Office for Nuclear Regulation

New Reactor Division – Generic Design Assessment

Summary of the Step 4 Assessment of the UK HPR1000 Reactor

(Picture courtesy of CGN)

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EXECUTIVE SUMMARY

The mission of the Office for Nuclear Regulation (ONR) is to protect society by securing safe nuclear operations. In the context of new nuclear power plants in the United Kingdom (UK), regulation is initially undertaken via the Generic Design Assessment (GDA) process. ONR and the Environment Agency developed the GDA process in 2006 in order to allow the nuclear regulators to assess reactor designs on a 'generic' basis, in other words, before a site has been determined, or an operating organisation or prospective licensee has been proposed. In essence, it considers the viability of reactor technologies ahead of any financial decisions or commencement of construction. This upfront process enables resolution of technical matters, and hence early identification of required improvements and necessary design changes, which reduces regulatory uncertainty for developers.

GDA is a voluntary process and not a legal requirement of Great Britain's licensing regime for new nuclear power plants. However, the UK Government recognises that the GDA process offers efficiencies and therefore expects reactor designers to follow it.

It is important to note that successful completion of GDA does not guarantee that regulatory permission will be granted to commence construction or operation of a nuclear power plant. A prospective operator must obtain a Nuclear Site Licence (NSL), and there is ongoing regulation under the NSL throughout the lifecycle of the plant.

To date, three reactor designs have been assessed under the GDA process and received a Design Acceptance Confirmation (DAC) from ONR and a Statement of Design Acceptability (SoDA) from the Environment Agency: the UK EPR™ received its DAC and SoDA in December 2012, the AP1000® in March 2017 and UK ABWR in December 2017. ONR's assessment reports on these technologies are published on the GDA joint regulators website.

In January 2017, the UK Government asked ONR and the Environment Agency to begin the GDA of the UK HPR1000. The UK HPR1000 is the reactor design proposed for deployment at Bradwell-on-Sea, Essex. General Nuclear System Limited is a UK-registered company that was established to implement the GDA of the UK HPR1000 reactor on behalf of three joint requesting parties, collectively referred to as the GDA Requesting Party (RP): China General Nuclear Power Corporation, Électricité de France SA and General Nuclear International.

The GDA process calls for a step-wise assessment of the RP's safety and security submissions with the assessments increasing in detail as the project progresses. Step 4 is the final and most detailed step in the GDA process where ONR judges whether a DAC should be issued.

In Step 4, the evidence that substantiates the arguments and claims in the safety and security cases is sampled by ONR, building upon the assessments conducted during the earlier Steps 2 and 3. Step 4 of the UK HPR1000 GDA started in February 2020 and during the subsequent 23 months, ONR undertook detailed assessments across 21 technical disciplines and cross-cutting topics.

Undertaking a GDA is a significant undertaking for both ONR and the RP, with ONR's regulatory team for Step 4 including over 40 specialist inspectors. To complete the assessments summarised in this report:

- ONR attended over 900 technical meetings and 40 project progress meetings with the RP. 656 technical meetings took place during Step 4.

- ONR raised 1681 Regulatory Queries (RQ) to request clarification and additional information throughout the GDA. 1098 of these were raised during Step 4. The RP provided responses to all these RQs during GDA.
- Regulatory Observations (RO) are raised when we identify potential regulatory shortfalls requiring action and new work by the RP to resolve. ONR raised 56 ROs in this GDA, including 26 during Step 4. The RP provided additional information and submissions to respond to all these ROs during GDA.
- ONR commissioned 26 individual technical support contracts with a total value of approximately £9.3m during GDA, providing additional specialist support to aid our regulatory judgements.
- The RP submitted, and ONR assessed on a sampling basis, over 3400 safety and security submissions during Step 4.

During GDA, the RP overcame the technical challenges identified and put measures in place to improve the areas highlighted by ONR's assessment and inspections. The RP identified, and considered holistically, 95 design modifications derived from the specific work done in GDA and these have been included in the final design reference for the generic UK HPR1000 design.

From our assessments we have concluded the following:

- All of the regulatory shortfalls identified throughout the process, including those captured in the 56 ROs we raised, have been adequately addressed, and the final position on those technical matters is reflected in the generic safety and security cases.
- Our assessment has identified 243 Assessment Findings for the licensee to resolve during the detailed design and site-specific stages.
- Our assessment has not identified any fundamental safety or security shortfalls that might prevent the issue of a DAC for the generic UK HPR1000 design.
- The RP has demonstrated for the purpose of GDA that the overall level of risk associated with the generic UK HPR1000 design has been or is capable of being reduced to As Low As Reasonably Practicable (ALARP).
- ONR is satisfied that version 2 of the Pre-Construction Safety Report and the Generic Security Report for the generic UK HPR1000 design, and the supporting documentation contained within the Master Document Submission List, are adequate for the purposes of issuing a DAC.
- Our assessments across all technical disciplines and cross-cutting topics have met the objectives of GDA.

Therefore, in ONR's opinion, the generic UK HPR1000 design could be built and operated in Great Britain, on a site bounded by the generic site envelope, in a way that is acceptably safe and secure, subject to:

- site-specific assessment, licensing and permissioning; and
- resolution of the 243 Assessment Findings

Based on the above, we recommend that a DAC should be granted for the generic UK HPR1000 design.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
ARN	(Argentina's) Autoridad Regulatoria Nuclear
BSI	British Standards Institution
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
C&I	Control and Instrumentation
CAE	Claims-Arguments-Evidence
CBSIS	Computer Based Systems Important to Safety
CBSy	Computer Based Security
CDM	Construction (Design and Management) Regulations
CEN	European Committee for Standardisation
CGN	China General Nuclear Power Corporation Ltd
CSRA	Cyber Security Risk Assessment
DAC	Design Acceptance Confirmation
DEC	Design Extension Condition
DMGL	Delivery Management Group Lead
DR	Design Reference
DRP	Design Reference Point
EDF SA	Électricité de France SA
EMIT	Examination. Maintenance, Inspection and Testing
ERIC	Eliminate, Reduce, Isolate, Control
GB	Great Britain
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GNI	General Nuclear International Ltd
GNSL	General Nuclear System Limited
GPP	General Principles of Prevention
GSE	Generic Site Envelope
GSR	Generic Security Report
HBSC	Human Based Safety Claim
HLW	High-Level Waste
HMI	Human Machine Interface
HPR1000WG	HPR1000 Design Specific Working Group (within MDEP)
HRA	Human Reliability Analysis
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency

ILW	Intermediate Level Waste
ISO	International Organisation for Standardisation
IVR	In-Vessel Retention
JPO	(Regulators') Joint Programme Office
KDS [DAS]	Diverse Actuation System
KSyPP	Key Security Plan Principle
MDEP	Multinational Design Evaluation Programme (within OECD-NEA)
MDSL	Master Document Submission List
MSQA	Management for Safety and Quality Assurance
MW	Megawatts
NDE	Non-Destructive Examination
NEA	Nuclear Energy Agency (within OECD)
NGO	Non-Governmental Organization
NNR	(South Africa's) National Nuclear Regulator
NNSA	(People's Republic of China's) National Nuclear Safety Administration
NPP	Nuclear Power Plant
NSL	Nuclear Site Licence
NSP	Nuclear Safety Principle
OECD	Organisation for Economic Cooperation and Development
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCER	Pre-construction Environmental Report
PCSR	Pre-construction Safety Report
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety, Security, and Environmental Report
PTI	Project Technical Inspector
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assembly
RCP	Reactor Coolant Pump
RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPS [PS]	Protection System
RPT	Radiological Protection Target
RPV	Reactor Pressure Vessel

RQ	Regulatory Query
RRM	Regulatory Review Meeting
RWM	Radioactive Waste Management Limited
SAP(s)	Safety Assessment Principle(s)
SCCA	Stationary Core Control Assembly
SFAIRP	So Far As Is Reasonably Practicable
SFA	Spent Fuel Assembly
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SG	Steam Generator
SoDA	(Environment Agency's) Statement of Design Acceptability
SSC(s)	Structures, Systems and Components
SyAP(s)	Security Assessment Principle(s)
TAG	Technical Assessment Guide
TSC	Technical Support Contractor
WENRA	Western European Nuclear Regulators' Association

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1 CONTEXT

1. In February 2020 the Office for Nuclear Regulation (ONR) announced that it was progressing to Step 4 of the Generic Design Assessment (GDA) of the UK HPR1000 reactor.

2. During the last 23 months, ONR has undertaken assessment across 21 technical disciplines and cross-cutting topics.

3. This is ONR's project assessment report for Step 4 of the UK HPR1000 GDA and for the completion of the GDA process for this reactor design. The report provides a summary of ONR's work and assessments undertaken during GDA and supports ONR's decision to grant a Design Acceptance Confirmation (DAC) to the UK HPR1000 GDA Requesting Party (RP).

2 INTRODUCTION

2.1 Background

4. In 2005, the UK Government requested the nuclear regulators to develop a new design assessment process in preparation for anticipated applications for new reactor construction in the UK. In response to this request, ONR and the Environment Agency developed the GDA process in 2006. GDA allows the nuclear regulators to assess reactor designs on a 'generic' basis, in other words, before a site has been determined, or an operating organisation or prospective licensee has been proposed. In essence, it considers the viability of reactor technologies ahead of any financial decisions or commencement of construction. This upfront process enables resolution of technical matters, and hence early identification of improvements and necessary design changes, which reduces regulatory uncertainty for developers.

5. It is important to note that GDA is a voluntary process and not a legal requirement of Great Britain's (GB) licensing regime for new Nuclear Power Plants (NPPs). However, the UK Government recognises that the GDA process offers efficiencies and therefore expects reactor designers to follow it.

6. Three reactor designs have been assessed under the GDA process and received a DAC from ONR and a Statement of Design Acceptability (SoDA) from the Environment Agency: the UK EPR™ in December 2012, the AP1000® in March 2017 and UK ABWR in December 2017.

7. In October 2016, General Nuclear System Limited (GNSL) wrote to ONR and the Environment Agency requesting entry to the GDA process for the UK HPR1000 reactor design. ONR and the Environment Agency considered the request and concluded that the project appeared viable and warranted the deployment of regulatory resource (Ref. 1). In January 2017, the Government asked ONR and the Environment Agency to begin the GDA of the UK HPR1000 (Ref. 2). The UK HPR1000 is the reactor design proposed for construction on the Bradwell-on-Sea site in Essex.

8. GNSL is a UK-registered company that was established to implement the GDA of the UK HPR1000 reactor on behalf of three joint requesting parties, collectively referred to as the GDA RP: China General Nuclear Power Corporation (CGN), Électricité de France SA (EDF SA) and General Nuclear International (GNI).

2.2 UK HPR1000 GDA Overview

9. The GDA process calls for a step-wise assessment of the RP's safety and security submissions with the assessments increasing in detail as the project progresses.

10. Step 1 of the UK HPR1000 GDA commenced in January 2017 and finished in November 2017. Step 1 of GDA was the preparatory step and during this period the RP set up its project management and technical teams and arrangements for GDA, and prepared submissions for Step 2, including the Preliminary Safety, Security, and Environmental Report (PSR) (Ref. 3). The RP also established a UK HPR1000 website (Ref. 4) publishing the PSR and providing the means for the public to raise comments.

11. In Step 1, ONR did not undertake any technical assessment. However, the regulators engaged with the RP to ensure that regulatory expectations were understood. Thus, during Step 1 of GDA, ONR held extensive discussions with the RP (including technical discussions both in the UK and China) to enable the RP's understanding of the requirements and processes that would be applied, and for our inspectors to start familiarising themselves with the HPR1000 design. In November 2017, we announced that we were progressing to Step 2 (Ref. 5).

12. Step 2 of the UK HPR1000 GDA commenced in November 2017 and marked the start of technical assessment. This step was focused on understanding and assessing the fundamental safety and security claims, and the acceptability of the generic UK HPR1000 design within the UK regulatory regime. Safety and security claims, or assertions, are statements that describe the design and explain why the facility is safe and secure. These were presented within the PSR and its supporting references. Step 2 ended in November 2018 and our work culminated in the production of a project assessment report (Ref. 6), underpinned by 19 technical assessment reports published on our GDA joint regulators' website (Ref. 7). The assessment did not identify any fundamental safety or security issues that might prevent the issue of a DAC.

13. Step 3 of the UK HPR1000 GDA commenced in November 2018. This step was focused on undertaking a more detailed assessment of the design, targeting the methods and approaches used by the RP to meet its safety and security claims. Step 3 was primarily a review by ONR of the arguments (or 'reasoning') supporting the RP's claims.

14. At the beginning of Step 3, the RP submitted version 0 of the generic Pre-construction Safety Report (PCSR) (Ref. 8) and the Generic Security Report (GSR) (Ref. 9) which summarised the safety and security cases at that point in time, along with numerous supporting references.

