TAG and IAEA standards.
- UK ABWR topic report “Assumption on LOOP frequency for UK ABWR internal event PSA at power” (Ref. 25): this document presents the derivation of, and justification for, the LOOP frequency that the RP intends to use initially in the UK ABWR PSA for internal initiating events during operation at power.
- UK ABWR topic report “Hitachi-GE standard ABWR estimations for internal and external hazards” (Ref. 4): this document presents the initial list of hazards that will be considered in the screening of hazards to be included in the PSA and a description of qualitative screening criteria. In addition, the document presents bounding estimates of the CDF associated with internal fire and flooding. The interfaces between the RP’s PSA team and external hazards and internal hazards teams are also outlined.
- UK ABWR topic report “Hitachi-GE standard ABWR initiating events and estimations for shutdown and SFP” (Ref. 3): this document summarises the approach used to develop Hitachi-GE’s standard ABWR PSA for internal events during shutdown operation and the associated risk profile. The document also provides a bounding estimate for the CDF associated with shutdown states and a qualitative evaluation of the UK ABWR SFP risk.
- UK ABWR topic report “Level 2 PSA methodology” (Ref. 6): this document summarises the approach that the RP will adopt to develop the UK ABWR level 2 PSA. This includes high level descriptions of the preliminary plant damage states (PDS), containment event trees and preliminary release categories. The document includes statements regarding the consistency of the approach proposed with the ONR PSA TAG and IAEA standards.
- UK ABWR topic report “Preliminary Level 3 PSA Methodology” (Ref. 7): this document outlines the RP’s proposed approaches for the development of the interface between the level 2 and level 3 PSA, the consequence model for the level 3 PSA, and, ultimately, for the demonstration that SAP NT.1, numerical targets 7, 8 and 9, will be met. The report explains that the majority of the level 3 PSA analysis will be performed during step 3. During step 4 the RP will conduct sensitivity analyses and deal with technical aspects identified during ONR’s assessment. The approach proposed in the report is to group similar

categories of radioactive releases arising from the level 2 PSA using deterministic analysis. These will form the basis of the comparison with SAP NT.1 numerical target 8, and the input into the level 3 PSA model to generate the risk figures for comparison with numerical targets 7 and 9. This report also outlines the methodology and tools that will be adopted in the atmospheric dispersion, environmental transfer, and dosimetric calculations in the probabilistic accident consequences analysis.

- UK ABWR topic report "PSA programme": this document presents a high level programme to develop the UK ABWR PSA in steps 3 and 4. The RP has committed to submit additional information regarding the internal events PSA at the beginning of step 3 and the level 1 and level 2 PSA for internal initiating events during operation at power by the end of 2014. The remaining parts of the PSA will follow later in GDA, including delivery of the hazards PSA well into step 4.
- UK ABWR topic report "Severe accidents analysis" (Ref. 9): this document presents a description of the severe accident progression expected for the UK ABWR, relevant severe accident phenomena, severe accident analysis code to be used (MAAP 4), and the results of some severe accident analysis already undertaken by the RP.
- Document "Resilience of design against Fukushima type events" (Ref. 10): this document describes the lessons learnt by the RP from the Fukushima accident and potential severe accident mitigation measures proposed for the UK ABWR.
- UK ABWR GDA tracking sheet (Ref. 26).
- Responses to RQs I have raised during step 2: RQ-ABWR-0057 to RQ-ABWR-0059, RQ-ABWR-0077, RQ-ABWR-0093 to RQ-ABWR-0097, RQ-ABWR-0159 and RQ-ABWR-0161 (Ref. 21).

37. In addition, in May 2014, the RP submitted to ONR for information an advance copy of the UK ABWR pre-construction safety report (PCSR). Chapters 21 and 22 (Ref. 27) address PSA and SAA respectively. I have not formally considered this report in my step 2 assessment. However, the initial review has indicated that some of the conclusions from my assessment of the PSA and SAA documentation submitted by the RP during step 2 are also applicable to the PCSR. As the UK ABWR PSA and SAA are under development, the corresponding chapters of the PCSR will need to be expanded and enhanced as the PSA and SAA development progresses.

4 ONR ASSESSMENT

38. My assessment has been carried out in accordance with ONR How2 BMS document PI/FWD, “Purpose and Scope of Permissioning” (Ref. 11).

39. My assessment has followed the strategy described in section 2 of this report; the assessment of the SAA has been undertaken with the assistance of technical support contractors who have carried out their work under my direction and supervision.

40. My step 2 assessment work has involved regular engagement with the RP’s PSA and SAA subject matter experts (SME). Two technical exchange workshops (one in Japan and one in the UK) and three progress meetings (mostly video conferences) have been held. I have also visited the ABWR units 6 and 7 at the Kashiwazaki-Kariwa nuclear power plant (NPP) where I could tour the majority of the facility to increase my familiarity with ABWR technology.

41. During my step 2 assessment, I have identified shortfalls in the RP’s safety case documentation, some of which have led to the issue of RQs; overall I have raised 12 RQs.

42. Details of my assessment of the preliminary safety case in the area of PSA and SAA, including the areas of strength that I have identified, as well as the items that require follow-up and the conclusions reached are presented in the following sub-sections.

4.1 Risk Associated with the UK ABWR

4.1.1 Assessment

43. The UK ABWR PSA is under development and has not been submitted to ONR in step 2. The PSR (Ref. 1) presents the CDF associated with internal initiating events during reactor operation at power obtained for the Japanese ABWR PSA. This CDF appears very low when compared with publicly available ABWR CDF figures (Refs. 28 and 29), including the value quoted by Hitachi-GE in their ABWR promotional brochure (Ref. 29). The PSR indicates that this difference is mainly due to discrepancies in data and in the treatment of recovery actions. For example, according to the PSR, the Japanese ABWR PSA uses Japanese national records (Ref. 30) which are claimed by the RP to be generally less conservative than those used in Ref. 31.

44. Upon my request, the RP undertook sensitivity analyses to estimate the impact of these differences on the PSA results. I have reviewed the approach, scope and results of the sensitivity analyses presented in Ref. 2. I also requested the RP to evaluate the risk associated with hazards and with the operation of the ABWR during shutdown and the fuel route activities, as these aspects were not considered in the sensitivity analyses. In response to my query, the RP has provided preliminary numerical bounding estimates for the UK ABWR CDF associated with internal initiating events during reactor shutdown (Ref. 3), and internal fire and flooding during operation at power (Ref. 4). The RP has also provided a qualitative evaluation of the risk associated with the SFP and fuel route activities which concluded that this risk was lower than the risk associated with the reactor during shutdown states. (Ref. 3).

