Office for Nuclear Regulation

Civil Nuclear Reactor Build - Generic Design Assessment

Step 2 Assessment of the Human Factors 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 Human Factors (HF) aspects of the Hitachi-GE 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 increasing in detail as the project progresses. Step 2 of GDA 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 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 HF to judge whether they are complete and reasonable in the light of our current understanding of reactor technology.

For HF, safety claims are interpreted as high level assertions pertaining to systematic application and achievement of modern HF standards throughout the evolution of the design. These need to cover the following aspects:

- Specific human-based safety claims (HBSC) or safety actions that contribute to the support and delivery of nuclear safety functions in all plant states and conditions that are systematically identified, together with statements about the feasibility of such actions. This includes identification of human failure events that may impact nuclear safety and risk.
- Concept of operations, function allocation, procedures and personnel competence that are appropriate for all modes of operations, including fault and emergency response.
- Workspaces, interfaces, equipment and task design which are compatible with human characteristics and limitations, accounting for all plant states and conditions.

The standards I have used to judge the adequacy of the HF claims have been primarily:

- ONR's Safety Assessment Principles (SAP), in particular those related to HF, key engineering principles, safety systems, design basis analysis and probabilistic safety analysis (PSA).
- ONR's Technical Assessment Guides dealing with HF, PSA, safety systems and the content of nuclear safety cases.

My assessment work has involved regular engagement with the RP in exchange workshops and progress meetings. In addition, my understanding of ABWR technology, and therefore my assessment, has significantly benefited from visits to Hitachi Works, Omika Works and to the ABWR units at the Kashiwazaki-Kariwa Nuclear Power Plant.

My assessment is based on the RP's Preliminary Safety Report (PSR) on HF, HF Integration Plan (HFIP) and supporting references. The preliminary HF safety case can be summarised as follows:

- The HF safety claims range from high level broad system design claims to specific HBSC, based on the maturity of the design at the end of Step 2. Wide consideration of HF exists within the design on which the UK ABWR is based.
- There is a comprehensive HF integration programme to ensure continued, holistic and systematic application of HF throughout GDA.
- Advances in automated control and protection have formed the basis of the ABWR and concept of operations and allocation of function (AoF) between humans and engineering. Automated systems deliver primary reactor safety functions; automation

has been designed to optimise operator workload, reduce human error and ensure compatibility with human characteristics and limitations.

My assessment of the HF aspects of the preliminary safety case has identified the following areas of strength:

- The PSR and HFIP provide adequate descriptions of the HF claims and HFI activities required to meet UK regulatory expectations for development of a modern standards HF safety case for the UK ABWR. The RP has been transparent in identifying shortfalls against modern HF standards, which I believe has contributed to the production of a balanced preliminary HF safety case. I have not identified any HF claims that I consider to be unreasonable, such that they would challenge the expectations of the SAPs, or be likely to result in fundamental plant design changes.
- The high level HF claims for the design on which the UK ABWR is based seem reasonable, and appear to be supported by an alternative approach to HFI, where aspects of HF good practice has been encapsulated within the RP's various design processes, standards and specification documents. The specific HBSCs for the UK ABWR appear typical of those for nuclear power plant.
- The RP has provided preliminary information to show that the UK ABWR function allocation has incorporated relevant insights from operational experience. Based on the PSR, at this stage of GDA, I am confident that the RP's design decisions for AoF and concept of operations follow a balanced approach which considers technical feasibility, what is necessary for safety, human capabilities and limitations.

I have identified the following areas that require follow-up during my Step 3 assessment activities:

- I have not seen evidence of systematic task-analytical based processes for identifying the factors that influence HBSC and for determining the specific level of HF attention given to the baseline ABWR design for all stages of the plant lifecycle and all operational states and conditions. Whilst this does not necessarily invalidate the claims or mean that adequate evidence does not exist; further detailed analyses by HF specialists is required to produce and / or validate such evidence.
- The number of specific HBSCs suggests a potentially high human contribution to risk. However, the significance of the human contribution to the overall risk is currently unknown due to the absence of a full scope PSA for the UK ABWR. This needs to be explicitly analysed by the RP, taking into account developments in other areas such as internal and externals hazards and severe accident analysis (SAA) etc, and the risk from human failures demonstrated to be ALARP for the UK ABWR. The absence of a UK ABWR full scope PSA (and supporting analyses) presents a significant project risk to overall completion of my GDA HF assessment.
- Evaluation is needed of the full implementation of the RP's HF organisation in response to the Step 2 Regulatory Observation on HF Specialist Resource and Organisation.
- There will need to be a review of the adequacy and independence of the RP's HF quality assurance and peer review.
- Detailed assessment of AoF and concept of operations is required.
- Appraisal will be required of RP responses to the Step 2 Regulatory Queries on Human Reliability Analysis.

Through my interactions with the subject matter experts (SME) in HF, I found the RP to be open and responsive and it satisfactorily addressed the issues I raised. The RP has enhanced its organisational HF capability during this Step and acquired a good understanding of the UK regulatory framework and expectations for modern standards HF. The need for further HF analysis work is clearly acknowledged by the RP.

Overall, I judge the preliminary HF safety case to be adequate and based on this I see no reason on HF grounds, why the UK ABWR should not proceed to Step 3. However, the chapters on HF in the draft PCSR recently provided to ONR for information, appear to fall short of ONR's expectations and what is set out in ONR's GDA Guidance, and these will require improvement to form an adequate basis for my Step 3 assessment. However, based on their current organisational capability, commitment to develop this further and the HFI programme, I have confidence that the RP will be able to articulate reasonable claims in the PCSR and underpin them with sufficient arguments and robust evidence.

LIST OF ABBREVIATIONS

ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
AoF	Allocation of Function
BMS	Business Management System
BS EN	British Standards European Norm
C & I	Control and Instrumentation
C E & I	Control Electrical and Instrumentation
DAC	Design Acceptance Confirmation
DEF STAN	Defence Standard (UK)
DSA	Deterministic Safety Analysis
EA	Environment Agency
EEMUA	Engineering Equipment and Materials Users Association
FDWC	Feedwater Control
HBSC	Human Based Safety Claim
HCI	Human Computer Interaction
HEP	Human Error Probability
HF	Human Factors
HFE	Human Failure Event
HFI	Human Factors Integration
HFIP	Human Factors Integration Plan
GDA	Generic Design Assessment
IEC	International Electrotechnical Commission
Hitachi-GE	Hitachi-GE Nuclear Energy, Ltd
HRA	Human Reliability Analysis
IAEA	International Atomic Energy Agency
ISO	International Standards Organisation
J-ABWR	Japanese Advanced Boiling Water Reactor

LIST OF ABBREVIATIONS

JPO	(Regulators') Joint Programme Office
NPP	Nuclear Power Plant
US NRC	United States Nuclear Regulatory Commission
NUREG	Nuclear Regulation (US NRC report)
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PSR	Preliminary Safety Report
RHR	Residual Heat Removal
RO	Regulatory Observation
ROA	Regulatory Observation Action
RP	Requesting Party
RQ	Regulatory Query
SAA	Severe Accident Analysis
SAP(s)	Safety Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
SME	Subject Matter Expert
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators' Association

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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's (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 (EA) 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, nuclear security and environmental safety claims with the aim of identifying any fundamental safety or security shortfalls in the proposed design that could prevent the issue of a Design Acceptance Conformation (DAC) for the UK ABWR.

4. This report presents the results of my assessment of the human factors (HF) aspects of the UK ABWR as presented in the RP's Preliminary Safety Report (PSR) on HF (Ref. 1, 1b) and supporting documentation (Refs. 2 - 4).

1.2 Human Factors in Context

5. HF is the scientific study of human physical and psychological capabilities and limitations, and the application of that knowledge to the design of work systems. Within the nuclear context, HF is concerned with the human contribution to nuclear safety during facility design, construction, commissioning, operation, maintenance and decommissioning, including fault and emergency conditions. ONR requires that a systematic analytical approach be applied to understanding the factors that affect human performance / reliability within the context, and a demonstration that the potential for human error to adversely affect nuclear safety is reduced As Low As is Reasonably Practicable (ALARP).

1.3 Methodology

6. My assessment has been undertaken in accordance with the requirements of the Office for Nuclear Regulation (ONR) HOW2 Business Management System (BMS) procedure PI/FWD (Ref. 5). The ONR Safety Assessment Principles (SAPs) (Ref. 6), together with supporting Technical Assessment Guides (TAG) (Ref. 7) have been used as the basis for this assessment.

7. The assessment followed my Step 2 Assessment Plan for Human Factors (Ref 8) prepared in December 2013 and shared with the RP to maximise the efficiency of our subsequent interactions. Although my assessment plan anticipated that the first safety case submission during Step 2 in the area of HF would be the pre-construction safety report (PCSR), following early engagement with ONR, the RP subsequently prepared and submitted a preliminary safety report (PSR) and supporting documentation in sufficient time to enable me to undertake a meaningful assessment during Step 2. The PCSR will be submitted at the end of Step 2 for commencement of assessment in Step 3. Whilst this reflects a minor deviation from my assessment plan, it is consistent with ONR's guidance to RPs (Ref. 9) and is overall beneficial to GDA HF. It facilitates a more structured and logical approach to my overall GDA assessment, provides a

baseline for HF in the UK ABWR and is consistent with the nature of the Step 2 safety case submissions in other topic areas.

2 ASSESSMENT STRATEGY

8. This section presents my strategy for the GDA Step 2 assessment of the HF of the UK ABWR. It also includes the scope of the assessment and the standards and criteria that I have applied.

2.1 Scope of the Step 2 Human Factors Assessment

9. The objective of my GDA Step 2 assessment was to review and judge whether the claims made by the RP related to HF, that underpin the safety and security aspects of the UK ABWR, are complete and reasonable in the light of our current understanding of reactor technology. In addition, my assessment also sought to ensure that the RP has sufficient organisational capability in HF and its integration into a major project.