15. Step 3 of GDA ended in February 2020 and culminated with the production of an assessment report (Ref. 10) that summarised the outcomes of our assessment work across 21 technical disciplines and topics of a cross-cutting nature. Our Step 3 assessment did not identify any fundamental safety or security shortfalls that might prevent the issue of a DAC.

16. In February 2020, ONR announced that it was progressing to Step 4 of the GDA of the UK HPR1000 reactor.

17. During the last 23 months, ONR has undertaken detailed assessment across 21 technical disciplines and cross-cutting topics. In Step 4 of GDA, the evidence that substantiates the arguments and claims in the safety and security cases was

sampled in detail by our team of technical specialist inspectors. Step 4 of GDA is the final step in the GDA process where ONR judges whether a DAC should be issued or not.

18. The aim of Step 4 of GDA was to:

- confirm that the higher-level claims and arguments were properly justified;
- progress the resolution of matters identified during Step 3 of GDA; and
- complete sufficient detailed assessment to allow ONR to come to a judgment of whether a DAC could be issued.

19. At the start of Step 4, the RP submitted version 1 of the generic PCSR (Ref. 11) and the GSR (Ref. 12) and supporting references. ONR's assessment led to further updates and new supporting evidence being developed by the RP. In total, over 3400 documents were submitted by the RP during Step 4 of GDA, including the PCSR version 2 (Ref. 13) and the GSR version 2 (Ref. 14), which are the final versions of both documents.

20. As part of our commitment to continuous improvement, ONR made modifications to the GDA process in 2019, taking account of learning from previous and ongoing GDAs. The 'modernised' GDA process introduces greater flexibility to support future assessments of small modular reactors and other advanced nuclear technologies. New GDA guidance to RPs reflecting the modernised process was published in October 2019 (Ref. 15). It is important to clarify that the modernised process and new guidance have not been applied to the UK HPR1000 GDA, which followed the extant GDA guidance (Ref. 16).

2.3 Post-GDA Work

21. It is important to note that successful completion of GDA does not guarantee that regulatory permission will be granted to commence construction or operation of a new NPP. A prospective operator will have to obtain a nuclear site licence (NSL), and there is ongoing regulation under the licence throughout the lifecycle of the plant. In particular, a licensee requires ONR's formal consent before nuclear safety related construction can commence. For this, it will need to develop and submit a site-specific pre-construction safety case, along with a site security plan and demonstrate compliance in accordance with Nuclear Industries Security Regulations 2003 (as amended) (Ref. 17).

22. To enable these processes, our regulatory philosophy is that after obtaining a DAC, the RP should transfer the outputs from the GDA to the licensee to be used to support the development of the site-specific safety case and the site security plan. This includes arrangements for ensuring and assuring that safety and security claims and assumptions will be realised in the final 'as-built' design, and arrangements for moving the safety case to the operating regime. ONR's assessment, ahead of permissioning the start of nuclear safety related construction under the NSL, will then focus on site-specific and licensee-specific aspects. ONR will also assess any modifications to the design since the DAC was issued, and/or further developments of the design, rather than conducting a full reassessment of the design and safety and security cases.

23. We encourage RPs to seek involvement of prospective licensees in GDA to ensure that operational considerations are included in the development of the safety and security cases, and to commence transfer of knowledge regarding the design and safety and security cases to the future operator. A prospective licensee would also

use information coming from GDA to develop the site suitability justification, which is an essential part of the NSL application.

3 MANAGEMENT OF THE UK HPR1000 GDA

3.1 Project Governance

24. ONR implemented robust governance processes and controls for the UK HPR1000 GDA. Multiple layers of governance and oversight were applied to the project to ensure its rigour, objectivity, and independence.

25. The UK HPR1000 GDA was a project under the HPR1000 Regulation sub-division within ONR's New Reactors Division. ONR's Head of HPR1000 Regulation had overall responsibility for the delivery of the GDA. An experienced programme manager provided administrative oversight throughout. Our GDA Step 4 strategy detailed the project governance, timeline, guidance, team structure, roles and responsibilities, engagement strategy, key milestones, and the specific activities to close the GDA (Ref. 18).

26. The HPR1000 Regulation sub-division had a technical board called the Regulatory Review Meeting (RRM) and a project board or sub-division board, both chaired by ONR's Head of HPR1000 Regulation. These provided a formal layer of governance to ensure that ONR's technical assessments and decisions were robust, and that the project was appropriately managed.

27. In addition, each technical discipline in ONR has a professional lead responsible for providing authoritative advice on matters pertinent to the specialism, and for ensuring consistent and proportionate implementation of standards. Therefore, ONR's professional leads provided technical oversight throughout Step 4 of GDA.

28. Senior oversight of the project was deployed in accordance with ONR's standard processes at divisional and senior leadership team levels. The decision on whether to grant a DAC is ultimately made by the Chief Nuclear Inspector, taking into consideration the recommendations made in this report.

29. In terms of managing the GDA team, each technical discipline was assigned to one of three delivery management groups ('engineering and layouts', 'operational design', and 'safety analysis'), each led by a Delivery Management Group Lead (DMGL) who coordinated the assessments and provided the first level of oversight and escalation.

30. A Project Technical Inspector (PTI) provided regulatory oversight of the RP's development of the safety case and design control, which included the UK HPR1000 design reference and design modifications. ONR put in place a formal modification review process to ensure that the technical impact of each design modification was considered holistically by ONR's assessment team, coordinated by the PTI.

31. To obtain independent assurance of the robustness of the project governance and the arrangements in place supporting ONR's decisions, the Head of HPR1000 Regulation commissioned a separate internal assurance review. The conclusions of this review confirmed that the Step 4 of GDA was completed in a manner compliant with the project's arrangements and provided assurance of the project governance (Ref. 19).

3.2 Assessment Strategy

32. Our assessment followed a Claims-Arguments-Evidence (CAE) hierarchy. Major technical interactions started in Step 2 with an examination of the main claims made by the RP for the generic UK HPR1000 design. In Step 3, the arguments which underpinned those claims were examined.

33. Step 4 has been the longest and most detailed phase of the assessment, looking in depth at safety and security evidence which supports the fundamental claims and arguments. We have considered how the totality of the information presented to ONR has been brought together by the RP to demonstrate that the UK HPR1000 can be built and operated safely and securely in GB.

34. Step 4 of GDA started in February 2020 and, soon after, travelling restrictions and other specific measures were put in place globally due to the Covid-19 pandemic. Our team adopted new ways of working, and meetings and inspections took place remotely for the remainder of the GDA. Remote interactions allowed our team to undertake a complete and meaningful assessment, proportionate to the maturity of the generic UK HPR1000 design, thus meeting the objectives of GDA. To illustrate this, 656 virtual technical meetings took place during Step 4 of GDA and those included technical engagements, inspections and workshops. For example, five Management for Safety and Quality Assurance (MSQA) inspections of the RP's arrangements took place during Step 4 of GDA.

35. ONR's assessment of the RP's Step 4 safety and security submissions has been undertaken by specialist inspectors covering 21 technical disciplines. ONR also identified cross-cutting topics which are of a multidisciplinary nature and for which ONR's GDA management team put in place a formal process to coordinate their assessment.

36. ONR undertook thorough preparations for Step 4 during Step 3 of the GDA. As part of these preparations, ONR's inspectors developed Step 4 assessment plans for their own disciplines. The objective of developing assessment plans was to provide a consistent assessment framework across all technical areas. Each assessment plan:

- Outlined the specific aspects on which the inspector would focus assessment during Step 4, including following up on any potential shortfalls identified in Step 3 of GDA.
- Identified the assessment standards that would be used.
- Identified the interactions with other disciplines which would enable completeness and consistency of assessments.
- Identified the key documentation the RP had planned to provide to supplement the specific chapter(s) of the PCSR and the GSR to serve as the basis for ONR's assessment.
- Delineated the Step 4 timeline tailored for each specific area, including planned activity that would enable timely completion and documentation of the assessment in each technical area (for example, meetings and workshops with the RP's specialists or inspections of the RP's arrangements).

37. The Step 4 assessment plans were shared with the RP to provide transparency.

38. During our assessment we used standard GDA tools to request further information or raise shortfalls. These are:

- Regulatory Queries (RQ). RQs are raised to request clarification and additional information and are not necessarily indicative of any perceived shortfall. ONR and the Environment Agency raised 1774 RQs throughout the GDA.

- Regulatory Observations (RO). ROs are raised when we identify potential regulatory shortfalls requiring action and new work by the RP to resolve. ONR and the Environment Agency raised 60 ROs in this GDA.
- Regulatory Issues (RI). RIs are raised when we identify serious regulatory shortfalls which have the potential to prevent provision of a DAC and require action and new work by the RP for them to be resolved. Neither ONR nor the Environment Agency raised any RIs in the UK HPR1000 GDA.

39. Over and above the detailed assessments that were being conducted by our team, early in Step 4 of GDA, ONR undertook an overall 'health check' of the UK HPR1000 safety and security cases. This consisted of a review of the generic UK HPR1000 safety and security cases, across all 21 technical disciplines, using bespoke suitability criteria and an associated question set based on ONR's safety case expectations (Ref. 20). The aim of this health check was to consolidate ONR's overall project view on the quality of the safety and security case submissions, which were the basis for our Step 4 assessments. The RP implemented an effective safety case improvement plant taking into consideration the findings from our safety case health check.

40. Throughout GDA, ONR has coordinated its assessment activities with the Environment Agency which considers the environmental acceptability of the design. In particular, we worked jointly with the Environment Agency in the area of MSQA and maintained very close coordination in the areas of Radioactive Waste Management, Decommissioning and Spent Fuel Interim Storage (SFIS). The Environment Agency reports its outcomes from GDA on the UK Government website (Ref. 21).

3.2.1 Cross-cutting Topics

41. Cross-cutting topics are those that have a bearing on a wide range of the disciplines assessed by ONR in GDA, and therefore benefit from adopting a holistic approach to their assessment. During Step 4 of GDA, ONR put in place a formal process to coordinate the assessment of cross-cutting topics, as many of these topics, such as Heating Ventilation and Air Conditioning (HVAC), were found to be challenging in previous GDAs. ONR identified 22 cross-cutting topics which were managed by the DMGLs and PTI with the support of multidisciplinary teams of inspectors.

42. Each cross-cutting topic was assigned a sponsor, a technical lead and a dedicated assessment team comprised of the relevant disciplines required to assess the topic. The role of the sponsor was to maintain oversight and to ensure that the regulators reached an overall consolidated position. The sponsor was responsible for facilitating resolution of any differences in professional opinion and ensuring that there was a clear basis for the regulatory decision. The technical lead was responsible for coordinating all relevant stakeholders, managing inputs and outputs, reporting progress in a timely manner, and ultimately delivering a regulatory position. Each multidisciplinary assessment team assessed the relevant submissions and reported any gaps or potential shortfalls to the technical lead who followed them up as appropriate.

43. The assessment for most of the cross-cutting topics, and conclusions reached, are reported in the relevant discipline assessment reports and summarised in Annex 1 of this report. Several cross-cutting topics relate to arrangements and methodologies

which apply to all the disciplines; those topics are reported in a separate cross-cutting assessment report (Ref. 22).

44. ONR considers that the management of the UK HPR1000 cross-cutting topics is good practice and an improvement to be taken forward in future GDAs.

3.3 Programme of Work Undertaken

45. The overall duration of the UK HPR1000 GDA was five years and throughout that time the regulatory team increased to meet the demands of each step. During Step 4 of GDA, the regulatory team totalled over 40 specialist inspectors supported by Technical Support Contractors (TSCs).

46. During the course of Step 4 of GDA, the RP submitted more than 3400 documents and ONR assessed those submissions on a sampling basis. The size and scope of our sample was chosen to ensure a meaningful assessment to underpin robust regulatory conclusions.

47. Throughout GDA, ONR and the Environment Agency attended over 900 technical meetings and 40 project progress meetings with the RP. 656 technical meetings (or 73% of the total number of technical meetings) took place during Step 4 of GDA.

48. Throughout the GDA process, ONR and the Environment Agency raised 1774 RQs, all of which were responded to by the RP.

49. During the assessment of the UK HPR1000 submissions, ONR and the Environment Agency raised 60 ROs; 56 of those were raised by ONR. All ROs had been closed out by the end of November 2021, with the full text of the ROs, the resolution plans, and the regulators' closure letters available on the GDA joint regulators website (Ref. 23). The breakdown of ROs by technical discipline is shown in Figure 1.