45. I have compared the bounding CDF figures for internal events, internal fire and flooding provided by the RP against SAP NT.1 numerical targets 7, 8 and 9. For this purpose I have assumed a conditional containment failure probability (CCFP) of 0.4 based on information in the PSR (Ref.1), which presents two figures for the CCFP of the Japanese ABWR: 0.1 produced by ‘utility analysis’ and 0.4 estimated by Japan Nuclear Energy Safety Organisation (JNES). I do not have information regarding the

approach and data used to calculate the CCFP values quoted in the PSR (Ref.1) and have therefore assumed the more conservative of the values in Ref. 1.

4.1.2 Strengths

46. In the absence of a PSA available in step 2, the RP has been responsive and has undertaken sensitivity analyses and preliminary risk evaluations to help ONR understand the risk associated with the UK ABWR.

47. The RP has committed to develop a full scope level 1, level 2 and level 3 PSA for the UK ABWR. Although the proposed methodology was only made available in outline during step 2, it provides initial confidence that the output will be relevant to the UK ABWR design and UK context.

4.1.3 Items that Require Follow-up

48. During my assessment of the RP's evaluation of the risk associated with the UK ABWR, I have identified a number of shortcomings that I will follow-up during step 3. These are summarised in the following paragraphs.

49. The bounding CDF estimated by the RP is above the International Nuclear Safety Group (INSAG)'s recommended CDF target for new reactors (Ref. 32). Furthermore, the bounding CDF could result in a release frequency above INSAG's recommended target for individual risk of fatality for new reactors, and risk / doses that challenge the basic safety objectives (BSOs) for SAP NT.1 numerical targets 7 and 8 (>1000 mSv) and the basic safety level (BSL) for target 9.

50. The RP has indicated that the evaluation of the bounding CDF is conservative. I agree that assumptions used in the RP's bounding analyses may be conservative, however, the analyses are simplified and appear to be incomplete, for example:

- The RP's analysis does not incorporate the risk associated with external hazards, internal hazards other than internal fire and flooding.
- The list of internal events considered in the RP's evaluation is only preliminary and not yet complete (see further information in Section 4.2.3).
- The RP's evaluations of the impact of internal fires and floods only consider loss of function. This may not be bounding of other potential effects not explicitly included in the fire analysis (for example electrical faults, explosions, missiles, collapse of structures, smoke and heat effects, single and multiple spurious actuation issues) or in the flooding analysis (for example spray, high temperature, humidity, jet impingement and pipe whip).
- The RP's evaluation assumes that fires and floods do not propagate to different areas.
- The RP's evaluation does not consider the effect of fire / flooding on human reliability. For example, stresses imposed by the accident situation and possible degradation of plant monitoring instrumentation may have detrimental impacts such as additional dependencies, effect on performance shaping factors and potential for operator errors in response to erroneous alarms.
- The RP's preliminary bounding estimate for the UK ABWR CDF for internal events during shutdown and the qualitative evaluation of the risk associated to the SFP and fuel route activities, appear to be based on loss of grid scenarios only, considered by the RP to be dominant contributors to the risk.

51. The RP is considering design modifications to improve the safety of the UK ABWR and reduce the level of risk, for example in the areas of C&I and electrical distribution (Refs. 33 and 34). Some features of the UK ABWR design proposed in step 2, for

example the back-up building, are not considered in the evaluation of the bounding CDF mentioned above. How these features will be captured in the UK ABWR PSA is unclear at the moment.

52. The approach proposed by the RP to calculate the frequency and consequences of accidents resulting in doses to any person off the site (relevant to SAP NT.1 target 8) seems to only consider core damage sequences currently included in the scope of the reference PSA. It is not clear if this approach will also consider other facilities apart from the reactor, or initiating events and level 1 PSA success sequences (that is without core damage) that could result in radioactive releases.

53. The RP has committed to submit the level 1 and level 2 PSA for internal initiating events during operation at power at the end of 2014; this, together with the information available to me so far, is not sufficient to provide the complete picture of the UK ABWR risk (for example, according to Hitachi-GE's bounding CDF evaluation, internal fire and flooding appear to be dominant contributors to the ABWR risk, and I do not know whether this is realistic). The remaining parts of the PSA will follow later in GDA, including delivery of the hazards PSA well into step 4. Therefore, the RP's PSA delivery plan may present risks to the completion of the UK ABWR GDA within expected timescales.

54. At the time of writing this assessment report, I am preparing a regulatory observation (RO) to state my expectations related to the development and delivery of the PSA for the UK ABWR as part of the GDA submission. The RP should develop and deliver the UK ABWR PSA in accordance with a detailed programme, reflected in the resolution plan to this RO, outlining specific PSA tasks required to be completed and providing clarity on, and timings for, the deliverables (including any required task procedures, task analysis files, models and databases as agreed with ONR). In response to the RO, the RP will be requested to provide the UK ABWR PSA and documentation in a staggered (but logical) manner, according to the resolution plan.

4.1.4 Conclusions

55. Based on the outcome of my assessment of the risk associated with the UK ABWR design, I have concluded that the bounding CDF estimated by the RP could result in risk figures that would not meet ONR's expectations for new reactors when compared against SAP NT.1 (numerical targets). At this point, I do not have sufficient information to properly understand the risk profile for this reactor, as this would require a full scope, modern standards PSA. According to the RP's proposed plan to deliver this PSA, an understanding of the UK ABWR risk profile will not be complete until well into step 4. This plan may prevent the completion of my assessment within the projected timescales of GDA. I will therefore follow this up early in step 3.

4.2 Adequacy, Validity and Scope of the UK ABWR PSA

4.2.1 Assessment

56. The RP has provided a strategy and programme to develop a modern standards full scope level 1, level 2 and level 3 PSA for the UK ABWR during GDA. This information has been provided only in the form of outline proposals. It has therefore not been possible to carry out a detailed assessment of its adequacy, validity and scope against regulatory expectations. However, I have been able to identify from this both strengths and items to follow-up, which are discussed in Sections 4.2.2 and 4.2.3. In particular, I have focused my review on the following aspects summarised below.