10. The Human Factors “safety claims” for the UK ABWR are interpreted as high level assertions pertaining to systematic application and achievement of modern HF standards throughout the evolution of the design. The claims need to cover the following aspects:

- Specific human-based safety claims (HBSC) or safety actions that contribute to the support and delivery of nuclear safety functions in all plant states and conditions that are systematically identified, together with statements about the feasibility of such actions. This includes identification of human failure events that may impact nuclear safety and risk.

- Concept of operations, allocation of function (AoF) between human actuations and automated engineered actuations, procedures and personnel competence are appropriate for all modes of operations, including fault and emergency response.

- Workspaces, interfaces, equipment and task design which are compatible with human characteristics and limitations, accounting for all plant states and conditions.

11. During GDA Step 2 I have also evaluated whether the safety claims related to HF are supported by a body of technical documentation sufficient to allow me to proceed with my GDA work beyond Step 2, and / or whether the RP has put in place methodologies and processes defining how HF evidence will be produced during GDA. For HF no “security claims” have been identified at this stage. I will keep this under review with the ONR security inspector as GDA progresses.

12. I have split my overall assessment strategy as described in my Step 2 Assessment Plan (Ref. 8) into three key areas or work streams for assessment of claims. This reflects a minor restructuring in the order of presentation to maximise synergies between certain work streams and has no effect on the technical content. This approach enabled me to concentrate my assessment on the RP’s capability in HF and understanding of UK regulatory expectations, the identification of claims, their reasonableness and any supporting analysis. I judge these to be the most important aspects of GDA Step 2 HF as they are enablers for subsequent GDA steps. This also ensured proportionate targeting of my assessment on the most important safety matters, to deliver appropriate coverage of the HF technical area and probe the RP’s HF capability, processes and procedures. The work streams are:

- HF claims
- HF integration; and
- concept of operations and preliminary AoF.

13. Finally, I have undertaken to following preparatory work for my Step 3 assessment:

- Overview of the RP's proposed PCSR structure and related programme of submissions for HF;
- Identification of regulatory assessment work streams, work scopes for Technical Support Contractors (TSC) and setting-up the process to put required contracts in place;
- Seeking assurance that the RP has sufficient HF specialist capability or processes to acquire this, to commence and deliver the Step 3 programme of work.

2.2 Standards and Criteria

14. The goal of ONR's Step 2 assessment is to reach an independent and informed judgment on the adequacy of a preliminary nuclear safety and security case. For this purpose ONR's assessment is undertaken in line with the requirements of the How2 Business Management System (BMS) document PI/FWD (Ref. 5). Appendix 1 of Ref. 5 sets down the process of assessment; Appendix 2 explains the process associated with sampling of safety case documentation.

15. In addition, the Safety Assessment Principles (SAPs) (Ref. 6) constitute the regulatory principles against which applicants' and duty holders' safety cases are judged. They are the basis for ONR's nuclear safety assessment and have been used for the GDA Step 2 assessment of the UK ABWR. The SAPs 2006 Edition (Revision 1 January 2008) was benchmarked against the IAEA standards (as they existed in 2004) and they are currently being reviewed. In the area of HF no significant changes to the SAPs are expected.

16. 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.

17. The relevant SAPs, standards of the International Atomic Energy Agency (IAEA) and WENRA reference levels are embodied and enlarged on in the Technical Assessment Guides on HF (Ref. 7). These guides provide the principal means for assessing the HF aspects in practice.

2.2.1 Safety Assessment Principles

18. The key SAPs (Ref. 6) applied within my Step 2 assessment are SAPs EHF1 (*Human factors – Integration with design, assessment and management*), EHF2 (*Human factors – Allocation of safety actions*), EHF3 (*Human factors – Identification of actions impacting safety*), EHF4 (*Human factors – Identification of administrative controls*), EHF10 (*Human factors – Human reliability*) and SC. 4 (*Safety cases - Characteristics*) (see also Table 1 for further details). In addition, the following SAPs are judged to be of some relevance to this preliminary safety case assessment stage, particularly in

relation to identification of claims. I have therefore kept their expectations in mind during my assessment: EKP.3 (*Engineering principles: key principles - Defence in depth*), EKP.4 (*Engineering principles: key principles -Safety functions*), EKP 5 (*Engineering principles: key principles -Safety measures*), ERL 3 (*Engineering Principles: safety systems - Engineered safety features*), ESS. 8 (*Engineering principles: safety systems – Automatic initiation),* FA 5 (*Fault analysis: design basis analysis - Initiating faults*), FA 6 (*Fault analysis: design basis analysis - Fault sequences*), FA.9 (*Fault analysis: design basis analysis - Further use of DBA*) and FA.13 (*Fault analysis: PSA – Adequate representation*).

19. It should be noted that not every SAP has been applied to each aspect of my assessment nor has my assessment been undertaken to the same level of detail in all areas. This reflects the targeting and proportionality of the regulatory assessment process. The focus of this assessment has been the application of the HF SAPs.

2.2.2 Technical Assessment Guides

20. The following Technical Assessment Guides have been used as part of this assessment (Ref. 7):

- NS-TAST-GD-058 Rev 2 Human Factors Integration. ONR February 2014
- T/AST/060 Issue 1 Procedure Design and Administrative Controls. ONR December 2011
- NS-TAST-GD-063 Rev 2 Human Reliability Analysis. ONR May 2013
- T/AST/064 Issue 1 Allocation of Function between Human and Engineered Systems. ONR December 2011
- NS-TAST-GD-030 Rev 4. Probabilistic Safety Analysis. ONR June 2013.
- NS-TAST-GD-003 Issue 6 Safety Systems. ONR July 2013.
- NS-TAST-GD-051 Rev 3 Guidance on the Purpose, Scope and Content of Nuclear Safety Cases. ONR July 2013.

21. The UK legislative framework for health and safety also applies the fundamental principle of reducing risk to as low as reasonably practicable (ALARP). This principle is at the forefront of my assessment, and my judgement on using the principles in the SAPs is always subject to consideration of ALARP. Also of relevance to this assessment is guidance contained in the TAG on the demonstration of ALARP, NS-TAST-GD-005.

2.2.3 National and International Standards and Guidance

22. The following national, international standards and guidance have also been used as part of this assessment:

- Relevant IAEA standards (Ref. 10):
  - SSR-2/1: Safety of Nuclear Power Plant: Design Specific Requirements
  - SSG-2: Deterministic safety Analysis for Nuclear Power Plant Specific Safety Guide
  - SSG-3: Development and Application of Level 1 Probabilistic Safety Analysis for Nuclear Power Plant. Specific Safety Guide

- SSG-4: Development and Application of Level 2 Probabilistic Safety Analysis for Nuclear Power Plant. Specific Safety Guide
- NS-G-1.3: Instrumentation and Control Systems Important to safety in Nuclear Power Plants
- NS-G-2.15: Severe Accident Management Programmes for Nuclear Power Plants.

- WENRA references (Ref. 11):

  There are no WENRA Reactor Safety Reference Levels, Waste and Spent Fuel Storage Safety Reference Levels or Decommissioning Safety Reference Levels that explicitly refer to HF. However, HF can be considered to permeate, to one extent or another, throughout the intent of many of these safety reference levels. In particular, ONR considers that HF is essential to support the WENRA reference levels for Training and Authorisation of Nuclear power Plant (NPP) Staff (Issue D), Design Basis Envelope (Issue E), Design Extension Conditions (Issue F), the Safety Analysis Report (Issue N) and the PSA (Issue O).

2.3 Use of Technical Support Contractors

23. During Step 2 I have not engaged Technical Support Contractors (TSCs) to support my assessment. My reason for this was that during Step 2, the RP was at an early stage with regards to its HF safety case submission. In addition, the nature of a preliminary safety case is that it contains broad principles, processes and claims in the area of HF, rather than comprehensive and detailed HF technical analyses that would require significant assessment resource. This Step 2 assessment was therefore manageable within ONR.

2.4 Integration with Other Assessment Topics

24. Early in GDA I recognised that during the project there would be a need to consult with other assessors (including Environment Agency's assessors) as part of my HF assessment process. Similarly, other assessors will seek input from my assessment of the HF for the UK ABWR. I consider these interactions very important to ensure the prevention of assessment gaps and duplications, and key to the success of the project. From the start of the project, I made every effort to identify as many potential interactions as possible between HF and other technical areas, with the understanding that this position would evolve throughout the UK ABWR GDA.

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

- Fault Studies / Design Basis Analysis (DBA): provide input to the identification of human-based safety claims. This formal interaction has commenced during GDA Step 2. This work is being led by the Fault Studies Inspectors.

- Probabilistic Safety Analysis (PSA): provides input to the identification of the human-based safety claims, human failure events and evaluation of their importance to UK ABWR risk. In addition, the HF assessment provides input to the PSA for the human reliability analysis (HRA) components. This formal interaction has commenced during GDA Step 2. This work is a coordinated effort between myself and the PSA inspector.

- Internal and external hazards assessments provide input to the identification of the human-based safety claims aspects of the HF assessment. This formal interaction has commenced during GDA Step 2. This work is being led by myself.

- The HF assessment provides input to and is informed by the assessment of electrical and, control and instrumentation (C & I) aspects of the UK ABWR. This work is jointly coordinated between the HF, electrical and C & I inspectors.

26. In addition to the above, there have been interactions between HF and other technical areas e.g. Reactor Chemistry, Civil and Mechanical engineering, Management of Safety and Quality Assurance, Radioactive Waste and Decommissioning and Mechanical engineering. Although these interactions, which are expected to continue and grow throughout GDA, are mostly of an informal nature, they are essential to ensure consistency across the technical assessment areas and ensure that all safety important HF claims are identified and proportionately substantiated.