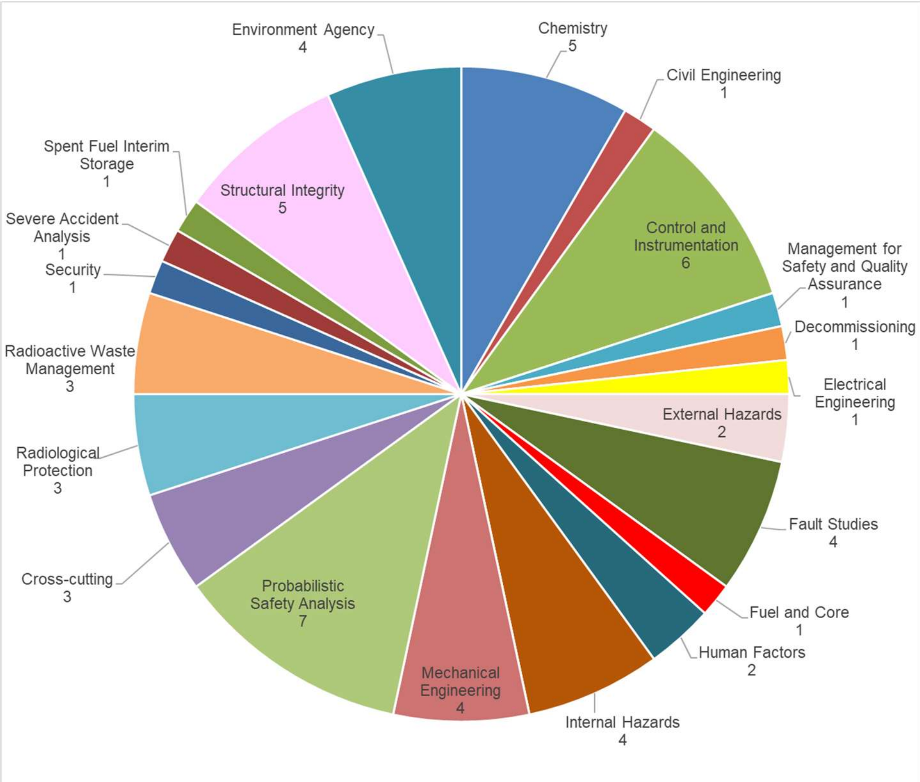


Figure 1: Regulatory Observations by Technical Discipline

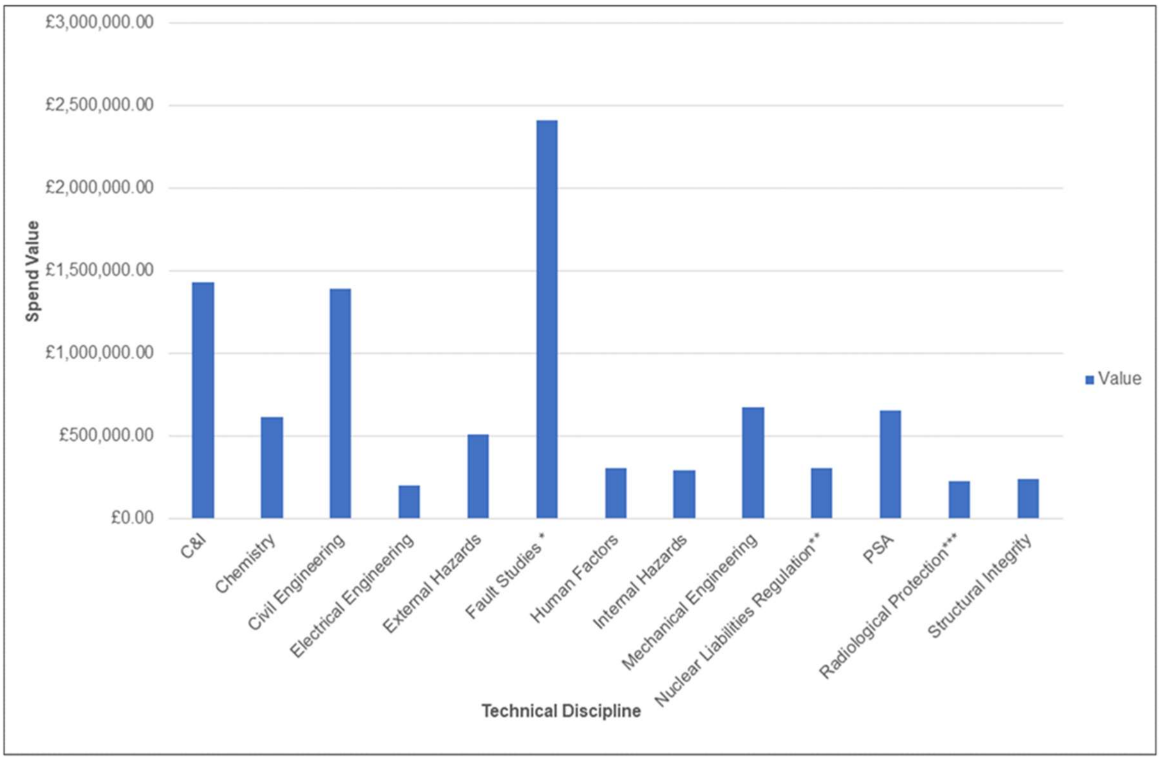
3.3.1 Technical Support Contractors

50. It is not uncommon for national or international regulatory bodies to procure expert support and advice from TSCs.

51. ONR uses TSCs if there is insufficient in-house capacity to deliver the work within the required timescales, or the work requires specialist inputs or tools not available in-house. Given the timescales for Step 4 of GDA, the volume of work, and the specific expertise required in some areas, ONR used TSCs in numerous technical disciplines. In those cases, the relevant assessment reports indicate the nature of the contribution from the TSCs.

52. However, where ONR decides that it needs to contract TSCs, they operate under clear work specifications defined by ONR, and under direct supervision and control of experienced ONR inspectors. ONR, acting as an 'intelligent customer', uses the outcomes from the TSC's work to make regulatory decisions and retains the sole responsibility for the discharge of its regulatory functions.

53. During the UK HPR1000 GDA, ONR raised 26 technical support contracts across 16 technical disciplines, with a combined value of approximately £9.3m. See Figure 2.



(*) Includes Fault Studies, Severe Accident Analysis and Fuel and Core Design
(**) Includes Radioactive Waste Management and Decommissioning
(***) Includes Radiological Protection and Criticality

Figure 2: Technical Support Contract Values by Technical Discipline (January 2017 to January 2022)

3.4 Assessment Standards

54. Our expectations for GDA are detailed in ONR's 'GDA Guidance to Requesting Parties' (Ref. 16). ONR expects new NPPs to be robust facilities that are designed to provide protection against those faults and hazards which, if inadequately controlled, could give rise to societal consequences and serious radiological effects to workers and the public. In order to demonstrate this, a GDA RP will need to develop and provide for ONR's assessment, generic safety and security cases. The UK HPR1000 GDA RP provided safety and security cases in the form of a PCSR and a GSR with numerous associated references.

55. The legal requirement (Ref. 24) for any nuclear facility proposed for construction in GB is to demonstrate that the level of risk has been reduced So Far As Is Reasonably Practicable (SFAIRP). The term As Low As Reasonably Practicable (ALARP) is considered equivalent to SFAIRP and, within ONR guidance, the term ALARP is commonly used. In this report we use the term ALARP.

56. The requirement to reduce the risk to a level that is ALARP is fundamental, and in simple terms is the requirement to take all measures to reduce health and safety risks where doing so is reasonable. Often, this is not done through explicit comparisons of costs and benefits, but rather by applying established Relevant Good Practice (RGP).

57. We expect the RP's demonstration that the risks have been reduced to ALARP (referred to as 'ALARP demonstration') to consider first and foremost the factors related to engineering, operations and the management of safety, which constitute RGP. Sources of RGP include Approved Codes of Practice, published regulatory guidance and standards produced by national and international standard-setting bodies such as the British Standards Institution (BSI), the International Organisation for Standardisation (ISO), the European Committee for Standardisation (CEN) or the International Atomic Energy Agency (IAEA), as well as the safety reference levels developed by the Western European Nuclear Regulators' Association (WENRA). Well-defined established standard practice adopted by industry bodies and professional institutes can also be considered RGP. Published regulatory guidance includes ONR's Safety Assessment Principles (SAPs) (Ref. 25) and Technical Assessment Guides (TAGs) (Ref. 26) which inform our view of RGP.

58. For the overall demonstration that the level of risk is ALARP, within GDA we expect the RP's safety case to address four key aspects (Ref. 27, Ref. 28):

- The rationale for the evolution of the proposed design from its forerunners and how a safer design was achieved.
- How RGP has been incorporated into all aspects of the design.
- Use of risk assessment to identify potential engineering and/or operational improvements in addition to confirming the numerical levels of safety achieved.
- A clear conclusion that there are no further reasonably practicable improvements that could be implemented, and therefore the level of risk has been reduced to ALARP. The RP should therefore implement measures to the point where the costs of any additional measures (in terms of money, time or trouble) would be grossly disproportionate to the further risk reduction that would be achieved.

59. During Step 2 of GDA, the RP provided its approach to ALARP, which included a description of the methodology adopted to ensure that the risks arising from the operation of the generic UK HPR1000 were reduced to ALARP. Step 3 of GDA

focused on the adequacy of the implementation of these arrangements, determining whether ALARP arguments were suitable and sufficient.

60. During Step 4, the RP continued to implement its ALARP methodology throughout the design including reviewing and updating the ALARP demonstration reports for each discipline where the overarching ALARP position was presented. The RP also submitted its 'Holistic ALARP demonstration report' (Ref. 29) which presented the main arguments and high-level evidence to substantiate that the risks associated with the generic UK HPR1000 design have been reduced to ALARP.

61. Our inspectors use ONR's SAPs (Ref. 25) and Security Assessment Principles (SyAPs) (Ref. 30) as the primary guidance for their assessment. The SAPs and SyAPs provide a framework for consistent regulatory judgements on the acceptability of the RP's safety and security cases. The SAPs also include numerical targets, including Basic Safety Levels (BSL) and Basic Safety Objectives (BSO), to be used by inspectors as an aid to judgement when considering whether radiological hazards are being adequately controlled and risks reduced to ALARP. However, neither SAPs nor SyAPs are intended, or sufficient, to be used as design standards.

62. Both the SAPs and SyAPs are consistent with IAEA standards and guidance and are supported by more detailed TAGs (Ref. 26).

3.5 Joint Working with the Environment Agency and Joint Programme Office

63. ONR and the Environment Agency have separate legal roles and responsibilities, but the GDA process is designed to ensure that regulators work in a coordinated manner to ensure consistent outcomes. This is aligned with the requirements within the 'Regulators' Code' (Ref. 31).

64. In order to ensure that both regulators work in a coordinated manner, one or more representatives from the Environment Agency are present in ONR's project team meetings, in RRMs and in the sub-division board. Many of the processes are common to both regulators, such as acceptance of design modifications and in some disciplines, like MSQA, both regulators have joint technical meetings, workshops and inspections.

65. ONR's guidance to RPs (Ref. 16) describes the coordination between both regulators. To help administer both regulators' GDA process, a Joint Programme Office (JPO) was set up. The JPO provided the primary administrative interface between the RP and the regulators (Ref. 18).

4 THE GDA REQUESTING PARTY

4.1 Organisation

66. CGN and EDF SA created GNSL as a joint venture company to undertake the GDA for the UK HPR1000 reactor. GNSL is owned by GNI (66.5%) and EDF Energy Holdings Limited (33.5%), the UK subsidiaries of CGN and EDF SA respectively. GNSL acted on behalf of the three joint requesting parties, CGN, EDF SA and GNI. Therefore, we have referred to the three joint requesting parties as the RP.

67. GNSL was supported by its parent organisations, that have defined their roles in the PCSR:

- CGN is the 'designer', responsible for undertaking technical aspects of the design and adaptation of the Hualong technology into the UK HPR1000 whilst considering UK context. Production of safety and environmental GDA submissions is primarily performed by CGN with support from EDF SA.

- EDF SA provides technical expertise to support the UK HPR1000 GDA project. This includes reviewing technical documentation, providing experience of constructing and operating plants in France and the UK, as well as the knowledge of international good practice applied to the existing nuclear fleet and in past GDA projects, in particular the UK EPR™ GDA.

68. In instances where the UK context is particularly relevant (for example in the production of security submissions), the RP recognised that wider collaborative effort was required. Where appropriate, the RP was supported by third party contract partners, based on technical competencies relevant to the project.

69. While CGN and EDF SA were two of the parties requesting the GDA, they were also formal service providers to GNSL, making the structure of, and logistics within, the RP complex.

4.2 Interactions with the Requesting Party

70. CGN and EDF SA brought a wealth of experience to the UK HPR1000 GDA, both as designers and operators of NPPs. During our interactions with both organisations, we observed on multiple occasions the extensive technical expertise that resides within both organisations. Therefore, the partnership between these organisations brought important benefits to the GDA, particularly when considering the knowledge of the UK regulatory environment within EDF SA.