57. I have review the adequacy of the proposed approach to ensure that the PSA will provide an adequate representation of the UK ABWR design and will be updated to reflect the evolution of the design, which is part of ONR's expectations in the SAP FA.11.

58. I have considered the completeness of the list of initiating events against ONR's expectations identified in SAP FA.12.

59. I have reviewed the following aspects of the PSA strategy submitted by the RP against ONR's expectations in SAP FA.13:

- The approach proposed to develop the thermal-hydraulic analysis supporting the UK ABWR PSA success criteria. In particular, I have raised RQ-ABWR-0097 (Ref. 21) to request clarification on the strategy that will be adopted to produce new analysis.
- The development of systems and accident sequences analyses. To complement the information that was available in this area, I requested the RP to present an example of system analysis and accident sequence analysis (under development for the UK ABWR PSA) during the PSA technical workshop in May 2014.
- The strategy proposed for the derivation of the initiating event frequencies and component random failure data for the UK ABWR PSA.
- The part of the RP's 'communication and quality control' process that is relevant to PSA.
- The Level 3 PSA outline proposals.
- The proposed approach to develop the UK ABWR hazards PSA. To obtain further information in this area, I have raised RQ-ABWR-94 (Ref. 21).

60. The information provided by the RP in the area of HRA has been reviewed by ONR's human factors inspector in Ref. 35.

61. The initial list of external hazards considered in the PSA screening has been reviewed by ONR's external hazards inspector in Ref. 36.

4.2.2 Strengths

62. The RP is establishing the basis for the development of a full scope PSA for the UK ABWR, ensuring a strong link with the UK ABWR design documentation. For example:

- The fault tree documentation reviewed during the PSA workshop in May 2014 (Ref. 37) has clear references to the design information.
- Assumptions made when design information is not available are collated in a database.
- The RP is developing a process to review the PSA to reflect design modifications during GDA. This process will be formally linked to the RP's design modification process.

63. Close working relationships between the RP's PSA team and other technical areas have been apparent during several PSA meetings. The PSA team appears to provide support to most of the RP's GDA teams, for example, engineering, fault studies, human factors and hazards teams. I have raised RQ-ABWR-162 (Ref. 21) to obtain further information regarding the aspects of the RP's 'communication and quality control' process that are relevant to the PSA to ensure that this communication will happen throughout the project so that high quality inputs from other teams are provided into the ABWR PSA. I will review this information during step 3.

64. The proposals for the level 3 PSA include the use of the recently updated (version 2.0.3) PC COSYMA computer code. This code was developed for the assessment of the off-site consequences of accidental releases of radioactive material to atmosphere. It was primarily designed for use in probabilistic risk assessments, but it can be used for deterministic or probabilistic assessments. Deterministic assessments give detailed results for a single set of atmospheric conditions; probabilistic assessments give results taking account of the full range of atmospheric conditions and their respective frequency of occurrence. It yields air concentration or deposition of particular nuclides, doses received by members of the public, the individual or collective risks of health effects in the exposed population, together with information relevant to countermeasures and economic costs. I anticipate that use of PC COSYMA will greatly help the RP to arrive at a robust, modern standards analysis and avoid problems encountered with previous GDAs, where the analyses carried out were biased towards non-UK methodology and regulatory requirements, leading to uncertainties when comparing the results with SAP NT.1 (numerical targets). It will therefore also facilitate ONR's assessment. This is further reinforced by the RP's use of UK-specific data and parameters required for the evaluation of accident consequences.

4.2.3 Items that Require Follow-up

65. During my assessment of the adequacy, validity and scope of the UK ABWR PSA, I have identified a number of shortcomings that I will follow-up during step 3. These are described in the following paragraphs.

66. The anticipated December 2014 level 1 and level 2 PSA for internal initiating events during operation at power, may not fully reflect the UK ABWR design. For example, UK ABWR success criteria analysis and failure modes and effects analyses (FMEA) supporting the UK ABWR fault schedule are not planned to be finalised in time to provide input to the December 2014 PSA. Hence this PSA will need to be updated during GDA. In RQ-ABWR-160 (Ref. 21), I have requested the RP to provide a schedule of PSA updates during GDA. I will assess the RP's response to this RQ in step 3.

67. The RP's preliminary list of internal initiating events during operation at power needs to be completed. For example, spurious signals that could result in initiating events or initiating events triggered by common cause failures of the support systems are missing. Similar concerns have been raised in ONR's review of the RP's list of faults considered in the design basis analysis (DBA); these are summarised in RO-ABWR-0007, RO-ABWR-0008 and RO-ABWR-0010 (further information can be found in Ref. 38). During step 3, I will undertake a detailed review of the identification and grouping of internal initiating events during operation at power to confirm whether the bases of the UK ABWR PSA are robust and to gain confidence in its completeness.

68. There is lack of clarity regarding the degree of conservatism of the analysis that will be developed to support the UK ABWR PSA success criteria. The RP has committed to provide a roadmap of the PSA success criteria analysis and a description of the new supporting analyses specific to the UK ABWR at the beginning of step 3. In step 3, I will review the adequacy of this approach against the PSA TAG.

69. The approach proposed to develop UK ABWR fault trees does not cover the modelling of maintenance unavailabilities and proposes the exclusion of high reliability components and low probability failure modes from the fault tree models. These aspects of the approach do not meet ONR's expectations. My review has also identified that the documentation of the identification of human failure events (HFE) needs to be enhanced. I have requested the RP to develop and provide a PSA system analysis task procedure at the beginning of step 3. This request is being formalised via

an RO (see Section 4.1.3). I will conduct a review of the RP's system analysis task procedure against the expectations in the PSA TAG.

70. I have requested the RP to provide its detailed approach used to develop and document the accident sequence analysis, at the beginning of step 3, as the method was unclear during our technical discussions on this topic in May 2014 in Japan. This request is being formalised via an RO (see Section 4.1.3). I will conduct a review of the RP's sequence analysis task procedure against the expectations in the PSA TAG.

71. The use of US generic data (Ref. 39) combined with Japanese operating experience for the derivation of some of the initiating event frequencies is not sufficiently documented and justified. In step 3, I will undertake a detailed review of the RP's evaluation process and justification for the frequencies assigned to the internal initiating events during operation at power of the UK ABWR PSA against the PSA TAG.