3 REQUESTING PARTY'S SAFETY CASE

27. This section presents a summary of the RP's preliminary safety case in the area of HF, with focus on claims relating to my three assessment workstreams. It also identifies the documents submitted by the RP which have formed the basis of my assessment. The RP submitted additional HF safety case documentation towards the end of Step 2, which provide more detailed assessments and arguments. In order to keep my assessment timely, the scope primarily focussed on the claims and consistent with other technical areas, these additional submissions have not formed an explicit part of my assessment. I will consider these in detail during Step 3 as part of my assessment of the PCSR.

3.1 Summary of the RP's Preliminary Safety Case in the Area of Human Factors

28. The RP has produced a Preliminary Safety Report (PSR) for HF, a HF Integration Plan (HFIP) and supporting early safety case documentation. The PSR is based primarily on the Japanese ABWR (J-ABWR) design and existing safety case, on which the UK ABWR is based. It also acknowledges latest developments for the UK ABWR. HF will be further developed throughout GDA to fully reflect the UK ABWR design, regulatory requirements and expectations. The mechanisms for achieving this are reflected in the HFIP.

29. The main HF aspects covered by the preliminary safety case (Ref. 1) can be broadly summarised as follows:

- Human Factors Claims: Safety claims for the HF aspects of the UK ABWR are presented in a hierarchical manner reflecting the breadth or level of detail of their nature i.e. broad system design claims to specific human-based safety actions. High-level HF claims state that the UK ABWR will be designed in accordance with HF modern standards and principles, particularly the design of the working environment, equipment and interfaces relating to tasks critical to nuclear safety. There is widespread consideration of HF and human error in the evolution from the earlier boiling water reactors (BWR) to the ABWR. This includes design and operational improvements making use of empirical observations from operational experience, reducing opportunities for human error by adoption of positive features and design elements and elimination of less successful features and design elements.

30. Subordinate to the high-level claims are specific human based safety claims (HBSC) that reflect operator safety actions and Type A, B and C* human failure events (HFE). These have been predominantly derived from the J-ABWR PSA, supplemented by latest developments in the UK ABWR safety case and design variations. The PSR also notes that several claims on operator action may be removed or re-allocated to automated engineered functions for the UK ABWR, to meet improved safety and different regulatory requirements. The HBSCs will be developed, augmented as appropriate, and sufficiently substantiated through the course of the UK ABWR GDA.

- Human Factors Integration (HFI): The UK ABWR will have a comprehensive and appropriately designed programme of HF integration (HFI), including activities for the substantiation of HBSC and ensuring that risks related to human error are identified and reduced to ALARP. In support of this claim the RP has produced a HFI plan (HFIP) that provides an organising framework for systematic and holistic application of HF for the UK ABWR. The HFIP describes the RP's HF organisation, HFI management and quality assurance (QA) arrangements, HF work breakdown structure describing the HF activities (work packages) planned throughout GDA and the standards, codes and guidance on which the UK ABWR HF aspects will be based. It also presents the RP's approach to the management and resolution of HF issues and assumptions.

- Allocation of Function (AoF) and Concept of Operations: Automation has been the general concept of operations for the ABWR. AoF has been influenced by evolution of the ABWR design, HF considerations and advances in digital technology. The design is optimised such that the risk of human error is reduced through appropriate levels of automation; the primary means of delivering safety functions and fault response being automatically initiated engineered systems. Operator workload has been optimised for each reactor operational mode, including during fault scenarios and accidents. This is achieved through carefully selected "breakpoints" requiring operator attention ("acknowledgment") between automated sequences. No safety-related protection, cooling or control rod movement system is lost in automation failure.

  To ensure the operator retains adequate situational awareness, key "supervisory" actions are required for confirmation of successful implementation of automated sequences, with clear indication of plant status provided at all times and facilitation of manual intervention when required. The staffing concept and command and control philosophy for normal operations, fault and emergency conditions will be similar to that for existing UK NPP. Procedures, personnel competence and training will satisfy relevant modern standards.

31. The automation strategy and AoF is expected to remain largely unchanged between the J-ABWR and UK ABWR. However, the RP acknowledges that AoF is an iterative process between the emerging design and safety analysis, hence will continue its functional analysis during GDA Step 3. Some aspects of the concept of operations will also be different for the UK ABWR and will likely create different design requirements (e.g. changes to achieve diversity in safety functions, operational and user differences between the UK and Japan). These matters and the concept of operations for other plant conditions, such as shut-down states (i.e. outages) and for non-reactor plant (i.e. fuel route and radwaste treatment system) will also be developed in early Step 3.

* *Type A HFEs are those pre-accident human errors that cause equipment to be unavailable when required post fault, e.g. mis-alignments and mis-calibrations. Type B HFEs are those human actions that either by themselves or in combination with equipment failures lead to initiating events. Type C HFEs are those human actions occurring post-fault; these can be errors that occur while performing safety actions or they can be actions that aggravate fault sequences.*

32. In support of the claims, a baseline HF assessment (Ref. 4) produced by the RP concludes that there is an abundance of fully-integrated consideration of HF within the current design processes at Hitachi-GE and within the J-ABWR reference design on which the UK ABWR is based. This HF integration extends to all stages of the ABWR plant lifecycle.

3.2 Basis of Assessment: RP's Documentation

33. The RP's documentation that has formed the basis for my GDA Step 2 assessment of the safety claims related to the HF for the UK ABWR is:

- UK ABWR 'Preliminary Safety Report on Human Factors' (Ref. 1). Describes the existing UK ABWR design, HF nuclear safety claims, integration of HF and the HF principles, standards and criteria that will be used for the UK ABWR design to demonstrate risks will be reduced to ALARP.
- UK ABWR 'Human Factors Integration Plan (HFIP)' (Ref. 2). This document describes how the RP is planning and managing the integration of HF into the development of the UK ABWR for the UK GDA project.
- UK ABWR 'HF Methodology Plan (Ref. 3). This document presents a general overview and description of the HF methodologies to be used for each activity within the HFI programme.
- UK ABWR 'Baseline Human Factors Assessment Report' (Ref. 4). This presents the RP's processes and assessment that was used to capture the nature and outcomes of the inclusion of HF in the existing J-ABWR design.
- UK ABWR 'Level 1 PSA Topic Report Chapter 7 Human Reliability Analysis' (Ref. 12). This document describes the HRA strategy / methodology for the UK ABWR PSA in GDA.
- UK ABWR GDA tracking sheet (Ref. 13).
- Responses to Regulatory Queries (RQ) RQ-ABWR-0052, 0053, 0167, 0169, 0170 and 0171 (Refs. 14). Other RQs have also been raised and adequate responses to these furnished by the RP. These refer to lesser clarifications of the HF safety case, approach and methods, hence are not explicitly discussed in this report.
- Resolution plan to respond to Regulatory Observation (RO) RO-ABWR-0005 "Hitachi-GE Nuclear Energy Ltd. Human Factors Specialist Resource and Organisation" (Ref. 15).

34. In addition, at the end of May 2014 the RP submitted to ONR for information an advance copy of the UK ABWR Pre-Construction Safety Report (PCSR). Chapters 18 and 23 (Ref. 16) address HF. Although I have not covered the PCSR chapters in my GDA Step 2 formal assessment, my initial opinion is that they appear to fall short of ONR's expectations for a PCSR and what is set out in the GDA Guidance to RPs (Ref. 9). The draft PCSR chapters do not present sufficient arguments or how they will be structured, to provide a coherent and substantiated link between the HF claims and evidence. My expectation is that the PCSR, as a minimum, needs to provides a summary of the HF arguments, albeit in textual style, explaining how the HF evidence for the UK ABWR is / will be logically combined to substantiate the claims. The draft PCSR chapters will require improvement to form an adequate basis for my Step 3 assessment. I have communicated this matter to the RP.

4 ONR ASSESSMENT

35. My HF assessment has been carried out in accordance with ONR HOW2 BMS document PI/FWD, "Purpose and Scope of Permissioning" (Ref. 5). It has followed the strategy described in Section 2 of this report.

36. My Step 2 assessment work has involved regular engagement with the RP's HF Subject Matter Experts (SME). Two technical exchange workshops (one in Japan and one in the UK), and a number of technical meetings have been held; these were undertaken for several reasons:

- Securing regulatory confidence in the RP's understanding of UK regulatory requirements and expectations for modern standards HF safety cases.
- Informing them of my assessment progress and emerging findings.
- Providing the opportunity to inform me of their ongoing design and HF analysis work (particularly in response to my RQs and ROs).
- Forming a judgement on the RP's capability in HF.

37. During my GDA Step 2 assessment, I identified some shortfalls in the RP's safety case documentation which have generally led to the issue of RQs; overall I have raised 29 RQs (Ref. 14). These provided a means for me to formally seek clarification or further information from the RP. Significant shortfalls or omissions in the safety case or the RP's ability to produce an adequate safety case for the UK ABWR generally lead to the issue of ROs. ROs enable ONR to bring significant assessment findings to the notice of the RP. I have raised one RO during GDA Step 2 (Ref. 15). The RQs and RO, along with this report, capture the 'regulatory footprint' of my HF assessment at this stage of GDA. Some of my RQs relate to detailed matters regarding HRA, which I issued towards the end of Step 2 in order that the RP can consider these in a timely manner in preparation for more detailed assessment in Step 3. Details of the scope and purpose of RQs and ROs are provided in "GDA Interface Arrangements with Requesting Parties" (Ref. 17).

38. Details of my GDA Step 2 assessment of the UK ABWR preliminary safety case in the area of HF, including areas of strength that I have identified, items that require follow-up and the conclusions reached are presented in the following sub-sections.

4.1 Human Factors Assessment

39. Generally, based on my assessment of the PSR and supporting documentation submitted by the RP, I am satisfied that these meet my expectations for the structure of a preliminary safety case interpreted to reflect HF. The scope and depth is commensurate with the GDA Guidance to Requesting Parties (Ref. 9) for applicants, and TAGs NS-TAST-GD-051 and NS-TAST-GD-053 (Ref. 7).