71. The RP's arrangements matured further during Step 4 of GDA, with clear evidence of GNSL, CGN and EDF SA capturing and acting upon learning from Steps 2 and 3. The coordination between the three organisations improved and procedures were developed, improved and embedded.

72. We found the RP willing to engage with ONR and in particular during Step 4 of GDA, ONR had detailed technical engagement across all technical disciplines, including several workshops and inspections.

73. During Step 4 of GDA, the RP overcame the technical challenges identified during this step and was responsive to the outcome of ONR's assessments, including the safety case health check and other project reviews. The RP put measures in place to improve the areas highlighted by those reviews, which included the support from UK contractors to improve the traceability of CAE, or 'golden thread', throughout the generic UK HPR1000 safety case.

5 COLLABORATION WITH OVERSEAS REGULATORS

74. ONR considers international cooperation important for the successful delivery of regulation of new reactors. Thus, in our GDA projects, we seek and welcome opportunities for collaboration with overseas regulators dealing with the same reactor designs. To do this we take into account international good practice, international standards and the assessment undertaken by overseas regulators. We also work with overseas regulators to benefit from their work and experience where appropriate.

75. It is important to stress, however, that any cooperation with other nuclear regulators does not replace ONR conducting its own independent assessment but supplements it with additional information and insights. The benefits of this international collaboration include obtaining access to independent analyses and audits, sharing

of technical opinion, early insights into construction and commissioning issues and promotion of a more consistent and harmonised international approach.

76. The generic UK HPR1000 design uses Chinese Hualong technology. The reference plant for the UK HPR1000 is Fangchenggang NPP Unit 3, undergoing commissioning in China. Therefore, establishing and maintaining collaboration with the Chinese nuclear regulator, the National Nuclear Safety Administration (NNSA) was a priority for ONR in the UK HPR1000 GDA.

77. In September 2017 NNSA and ONR and Environment Agency launched a bilateral China/UK regulatory working group with two key objectives:

- to share information and experience; and
- to identify opportunities for joint visits and inspections.

78. A work plan was established and deployed based on bilateral workshops covering a variety of topics of mutual interest such as safety review standards, civil nuclear security requirements, radioactive waste management and human factors.

79. Four senior bilateral steering group meetings were held during GDA. The fourth meeting took place in November 2021. During this meeting, the regulators discussed progress of the UK HPR1000 GDA, regulatory expectations in relation to spent fuel transport cask drop accidents, and experience and lessons learnt from the construction of Fangchenggang NPP Units 3 and 4 and Hinkley Point C, the commissioning of Fangchenggang NPP Unit 3, and the first years of operation of Taishan NPP. The UK and the Chinese regulators found the exchange of information mutually beneficial.

80. In parallel to the bilateral regulatory cooperation between China and the UK, in September 2017 a HPR1000 design specific working group (HPR1000WG) was created within the Organisation for Economic Cooperation and Development-Nuclear Energy Agency’s (OECD-NEA) Multinational Design Evaluation Programme (MDEP). The members of this working group are NNSA, ONR, Argentina’s Autoridad Regulatoria Nuclear (ARN), and South Africa’s National Nuclear Regulator (NNR). Two technical expert subgroups within the HPR1000WG were created relating to severe accidents and treatment of external and internal hazards.

81. The programme of work of the HPR1000WG included the development of common positions and technical reports on a variety of key topics of interest such as:

- Lessons learnt from the Fukushima-Daiichi NPP accident.
- Regulatory approaches to severe accident analyses.
- Post loss-of-coolant-accident strainer performance.
- Hydrogen management during severe accidents.
- First plant only tests.
- Regulatory positions on internal and external hazards.

82. In 2020, the HPR1000WG published three reports to which ONR made significant contributions:

- TR-HPR1000WG-01: ‘Hydrogen Control During Severe Accidents’, September 2020 (Ref. 32)
- TR-HPR1000WG-02: ‘Technical Report on Regulatory Requirements and Practices for Severe Accidents’, December 2020 (Ref. 33)
- CP-HPR1000WG-01: ‘Common Position Addressing Fukushima Daiichi NPP Accident-Related Issues’, November 2020 (Ref. 34)

83. The outputs and insights obtained from our international cooperation have been valuable to inform our assessment.

6 GDA COMMENTS PROCESS AND PUBLIC ENGAGEMENT

84. ONR places great importance on being open and transparent to ensure the public is informed of its work and its regulatory decisions, to inspire public trust and confidence. Within GDA, ONR does this by publishing, on the GDA joint regulators website (Ref. 7), our GDA guidance, the ROs raised during our assessment and corresponding resolution plans, and our assessment reports.

85. As part of the GDA process GNSL published information on the reactor design as well as the technical submissions such as the PSR ahead of Step 2, the PCSR, GSR and Pre-construction Environmental Report (PCER) ahead of Step 3, and updated versions of these three documents ahead of Step 4. GNSL's website (Ref. 4) included a comments process where the public could comment on any aspect of the UK HPR1000 reactor technology, design, safety, security and environmental features via the website or by post. The comments process opened in November 2017 and closed in September 2021.

86. During GDA, GNSL received a total of 73 public comments and 16 of these comments were considered out of the scope of GDA. ONR's consideration of the public comments made before Step 4 is reported in previous ONR's summary reports (Ref. 6, Ref. 10).

87. During Step 4 of GDA, GNSL received 28 public comments (February 2020 – September 2021), some of which were out of the scope of GDA as they referred to site-specific matters. The comments within scope related to technical aspects of the reactor technology, design, safety, security and environmental features. Some of the recurring technical themes were climate change, nuclear waste and spent fuel management, as well as queries on unproven technology and security.

88. The RP responded to all comments. All comments and responses were shared with the regulators for consideration in the assessment process as appropriate. All of the technical matters raised via the RP's public comments process, and within the scope of GDA, have been covered by our assessment.

89. In addition, as part of its GDA process, the Environment Agency consulted on its preliminary conclusions following the detailed assessment of the environmental aspects of the generic UK HPR1000 design. The consultation ran for 12 weeks from January to April 2021 and included nine public engagement events. We supported the Environment Agency in all these events, responding to questions from the attendees which were relevant to ONR.

90. Out of all the public responses to the Environment Agency's consultation, 16 related to ONR's vires and covered technical aspects such as extreme weather, cyber security, on-site waste storage, decommissioning, passive safety, accident scenarios and substantiation of systems. ONR evaluated the public comments to obtain further insights to inform our assessment. We can confirm that all the technical matters relevant to ONR's work raised via the Environment Agency's public consultation process have been covered by our assessment.

91. Finally, throughout GDA, ONR had further engagements with Non-Governmental Organisations (NGOs) and local councils around the Bradwell B site to discuss the GDA scope, process, and site-specific matters in relation to Bradwell B. During those discussions, NGOs mentioned the importance to report how the IAEA fundamental

safety principles have been considered by ONR in GDA. We have taken on board this comment and addressed it in sub-section 8.1 of this report.

7 OVERVIEW OF THE UK HPR1000

7.1 General Description

92. The generic HPR1000 design is described in the UK HPR1000 PCSR (Ref. 13). The UK HPR1000 is a Pressurised Water Reactor (PWR) designed by CGN using the Chinese Hualong technology. Its electric output is approximately 1180MW.

93. The UK HPR1000 has evolved from a sequence of reactors that have been constructed and operated in China since the late 80s, including the M310 design used at Daya Bay and Ling'ao (Units 1 and 2), the CPR1000, the CPR1000^{+} and the more recent ACPR1000. The first two units of CGN's HPR1000, Fangchenggang NPP Units 3 and 4, are under construction in China. Fangchenggang NPP Unit 3 is the reference plant for the UK HPR1000. The PCSR (Ref. 13) indicates that the design is claimed to have a lifetime of at least 60 years.

94. The generic UK HPR1000 design is a three-loop PWR. Each loop consists of primary pipes connected to the Reactor Pressure Vessel (RPV) (referred to as cold and hot leg respectively), one Reactor Coolant Pump (RCP) in the cold leg, and one Steam Generator (SG). One of the loops contains a pressuriser connected to the hot leg. The pressuriser function is to maintain high pressure within the primary reactor circuit and to avoid boiling of the reactor coolant. The operational pressure of the primary circuit is 15.5 MPa (abs).

95. Light water is used as coolant to extract the heat from the reactor. This water is also necessary to maintain the nuclear reaction in the core. Hot water leaves the reactor via the hot legs and enters the SGs where it transfers the heat to the secondary side. The primary coolant leaving the SGs, which is now at lower temperature, is then pumped back into the reactor via the cold legs. The steam produced from the heat transferred to the secondary side of the SGs drives a turbine that, ultimately, via a generator produces electricity.

96. The RPV is a cylindrical steel vessel designed to withstand high temperatures and pressures. The RPV hemispherical upper head is removable to allow refuelling of the reactor every 18 months. The RPV houses the reactor core and in-core instrumentation, and the reactor internals. The reactor core is made up of 177 fuel assemblies and 68 control rod assemblies; each fuel assembly contains 264 fuel rods, 24 guide tubes and one instrument tube arranged in a 17x17 array. Each fuel rod consists of a metallic cladding made of a zirconium alloy housing the nuclear fuel, which is in the form of small ceramic pellets, made of uranium dioxide, stacked up inside the cladding.

97. The Reactor Building houses key equipment such as the RPV, RCPs, SGs, pressuriser, primary and secondary circuit piping and the safety injection system accumulators. The Reactor Building is based on a double-walled containment with large free volume. There is ventilation in the annulus between the two walls to reduce the risk of uncontrolled radioactive releases to the environment in case of accidents. A large tank of water located inside the containment (in-containment refuelling water storage tank) provides the source water for the low and medium head safety injection systems.

98. Three Safeguard Buildings adjacent to the Reactor Building house key safety systems. The main control room is located in one of the Safeguard Buildings. The

Fuel Building is also adjacent to the reactor. It contains the fuel handling and short-term storage facilities.

99. The PCSR (Ref. 13) indicates that the Reactor Building, the Fuel Building and all three Safeguard Buildings are designed to withstand an earthquake of magnitude 0.3g. The PCSR also indicates that the containment, the Fuel Building and one of the Safeguard Buildings are resistant to the crash of a large commercial aircraft. The Reactor Building, Safeguard Buildings, Fuel Building and Nuclear Auxiliary Building are key facilities in the area generally referred to as the nuclear island (Figure 3). The Turbine Building is the central part of the so-called conventional island.

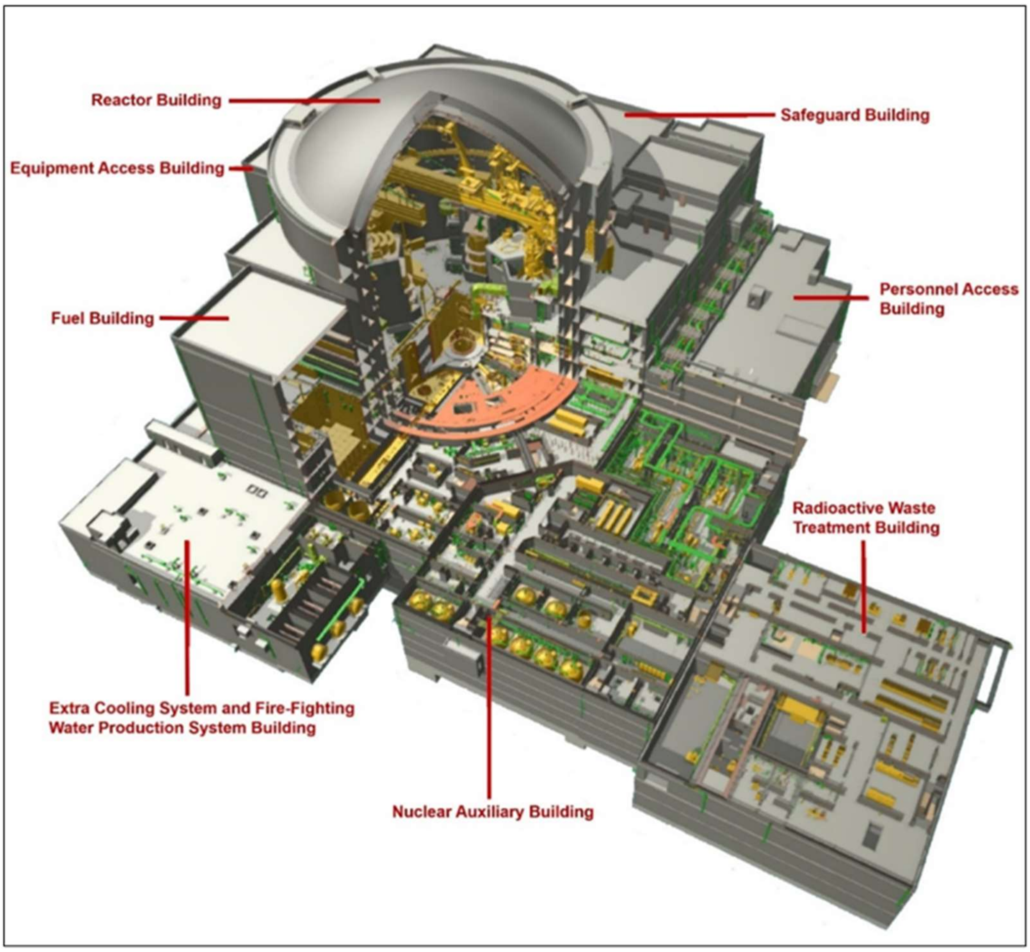


Figure 3: Nuclear Island (Picture courtesy of CGN)

7.2 Safety Systems

100. In case of events that take the reactor out of its normal operating regime there are safety systems to shutdown the reactor and maintain it in a shutdown state, to cool down the reactor and to prevent the release of radioactive material and take the reactor to a safe and stable condition. Brief introductions to the UK HPR1000 safety systems can be found in Chapter 2 of the PCSR (Ref. 13) and are described in more detail in Chapter 7, and therefore not repeated here. It is however worth highlighting a few key features related to the safety of the generic UK HPR1000 design.