72. I do not have sufficient information to appraise the adequacy of the data sources selected to underpin the component reliability data intended for use in the UK ABWR PSA. I have requested the RP to provide justified component reliability data and clarity of the component boundaries for the UK ABWR PSA, at the beginning of step 3. This should also include common cause failure data. This request is being formalised via an RO (see Section 4.1.3). I will undertake a detailed review of the adequacy of the RP's component data sources during step 3.

73. Further information is required regarding the process to update the PSA to reflect design modifications and to capture and review assumptions embedded in the PSA. The RP has committed to deliver the details of these processes during step 3 in response to RQ-ABWR-160 (Ref. 21). I will review this information in step 3.

74. For the purposes of level 3 PSA the RP proposes to use some data and parameters in the modelling which are not generic, but are specific to the Wylfa site. Whilst this has the benefit that it tailors the GDA PSA better to address site specific matters for Wylfa's submissions in due course, it limits the applicability of the GDA consequence analysis for other possible UK ABWR sites. This has the potential to give rise to a GDA finding which would place requirements for further consequence analysis for other UK sites (as and when required) if the Wylfa data and parameters do not envelope those sites.

75. The screening of internal and external hazards for the UK ABWR PSA is not finalised. The screening criteria are not clear, for example a numerical criterion has not been defined. At the time of writing this report, the initial list of internal and external hazards was not finalised. Furthermore, the list needs to be expanded to consider combination of hazards and other facilities apart from the reactor building. In addition, external hazard curves for the UK ABWR GDA generic site and design information required for the screening process are not yet available. I will undertake a detailed review of the finalised hazards screening against the expectations of the PSA TAG during step 3.

76. There is lack of clarity regarding the methodology and scope of the UK ABWR hazards PSA. As indicated previously, the hazards PSA will be completed in step 4. The current plan is that the RP will provide detailed information on the approach in spring 2015. Some of the aspects of this approach have been outlined in response to RQ-ABWR-94 (Ref. 21). However, the information provided is not sufficient to provide confidence at this stage that ONR's regulatory expectations will be met. In view of the potential high risk contribution from the internal hazards estimated by the RP (see Section 4.1), these dates appear late in the GDA process. I will follow-up this issue in step 3.

77. A UK ABWR PSA for the fuel route needs to be developed. Similarly, the fuel route activities need to be considered in the design basis safety case as identified in RO-ABWR-0011 (see further information in Ref. 38). The RP has committed to provide a shutdown and fuel route PSA by mid-2015. I will review these parts of the PSA during steps 3 and 4.

78. As mentioned in the paragraphs above and also in Section 4.1.3, I am in the process of issuing an RO requesting the RP to provide the UK ABWR PSA and documentation in a staggered (but logical) manner, in accordance with a detailed programme, which should be reflected in the resolution plan to this RO, outlining specific PSA tasks required to be completed and clarity on, and timings for, the deliverables (including any required task procedures, task analysis files, models and databases, as agreed with ONR). The staggered submission to ONR of information (documentation and computer models and / or databases, as appropriate) related to individual PSA tasks will facilitate both ONR's assessment and early identification of any technical concerns, and Hitachi-GE's ability to address such concerns in a timely manner.

4.2.4 Conclusions

79. Based on the outcome of my assessment of the adequacy, validity and scope of the UK ABWR PSA, I have concluded that further information is needed to provide confidence that the UK ABWR PSA will meet regulatory expectations identified in SAPs FA.11, FA.12 and FA.13.

80. Except in relation to the hazards PSA, I believe that the RP has set up the basis to develop and deliver the PSA information that I require for a meaningful assessment, during step 3, of the safety case arguments relating to PSA. For example, the RP has committed to submit additional information regarding the internal initiating events PSA at the beginning of step 3 and a level 1 and level 2 PSA for internal initiating events during step 3. The delivery plan for the hazards PSA has been highlighted as a concern in the previous section.

81. The timely delivery by the RP of the level 1 and level 2 PSA for internal initiating events during operation at power (proposed for December 2014), and the quality of this part of the PSA, will be key to providing me with confidence of the RP's ability to deliver a full scope PSA which:

- meets ONR's expectations;
- provides a clear understanding of the UK ABWR risk;
- supports the demonstration that the level of risk is ALARP.

Should the RP not deliver the analyses as per the programme, or the quality be lacking, ONR has additional regulatory options.

4.3 Use of the PSA to Support the UK ABWR Design Process

4.3.1 Assessment

82. I have reviewed the adequacy of the use of the PSA to support the development of the UK ABWR design, against regulatory expectations in SAP FA.10 and FA.14. The RP's safety submissions did not provide information on this topic. I therefore raised RQ-ABWR-0161 (Ref. 21) and assessed the RP's response to the following queries:

- How has the PSA been used to support the development of the generic ABWR design?

- The RP's process to use the PSA to support all aspects of the evolution of the design of the UK ABWR and how this is integrated into the UK ABWR design management process.

4.3.2 Strengths

83. Ref. 40 (US Nuclear Regulatory Commission's (NRC) ABWR Final Safety Evaluation Report published in July 1994) explains that at the early stages of the ABWR design, the PSA was used to help to simplify the design in a way in which the core damage frequency was maintained or improved compared with estimates for operating plants at the time. Subsequently, the ABWR standard design was assessed and certified by the US NRC during the 1990s. During the ABWR design certification process, additional design changes were made. Ref. 40 indicates that these changes were mainly design improvements that significantly added to the defence in depth. According to Ref. 40, these changes reduce uncertainties that the design would meet the NRC Commission's safety goals and goals proposed by the Electric Power Research Institute (EPRI) for evolutionary reactors. For example, a water addition system independent from alternating current (AC) was added. Ref. 40 indicates that this system provided benefits for station blackout, fires, internal floods and seismic events.

84. The RP has provided a strategy to use the PSA to inform the UK ABWR design process and to demonstrate that the level of risk associated with the UK ABWR is ALARP.

4.3.3 Items that Require Follow-up

85. During my assessment of the use of the PSA to support the UK ABWR design process, I have identified some shortcomings, discussed in the following paragraphs, that I will follow-up during step 3.

86. Further detail is needed on the procedure to risk inform the UK ABWR design and the severe accident prevention and mitigation features and to formally link this with the UK ABWR design management process. The RP has indicated that this activity will be part of its quality assurance process. I have requested further information regarding the RP's PSA quality assurance process in RQ-ABWR-0162 (Ref. 21). I will review the response to this query in step 3. I will also consider the need to undertake an inspection of the implementation of the proposed process with the support of the GDA management of safety and quality assurance (MSQA) team.