4.1.1 Assessment: Human Factors Claims

40. The RP claims that there is widespread consideration of HF in the evolution from BWR to ABWR. In support of this, a baseline HF assessment (Ref. 4) was produced by the RP to provide a demonstration that the reference design for the UK ABWR incorporates significant HF considerations. This assessment provides a supporting reference regarding the baseline level of HF in the J-ABWR for inclusion in the UK ABWR safety case. In addition, the assessment was used to inform the UK ABWR HFI programme. The findings and conclusions of the baseline HF assessment are clearly

an important component of the RP's preliminary safety case. I therefore consider them to be claims, albeit implicit and subordinate to the main HF claims in the PSR.

41. The RP's baseline assessment concludes that there is abundant and well-integrated consideration of HF within the processes at Hitachi-GE and within the J-ABWR design on which the UK ABWR is based. It also claims that the baseline ABWR design is such that it can be expected to fully support successful task performance for the list of HBSC from the J-ABWR. This consideration of HF extends to all stages of the ABWR plant lifecycle and exists throughout the entirety of the design.

42. From own my review of the baseline assessment, I am satisfied that a wide-scoping HF review was carried out. This should contribute to the RP's foundation of HF evidence that can be used and built upon through further HF analysis and validation for the UK ABWR. Differences in UK regulatory expectations, modern HF practices and standards were considered by the RP as part of the baseline assessment and used to inform development of the HFI programme for the UK ABWR. I acknowledge this as a good practice step to assist in deriving HFI requirements for the UK ABWR.

43. My judgement on what is provided in the RP's baseline HF assessment is that it reflects arguments for HF adequacy, rather than a specific evidence base. Historically, the RP's approach to the inclusion of HF in the ABWR appears to have been primarily through application of standards-in-design. This offers an alternative approach to HFI, where aspects of HF good practice have been encapsulated within their various design standards and specification documents. I have not seen any evidence of systematic task-analytical processes (*SAP EHF. 5*, Ref. 6) for identifying the factors that influence HBSC and for determining the specific level of HF attention provided to any part of the plant, task and equipment design. This does not mean that what the RP is claiming is invalid, or that adequate HF evidence does not exist; simply that such claims of general HF adequacy will need to be further validated for the UK ABWR through detailed analyses conducted by HF specialists during GDA Steps 3 and 4. This is also necessary to substantiate HBSC and their reliability in both normal operations and dynamic situations to demonstrate the ability of operators to assure plant control and a safe state under such conditions.

44. In addition, many aspects of the plant lifecycle that are required within the scope of the UK ABWR safety case (e.g. decommissioning, consideration of mis-diagnosis, spent fuel pond, radioactive waste management, severe accident response) are not included in the J-ABWR (*RQ-UK ABWR-0171 PSR on Human Factors – Plant Lifecycle HF*, Ref. 14). These are additional areas that need to be considered and analysed from a HF perspective during Step 3.

45. The UK regulatory expectations and modern standards approach to HF are clearly set out in the preface to the HF section of ONR SAPs (Ref. 6), which expect that "*a systematic approach to understanding the factors that affect human performance, and minimising the potential for human error to contribute to faults, should be applied throughout the entire facility lifecycle. Assessments of the way in which individual, team and organisational performance can impact upon nuclear safety should influence the design of the plant, equipment and administrative control systems. The allocation of safety actions to human or engineered components should take account of their differing capabilities and limitations. The assessment should demonstrate that interactions between human and engineered components are fully understood and that human actions that might impact upon nuclear safety are clearly identified and adequately supported*". SAP EHF 5 then goes on to require that "*analysis should be carried out of tasks important to safety to determine demands on personnel in terms of perception, decision-making and action"*. This is supplemented by the SAPs

expectation that such analysis will include consideration of physical, psychological and cognitive factors that could impact on human performance.

46. HF for the J-ABWR was traditionally managed by the RP's electrical and control and instrumentation engineers. These specialists are, generally, not HF specialists and I am concerned that they are not fully conversant in modern HF standards and techniques, or be able to fully identify and understand the physical, cognitive and environmental factors that may impact human performance during NPP operations. Nonetheless the main interfaces and workspaces of the J-ABWR main control room and other human-machine interface system (HMIS) areas have been designed using modern standards; this gives me some confidence that a number of aspects are likely to be compatible with human characteristics through meeting good ergonomic practice.

47. The RP's traditional approach to HF integration, being based on applying standards–in-design through its engineering processes, falls short of UK regulatory expectations for HF. Whilst I accept that applying HF standards is necessary and will address factors that influence human performance, this generally provides HF adequacy for normal operations and from a usability perspective but is unlikely to be true in all cases. For example, with safety significant human actions, particularly in faulted states / accident conditions, the demonstration of safety and human reliability is often more complex, and the circumstances are not always fully within the scope of HF standards. Additional measures are usually required to reduce the risk from human failures in these contexts and to substantiate HBSC. The risks associated with the RP's traditional approach to HF include mis-interpretation of standards, failure to recognise factors that influence human performance, HF trade-offs unidentified and important HF design provisions being overlooked.

48. I have communicated my findings on these matters to the RP through the RQs I raised. The RP has acknowledged that more structured, systematic and focussed HF analysis work is required for the UK ABWR and this is reflected in its HFI programme.

4.1.1.1 Human Based Safety Claims (HBSC)

49. In addition to the general HF claims, the RP presented a preliminary listing of specific HBSC in the PSR. Initially I judged that this was insufficient for the purposes of GDA Step 2 to enable me to form a regulatory judgement on the reasonableness of the claims or otherwise. I held a number of regulatory interactions with the RP and issued an RQ (Ref. 14) requesting that they addressed this shortfall. My main concern was that the list of HBSC as originally presented in the RP's initial PSR submission did not reflect the latest UK ABWR design and safety case scope, being based on the J-ABWR PSA. Hence it did not provide sufficient indication of the likely human contribution to the safety of the UK ABWR. Other important information that I expected to see was the likely context and conditions in which the HBSC are required, how many times a particular claim is made and for how many faults.

50. In response, the RP developed and presented the HF claims in a more coherent, comprehensive and contextual manner within the PSR (Ref. 1). Whilst the specific HBSC are still largely based on the J-ABWR PSA, they have been supplemented with a systematic review of HF claims emerging from other UK ABWR GDA areas such as fault studies, radioactive waste, fuel route / spent fuel pond and early severe accident considerations. The identification of HBSC has considered preliminary knowledge of UK ABWR pre-initiator human actions / failures, initiator, post-fault / recovery and some accident management actions. I am now satisfied that the RP has developed and employed a systematic approach to identifying the HBSC for the UK ABWR, as far as it is reasonably practicable to do so during this early stage of GDA. I am content that this approach is suitable to enable refinement of HBSC through Step 3.

51. In support of my assessment of the HBSC, I drew up my own tentative listing of potential HBSC for the UK ABWR. This was based on my review of the J-ABWR PSA, early deterministic safety analysis (DSA) and fault schedule submissions from the RP. This was supplemented with information contained in various presentations and discussions held with the RP throughout Step 2 on a number of safety case topic areas. I also informed my listing from discussions with the ONR fault studies, electrical, C &I, internal hazards and PSA inspectors. This approach provided an independent structure against which I could assess the RP's identification of HBSC, the comparison of two independent structures being more powerful at revealing significant omissions than checking a single structure. From this assessment, I am satisfied that the claims independently identified by myself and by the RP at this stage broadly align, noting that the extent and nature of HBSC is expected to change as the UK ABWR safety case matures. The RP makes it clear in the PSR that further human error analysis and identification of HBSC are planned for the UK ABWR. I am satisfied that the HFIP includes specific work packages for delivering this.

52. Notwithstanding the points above regarding high level claims, what the RP has provided in the area of HF claims gives me initial confidence that the HFI programme is being implemented and a systematic approach to HF analysis is being employed for the UK ABWR. Overall, I judge the preliminary identification of HBSC for the UK ABWR to be typical of existing NPP operator safety actions and associated HFEs. It appears that the majority of HBSC are for reactor shutdown states, fuel route, radioactive waste management, spent fuel pond cooling, post-fault responses and severe accident management. I note that some HBSC may also be required to provide additional diversity for safety function actuations. However, this is still undecided by the RP.

53. The number of HBSC qualitatively suggests a potentially high human contribution to the overall safety of the UK ABWR. Although, I acknowledge that some may be re-allocated to engineered / automated functions to meet UK regulatory expectations for safety systems. In addition, the contribution to risk from any specific HBSC may turn out to be low, as many are only likely to be required following failure of diverse automatically initiated engineered safety systems or where long grace times exist. However, this needs to be verified and I note that further HBSC are likely to emerge once information pertaining to the function and operation of the UK ABWR back-up building is defined, external and internal hazards analysis and severe accident analysis (SAA) are developed. At the end of Step 2 I have no knowledge of the human contribution to the overall risk due to the absence of a full scope UK ABWR PSA (and supporting analyses).

54. During Steps 3 and 4, I will expect the human contribution to risk to be explicitly analysed by the RP, and a robust substantiation provided that all reasonably practicable measures have been taken to reduce reliance on human action to maintain safety and minimise HFEs to ALARP. Modern reactors should have less reliance on human action to deliver safety than the existing fleet of UK reactors. I will assess this along with the completeness and adequacy of the RP's identification and substantiation of HBSC, and for consistency with other aspects of the developing UK ABWR design and safety case. The absence of a PSA also presents a significant project risk to overall completion of my GDA HF assessment within expected GDA timelines, as HF has an intrinsic dependency on this in terms of the identification and understanding of the risk-significance of operator actions.

55. At this stage, I have not identified any claims that I judge to be unachievable or unreasonable from a HF perspective, such that they would likely result in fundamental system and plant design changes for the UK ABWR. However, their subsequent detailed analysis might show HFEs to be non-trivial contributions to plant risk; hence

some design changes / re-allocation of function may be required to reduce reliance of the UK ABWR safety on HBSC and to demonstrate that the design is an ALARP solution.