101. The design philosophy underpinning the UK HPR1000 reactor cooling safety function is based on three independent trains of engineered safety features physically

separated in the three Safeguard Buildings discussed above. This arrangement offers 3x100% redundancy. Each Safeguard Building houses:

- One train of the (motor-pump driven) emergency feedwater system to feed water into the SGs in case of loss of normal feedwater.
- One train of the safety injection system. The safety injection system has three sub-systems, namely, the low head safety injection (also used for residual heat removal during normal shutdown), the medium head safety injection, and the accumulators (note that the accumulators are located inside the Reactor Building).

102. Although the safety philosophy is mainly based on active systems, the generic UK HPR1000 design includes additional passive features of importance to safety. These are the passive secondary residual heat removal system, and the passive reactor cavity injection system:

- The passive secondary residual heat removal system has been designed to remove heat from the SGs (and thus from the reactor) in the event of complete loss of both normal and emergency feedwater. It consists of a large water tank located surrounding the upper part of the outer containment wall, and associated piping and connections to the SGs. It is designed to condense the steam from the SGs using natural circulation, in the event of total loss of normal and emergency feedwater (See Figure 4).
- The passive reactor cavity injection system supports the In-Vessel Retention (IVR) function. For the generic UK HPR1000 design, the design choice to manage severe accident scenarios where there is core degradation is based on retention of the molten debris inside the RPV using engineered means to externally flood the RPV. This strategy is called IVR.

103. It is worth noting that the accumulators in the safety injection system, which have also been a safety feature in PWRs of previous generations, are also passive.

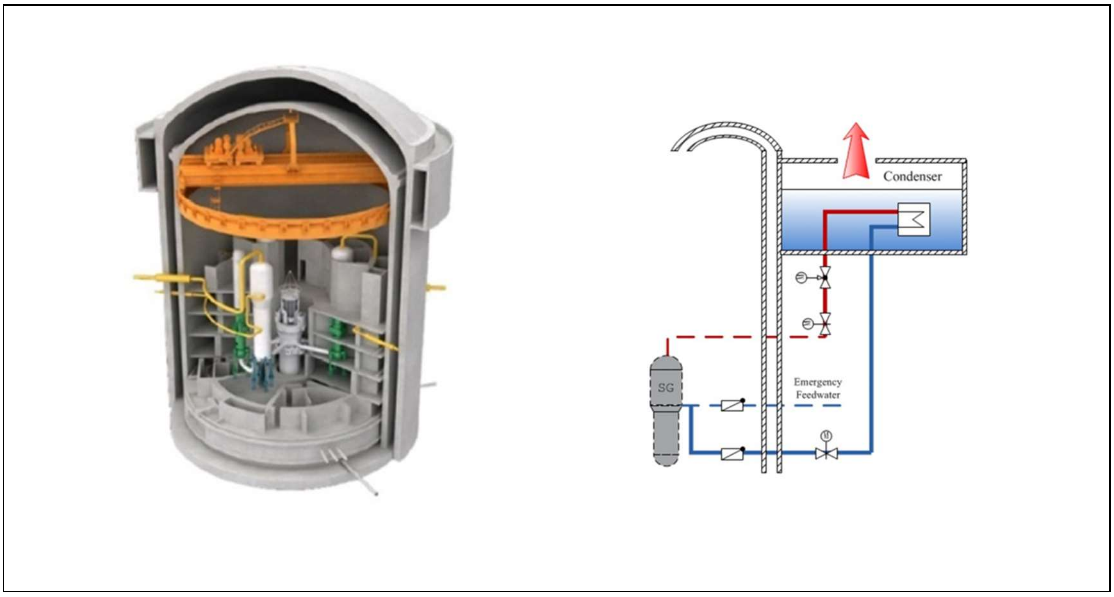


Figure 4: Secondary Passive Residual Heat Removal System (Picture courtesy of CGN)

7.3 GDA Scope

104. The scope of the UK HPR1000 GDA was originally formalised by the RP in June 2018 (Step 2 of GDA) and presented in terms of Structures, Systems and Components (SSCs) within scope, Generic Site Envelope (GSE), technical disciplines covered within GDA, and nine cross-cutting / multidisciplinary topics (Ref. 35). This was a useful document for our inspectors to have a clear understanding of what the RP considered to be within the scope of GDA, and to challenge, as appropriate, if there were discrepancies between ours and the RP's understanding of what should be within scope. At the end of Step 3, we reported that, for the most part, ONR had been satisfied with the updated scope report provided by the RP (Ref. 36), but also that further refinements of the scope might be necessary during Step 4 (Ref. 10). This has been the case and the granularity on the UK HPR1000 GDA scope was developed further throughout the assessment carried out during GDA Step 4.

7.4 UK HPR1000 Safety and Security Cases

105. The scope of the UK HPR1000 GDA, and therefore the extent and boundaries of the DAC decision made by ONR, is underpinned by four major documents produced by the RP:

- (Generic) Pre-Construction Safety Report
- Generic Security Report
- Master Document Submission List (MDSL)
- GDA Design Reference

106. The RP's generic UK HPR1000 safety and security cases are arranged in a tiered structure (Figure 5) and it follows a CAE approach consistent with ONR guidance (Ref. 20) to demonstrate that the risks have been reduced to ALARP. The PCSR and GSR are tier 1 documents that contain the claims; the generic PCER is also a tier 1 document. Those documents are often referred to as 'head' documents because they provide an overview of the design, safety, security and environmental cases. The key documents describing the design, design basis, methodologies and key processes are tier 2 documents. Those documents provide the arguments (or reasoning) supporting the claims in the PCSR and GSR. The additional documents required to provide detailed supporting evidence were tier 3 documents.

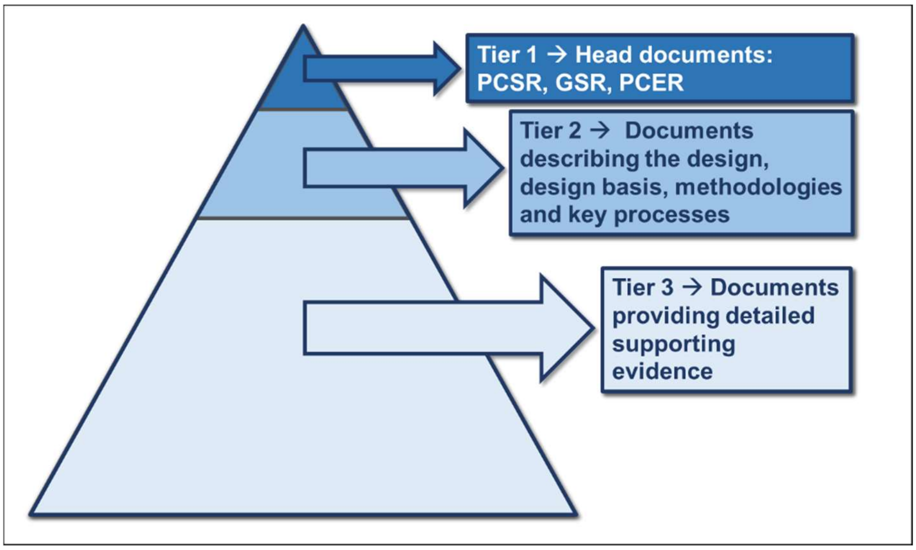


Figure 5: Safety and Security Case Hierarchy

107. The generic PCSR is structured into 33 chapters that cover the plant description, the generic site characteristics, the SSCs within the scope of GDA, safety analysis, operational aspects, and an ALARP evaluation of the design. The overarching safety objective described in the PCSR is that the generic design could be constructed, operated, and decommissioned in the UK on a site bounded by the GSE in a way that is safe, secure and protects people and the environment. The RP then defines a series of high-level claims to provide structure to its safety case. PCSR version 2 (Ref. 13) is the final version of the generic PCSR.

108. The GSR is the RP's 'head' document for security and provides an overview of the generic security case for the UK HPR1000. It also offers a road map of tier 2 and tier 3 submissions and how they inform the RP's high-level security concept. GSR version 2 is the final version of the GSR (Ref. 14).

109. The MDSL lists all the consolidated safety case documents submitted to the regulators, these include the PCSR, GSR, PCER, all the tier 2 documents, and all the tier 3 documents that have been submitted to the regulators for assessment. The RP has undertaken verifications of the MDSL to ensure that it contains the latest revisions of all the safety, security and environmental submissions. The final MDSL is dated November 2021 (Ref. 37).

110. At the core of GDA is the Design Reference (DR), which lists the documents that describe the design of the reactor and associated plant that the GDA submissions refer to Fangchenggang NPP Unit 3 is the reference design for the generic UK HPR1000 design. This baseline was formalised in an initial issue of a GDA DR report, DR1, in 2018. DR1 was used as the basis for version 0 of the PCSR, GSR and PCER.

111. The RP followed its own design review process to ensure that all the design changes introduced during GDA were captured at each DR, which was revised several times to reflect the latest design reference. For example, 49 design modifications derived from Fangchenggang NPP Unit 3 were identified by the RP in Step 3 and included in the scope of the GDA.

112. The GDA design is 'frozen' at a specific date known as the Design Reference Point (DRP). In December 2019, DRP for UK HPR1000 was declared and DR2.1 was established. In GDA the RP may wish / need to develop its design beyond the DRP, for example, in response to ROs. However, from the moment the DRP is declared, the regulators have a role in accepting further design modifications into the scope of the GDA. During Step 4 of the GDA, two further design references have been established (DR2.2 and DR3.0).

113. In total 95 design modifications derived from the specific work done in GDA have been included in the scope of GDA with the following breakdown:

- 23 design modifications included throughout DR1, DR2 and DR2.1
- 58 design modifications included in DR2.2
- 14 design modifications included in DR3.0

114. DR3.0 is the final design reference for the generic UK HPR1000 design and is reflected in the DR3.0 report (Ref. 38). Versions 2 of the PCSR and GSR are aligned with DR3.0.

8 ASSESSMENT WORK CARRIED OUT BY ONR

115. The following sub-sections provide a summary of the assessment undertaken by ONR during Step 4 of GDA. This includes:

- a high-level summary of how our assessment has considered the fundamental safety and security assessment principles;
- the key outcomes of our assessment across the 21 technical disciplines;
- the key outcomes of our assessment for the topics covered in the cross-cutting report; and
- our overall judgment on the adequacy of the safety and security cases and of the RP's ALARP demonstration.

116. The sub-sections summarising our assessment across the 21 technical disciplines and the sub-section on the cross-cutting report are structured consistently. For each topic we provide an introduction of the topic, an overview of the assessment carried out in Step 4 highlighting the areas of focus, and then we present our conclusions and a recommendation on whether, from the perspective of each technical discipline, a DAC may be granted. We also refer to the individual assessment reports where the detailed assessments are presented.

117. For completeness, Annex 1 provides an overview of the remaining cross-cutting topics which are not summarised explicitly in the following sub-sections, indicating where those are reported.

8.1 Fundamental Principles

118. ONR's fundamental safety principles (SAPs FP.1 to FP.8) (Ref. 25) are considered to be the foundation for the safety and radioactive waste management principles in the SAPs. They reflect UK law and accepted international good practice, in particular the IAEA fundamental safety principles (Ref. 39). Similarly, ONR's fundamental security principles (SyAPs FSyP 1 to FSyP 10) (Ref. 30) are considered to be the foundation for the security delivery principles in the SyAPs. They reflect UK law, obligations under the Convention on the Physical Protection of Nuclear Material and accepted international good practice in the Nuclear Security Series documents published by the IAEA.