87. The RP has indicated that the use of the PSA to support the design change decision making process will depend on the design review grading assigned to the design change. I have not yet had visibility of the specific criteria and approach used by the RP to assign (safety significance) grades to the design modifications. I have raised RQ-ABWR-0160 (Ref. 21) to obtain further information on this topic.

88. In view of the bounding CDF estimated by the RP mentioned in previous sections, the PSA that will be used to risk inform the design will not provide the complete picture of the UK ABWR risk until late in GDA. Response to RQ-ABWR-0161 (Ref. 21) recognises this matter and states that the approach to use the PSA to support decision making will depend on the PSA development progress at the moment of the decision making. In step 3, I will review the adequacy of the proposed approach.

4.3.4 Conclusions

89. Based on the outcome of my assessment of the use of the PSA to support the UK ABWR design process, I have concluded that the information presented provides me with confidence that:

- The generic ABWR design has been influenced by the outcome of PSA.
- The RP has set up the basis, in principle, to ensure that the PSA will be used to continue the development of the UK ABWR design during GDA. However, to enable a detailed assessment against ONR's expectations in SAPs FA.10 and FA.14 further information is needed and ultimately a UK ABWR PSA is required to support design and operational features. I will review the details of the approach proposed and related processes in step 3.

4.4 Severe Accident Phenomena Considered in the UK ABWR SAA

4.4.1 Assessment

90. I have assessed the completeness of the severe accident phenomena described in Ref. 9 against international good practice summarised in Ref. 19 and regulatory expectations in SAP FA.15.

4.4.2 Strengths

91. The high level description of the severe accident phenomena provided by the RP covers key phenomena of both in-vessel and ex-vessel phases of severe accidents which are expected to be relevant for BWRs in general.

4.4.3 Items that Require Follow-up

92. During my step 2 assessment of severe accident phenomena considered in the UK ABWR SAA, I have identified a number of shortcomings discussed in the following paragraphs and which I will follow-up in step 3.

93. The description of the severe accident phenomena provided by the RP is generic; for some phenomena explanations need to be extended to provide specific details for the UK ABWR. For example, it would be useful to have further information on the following:

- Molten core concrete interaction (MCCI) regarding the consideration of axial and radial erosion, influence of the type of concrete, melt fragmentation and coolability. Melt fragmentation and coolability depend on whether the conditions inside the cavity below the reactor pressure vessel (RPV) during the relocation of the corium, are dry or wet. For example, if the corium is relocated into a water pool it will be fragmented which may have a positive effect as the efficiency of the corium 'coolability' may increase and a detrimental effect as the probability of occurrence of steam explosions may also increase.
- Depressurisation of the containment (for example, strategy, system design and filter design).

94. The description of some of the severe accident phenomena is missing. For example, a description of the following phenomena should be provided:

- In-vessel core degradation: consideration of destruction of fuel assembly canisters, melt relocation inside the core and into the lower plenum, degradation of the control rod guide tubes, and molten pool formation in the lower plenum with regard to multiple internal structures.
- Failure of components due to creep rupture (for example, in the main steam line) in high pressure sequences.
- Behavior of radionuclides (in-vessel and ex-vessel).

95. The severe accident phenomena considered should be expanded to cover accident sequences starting from all the operating modes and the relevant facilities, in addition

to the operation of the reactor at power. The need for severe accident analysis for the fuel route has also been raised in RO-ABWR-0011 (further information can be found in Ref. 38).

96. As indicated previously, fission product release, behaviour in the containment and radioactive releases into the environment have not been considered at this stage. The RP has committed to provide source term analyses in step 3. The RP has presented information regarding the suppression pool chemistry which is claimed to reduce the release of radioisotopes from the containment so far as is reasonably practicable during accident scenarios (Ref. 41). This information has been assessed by the ONR chemistry inspector in Ref. 42.

97. The RP's description of some of the severe accident phenomena includes statements regarding how the phenomena can be mitigated by engineered features (for example, to cool the corium in the lower plenum of the RPV or in the lower part of drywell after RPV failure). The justification of the capability of these measures needs to be provided.

98. The analyses presented do not consider the uncertainties in the modelling of the relevant phenomena. These uncertainties need to be identified and the analysis expanded to consider their implications from the point of view of understanding the severe accident progression for ABWRs.

4.4.4 Conclusions

99. Based on the outcome of my assessment of the severe accident phenomena considered in the UK ABWR SAA, I have concluded that although the key phenomena expected to be relevant for BWRs is covered in general, the documentation needs to be extended to provide specific explanations for the UK ABWR. The analysis needs to be expanded to consider additional severe accident phenomena, accident sequences and facilities. The implications of the known uncertainties from the point of view of understanding the severe accident progression for ABWRs need to be covered. This information will be required to demonstrate that regulatory expectations in SAP FA.15 can be met. I will follow-up these matters in my step 3 assessment.

4.5 Specific Engineered Features, Strategies and Procedures to Deal with Severe Accident Sequences in the UK ABWR

4.5.1 Assessment

100. I have reviewed the information provided regarding specific engineered features, strategies and procedures to deal with severe accident sequences in the UK ABWR in Ref. 9 against international good practice and expectations compiled in Ref. 19 and SAP FA.16.

4.5.2 Items that Require Follow-up

101. The information available at the time of my assessment was not sufficiently detailed to enable the identification of strengths or specific items to follow-up in this area. Much more information is required, for example to clarify the following aspects:

- UK ABWR severe accident management concept;
- an overview of the UK ABWR severe accident strategies and procedures;
- design of the proposed engineered features to deal with severe accidents in the UK ABWR;

- information on the effectiveness of the proposed engineered features, strategies and procedures (for example, through severe accident analyses with consideration of the engineered features); and
- requirements for the safety classification of the proposed severe accident engineered features.

102. The RP has indicated that more information on the severe accident systems and a demonstration of their capability to deal with the severe accident sequences will be provided in step 3.

4.5.3 Conclusions

103. The information provided during step 2, regarding specific engineered features, strategies and procedures to deal with severe accident sequences in the UK ABWR, is preliminary in nature and was not sufficient to enable an assessment of the RP claims in this area. More information will be required to provide the basis for a meaningful assessment during steps 3 and 4 of GDA and to demonstrate that regulatory expectations in SAP FA.16 can be met and the engineered features and strategies to deal with severe accident sequences in the UK ABWR reduce the level of risk ALARP. I will follow-up this issue early in step 3 and review whether it will be addressed by the additional information that the RP plans to provide in step 3.