4.1.2 Assessment: Human Factors Integration

56. The focus of this work stream is on claims relating to the general processes and mechanisms put in place to deliver high quality HF input to the UK ABWR design and safety case. This is particularly important in light of ONR's sampling and targeted approach to assessment. As my assessment will not scrutinise in detail the entirety of the RP's safety case submission, this work stream aims to provide me with a level of confidence that the HF analyses I have not assessed, will be of a suitable quality to inform the design and safety submission, and ultimately to support reliable human intervention. It is also aimed at giving me confidence that the RP has and can sustain adequate HF specialist capability to deliver its HFI programme.

57. The principal criterion for this aspect of my assessment in this area was SAP EHF. 1 (Ref. 6): "*A systematic approach to integrating human factors within the design, assessment and management of systems should be applied throughout the entire facility lifecycle*". Further to this the other HF SAPs (EHF.2 – EHF.10) (Ref. 6) represent the totality of necessary HF consideration during the design, development and operation of a nuclear plant. I also used TAG NS-TAST-GD-058 – *Human Factors Integration* (Ref. 7) during my assessment. Other standards and guides I have consulted are provided in References 18 to 20.

58. My assessment in this area has covered the following components: (1) the RP's practice and processes for HFI, (2) HF standards (3) HFI organisation and (4) implementation of HF. In addition, I also report on some HRA assessment matters as these relate to practice and processes.

4.1.2.1 RP's HFI Practice and Processes

59. HFI in the UK is typically driven via a HF Integration Plan (HFIP) and a suite of HF safety management processes. I judge the RP's HFIP to adequately cover how HF is and will continue to be implemented to meet modern standards expectations throughout the UK ABWR GDA. Confidence in this judgement comes from the fact that the HFIP is consistent with the good practice expectations set out in ONR's guidance TAG NS-TAST-GD-058. I consider the HFIP to provide a reasonable organising framework that should help the RP to ensure all relevant HF issues will be identified and addressed in-step with other aspects of the developing UK ABWR design and safety case. The HF safety case submissions to date have been consistent with the HFI programme.

60. The HFI processes cover the aspects and activities that I would expect to see and provide reasonable arrangements for their implementation. The processes cover HF requirements, assumptions and issues capture, HF assessment and management and quality assurance, stakeholder identification and management and HFI programme progress monitoring and reporting arrangements. The RP has incorporated these processes into its project management arrangements and intends to manage HFI as a 'live' process. This will be evidenced through periodic review and updates of the HFIP and HF 'issues and assumptions' registers developed by the RP. These will provide a continual evidence base against which I can examine HFI management and implementation, particularly as GDA becomes more involved through Steps 3 and 4. The HF registers will also be used as part of the handover from the RP to the site licensee to ensure that the basis for the UK ABWR HF analyses, assumptions and any unresolved issues are understood, and can be addressed and validated post GDA. I

consider these processes to reflect good practice and I will sample the effectiveness of implementation and the HF outcomes throughout Steps 3 and 4.

4.1.2.2 RP Standards and Guidance

61. I undertook a high-level assessment of the HF standards and guidance reported in the PSR on which the UK ABWR HF will be based. Of relevance to this assessment is RQ-UK-ABWR 0170 (Ref. 14) and the guidance in the TAG on the demonstration of ALARP, NS-TAST-GD-005 (Ref. 7), which states amongst other matters, that "*the good practice or standard should be up-to-date, taking account of the current state-of-the-art; any practice or standard more than a few years old, or not subject to active on-going monitoring and review or not written by acknowledged experts may be suspect*."

62. I believe the RP has provided a comprehensive listing of relevant and current HF and HF-related modern standards and guides. The standards identified are mainly International Electrotechnical Commission (IEC), British Standards European Norm International Standards Organisation (BS EN ISO) and British Standards European Norm (BS EN), along with additional guidance and standards identified from the IAEA Safety Standards Series, US Nuclear Regulatory Commission (USNRC), Engineering Equipment and Materials Users Association (EEMUA) and UK MoD Defence Standards (DEF STAN). These standards and guides are produced and published by recognised international and national technical and safety bodies, committees, agencies and regulatory authorities. Hence, I consider that this meets the expectation of TAG NS-TAST-GD-005 quoted above. At this stage I have no reason to believe that the standards are inappropriate, or will be inadequately applied, if the HFI activities are performed as planned and to quality.

63. The RP has appropriately acknowledged that not all, or the entire contents of the standards will apply to every aspect of the UK ABWR and they have confirmed that the relevance of standards / aspects of them will be assessed and justified for both general and specific HF applications and design requirements. This will be based on the outcomes of the HFI activities and tasks analyses. I am satisfied that this process also includes assessment of any potential conflicts between standards, and determination of the most appropriate option if similar standards offer more than one design solution. I judge this to be a reasonable approach to the selection, application and use of particular HF standards for the UK ABWR. It should ensure HF issues identified from the various analysis activities will be appropriately addressed, or additional measures identified, wherever the scope of standards is shown to be insufficient for a particular application. The specific selection and use of HF standards for the design and safety case application they are chosen for will be an integral part of my Step 3 assessment.

64. I have informed the RP of the UK regulatory expectation that for a new design, conformance with current good practice and standards alone is the starting point for demonstrating that risks have been reduced to ALARP. Other potential options should also be considered to determine whether further risk reduction measures are reasonably practicable. I will seek evidence of this during Steps 3 and 4.

4.1.2.3 RP's Organisation for HFI

65. At the start of GDA Step 2, a key focus of my assessment was to ensure that the RP has a sufficient and capable HF organisation, with an understanding of UK regulatory requirements to deliver GDA and the authority to influence design decisions.

66. During the early phase of Step 2 the RP's HF was being managed as part of its electrical, control and instrumentation department. No HF specialists were appointed as subject matter experts (SMEs). I considered this and the level of HF resource

allocated to GDA to be insufficient to deliver the required quantity and quality of the GDA activities and outcomes on HF. I also judged this matter to present a significant project risk for the RP delivering a successful GDA safety case. I therefore raised an RO, RO-UKABWR-005 "*Hitachi-GE Nuclear Energy Ltd. Human Factors Specialist Resource and Organisation*" (Ref. 15), to ensure the RP develops and acquires adequate HF specialist capability and organisation to meet ONR regulatory expectations.

67. The RP responded positively to this RO and has already addressed some of the actions and partially completed others. I believe that the RP's resolution plan to the RO shows an acknowledgement of the importance of HF for the UK ABWR, and willingness and commitment to ensure HF is thoroughly considered and resourced. I recognise that there has been a significant RP organisational commitment and change to re-position the manner in which it deals with HF. Most notably, is the appointment of a suitably qualified SME to lead the HF activities and team, and the formation of a dedicated HF team within the RP's nuclear engineering organisation. This team has clear links to other departments, formal authority and accountability to determine the extent of HF input to the UK ABWR design and safety case.

68. The RP's organisational capability in the area of HF is described in detail Section 3 of its HFIP. As GDA progresses the extent of HF effort required to support the HFI programme will increase. I am satisfied that the RP has developed a suitable HF resource plan to facilitate this that is linked to the HFIP.

69. QA of the HFI programme follows the broader QA processes for the UK ABWR. The RP's QA department is responsible for planning and approving HF verification and validation activities. To achieve this, independent HF specialists have been appointed within the Assurance Function QA Team. Robust and independent QA and peer review is a key aspect of any safety case development process to give assurance that nuclear risks are identified and managed. I will therefore sample the adequacy and independence of this process for the Step 3 and 4 safety case submissions during Steps 3 and 4. I am satisfied that the Step 2 safety case documents have been adequately quality checked and reviewed.

70. At of this stage of GDA, I am satisfied that the RP has a capable and competent HF organisation. From sight of the early drafts of HF safety case documentation through to the formal Step 2 submissions, I judge the quality of the HF safety case to have considerably improved, reflecting the RP's re-organisation and appointment of HF specialist resources. I am also confident, based on the RO Resolution Plan that this will continue to be managed to meet the continuing work demands of GDA.

4.1.2.4 RP's Implementation of HFI

71. This aspect of my assessment sought high level evidence (as appropriate at Step 2) that the RP has identified necessary and appropriate HF activities (work packages) to produce a modern standards HF safety case for GDA.

72. I consider that the HFIP provides an adequate description of the HF activities required during the UK ABWR GDA and that these reflect modern standards expectations. The activities are specified in detailed work package specifications that specify. The necessary inputs, outputs, dependencies, resources etc. The HFI work packages will be augmented as appropriate and further detail added as GDA progresses. I am satisfied with this approach as it reflects 'live' HFI management, and the work packages already provide indicative HF activities for the later stages which appear reasonable. I have identified some inconsistencies amongst the proposed timings of the HFI work packages. However, given that the RP has linked the HFI schedule of

activities with the overall project programme schedule, this should enable the timing of activities and deliverables to be reviewed and optimised as GDA progresses.

73. The RP correctly acknowledges in the PSR the importance of clearly defining and justifying the HF methodologies to be used for each activity within the HFI programme. To ensure that consistent and suitable HF approaches and methods are employed, the RP has produced a UK ABWR HF Methodology Plan (Ref. 3). This sets out the general methods to be applied and gives a rationale for selection of a particular HF analysis method / tool in terms of its suitability for a HF work package. I have conducted a general overview of this document and I am satisfied that the HF methods being used / proposed for use, are appropriate and reflect typical modern HF practices. They cover screening analysis, human error identification, analysis and quantification, AoF analysis and various task analyses for substantiation of HBSC and to inform HRA quantification. I have no concerns over the proposed HF methods at this stage. During Steps 3 and 4, I will assess the RPs justification for a particular choice of HF method as applied to a specific or general aspect of HF substantiation in the context of the tasks / scenarios being analysed.

74. Overall, I am content at the end of GDA Step 2 that the RP has developed and is implementing a modern standards approach to HFI for the UK ABWR.