119. This sub-section provides a discussion of how our assessments have considered the fundamental principles. Although not all fundamental principles are pertinent to GDA, the intent of all of them has been considered in our assessment. However, this discussion is focused on those principles directly applicable to GDA. The fundamental principles in the SAPs mirror some of the IAEA fundamental safety principles (Ref. 39), noting that the IAEA principles cover a wider scope than safety assessment, such as situations outside ONR's vires or the role of government. Both ONR's and IAEA's principles are referenced for clarity, together with the additional information provided in the IAEA standard (Ref. 39).

120. SAP FP.3, 'Optimisation of protection' or IAEA Principle 5 states that the "protection must be optimised to provide the highest level of safety that is reasonably practicable". The IAEA standard provides further guidance on what the principle implies, which includes determining whether radiation risks are as low as reasonably achievable. We considered this when assessing the RP's demonstration that the risks had been reduced to ALARP. This was completed at the technical discipline level and was also taken into account during ONR's assessment of the RP's holistic ALARP argument, summarised in sub-section 8.24.

121. SAP FP.4, ‘Safety assessment’ relates to the demonstration by the dutyholder (in this case the RP) that the hazards are understood and controlled, and this is demonstrated through the safety case. Our assessment focused on the adequacy of the RP’s generic safety case and this is reported at the technical discipline level and through the cross-cutting topics. Our assessment included the identification and traceability of requirements through the safety case (sub-section 8.23), one of the key characteristics of an adequate safety case.

122. SAP FP.5, ‘Limitation of risks to individuals’ or IAEA Principle 6 states that the “measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm”. The IAEA standard (Ref. 39) provides further guidance and explains that doses and radiation risks must be controlled within specified limits. We assessed the RP’s design against ONR’s numerical targets and UK legal limits which led to a number of improvements and design modifications. The limitation on risks to individuals is part of the ALARP argument and it was assessed at the technical discipline level. In addition, key cross-cutting topics, such as the fuel route safety case, were assessed by ONR to ensure that this principle had been addressed across all relevant aspects of the design and safety case.

123. SAP FP.6, ‘Prevention of accidents’ states that “all reasonably practicable steps must be taken to prevent and mitigate nuclear or radiation accidents”. FP.6 mirrors IAEA Principle 8 that establishes defence-in-depth as the primary means of preventing accidents. We assessed the defence-in-depth of the design at a discipline level and as a cross-cutting topic, where the safety analysis, engineering and operational aspects were considered holistically.

124. SAP FP.7, ‘Emergency preparedness and response’ or IAEA Principle 9 aims to ensure that adequate arrangements are made for emergency preparedness and response in case of nuclear or radiation accidents. Although emergency preparedness and response are not expected to be covered in detail in GDA, assumptions about the local population distribution and density feed into the GSE, the demonstration of compliance with numerical targets and the Level 3 Probabilistic Safety Analysis (PSA). These technical aspects were assessed by ONR. In addition, ONR assessed the RP’s high-level claims and arguments made in Chapter 32 of the PCSR, ‘Emergency preparedness’, in the Radiological Protection and Criticality Step 4 assessment, and in cross-cutting topics, such as defence-in-depth.

125. SAP FP.8, ‘Protection of present and future generations’ states that “people, present and future, must be protected against radiation risks”. FP.8 mirrors IAEA Principle 7, with the exception that IAEA Principle 7 also covers environmental aspects but, in England, those are assessed by the Environment Agency. The nuclear safety aspects and in particular the management of the radioactive waste have been considered by the following disciplines: Radioactive Waste Management, Decommissioning and SFIS. ONR also assessed the multidisciplinary aspects of the radioactive waste safety case and the SFIS as cross-cutting topics.

126. Most of the fundamental security principles in ONR’s SyAPs (Ref. 30) are not relevant during GDA, as they require dutyholder choices, detailed design information and site-specific aspects that are outside the scope of GDA. However, FSyP 6 (‘Physical protection systems’) and FSyP 7 (‘Cyber security and information assurance’) are relevant and have been considered as part of our Security assessment (Ref. 40). These fundamental security principles are based on a risk-based approach and the application of security industry RGP such as defence-in-depth. These principles describe the need for risk-based assessments, the application of a ‘secure by design’ approach and a framework for delivering the

appropriate mitigation. The RP has also structured its analysis and reports around these principles.

127. SyAP FSyP 6, 'Physical protection systems' aims to ensure that the physical protection system integrates technical and procedural controls to form layers of security that build defence-in-depth and are graded according to the potential consequence of a successful attack. This was considered in the Security assessment, specifically, the RP's conceptual physical protection system design framework was assessed against security delivery principle 6.3 ('Physical protection system design').

128. SYAP FSyP 7, 'Cyber security and information assurance' requires arrangements that integrate technical and procedural controls to protect the confidentiality, integrity and availability of sensitive nuclear information and technology. In particular, the RP's framework for resilience against cyber threats described at security delivery principle 7.3 ('Protection of nuclear technology and operations') was assessed.

129. In summary, our assessment has considered all fundamental principles at a technical discipline level and at a multidisciplinary level through the cross-cutting topics. Some of the cross-cutting topics include aspects such as the numerical targets or defence-in-depth, which are intrinsic to the fundamental principles.

8.2 Chemistry

130. Chemistry can affect materials, systems and processes and their associated hazards in a variety of ways. In the broadest sense, chemistry assessment during GDA can be considered to cover the influence of chemistry on reactivity, pressure boundary integrity, fuel and core component integrity, radioactive waste generation and radiological doses to workers and the public. The objective is for the RP's safety case to demonstrate that relevant effects are understood, and their impact on safety is minimised, to reduce relevant risks to ALARP. This is considered by ONR under the Chemistry technical discipline.

131. ONR's assessment considered a number of main themes of relevance to chemistry control. These were: control of coolant reactivity, protection of the main structural materials, maintaining fuel integrity and performance, minimisation of out of core radiation fields and minimisation of releases of radioactivity and flammable gases during fault / accident conditions. The assessment focused on the influence of chemistry during normal operating conditions, in particular on the safety claims made on controlling the chemistry within defined limits, the adequacy of these and the consequence(s) of operating outside the limits. ONR also considered the effects of chemistry during fault / accident conditions as part of this topic, as this can influence the progression and ultimate consequences of a particular fault / accident. This includes the generation, transport and behaviour of radionuclides and reactive species and focused on the adequacy of relevant assumptions in the supporting safety analysis. This spans the full range of fault / accident conditions from design basis faults up to and including severe accidents.

132. Throughout GDA, the RP made significant improvements to its safety case for chemistry, improving the level of detailed evidence provided in support of claims and arguments, and including a narrative in the safety case that links with the CAE structure and results in a case that is straightforward to navigate. The RP also identified a number of chemistry-related improvements to the generic UK HPR1000 design that helped to demonstrate that relevant risks had been reduced to ALARP.

133. The conclusions of ONR's assessment are:

- The RP has identified a suitable set of claims on the operating chemistry for all modes of operation. In most cases, the RP has provided adequate supporting evidence to demonstrate that the claims can be achieved by the generic design.
- The RP has provided an appropriate demonstration that the generic plant design and engineering are adequate to achieve effective control of chemistry for relevant systems (including dosing, monitoring and clean-up), and to maintain the chemistry within the limits defined within the safety case.
- The different chemistry requirements likely to be necessary during different operating modes, and during different stages of the plant's lifetime have been suitably considered. The major chemistry parameters which would be expected to form part of the plant operating rules have been identified and limits have been appropriately justified.
- The RP has appropriately considered the through-life performance of the chemistry-related SSCs, and the effects of the chemistry regime on the susceptibility to material degradation mechanisms, in making suitably justified materials selection decisions.
- The generation, transport and accumulation of radioactivity has been suitably analysed and quantified and the safety case successfully developed to provide an adequate demonstration, for GDA, that radioactivity will be reduced to ALARP.
- An adequate demonstration has been made that the effects of chemistry during fault / accident conditions, including the generation, transport and behaviour of radionuclides and reactive species, are understood and that relevant risks have been reduced to ALARP.
- For those risks on which chemistry can have an influence, an appropriate overall demonstration has been made that chemistry effects are understood and that relevant risks have been reduced to ALARP.

134. Full details of ONR's assessment of this topic can be found in the Chemistry Step 4 assessment report (Ref. 41). ONR recommends that from a Chemistry perspective a DAC may be granted.

8.3 Civil Engineering

135. Civil engineering structures provide support to SSCs and protect them against the environment. Nuclear safety significant structures will also confine, shield and mitigate radioactive release. The scope of ONR's Civil Engineering assessment was to review the safety aspects of the generic UK HPR1000 design by examining the claims, arguments and supporting evidence in the safety case.

136. ONR's assessment focused on the following aspects of the generic UK HPR1000 safety case:

- residual matters from previous GDA steps;
- structure and content of the civil engineering safety case;
- design principles and methods for reinforced concrete primary structures;
- application of design principles and methods to:
    - Sample 1 – Seismic category 1 structure on common raft - Fuel Building
    - Sample 2 – Internal containment
    - Sample 3 – Common raft foundation

- Sample 4 – Seismic category 1 structures on individual rafts: Nuclear Auxiliary Building, Emergency Diesel Generator Building B and Station Black Out Diesel Generator Building
- Sample 5 – Seismic category 2 structure: Equipment Access Building
- Sample 6 – Malicious aircraft impact protection; and

- further safety case considerations including safety case consolidation.

137. The conclusions of ONR's assessment are:

- Residual matters from the Civil Engineering Step 3 assessment have been adequately resolved within this assessment.
- Regarding the civil engineering safety case, the overall structure, scope and limitations are appropriate for generic design assessment, and the cross-cutting inputs are predominantly coherent. The traceability and clarity of the safety functions and the RP's use of safety functional requirement schedules are adequate. The RP has developed the civil engineering safety case to a proportionate level that meets the purpose of GDA. This provides an adequate reference point from which to develop it more fully in the site-specific stage.
- The civil engineering design principles and methods articulated by the RP are appropriate for the purposes of GDA and are adequately aligned with RGP and the intent of the SAPs. These methodologies provide a robust baseline ready for future augmentation to include further detail and site-specific aspects.
- From the ONR assessment of the application of the design principles and methodologies to the six sample areas, it has been confirmed that the RP has presented an adequate demonstration of the application of its design principles and methodologies.
- Those aspects of novelty, radiation protection, defence-in-depth, constructability, examination, inspection, maintenance, testing and decommissioning have been adequately considered.
- In summary, the RP has adequately demonstrated the application of RGP. Furthermore, the RP has demonstrated that, for the purposes of GDA, the safety case demonstrates that risks are reduced to ALARP.

138. Full details of ONR's assessment of this topic can be found in the Civil Engineering Step 4 assessment report (Ref. 42). ONR recommends that from a Civil Engineering perspective a DAC may be granted.

8.4 Control & Instrumentation

139. Control & Instrumentation (C&I) performs a significant nuclear safety role through the provision of automatic and manual control of equipment that has a nuclear safety function, and by providing feedback on the status of the reactor and associated equipment to operators and support staff.

140. ONR's C&I assessment covered the design, analysis, commissioning, operation, testing and maintenance of the main safety and safety related C&I systems for the UK HPR1000, and considered the extent to which the design of the C&I architecture, as well as the systems and the platforms on which those systems are based, have met the requirements and expectations of RGP.

141. The main themes considered by ONR's assessment were the structure and clarity of the C&I safety case, adequacy of the C&I architecture, adequacy of the C&I

platforms, adequacy of the C&I systems (including Human Machine Interface (HMI) devices and justification of smart devices), and cyber security of C&I systems.

142. The conclusions from ONR's assessment are:

- The C&I safety case, comprising the PCSR, supporting 'basis of safety case' documents and the underpinning evidential documentation, has been adequately developed for the purposes of GDA.
- The C&I architecture is consistent with RGP, as defined in international standards and guidance, and has been adequately substantiated for the purposes of GDA.
- The RP has identified significant shortfalls in the production excellence of the FirmSys platform against the expectations of safety class 1 and has developed a suitable programme of work to address these shortfalls. The licensee will need to ensure the implementation of the programme of work.
- The development of a hardware-based platform for the secondary protection system provides adequate diversity between different layers of defence in the C&I architecture.
- The RP has identified appropriate standards against which the centralised C&I systems will be designed and has identified compensating measures to resolve shortfalls that were revealed by compliance analysis. However, significant further work is required from the licensee as part of the detailed design to complete the safety justification of the C&I platforms and systems.
- From a C&I perspective the RP has demonstrated that the risk of a cyber-attack compromising safe operations is adequately controlled.
- The consideration of HMI in the C&I safety case is sufficiently well developed for the purposes of GDA.
- The RP has developed a suitable and sufficient methodology for the safety justification of smart devices and has demonstrated that this methodology can be practicably implemented.

143. Full details of ONR's assessment of this topic can be found in the C&I Step 4 assessment report (Ref. 43). ONR recommends that from a C&I perspective a DAC may be granted.