4.6 Analysis of the Progression of the Severe Accident Sequences and the Behaviour of Fission Products in the UK ABWR

4.6.1 Assessment

104. I have reviewed the RP's analysis of the progression of the severe accident sequences and the behaviour of the fission products in the UK ABWR provided in Ref. 9 against international good practice and expectations compiled in Ref. 19 and SAP FA.15.

4.6.2 Strengths

105. Severe accident progression analyses for the UK ABWR are being developed using MAAP4, which is an internationally established computer code.

4.6.3 Items that Require Follow-up

106. During my assessment of the progression of the severe accident sequences and the behaviour of the fission products in the UK ABWR I have identified a number of shortcomings. These are discussed in the following paragraphs, which I will follow-up in step 3.

107. The criteria used by the RP for the selection of the accident sequences to be analysed needs to be described.

108. The scope of the events covered by the analyses will need to be expanded. For example, severe accident sequences resulting from initiating events during shutdown operations and from SFP initiating events have not been considered at this stage. Similarly, accident sequences that may result from internal and external hazards may lead to plant damage states different to those from internal fault initiating events; these need to be considered in the accident progression analyses.

109. As discussed above, a demonstration of the effectiveness of the severe accident management measures should be provided. The engineered features and procedures for severe accident management need to be included in the deterministic accident progression analyses. The RP has indicated that these analyses will be developed in

step 3. I expect that, for this purpose, the RP will use a detailed model of the primary containment and of the reactor building, as appropriate.

110. The UK ABWR severe accident analyses needs to be documented thoroughly. The documentation should include the input data files, description of the boundary conditions of the analyses and detailed explanation of the results by using a wider variety of trend plots (than that provided in the RP's documentation submitted to date).

111. The description of the severe accident progression should be completed for the range of sequences analysed. For example, core degradation, hydrogen generation, behaviour of fission products, and details of MCCI after RPV failure have not been discussed for the sequences analysed. In addition, a description of the primary containment failure mode/s assumed in the analyses and the consequences inside the reactor building (outside the primary containment) need to be provided.

112. The uncertainties within the analyses need to be considered and the potential impact on the results addressed.

113. A determination of possible release paths for the UK ABWR plant and analyses of releases of radionuclides need to be provided. The RP has indicated that source term analysis will be developed in step 3.

4.6.4 Conclusions

114. Based on the outcome of my assessment of the information provided by the RP regarding the progression of UK ABWR severe accident sequences and the behaviour of the fission products in such sequences, I have concluded that the analyses should be expanded further and should be documented thoroughly. In particular, the analyses need to be extended to cover all the relevant severe accident scenarios for the UK ABWR and show the effectiveness of the foreseen severe accident management measures. Analysis should also be provided to determine the possible release paths for the UK ABWR and the source terms. I expect that the additional information and analysis that the RP plans to provide in step 3 will address some of the identified limitations. This information is necessary to demonstrate that SAP FA.15 can be met. I will follow-up these matters in my step 3 assessment. I will also consider the need to undertake independent confirmatory severe accident analyses later in GDA.

4.7 Considerations in the Light of the Fukushima Accident

4.7.1 Assessment

115. As part of my assessment, I have considered the lessons learnt from the Fukushima accident and recommendations in the area of severe accident analysis contained in ONR's report "Japanese earthquake and tsunami: Implications for the UK nuclear Industry" (Ref 43). I have also considered similar conclusions drawn internationally, for example, in countries like Japan and Germany and from within organisations like WENRA. On this basis, I have reviewed the information provided by the RP in Ref. 9 and particularly in Ref. 10.

4.7.2 Strengths

116. The RP's lessons learnt from the Fukushima accident presented in Ref. 10 are generally in line with international findings. In particular, ONR's Chief Inspector's recommendations in Ref. 43 are explicitly considered by the RP in Ref. 10.

4.7.3 Items that Require Follow-up

117. During my assessment of the considerations in the light of the Fukushima accident, I have identified the following shortcomings that I will follow-up during step 3:

- More specific details on the backup building, which is described as central to severe accident management strategies for the UK ABWR, are needed.
- Severe accident measures proposed by the RP in Ref. 10 need to be substantiated with detailed information on the actual design (for example: number, type, and location of connection points in the reactor building; mobile equipment; and the way to provide coolant injection to the containment head) and their implementation into the severe accident management strategy and guides. For example, a demonstration that flooding of the upper reactor well would effectively prevent leakage from the primary containment through the drywell head flange, for the expected temperature and pressure loads during a severe accident, is currently missing.
- Measures for hydrogen management outside the primary containment should be discussed in more detail.
- The UK ABWR SAA safety case should explicitly reflect the severe accident strategies and other outcomes resulting from the considerations in the light of the Fukushima accident. The current SAA topic report (Ref. 9) does not reflect these considerations explicitly. However, Fukushima relevant phenomena like hydrogen combustion and explosions in the reactor building are discussed.

4.7.4 Conclusions

118. Based on the outcome of my assessment of the considerations in the light of the Fukushima accident, I have concluded that, as part of the SAA, the RP needs to provide further information regarding how the UK ABWR design addresses Fukushima related severe accident management issues. I will follow-up these matters in my step 3 assessment.

4.8 ALARP Considerations

4.8.1 Assessment

119. I have considered the adequacy of the RP's safety submissions to demonstrate that the level of risk associated with the UK ABWR is ALARP against ONR's expectations in SAP FA.10. The need for the RP to demonstrate that the engineered features and strategies to deal with severe accident sequences in the UK ABWR reduce the level of risk ALARP has been discussed in Section 4.5 of this report.

4.8.2 Strengths

120. The RP has claimed that the PSA will be used to support the demonstration that the UK ABWR level of risk is ALARP.

4.8.3 Items that Require Follow-up

121. During my assessment of the ALARP considerations, I have identified the following shortcomings that I will follow-up during step 3:

- On the basis of the information reviewed in step 2, I do not have clarity of whether the level of risk associated with the UK ABWR is ALARP. A full scope PSA for the UK ABWR needs to be developed to support the RP's demonstration that the level of risk is ALARP. In step 3, I will review the use of the internal events PSA results to identify potential design improvements or to justify any claim that no additional design modifications are required to reduce the level of risk.