4.1.2.5 Human Reliability Analysis (HRA)

75. Claims related to human reliability are an integral part of the PSA and are used to inform the specification of design provisions and to demonstrate a balanced design in terms of allocation of protection. Any inadequacies in the analyses or optimism in assessed levels of human reliability may imply a higher level of safety than is likely to be the case in accident conditions. In turn, this may result in design features necessary to eliminate or minimise human error or support HBSC being omitted. Therefore as part of my Step 2 assessment, I considered it was important to review the RP's approach and methods for HRA. My regulatory expectations for the treatment of HRA are cited principally in TAG NS-TAST-GD-063 (Ref. 7). I also used the IAEA Safety Standards Series SSG-3 (Ref. 10) as part of my initial HRA assessment benchmark.

76. I raised RQs (Ref. 14) seeking clarification of the RP's proposed methods and approach for HRA, in order to gain confidence that modern standards and UK regulatory expectations will be met. Overall, I am satisfied with the technical content of the RP's responses to these and the assurances they provide. I consider two of the RQs to be of particular importance for the development of the UK ABWR safety case / PSA, to minimise potential for optimism in the risk assessment. These are discussed further below.

77. I note that the RP intends to use the Technique for Human Error Rate Prediction (THERP) (Ref. 21) for the UK ABWR HRA in level 1 PSA. I have no concerns regarding the use of THERP in this manner as it was effectively designed for L1 PSA purposes. IAEA SSG-3 identifies that the state of the art in the HRA area is still evolving, and as such the classical static representation of human behaviour in Level 1 PSA can still be considered good practice. THERP has also been widely applied and generally accepted for use in UK NPP quantitative risk assessment. However, THERP was first published in 1982; the era of second generation NPP consisting of hard-wired control and instrumentation. The THERP manual (Ref. 21) explicitly highlights that "*the handbook does not provide estimated HEPs related to the use of new display and control technology that is computer based*". The level of automation, computerised control and instrumentation interfaces on the UK ABWR call into question the applicability of THERP human error probability (HEP) data for use in modern NPP HRA / PSA in this context.

78. The RP therefore needs to consider the applicability of extant HRA methods to the UK ABWR HRA and note my regulatory expectations regarding this as cited in SAP EHF.10 (paragraph 390: *"The selection and application of probability data for human errors should be…….justified and its relevance for the task and context demonstrated"*). RQ-ABWR-0052 (Ref. 14) reflects this concern regarding use of extant HRA techniques (e.g. THERP) to predict HEPs associated with human interaction with computerised (advanced) interfaces; this is because HEP data supporting most HRA techniques pre-date modern computerised interfaces.

79. ONR has previously commissioned research into (derived) HEP data from contemporary literature (Ref. 22). The provisional conclusion of this research is that THERP HEP estimates for reading displays and for control and display selection, if applied to human-computer-interaction (HCI), are likely to provide optimistic estimates of human reliability by up to two orders of magnitude. I consider this, along with THERP's own warning, to be sufficient cause for concern to warrant a more prudent approach in this area.

80. My expectation is that the RP should reference and use human performance data associated with use of such interfaces to inform the HRA. Alternatively, a more contemporary technique should be used, or subset of scenarios quantified using another technique to determine sensitivity to this issue. In response to the RQ, the RP is researching available data sets to make an assessment of the most appropriate and correctly representative data to use for the UK ABWR HCI human error quantification. If suitable data cannot be found, the RP has stated that conservative HEP data will be used and justified for the operational context being assessed, and the conservatism clearly demonstrated. I will expect this to be accompanied by sufficient sensitivity analyses to properly understand the risk impact / implications of the use of any conservatism. I judge this commitment and approach to addressing this important HRA matter to be reasonably practicable in light of current knowledge and evidence at this stage of GDA. The RP's justification for the applicability of HRA methods used for the UK ABWR HRA / PSA will be an important element of my Step 3 (and 4) assessment.

81. RQ-UKABWR-0053 (Ref. 14) relates to the assessment and modelling of cognitive errors such as mis-diagnosis. THERP makes use of time response curves (which have been invalidated on a number of occasions), and predicts HEPs for diagnostic failure in a given time rather than mis-diagnosis i.e. is technically for error of omission rather than commission. In addition, research conducted by ONR during the previous GDA project (Ref. 22), concluded that no data exists to suggest that cognitive performance can reach the human performance limiting values suggested in THERP. ONR found that the estimated range for cognitive performance suggested by HEPs reported in the available literature on this topic is considerably more conservative than those offered by THERP. Even with automated HCI based task support, cognitively intensive decision-making tasks can be unreliable. My expectation is that a modern standards safety case and PSA should explicitly identify and model diagnosis and decision errors, underpinned by appropriate task analyses. This is also important in order to evaluate whether a particular fault sequence can be exacerbated or different fault trajectories created.

82. The RP has responded proactively to this RQ, recognising that explicit modelling of such human failure events within the J-ABWR safety case has not been done but has committed to addressing this for the UK ABWR GDA. This will employ task analysis and more appropriate HRA quantification method.

83. As noted in section 2.2, I have also raised more detailed RQs on HRA to ensure that modern standards expectations are met, for which I require responses from the RP at the commencement of Step 3. These RQs cover aspects such as HRA in Level 2 PSA,

identification and assessment of Type B HFE, use of simulator and plant exercise observations and operational input to inform the HRA, assurance of the comprehensiveness of HRA, treatment of dependency, the RP's policy for use of limiting values for individual errors and cut-sets, consideration and justification of maintenance and calibration errors and assessment of the overall human reliability contribution to UK ABWR risk.

4.1.3 Assessment: Allocation of Function and Concept of Operations

84. The UK ABWR applies advanced computerised technology extensively, particularly in the Main Control Room (MCR) and generally to a greater extent than for current UK NPPs. The UK ABWR is an evolutionary ABWR design based on the recent Japanese series of ABWR plants. The fact that the UK ABWR stems from 'proven' plant gives me some confidence at this stage, without detailed assessment, that function allocation and the human machine interface system (HMIS) have been adequately designed from a HF perspective.

85. Where processes are automated I have sought to gain initial confidence that the operator can maintain an appropriate level of situational awareness, which is particularly important should automated systems fail and require restorative operator input. In addition, an appropriate AoF should not result in an unacceptably high or low workload.

86. The principal criterion for my assessment is SAP EHF.2: "*when designing systems, the allocation of safety actions between human and technology should be substantiated and dependence upon human action to maintain a safe state should be minimised*." I also considered SAPs ERL 3 (*Engineering Principles: safety systems - Engineered safety features*) and ESS.8 (*Engineering Principles: safety systems - Automatic initiation*).

87. My initial assessment for this component focussed on identifying claims and exploring the AoF methodology. My assessment of the AoF is constrained to a high level review due to limited availability of analytical and design information. This is not unusual for early designs. Detailed assessment of AoF and the concept of operations, including the RP's demonstration of consistency between these, will form a key component of my Step 3 assessment. My expectation during the early design stage is that the RP provides sufficient information to show that its philosophy for AoF is based upon the operational concept, sound design, HF principles and processes, incorporating relevant insights from operating experience. Based on what has been reported in the PSR and supporting references (Refs. 1/1b, 4 and 23), I am satisfied that the RP has met this expectation.

88. To inform my assessment and judgement, I used available documentation describing RP's AoF process and the initial results of this process as reported in the PSR and Ref. 4. As well as examining this preliminary safety case documentation, the AoF and automation strategy was discussed with relevant SMEs during a workshop held in Japan.

89. The primary means of delivering safety functions on the UK ABWR is through automatically initiated engineered safety systems. High level of automation has been the general concept of operations for the ABWR design. However, there are a number of HF issues related to the use of automation and computerised technology. Whilst automation has the potential to significantly enhance human performance, such technology also has the potential to degrade human performance, e.g. due to loss of situational awareness, automation commission-error, automation-induced dependency and erosion of operator competence. It is therefore important to ensure that increased

use of automatic control is appropriate and does not introduce such new issues. Reduced reliance on operator actuation of safety systems on the UK ABWR also has the potential to shift reliance on human action and vulnerability to human error, related to maintenance of equipment (including the potential importance of software instrumentation maintenance to safe plant operation, calibration, testing and surveillance). I have raised these concerns with the RP and I expect to see detailed substantiation of the automation strategy, AoF and HCI for the UK ABWR. Consequently, this will be an important consideration for my Step 3 assessment.

90. The choice of 'breakpoint' automation, where carefully selected "breakpoints" require operator attention and acknowledgment between automated sequences for reactor operations, appears to be a reasonable approach to maintaining operator situational awareness. However, the claim made in the PSR that no safety-related protection systems are lost in automation failure is an aspect that will need to be substantiated by the RP and assessed by my fault studies and C & I colleagues. From a HF perspective, my expectation is that the RP provides adequate evidence to demonstrate that failure / loss of automation is obvious to operators, that it is unambiguously indicated and that the required recovery is feasible. This is important to ensure that any change in plant safety functions and plant safety status is promptly and easily recognised, diagnosed and appropriately restored by operators. This will be an area of focus during my Step 3 GDA assessment of AoF.

91. In addition, through discussions I have held with the RP's SME, it is clear that the cognitive implications of AoF and automation strategy for the ABWR have been carefully considered. Evidence for this judgement comes from a number of features such as selection of 'breakpoint' automation and provision of a small number of key parameters that need to be monitored to understand plant behaviour and status and diagnose faults. This potentially reduces human unreliability that can occur with re-allocation of function if automated control reverts to manual operation under conditions of failure. These parameters are also relayed to back-up, hardwired interfaces.