8.5 Conventional Fire Safety

144. The Conventional Fire Safety assessment focuses on those areas presenting the greatest life safety risk. These are locations where building design varies from conventional expectations for means of escape in case of fire. ONR assessed the structural fire protection and internal layout arrangements of buildings on the nuclear island, to ensure that the design enables the occupier to comply with UK legal requirements for fire safety and provide adequate means of escape for the occupants in case of fire. Additionally, ONR assessed the design to ensure that adequate protection and suitable facilities are in place for firefighters. ONR assessed non-structural fire protection arrangements, when they were relevant and provided supporting mitigation for design features which do not meet recommendations contained within codes of practice in design of buildings for fire safety. ONR's assessment included:

- Nuclear Auxiliary Building
- Radioactive Waste Building
- Extra Cooling System and Fire-fighting System Building
- Diesel Generator Building
- Personnel Access Building

- Reactor Building
- Safeguard Building
- Fuel Building

145. ONR's Conventional Fire Safety assessment focused on the following aspects of the generic UK HPR1000 safety case:

- Confirmation that the generic UK HPR1000 design can satisfy UK legal requirements for fire safety in the design of buildings.
- Benchmarking the structural arrangements and fire protection against RGP to ensure that adequate means of escape in case of fire are available for the occupants and the design incorporates adequate facilities for firefighters.
- Other non-structural fire protection measures, where these are claimed as mitigation to support means of escape.

146. Where improvements in fire safety were required, the RP addressed them by implementing measures including structural modifications to the design and provision of fire engineered arrangements to adequately mitigate risk.

147. The conclusions from the Conventional Fire Safety assessment are:

- The fire safety strategy and other supporting documents, developed for each building, confirm that the generic UK HPR1000 design can satisfy UK legal requirements for fire safety in building design.
- Adequate structural fire protection and arrangements for means of escape are in place for the safety of occupants and suitable facilities are provided for firefighters.
- Where the design varies from RGP, suitable alternative arrangements are provided to ensure that risks are reduced to ALARP.

148. Full details of ONR's assessment of this topic can be found in the Conventional Fire Safety Step 4 assessment report (Ref. 44). ONR recommends that from a Conventional Fire Safety perspective a DAC may be granted.

8.6 Conventional Health and Safety

149. ONR regards the generic UK HPR1000 design, intended for construction and operation in GB, to be a construction project under Construction (Design and Management) Regulations 2015 (CDM 2015) (Ref. 45). ONR's assessment of Conventional Health and Safety focused on elements of the generic UK HPR1000 design with the potential to pose significant conventional (non-nuclear) risks to the health and safety of persons who are either engaged in the construction, operation, maintenance or decommissioning of the NPP, or may be affected by these undertakings.

150. The main themes considered during ONR's assessment of the generic UK HPR1000 design were whether the RP had demonstrated sufficient understanding and appreciation of GB conventional health and safety legislative requirements and RGP, and whether conventional health and safety risks to workers and others who may be affected by the design have been reduced to ALARP by applying the General Principles of Prevention (GPP) and Eliminate, Reduce, Isolate, Control (ERIC) principles during design work.

151. The conclusions of ONR's assessment are:

- The RP demonstrated sufficient appreciation, understanding and application of GB conventional health and safety requirements whilst undertaking the generic design of the UK HPR1000.
- The RP developed a CDM strategy and procedure which required the application of the GPP and ERIC principles during the design of the UK HPR1000.
- The evidence supplied by the RP has demonstrated the application of the GPP and ERIC principles during design work.
- Where possible within the generic UK HPR1000 design conventional health and safety risks have been reduced to ALARP.
- Where residual hazards and risks remain, which cannot be fully addressed during GDA, they have been systematically recorded to ensure that they can be effectively communicated for consideration during future design work.

152. Full details of ONR's assessment of this topic can be found in the Conventional Health and Safety Step 4 assessment report (Ref. 46). ONR recommends that from a Conventional Health and Safety perspective a DAC may be granted.

8.7 Decommissioning

153. Decommissioning is the last stage in the lifecycle of a nuclear facility, which has been defined in international guidance as "the administrative and technical actions needed to remove some or all of the regulatory controls from a facility." Although decommissioning is not expected to take place for many years, ONR assessed the safety of decommissioning during GDA, with the aim of establishing that the UK HPR1000 can be decommissioned safely using currently available technologies for dismantling and decommissioning, not on technologies that may become available in the future. ONR's guidance for GDA (Ref. 16) indicates that new NPPs should be designed and operated so that the risks from future decommissioning are minimised to ALARP. A key aspect of the assessment was consideration of design for safe decommissioning, including features that facilitate decommissioning.

154. The main themes considered in ONR's assessment of decommissioning were design, the strategy and plan, methods and plans for decontamination and dismantling, source term and management of decommissioning wastes, with the overall objective of determining that relevant risks have been reduced to ALARP and that the design has taken due account of relevant Operating Experience (OPEX).

155. Throughout GDA, the RP made significant improvements to its safety case for decommissioning, which demonstrated that the generic UK HPR1000 design includes features that facilitate decommissioning, and that the RP has made good use of OPEX in developing the design.

156. The conclusions of ONR's assessment are:

- The decommissioning source term has been derived using appropriate techniques underpinned by a verified and validated model and/or relevant OPEX. The conservatism applied is appropriate to address uncertainties, meets relevant regulatory expectations and is appropriate to GDA. The source term provides an appropriate basis for the preliminary assessment of radiological risks and estimating the inventory of decommissioning wastes.
- The selected decommissioning strategy of immediate dismantling is adequately underpinned and is consistent with regulatory expectations and government guidance on 'Funded Decommissioning Programme Guidance

for New Nuclear Power Stations' (Ref. 47) which sets out the strategic 'base case' assumptions.
- The RP has taken due account of international OPEX in decommissioning.
- The RP has provided information on decontamination and dismantling techniques and processes which is adequate to demonstrate that the UK HPR1000 can be decommissioned safely using current methods and technologies.
- The RP has provided information on the management of decommissioning wastes which meets relevant regulatory expectations, is appropriate to GDA and demonstrates that disposal routes are available (or, with the development of a Geological Disposal Facility (GDF), will be available) for radioactive wastes arising during decommissioning.
- The RP has provided information on planning for decommissioning that meets relevant regulatory expectations and is appropriate to GDA.
- The RP has provided information on design for decommissioning that adequately demonstrates that the generic design and intended operation will facilitate safe decommissioning.
- The RP has provided an adequate demonstration that relevant risks of decommissioning are reduced to ALARP.

157. Full details of ONR's assessment of this topic can be found in the Step 4 Decommissioning assessment report (Ref. 48). ONR recommends that from a Decommissioning perspective a DAC may be granted.

8.8 Electrical Engineering

158. The electrical power system at a NPP performs a significant nuclear safety role through providing power to all SSCs with electrically driven equipment that have a nuclear safety function. ONR's Electrical Engineering assessment considers the design, installation, operation and maintenance of the electrical power distribution network.

159. The main themes considered by ONR's assessment were whether the RP had demonstrated that the electrical systems and equipment are adequately designed to fulfil their role of supporting nuclear safety functions, rated for their duty in all defined operating conditions, including fault conditions. ONR's assessment has also considered if the power plant was capable of being connected to the UK transmission system.

160. Throughout GDA, the RP has made significant improvements to the structure of its safety case for electrical engineering and identified a number of improvements to the generic UK HPR1000 design that further reduce the risks to ALARP.

161. The conclusions of ONR's assessment are:

- The generic safety case, comprising of the PCSR, supporting basis of safety case and analyses, adequately demonstrates for the purposes of GDA that the electrical power system is capable of supporting plant safety functions in design basis and Design Extension Conditions (DEC).
- The architecture of the electrical power system is consistent with international guidance.
- The electrical system studies demonstrate the ability of the electrical power system to support SSCs important to safety at the power plant.
- Using generic connection data, the RP has shown that the power plant could be capable of being connected to the UK transmission system.

162. Full details of ONR's assessment of this topic can be found in the Electrical Engineering Step 4 assessment report (Ref. 49). ONR recommends that from an Electrical Engineering perspective a DAC may be granted.

8.9 External Hazards

163. External hazards include those natural or man-made hazards that originate externally to both a site and its processes, and over which the operator has little control. ONR's External Hazards assessment has sought to ensure that the effects of external hazards are minimised and adequate protection against them has been provided for in the generic UK HPR1000 design. This is to ensure that external hazards do not adversely affect the functionality or reliability of items important to safety (both safety and safety related systems), and that potential common cause effects of external hazards have been adequately addressed.

164. ONR's External Hazards assessment has focused on the following areas:

- Identification and screening of external hazards, including combinations of hazards.
- Definition of a GSE within which the plant is designed to operate safely, including those external hazards screened-in to GDA.
- The adequacy of the deterministic analysis for the generic UK HPR1000 design against external hazards and combinations of hazards retained in GDA.
- The interface between hazard analyses, protection measures and the generic UK HPR1000 safety case via the external hazards schedule.
- Analysis of the generic UK HPR1000 design against cliff-edge effects and beyond design basis events.
- Whether the generic UK HPR1000 design reduces risks from external hazards to ALARP.

165. Through GDA the RP has analysed the generic UK HPR1000 design against external hazards effects and loadings, identified improvements to further reduce the risks from external hazards to ALARP and has also made improvements to its generic UK HPR1000 safety case for external hazards.

166. The conclusions of ONR's External Hazards assessment are:

- A suitable range of external hazards and hazard combinations have been screened-in to GDA, with suitable justification provided for hazards that are screened out.
- The RP has defined an adequate GSE, with external hazards defined on a conservative basis.
- The RP's deterministic analysis shows that the generic UK HPR1000 design is robust against external hazards and hazard combinations, with measures provided to protect against hazard effects and/or qualification of items important to safety. The generic UK HPR1000 design also adopts good engineering practice including redundancy, diversity and segregation of safety trains to mitigate common cause effects of external hazards.
- The analysis has demonstrated an absence of cliff-edge effects.
- The generic UK HPR1000 design at this stage of development reduces the risks from external hazards to ALARP. The generic UK HPR10000 design will be further developed post-GDA to account for the conditions and hazards at a site selected for deployment of the reactor technology.

167. Full details of ONR's assessment of this topic can be found in the External Hazards Step 4 assessment report (Ref. 50). ONR recommends that from an External Hazards perspective a DAC may be granted.

8.10 Fault Studies

168. NPP safety cases need to consider the risks arising both from normal operation and from fault / accident conditions. Within ONR, the Fault Studies technical discipline takes a leading role in considering the latter. This is predominately through the assessment of a RP's deterministic analysis of design basis faults. However, reflecting modern RGP, the fault studies' scope also extends to the deterministic consideration of events outside design basis: DEC that do not result in significant fuel damage, also known as DEC-A events.

169. ONR's assessment was based on a consideration of the RP's framework for identifying faults, defining the limits of the design basis and performing the deterministic assessment. Following this, ONR assessed a sample of the RP's deterministic assessment of reactor faults, fuel route faults and non-reactor faults and considered the potential consequences against regulatory criteria.

170. Throughout GDA the RP made significant improvements to its safety case for fault studies and also identified a number of improvements to the design of UK HPR1000 that further reduce the frequency and consequences of potential faults to ALARP.

171. The conclusions of ONR's assessment are:

- The RP has adequately identified design basis faults and DEC for all reactor operating modes and has given appropriate consideration to fuel route and non-reactor facilities with significant radiological hazards.
- The RP has produced an adequate fault schedule with contents consistent with ONR's expectations.
- The RP has appropriately assessed faults with adequate tools and methods, with appropriate levels of conservatism.
- The RP has shown through its analysis that the successful operation of the safety measures identified in the fault schedule allows all relevant acceptance criteria to be met for reactor faults.
- The RP has demonstrated that the design is capable of protecting against a loss of Spent Fuel Pool (SFP) cooling and that the consequences of a loss of inventory from the SFP will be limited or that they can be isolated and water level maintained.
- There are no faults arising within the waste route which qualify for treatment as design basis faults.
- Where faults lead to a loss of one or more containment barriers the predicted radiological doses have been shown through conservative analysis to be acceptable against numerical targets established in ONR SAPs.
- Fault studies has been used to support general ALARP claims on the adequacy of the generic UK HPR1000 design. This has been supplemented in a number of areas by detailed optioneering studies where further design changes have been considered.

172. Full details of ONR's assessment of this topic can be found in the Fault Studies Step 4 assessment report (Ref. 51). ONR recommends that from a Fault Studies perspective a DAC may be granted.

8.11 Fuel and Core

173. Within the topic of Fuel and Core design, ONR considers the design and performance of the reactor fuel and in-core components under a wide range of conditions, both in normal operation and faults. The expectation is that with the installed protection and monitoring, the fuel and core system will continue to perform its safety functions under anticipated conditions.