- As indicated previously, the PSA will not provide the complete picture of the UK ABWR risk profile until well into step 4. A complete ALARP demonstration will therefore not be possible until then.

4.8.4 Conclusions

122. As the UK ABWR PSA is under development, I do not have sufficient information to understand whether the level of risk associated with the UK ABWR is ALARP. The consideration of the adequacy of the input of the PSA into the ALARP demonstration against ONR's expectations in SAP FA.10 will be a key part of my assessment beyond step 2.. During step 3 I will review of the adequacy of the RP's approach to use the PSA for internal initiating events to underpin the ALARP demonstration and to identify further design improvements if required, against ONR's expectations in SAP FA.10.

4.9 Comparison with Standards, Guidance and Relevant Good Practice

123. In Section 2.2 I have listed the standards and criteria I have used during my assessment of the PSA and SAA to judge the adequacy of the preliminary safety case. My overall conclusions in this regard can be summarised as follows:

- PSA SAPs: My step 2 assessment concludes that the existing PSA, which forms the basis for the PSR, is not suitable or sufficient to support the UK ABWR GDA safety submission. The RP recognises this and is developing a full scope PSA for the UK ABWR. The RP needs to provide further information on the approach and methodologies to build confidence that this PSA will meet ONR's regulatory expectations. For example, the bounding CDF estimated by the RP in step 2 could result in risk figures that would not meet ONR's expectations for new reactors when compared against SAP NT.1 (numerical targets). I believe that the RP has set up the basis to deliver this information during step 3 for internal initiating events. However, the hazards PSA delivery plan may present risks to the completion of the UK ABWR GDA within expected timescales.
- SAA SAPs: The SAA information provided by the RP during step 2 is preliminary in nature. More information will be required to demonstrate that regulatory expectations can be met. For example, the description of the severe accident phenomena is generic. More detail will be necessary about the proposed engineered features, strategies and procedures for the UK ABWR severe accident management. The scope of the events covered by the analyses will need to be expanded.
- TAGs: The information provided was limited and did not enable a meaningful assessment against regulatory expectations in the PSA TAG.

4.10 Interactions with Other Regulators

124. As indicated previously, the ABWR standard design was assessed and certified by the US NRC during the 1990s. The results of NRC's evaluation are published in Ref. 40.

125. The US NRC is currently working on the design certification renewal for GE-Hitachi's ABWR, Toshiba's ABWR and on the review of South Texas Project's (Toshiba's 1300MWe ABWR) application for a Combined Operating Licence (COL). GE-Hitachi's and Toshiba's ABWR design certification renewal applications were submitted in December and October 2010 respectively. Following initial reviews of the submissions, NRC brought to the attention of both applicants a number of changes for consideration to be included in the applications (28 for GE-Hitachi and 22 for Toshiba). The relevant US NRC letters to the vendors (where these findings are listed) can be found on NRC's website (Ref. 44).

126. As indicated previously, I had a limited amount of information regarding the UK ABWR PSA available for my step 2 assessment. To get familiar with the ABWR technology and PSA, I visited the US NRC in May 2014. NRC offered me the opportunity to see the PSA chapter of GE-Hitachi's ABWR Standard Safety Analysis Report (SSAR) that underpins Chapter 19 of the ABWR Design Control Document (DCD) Rev. 4 (Ref. 31). The ABWR PSA documentation I saw helped increase my awareness of the PSA analysis behind the CDF figure available in the public domain and how it compares with the standard ABWR PSA information made available to ONR by the RP, including the results of the sensitivity analyses (Ref. 2).

127. I also discussed the outcomes of NRC's review of GE-Hitachi's ABWR renewal application with NRC's PSA team to enhance my understanding of NRC's technical assessment, findings and conclusions behind the PSA and SAA related items raised for consideration by GE-Hitachi (Ref. 45). On the basis of these discussions, I consider that a number of ABWR design certification renewal changes, proposed by NRC for GE-Hitachi's consideration, are important for my GDA assessment. During step 3 and 4 I will follow any developments on these areas in the US:

- Update the level 1 and 2 full-power probabilistic risk assessment (PRA) for the ABWR, including its description and results in Chapter 19 of the DCD.
- Complete a level 1 and 2 shutdown PRA for the ABWR, including its description and results in Chapter 19 of the DCD.
- Update Appendix 19K of the DCD to develop a comprehensive list of risk-significant structures, systems and components (SSC).
- Update emergency procedure guidelines and severe accident management guidelines consistent with NEI 91-04 (Ref. 46).

128. During step 3 and 4, ONR will continue working with NRC in the areas of PSA and SAA, through bilateral exchanges when possible, or via ONR's participation in the ABWR Working Group of the Multinational Design Evaluation Programme (MDEP) created in January 2014.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

129. The RP has provided a PSR for the UK ABWR for assessment by ONR during step 2. The PSR together with additional more detailed reports relevant to PSA and SAA, as well as the RP's response to RQ-ABWR 0159 (Ref. 21), present the claims in the area of PSA and SAA that underpin the safety of the UK ABWR.

130. During step 2 I have conducted an assessment of the parts of the PSR and additional reports that are relevant to the areas of PSA and SAA against the expectations of the SAPs and TAGs. From the UK ABWR assessment done so far I conclude the following:

- The RP has articulated reasonable, but high level, claims in the areas of PSA and SAA.
- The shortcomings identified in my review indicate that the RP will need to undertake a considerable amount of work to complete the UK ABWR PSA and SAA to meet regulatory expectations which is required to underpin the PSA and SAA claims outlined in step 2.
- The RP's current PSA delivery plan may present risks to the completion of the UK ABWR GDA within expected timescales.

131. I have found the RP to be knowledgeable, responsive and open which provides me with confidence that it will be capable of delivering the PSA and SAA work required during GDA.

132. Based on the RP's short-term programme of deliverables in the PSA and SAA areas, I see no reason, on PSA and SAA grounds, why the UK ABWR should not proceed to step 3 of the GDA process. However, the timely delivery by the RP of the level 1 and level 2 PSA for internal initiating events during operation at power (proposed for December 2014), and the quality of this part of the PSA, will be key to providing me with confidence of the RP's ability to deliver a full scope PSA which:

  - meets ONR's expectations;
  - provides a clear understanding of the UK ABWR risk; and
  - supports the demonstration that the level of risk is ALARP.