92. The RP's initial AoF analysis concludes that no changes to the AoF for Residual Heat Removal (RHR) and Feedwater Control (FDWC) are required. I consider it is premature to draw such conclusions regarding AoF at this stage of GDA, given the likelihood of changes related to safety functional categories and requirements, safety case expectations, staffing structures etc. For example, from discussions with my fault studies colleagues, concerns exist over the potential for multi-safety functional claims on the RHR system and the ability to manually operate and configure it under certain fault conditions (Ref. 24). In addition, a number of manually operated valves are currently required for delivery of spent fuel pond cooling; however, the conditions under which such valves may need to be opened could dictate that some need to be automated. The results of the PSA may also indicate that performance requirements of a given function exceed the capabilities of humans. Hence there are clear candidates where the AoF will need to be re-analysed as the safety case and design develop. Accordingly, the PSR acknowledges that AoF analysis will be continued and iterated throughout Step 3 based on the fault analysis, task analysis and any design changes required for the UK ABWR.

4.1.3.1 Concept of operations

93. My expectations for the concept of operations are that the PSR provides a description of how the system design and operational characteristics relate to the proposed organisational structure and staffing (to manage normal operations, accidents, outage and emergencies). Consideration of the command and control philosophy during normal operations, fault and accident conditions should also be discussed. I consider that information of this nature is important to help inform a contextual view of how the

HBSC contribute to safety and under what conditions. Following issue of RQ-ABWR-0169 (Ref. 14), I am satisfied that the PSR adequately addresses this. The command and control philosophy for normal operations, fault and emergency conditions will be similar to that used in existing UK NPP. I believe that it will be beneficial for a future licensee to implement broadly familiar UK NPP systematic approaches to training, procedure design and emergency arrangements. This should assist with avoiding unfamiliarity issues and the potential for significant re-training burden.

94. The RP has also provided a more detailed concept of operations report (Ref. 23), which I will assess as part of my Step 3 assessment of the AoF. My initial opinion is that it appears to address my expectations regarding concept of operations. The RP recognises that a number of aspects of the concept of operations will be different for the UK ABWR and will likely create some different design requirements e.g. design changes required to achieve diversity in safety functions, operational and user differences between the UK and Japan. The concept of operations during other plant states, such as shut-down states (i.e. outages) and for non-reactor plant (i.e. fuel route and radwaste treatment system) will be developed early in Step 3. As part of my Step 3 assessment, I will also satisfy myself that the operational concept is consistent with the UK ABWR AoF and general system design.

95. Overall, at the end of Step 2, I am satisfied that the RP is employing an interdisciplinary and modern standards approach to AoF and concept of operations. This is based on the initial AoF analysis, descriptions provided in the PSR and comparison of these with the expectations set out in ONR's TAG 064 (Ref. 7). The RP's decisions regarding AoF and concept of operations appear to use a balanced approach that considers technical feasibility, what is necessary for safety, human capabilities and limitations. Generally, AoF decisions for the ABWR appear broadly compatible with the principle on hierarchy of control set out in SAP EKP 5.

4.1.4 Strengths

96. The PSR and HFIP provide adequate descriptions of the HF claims and HFI programme required to meet ONR regulatory expectations for development of a modern standards HF safety case for the UK ABWR. The methods applied in Step 2 and those proposed for Step 3 and beyond are generally recognised good practice and standard approaches for HF analysis. The PSR and HF claims therein, offer useful insight into the nature of HF for the UK ABWR, how it will be integrated and the potential contribution that humans will make to the overall safety of the plant. The need for further HF analysis work is clearly acknowledged.

97. The RP's responses to my RQs have been satisfactory to date. There has been a willingness to respond and responses have been delivered on time. From the quality and nature of the responses and safety case submissions for Step 2, I consider that the RP has developed a good understanding of ONR's regulatory expectations for HF.

98. I judge that the enhancements made to the RP's HF organisation are a significant commitment that should enable it to deliver the necessary GDA outcomes for the UK ABWR.

4.1.5 Items that Require Follow-up

99. During my GDA Step 2 assessment I have identified the following shortcomings:

- I have not seen evidence of systematic task-analytical based processes for determining the specific level of HF attention given to the ABWR design. Whilst this does not necessarily invalidate the claims or mean that adequate evidence

does not exist, further detailed analyses conducted by HF specialists is required to produce this evidence for the UK ABWR.

- The number of specific HBSC qualitatively suggests a potentially high human contribution to risk. At the end of Step 2 the significance of the human contribution to the overall UK ABWR risk is unknown due to the absence of a UK ABWR full scope PSA (and supporting analyses). This needs to be explicitly analysed by the RP, taking into account developments in other areas such as internal and external hazards and SAA etc. The RP needs to demonstrate that the risk from human failure for the UK ABWR is ALARP.

- The actions from RO-ABWR-005 (Hitachi-GE HF Specialist Resource and Organisation), need to be completed or significantly progressed to ensure that the RP maintains sufficient HF specialist capability to deliver GDA. In particular, additional resourcing of the HF department will be needed for Step 3.

100. I have also identified the following additional matters that I will follow-up during Step 3 as part of my assessment activities:

- Assessment of HF evidence that underpins the RP's baseline HF position.

- Sample the adequacy and independence of the RP's HF QA and peer review.

- Assessment of the UK ABWR AoF and concept of operations substantiation.

- RP's responses to RQs on HRA and ensure the requirements and expectations are appropriately incorporated into the PCSR and supporting HF analyses.

101. During my GDA Step 2 assessment I have identified the following area that may require additional research to be undertaken by the RP in order to underpin the safety claims in HF. I will follow these matters, as appropriate, during Step 3:

- Research into available data sets in order that the most appropriate and representative HEP data will be used for analysis of advanced HMI.

4.1.6 Conclusions

102. Based on the outcome of my assessment I judge that the RP has produced an adequate Step 2 preliminary HF safety case submission for the UK ABWR. The HF claims related to safety broadly reflect ONR's expectations. I judge that the HF claims have been systematically identified, are adequately presented and overall appear reasonable, based on current knowledge of the UK ABWR safety case evolution. However, I have not seen evidence of systematic task-analytical based processes for determining the specific level of HF attention given to the ABWR design in relation to the claims made. Additional detailed analyses are required to produce such evidence for the UK ABWR. The number of specific HBSCs qualitatively suggests a potentially high human contribution to risk at this stage. This requires further analysis consistent with the UK ABWR PSA (and its supporting analyses).

103. The RP has acknowledged limitations in the current listing of HF claims due the developing nature of the UK ABWR design and safety case requirements. The RP has developed and implemented a suitable HFI programme, which should provide resolution of my concerns regarding claims, and deliver the necessary arguments and evidence to substantiate the HF claims for the UK ABWR.

104. At this stage, based on the Step 2 safety case submissions, I am confident that adequate modern standards HFI processes have been developed and adopted by the RP that should ensure, from a HF perspective, that the UK ABWR will meet the legal duty in Great Britain to ensure that risks are reduced so far as is reasonably practicable.

4.2 Out of Scope Items

105. The following item has been omitted from the scope of my GDA Step 2 assessment of the UK ABWR HF:

- Detailed assessment of the UK ABWR AoF and concept of operations. My reason for leaving this out of scope is that a number of aspects the design and safety case for the UK ABWR will change from that of the J-ABWR due to additional requirements to enhance safety. Hence I did not believe that any significant benefit would be gained from a regulatory intelligence perspective, by performing a detailed assessment of the J-ABWR AoF and concept of operations during Step 2. I therefore restricted my assessment to a high level review of claims in this area and the general approach being adopted by the RP. I judge that this aspect of my GDA HF assessment would be reasonable and appropriate to include in Step 3, when more detailed and firm information is available for the RP to conduct a more thorough analysis that fully reflects the UK ABWR design.

106. The above omission does not invalidate the conclusions from my Step 2 assessment. I will follow this up item as appropriate during Step 3; I will capture this within my Step 3 Assessment Plan.

4.3 Comparison with Standards, Guidance and Relevant Good Practice

107. In Section 2.2 I listed the standards and criteria that I used to judge the adequacy of the preliminary safety case. My overall conclusions in this regard can be summarised as follows:

- SAPs: The RP's preliminary safety case and supporting documentation demonstrate at a high level but sufficient for Step 2 GDA, that the principles set out in the key HF SAPs that I used to guide my assessment are broadly met. The PSR and HFIP provide a good foundation for the RP to build upon and develop the HF safety case for the UK ABWR with sufficiently detailed arguments and evidence such that all relevant HF and HF-related SAPs should be met. Table 1 provides further details.

- TAGs: I am satisfied that the expectations of the relevant ONR TAGs on HF are evident in the preliminary safety case submissions and have also been largely incorporated into the RP's own HF requirements, HFI programme, approaches and methods for GDA.

4.4 Interactions with Other Regulators

108. During my interactions with the RP HF team during Step 2, I was accompanied by the EA inspector responsible for HF. The purpose of these interactions was to ensure that the RP is holistically considering HF for both safety functional and environmental protection aspects of the UK ABWR. This is consistent with the IAEA approach in its Safety Fundamentals, which incorporate environmental protection into the definition of safety. The interactions are expected to continue during Step 3.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

109. The RP has provided a PSR for the UK ABWR for assessment by ONR during Step 2 of GDA. The PSR presents the claims in the area of HF that underpin the safety of the UK ABWR in a hierarchical schedule, from broad system design claims to specific human-based safety claims (HBSC). The HF claims are based on the J-ABWR and maturity of the UK ABWR safety case to date. The HFI programme for the UK ABWR is described, with the detail presented in a HF Integration Plan (HFIP). The PSR also describes at a high level, the concept of operations and how allocation of safety actions have been / will be determined.

110. During Step 2 I have conducted an assessment of the PSR on HF and supporting documentation against the expectations of the SAPs and TAGs. From the assessment done so far I conclude the following:

- The PSR meets UK regulatory expectations for an early design safety case in the area of HF. The RP's safety case claims that the UK ABWR will be designed in accordance with HF modern standards, particularly the design of working environment, equipment and interfaces for optimal performance of tasks related to nuclear safety. Widespread consideration of HF already exists in the evolution from BWR to ABWR. The RP's claims are supported by a baseline HF assessment, which concludes that there is fully-integrated HF in the design on which the UK ABWR is based and this extends to all stages of the ABWR plant lifecycle.