Should the RP not deliver the analyses as per the programme, or the quality be lacking, ONR has additional regulatory options.

5.2 Recommendations

133. My recommendations are as follows.

- Recommendation 1: The UK ABWR should proceed to step 3 of the GDA process.
- Recommendation 2: All the items identified in step 2 as important to be followed-up should be included in ONR's step 3 assessment plans for the UK ABWR PSA and SAA.

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Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No and Title	Description	Interpretation	Comment
FA.10 **Fault analysis – PSA – Need for a PSA**	"Suitable and sufficient PSA should be performed as part of the fault analysis and design development and analysis"	This principle sets the framework and requirements for a PSA study. The overriding aim of the PSA assessment is to assist ONR's judgements on the safety of the facility and whether the risks of its operation are being made as low as reasonably practicable.	Addressed in Section 4 of this report. The need for PSA has been recognised from the outset. However this assessment report concludes that the existing PSA which forms the basis for the PSR is not suitable and sufficient to support the UK ABWR GDA safety submission. Hence the SAP is not fully met.
FA.11 **Fault Analysis – PSA – Validity**	"PSA should reflect the current design and operation of the facility or site"	This principle establishes the need for each aspect of the PSA to be directly related to existing facility and site information, documentation or the analysts' assumptions in the absence of such information. The PSA should be documented in such a way as to allow this principle to be met.	Addressed in Section 4 of this report. This assessment report concludes that the RP has started to set up the basis to develop a full scope PSA in a way that ensures a strong link with the UK ABWR design. However, further information is needed and ultimately a UK ABWR PSA is required. Hence the SAP is not fully met.
FA.12 **Fault Analysis – PSA – Scope and extent**	"PSA should cover all significant sources of radioactivity and all types of initiating faults identified at the facility or site"	In order to meet this principle the scope of the PSA should cover all sources of radioactivity at the facility (for example, fuel ponds, fuel handling facilities, waste storage tanks, radioactive sources and reactor core), all types of initiating faults (for example, internal faults, internal hazards and external hazards) and all operational modes (for example, nominal full power, low power, shutdown, start-up, refuelling and maintenance outages).	Addressed in Section 4 of this report. As indicated previously the PSA is under development. This assessment report concludes that further information is needed to provide confidence that the UK ABWR PSA will meet the regulatory expectations in this area. In addition, the timescales for the delivery of the hazards PSA has been highlighted as a concern. Hence the SAP is not fully met.
FA.13 **Fault Analysis – PSA – Adequate representation**	"The PSA model should provide an adequate representation of the site and its facilities"	The aim of this principle is to ensure the technical adequacy of the PSA. Inspectors should review PSA models, data and results to be satisfied that the PSA has a robust technical basis and thus provides a credible picture of the contributors to the risk from the facility.	Addressed in Section 4 of this report. As indicated previously the PSA is under development. This assessment report concludes that further information is needed to provide confidence that the UK ABWR PSA will meet the regulatory expectations in this area. Although, I believe that the

SAP No and Title	Description	Interpretation	Comment
			RP has set up the basis to deliver the information required for a meaningful assessment during step 3, the SAP is not fully met.
FA.14 **Fault Analysis – PSA – Use of PSA**	"PSA should be used to inform the design process and help ensure the safe operation of the site and its facilities"	The aim of this principle is to establish the expectations on what uses the duty-holders should make of the PSA to support decision-making and on how the supporting analyses should be undertaken.	Addressed in Section 4 of this report. This assessment concludes that the RP has set up the basis to ensure that the PSA will be used to continue the development of the design and the severe accident features and strategies during GDA. However, further information is needed and ultimately a UK ABWR PSA is required to support design and operational features. Hence the SAP is not fully met.
FA.15 **Fault Analysis – Severe Accident Analysis – Fault sequences**	"Fault sequences beyond the design basis that have the potential to lead to a severe accident should be analysed"		Addressed in Section 4 of this report. This assessment report concludes that the severe accident analyses reviewed should be expanded. In particular, analysis needs to be extended to cover all the relevant severe accident scenarios for the UK ABWR and to show the effectiveness of the foreseen severe accident management measures. Hence the SAP is not fully met.
FA.16 **Fault Analysis – Severe Accident Analysis – Use of severe accident analysis**	"The severe accident analysis should be used in the consideration of further risk-reducing measures"		Addressed in Section 4 of this report. This assessment report concludes that the information provided regarding specific engineered features, strategies and procedures to deal with severe accident sequences in the UK ABWR, is preliminary in nature and was not sufficient to enable my assessment. More information will be required to provide the basis for a meaningful assessment during steps 3 and 4 of GDA. Hence the SAP is not fully met.
NT.1 **Numerical Targets – Target 7**	Individual risk to people off the site from accidents	BSL 10^{-4}/yr BSO 10^{-6}/yr	The UK ABWR PSA is under development. The RP has provided a preliminary bounding estimate for the Core Damage Frequency (CDF) for internal

SAP No and Title	Description	Interpretation	Comment
NT.1 **Numerical Targets – Target 8**	Frequency dose targets for accidents on an individual facility – any person off the site	<table><tr><td></td><td>BSL</td><td>BSO</td></tr><tr><td>Offsite dose 0.1-1 mSv</td><td>1</td><td>10^{-2}</td></tr><tr><td>Offsite dose 1-10 mSv</td><td>10^{-1}</td><td>10^{-3}</td></tr><tr><td>Offsite dose 10-100 mSv</td><td>10^{-2}</td><td>10^{-4}</td></tr><tr><td>Offsite dose 100-1000 mSv</td><td>10^{-3}</td><td>10^{-5}</td></tr><tr><td>Offsite dose >1000 mSv</td><td>10^{-4}</td><td>10^{-6}</td></tr></table>	events, and internal fire and flooding. This assessment report concludes that the bounding CDF could results in risk / doses that challenge the Basic Safety Objectives (BSOs) for SAPs' targets 7 and 8 (>1000 mSv) and the Basic Safety Level (BSL) for target 9. Currently there is not sufficient information to properly understand the risk profile for this reactor, as this would require a full scope, modern standards PSA. Hence the SAP is not met.
NT.1 **Numerical Targets – Target 9**	Total risk of 100 or more fatalities	BSL 10^{-5}/yr BSO 10^{-7}/yr	