- Specific HBSC or safety actions required to deliver or contribute to safety functions have been systematically identified. I acknowledge that some of these are likely to be re-allocated to engineered functions in order to meet improved safety system requirements for the UK ABWR, additional claims maybe identified and others are only likely to be required following failure of diverse engineered safety systems or where large grace times exist. This will need to be assessed and verified as the HRA / PSA is developed during GDA Steps 3 and 4.

- The UK ABWR has a comprehensive HF integration programme to ensure continued, holistic and systematic application of HF modern standards throughout GDA to meet UK regulatory expectations and demonstrate that the UK ABWR design has reduced the risk from human error to ALARP. I am satisfied that the HFIP produced in support of the HFI programme meets modern standards expectations, and if adequately implemented, should ensure the HF claims will be robustly substantiated.

- The RP's claims broadly meet ONR's interpretation and expectations of HF safety claims as outlined in Section 2 of this report.

111. During my GDA Step 2 assessment of the HF aspects of the UK ABWR safety case, I have identified the following areas of strength:

- The PSR and HFIP provide adequate descriptions of the HF claims and HFI activities required to meet UK regulatory expectations for development of a modern standards HF safety case for the UK ABWR. The RP has been transparent in identifying shortfalls against modern HF standards, which I believe has contributed to the production of a balanced preliminary HF safety case. I have not identified any claims that I consider to be unreasonable from a

HF perspective, such that they would challenge the expectations of the SAPs, or be likely to result in fundamental plant design changes for the UK ABWR. The high level HF claims for the design on which the UK ABWR is based seem reasonable, and appear to be supported by an alternative approach to HFI, where aspects of HF good practice have been encapsulated within the RP's various design processes, standards and specification documents.

- Based on the PSR, at this stage of GDA, I am confident that the RP's design decisions for AoF and concept of operations follow a balanced approach that considers technical feasibility, what is necessary for safety, human capabilities and limitations.

112. During my GDA Step 2 assessment of the HF aspects of the UK ABWR safety case, I have identified the following areas that require follow-up during my Step 3 assessment activities:

- I have not seen evidence of systematic task-analytical based processes for identifying the factors that influence HBSC and for determining the specific level of HF attention given to the baseline ABWR design for all stages of the plant lifecycle and all operational states and conditions. Whilst this does not necessarily invalidate the claims or mean that adequate evidence does not exist; further detailed analyses by HF specialists is required to produce and /or validate such evidence.

- The number of specific HBSC suggests a potentially high human contribution to risk. However, the significance of the human contribution to overall risk is currently unknown due to the absence of a full scope PSA for the UK ABWR. This needs to be explicitly analysed by the RP, taking into account developments in other areas such as internal and externals hazards, SAA etc, and the risk from human failures demonstrated to be ALARP. The absence of a full scope UK ABWR PSA (and its supporting analyses) also presents a significant project risk to completion of my overall GDA HF assessment, as HF has an intrinsic dependency on this in terms of the identification and understanding of risk-significance of operator actions.

- Evaluation is needed of the full implementation of the RP's HF organisation in response to the Step 2 RO on HF Specialist Resource and Organisation.

- There will need to be a review of the adequacy and independence of the RP's HF QA and peer review.

- Detailed assessment of AoF and concept of operations is required.

- Appraisal will be required of RP responses to the Step 2 RQs on HRA.

113. Based on my interactions with the RP's HF Subject Matter Experts (SMEs), I have found the RP to be very open and responsive to the issues I raised. Throughout Step 2 the RP has enhanced their HF organisational capability and it has become apparent they have acquired a good understanding of the UK regulatory framework and expectations for modern standards HF for UK NPP. The RP acknowledges the need for further analysis work through a structured HFI programme.

114. Overall, I judge the RP's preliminary HF safety case to be adequate and based on this I see no reason on HF grounds why the UK ABWR should not proceed to Step 3 of the GDA process. However, the chapters on HF in the draft PCSR, recently provided to ONR for information, appear to fall short of ONR's expectations for a PCSR and what

is set out in the GDA Guidance to RPs. These will require improvement to form an adequate basis for my Step 3 assessment. However, based on their current organisational capability, commitment to develop this further and the HFI programme, I have confidence that the RP will be able to articulate reasonable claims in the PCSR and underpin them with sufficient arguments and robust evidence.

5.2 Recommendations

115. 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 Plan for HF.
- Recommendation 3: The out-of-scope item identified in sub-section 4.2 of this report should be included in ONR's Step 3 Assessment Plan for HF.

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Table 1

Relevant Safety Assessment Principles Considered During the Assessment

SAP No and Title	Description	Interpretation	Comment
EHF.1 Human factors: Integration with design, assessment and management	'A systematic approach to integrating human factors within the design, assessment and management of systems should be applied throughout the entire facility lifecycle'	This principle sets the framework and requirements for ensuring that HF is systematically considered in the design and safety case assessment process at an early stage and continued throughout the entire design process and facility lifecycle. The intent of HF integration is to provide an organising framework for ensuring that all relevant HF issues are identified and addressed such that properly informed decisions on risk and design can be made. Soundly demonstrated HF integration can provide the basis for regulation of the HF aspects of a project and provide assurance to ONR inspectors that HF is being adequately accounted for.	Addressed in Section 4 of this report. The need for HF has been recognised by the RP from the outset. This assessment report concludes that a good practice HFI programme and plan exists, which if properly implemented, should ensure adequate and proportionate integration of HF into the UK ABWR design and safety case, along with the specification of assumptions, issues and requirements for the licensee organisation to take forward, verify and integrate into the plant's operational regime. The SAP is considered to have been fully met for Step 2 GDA. As this is a life-cycle principle, compliance will be checked throughout Steps 3 and 4.
EHF.2 Human factors: Allocation of safety actions	'When designing systems, the allocation of safety actions between humans and technology should be substantiated and dependence on human action to maintain a safe state should be minimised'	This principle is about demonstrating an appropriately balanced AoF and its substantiation. This should take into human capabilities and limitations, what is appropriate for nuclear safety and what is technically feasible, whilst recognising the need to minimise reliance on human action to provide safety functions. It expects that an interdisciplinary approach to AoF and application of good practice methods are adopted for AoF analysis and making design decisions relating to this.	Addressed in Section 4 of this report. The primary means of delivering safety actions on the UK ABWR is automatically initiated engineered systems. The RP has indicated that it employs a modern standards and multi-disciplinary approach to AoF analysis. There is still some uncertainty related to function allocation, which will require further AoF analysis and design decisions as GDA progresses. This is to be expected at this early design stage for the UK ABWR. For Step 2, on the basis of the RP's approach and methods for AoF and the preliminary information provided in the PSR, I consider this SAP to be met in the interim. Detailed assessment will be necessary during Step 3 (and 4) in order to be able to fully judge the extent that this principle is satisfied for the UK ABWR.
EHF.3 Human	'A systematic approach should	These principles have been combined as they relate	Addressed in Section 3 of this report. The RP has

factors: Identification of action impacting safety **EHF.4 Human factors: Identification of administrative controls**	be taken to identifying human actions that can impact on safety' 'Administrative controls used to remain within the safe operating envelope should be systematically identified'	to ensuring all human-based safety claims (HBSC) relevant to all plant states and conditions, including operator actions that implement administrative controls, are systematically identified in order that their feasibility, reliability and adequacy can be substantiated as part of the safety case.	provided a schedule of specific HBSC as part of the PSR. This provides an initial qualitative indication of the when and where human actions and implementation of administrative controls may impact safety and likely human contribution to safety of the UK ABWR under different states. The claims have been systematically identified (based on the extant ABWR and emerging UK ABWR design and safety analysis information available to date).It is recognised that the identification and substantiation of HBSC will continue throughout GDA in step with fault studies, PSA, internal and external hazards assessments. In addition, it will only be possible to identify the specific administrative controls that will be required towards the end of GDA Step 3 and into Step 4, once the fault analysis, internal, external hazard analyses and PSA have been completed. Therefore, these SAPs can reasonably be considered to be partially met at the end of Step 2.
EHF. 10 Human factors: Human reliability analysis	'Risk assessments should identify and analyse human actions or omissions that might impact on safety'	This principle is about demonstrating that a suitable and sufficient risk assessment and PSA is produced that incorporates all the ways in which risks can arise from human failures. It requires assurance that all Type A – C HFEs are identified and analysed, dependence mechanisms and failures are appropriately accounted for, that quantitative HEPs are derived using relevant and justified data and techniques and that this is underpinned by qualitative task analyses.	Addressed in Section 4 of this report. The RP has demonstrated its approach for HRA, which includes both qualitative and quantitative analysis and broadly meets ONR expectations contained within this principle. Recognised HF and HRA quantification techniques will be used, along with input from operational experience data as appropriate. Concerns have been raised with regards to HEP data for advanced HMI and cognitive error modelling, although the RP has agreed to address these to my satisfaction. In addition, a number of RQs have been raised relating to HRA and the RP's approach to this for the UK ABWR. At this stage I am confident that SAP EHF.10 will be met for the UK ABWR.
SC.4: The regulatory assessment of	'A safety case should be accurate, objective and demonstrably complete for its	The principle essentially relates to ensuring that safety cases are fit-for-purpose for the life-cycle stage to which they relate, are suitably	The PSR on HF and supporting documentation are judged to satisfy the expectations of this principle for an early HF safety case. The PSR is consistent with

safety cases, safety case characteristics	intended purpose’	comprehensive, balanced, honest and provide the necessary information for the management of safety, the making of risk-informed decisions, and provide the demonstration that legal requirements have been met or how this will be achieved	the guidance provide in the document, GDA Guidance to Requesting Parties ONR-GDA-GD-001 Rev 1 and TAG 051, interpreted for HF requirements. On this basis principle SC.4 is considered to have been met for Step 2.