174. The main themes considered by ONR's assessment were the reactor core nuclear design, reactor core thermal hydraulic design and reactor fuel system thermo-mechanical design. ONR also considered:

- the adequacy of reactor fuel and core data generated for the purpose of design basis analysis;
- parts of the reactor core safety case associated with how the UK HPR1000 plant will be operated;
- the evidence underlying the validity of the reactor fuel and core computer codes used; and
- the explicit demonstration that the reactor fuel and core designs reduce risks to ALARP.

175. Throughout GDA, the RP made significant improvements to its safety case for fuel and core design. The RP also made a small number of improvements to the generic design that further reduce risk.

176. The conclusions of ONR's assessment are:

- The reactor core nuclear design, reactor core thermal hydraulic design and reactor fuel system thermo-mechanical design are adequate for GDA.
- Reactor core data provided for the purpose of design basis analysis are adequate but there are shortfalls in the submitted evidence underlying a small selection of the fuel acceptance criteria, which should be addressed by the licensee.
- Parts of the reactor core safety case in which interactions between nuclear, thermal hydraulic and/or thermo-mechanical phenomena in the reactor core are particularly important are adequate for GDA, but there are areas where further work is needed to fully substantiate the RP's claim that a coolable geometry will be maintained in the unlikely event of a large break-loss of coolant accident.
- Parts of the reactor core safety case associated with how the UK HPR1000 will be operated are adequate for the purpose of GDA, but there are shortfalls against RGP in the strategy for failed fuel management during operation.
- Further work is required post-GDA to ensure that all safety case assumptions and requirements associated with operating rules, commissioning and Examination, Maintenance, Inspection and Testing (EMIT) are sufficiently clear and traceable.
- The evidence underlying the validity of the reactor fuel and core computer codes and associated documentation are adequate for the purposes of their specific applications in the fuel and core safety case in GDA.
- An explicit demonstration has been provided that the reactor fuel and core designs reduce risks to ALARP, which addresses ONR's key expectations for new reactor designs and is adequate for GDA.

177. Full details of ONR's assessment of this topic can be found in the Fuel and Core Step 4 assessment report (Ref. 52). ONR recommends that from a Fuel and Core perspective a DAC may be granted.

8.12 Human Factors

178. Human factors 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, human factors is principally concerned with the human contribution to nuclear safety during facility design, construction, commissioning, operation, maintenance and decommissioning, including normal, fault and emergency conditions. However, it is also appropriate to consider human factors where a conventional health and safety or security risk exists.

179. ONR's Human Factors assessment focused on the following aspects of the generic UK HPR1000 safety case: human factors integration; the approach to allocation of function; human factors engineering; and the identification, analysis and substantiation of Human Based Safety Claims (HBSCs). It also considered whether the RP had suitably demonstrated that the design met the principle of ALARP and the suitability and sufficiency of the human factors' safety case.

180. During GDA, the RP significantly increased its human factors capacity and capability. This had a demonstrable benefit to the safety of the generic UK HPR1000 design as it has produced a number of design enhancements and a more rounded overall safety case.

181. The conclusions of ONR's assessment are:

- The probabilistic Human Reliability Analysis (HRA) case shows that the design is suitably tolerant to human error against ONR's risk targets. However, further work will be needed to ensure the integration between Human Factors and PSA-led HRA. Similarly, the approach to HRA, which fails to suitably take account of, and model, the impact of credible errors on factors such as task timing, dependent failures, and workload requires improvement. This was mitigated for GDA by appropriate sensitivity analysis within the HRA
- The RP has demonstrated effective management of HBSCs during GDA. This is an important enabler for the licensee. HBSCs are actively captured in the fault schedule, PSA, and internal and external hazard schedules.
- The safety functional allocation between the technology and the human has been appropriately validated using a new proprietary method developed by the RP for GDA. This method has been shown to exceed RGP as it considers the complex nature of allocation that new technologies support. The RP recognises where further work will be necessary by the licensee, to consider a wider range of safety functions, such as activities relating to maintenance.
- The RP has proactively assessed its own performance in the human factors area during the course of GDA and has submitted a further action plan to demonstrate that it recognises the inherent scope limitations of Human Factors analyses during GDA and set out what additional work will be required during the site-specific stages. This closely aligns with ONR's assessment and reflects a realistic appraisal of performance providing confidence that in the generic UK HPR1000 safety case is clear what additional work will be required during the site-specific stages.

- The assessment identified a number of shortfalls against regulatory expectations, however these are matters of detailed design and are judged not to undermine the conclusions of the Human Factors assessment.

182. Full details of ONR's assessment of this topic can be found in the Human Factors Step 4 assessment report (Ref. 53). ONR recommends that from a Human Factors perspective a DAC may be granted.

8.13 Internal Hazards

183. ONR defines internal hazards as those hazards to plant, structures and personnel which originate within the site boundary but are external to the primary circuit in the case of power reactors. That is, the licensee has control over the initiating event in some form.

184. The main themes considered by ONR's assessment were whether the RP had adequately identified relevant internal hazards, applied appropriate hazard analysis methodologies and used them to determine the hazard consequences to nuclear safety significant SSCs to demonstrate that the risks from internal hazards had been reduced to ALARP.

185. Throughout the GDA, ONR held significant engagement with the RP. As result of these engagements and our assessment, the RP implemented various improvements to the safety case and modifications to address identified shortfalls and to reduce risks from hazards.

186. The conclusions of ONR's Internal Hazards assessment are:

- The RP has provided sufficient evidence to substantiate the claims arguments and evidence detailed in the PCSR, for the sample areas assessed.
- Detailed assessment of the methodologies applied for each internal hazard have been undertaken. The methodologies are broadly based on RGP. Where shortfalls were identified by ONR these have been resolved by the RP for the highest risk areas. Although some shortfalls remain, this is judged not to undermine the conclusions within the Internal Hazards assessment.
- The RP has provided adequate details of its hazard identification and screening processes to demonstrate that the key hazard areas have been identified and analysed.
- The generic UK HPR1000 design provides adequate segregation between the principal nuclear safety related buildings. This segregation is provided through claimed divisional barriers, the majority of these barriers have been sufficiently substantiated. Where this has not been the case the RP has undertaken analysis to demonstrate that this does not have a significant impact on nuclear safety.
- The generic UK HPR1000 design has adequately identified areas where exception to segregation exist. In these situations, the design has been shown to be tolerant of loss of the systems in these areas and no significant impacts on nuclear safety were identified.
- The RP has reviewed the risks from hazards to high integrity components within the generic UK HPR1000 design. The outcomes of this work were the reorientation of approximately 300 valves across the three trains, modification to various components and installation of additional pipe whip restraints. Where hazards could not be avoided due to the limitations of the design, adequate analysis in line with RGP has been provided to demonstrate that the integrity of the components would be maintained.

- Based on the segregation design and analysis undertaken, the RP has provided sufficient evidence to demonstrate that the layout of the plant is acceptable. Several shortfalls have been identified that need to be addressed at the detailed design stage when the plant layout is fully developed and site-specific information available, however these shortfalls are judged not to undermine the conclusions of the Internal Hazards assessment.
- The RP has provided adequate coverage of the principal safety measures protecting against internal hazards for the sampled areas. However, further work is required during detailed design stage to identify and fully substantiate all safety measures, particularly for defence-in-depth, and consolidate these within the hazard schedule.

187. Full details of ONR's assessment of this topic can be found in the Internal Hazards Step 4 assessment report (Ref. 54). ONR recommends that from an Internal Hazards perspective a DAC may be granted.

8.14 Management for Safety and Quality Assurance

188. During GDA, ONR expected the RP's organisation and management system arrangements and processes to be able to deliver the GDA to time and quality. Early in GDA, the RP sought to develop robust arrangements to manage the GDA project to produce the generic UK HPR1000 design and the safety and security cases.

189. To ensure ONR's expectation was fulfilled, ONR undertook assessment and regulatory interventions, jointly with the Environment Agency, to gain confidence in the adequacy of the RP's MSQA arrangements.

190. The MSQA assessment focused on the following aspects related to the generic UK HPR1000 design and safety case:

- The development and implementation of the RP's MSQA general arrangements and the resolution of shortfalls identified in Step 3 of GDA.
- The RP's arrangements to control the development of the generic UK HPR1000 safety case.
- The management system arrangements for the use of OPEX in the generic UK HPR1000 design and safety case.
- The management of safety case requirements, assumptions and commitments.
- The management system arrangements for producing the design and controlling subsequent changes to the generic UK HPR1000 design.

191. The conclusion of ONR's MSQA assessment is that the RP's organisation and management system arrangements and processes are adequate for GDA.

192. Full details of ONR's assessment of this topic can be found in the MSQA Step 4 assessment report (Ref. 55). ONR recommends that from a MSQA perspective a DAC may be granted.

8.15 Mechanical Engineering

193. Mechanical Engineering applies engineering principles to consider design, analysis, manufacturing, installation, maintenance and decommissioning of mechanical SSCs. It includes everything from small individual parts and devices to large, complex systems. It applies to a range of static and dynamic SSCs providing important nuclear safety functions as part of the design.

194. The Mechanical Engineering assessment considers whether the relevant safety case requirements can be delivered by the sampled SSCs within the generic UK HPR1000 design. This includes the use of appropriate codes and standards and the application of RGP.

195. The Mechanical Engineering assessment sampled systems and components which were considered important to nuclear safety. The assessment also focused on the mechanical engineering items for follow-up from Step 3 of GDA.

196. The conclusions of the Mechanical Engineering assessment are that, for the sampled SSCs and the purpose of GDA, the RP has:

- substantiated the HVAC system design;
- produced a suitable safety categorisation and classification methodology;
- implemented a coding system to trace safety functions;
- improved its equipment qualification arrangements;
- understood RGP and implemented this during design changes;
- understood EMIT requirements, including safe isolation of plant and equipment;
- applied the ALARP principle when making design changes;
- replaced fibrous material insulation with reflective metallic insulation, reducing associated risks to ALARP in containment;
- understood RPV head lifting risks, reducing these to ALARP;
- improved its fuel handling equipment design; and
- improved its spent fuel pool crane design.

197. Full details of ONR's assessment of this topic can be found in the Mechanical Engineering Step 4 assessment report (Ref. 56). ONR recommends that from a Mechanical Engineering perspective a DAC may be granted.

8.16 Probabilistic Safety Analysis

198. PSA is an integrated, structured, logical safety analysis that combines engineering and operational features in a consistent overall framework. It is a quantitative analysis that provides measures of the overall risk to the public that might result from a range of faults (for example, failure of equipment to operate, human errors, or hazards such as fires). PSA enables complex interactions (for example between different systems across the reactor) to be identified and examined and it provides a logical basis for identifying any relative weak points in the proposed reactor design. For GDA, ONR expected that the RP submission should include a fully documented full scope PSA, covering all the relevant sources of radioactivity, all relevant initiating events (including internal and external hazards) and all operation modes.

199. The main themes considered by ONR's assessment were whether:

- the RP had adequately used appropriate PSA methods;
- the PSA submissions had sufficient scope for GDA and were complete;
- the quality of the PSA documentation was adequate;
- the substantiation of the PSA models was clear; and
- the RP had used the insights from its PSA to inform the generic UK HPR1000 design and safety case.

200. Throughout GDA, the RP improved its PSA models and identified a number of improvements to the design of UK HPR1000 that further reduced the risks to ALARP including adding diversity to many of the HVAC systems, and a modification to the Fuel Building crane.

201. The conclusions of ONR's assessment are:

- The UK HPR1000 PSA methods, scope, completeness, justification and quality of the documentation, and the clarity of the substantiation, meet the expectations of ONR's SAPs, PSA TAG and are adequate to support the safety case.
- The UK HPR1000 PSA has a credible and defensible basis and allows for comparison against Targets 7, 8 and 9 contained in ONR's SAPs. Comparison of the results of the UK HPR1000 PSA to Targets 7 and 8 shows that the estimated level of risk is below the BSO. Comparison of the results of the UK HPR1000 PSA to Target 9 shows that the estimated level of risk is well below the BSL, however the level of risk is slightly above the BSO for Target 9. ONR is content that the RP has adequately demonstrated that the overall risks are reduced to ALARP.
- The PSA has been used as an input to the modifications process during GDA to ensure that risks are ALARP. The PSA has been used to identify improvements which have been incorporated into the final design reference and to calculate the risk significance of these changes to the design. ONR has not found any risk significant areas of the plant design for which additional ALARP analysis was needed in GDA or where alternative design features were required.
- The scope and content of the PSA is adequate for GDA. However, given the nature of PSA, it will need to be revised beyond GDA as normal business by the licensee to reflect the final detailed design, including site-specific characteristics and operational matters and to allow for these aspects to be risk informed using the PSA.

202. Full details of ONR's assessment of this topic can be found in the PSA Step 4 assessment report (Ref. 57). ONR recommends that from a PSA perspective a DAC may be granted.

8.17 Radiological Protection and Criticality

203. The main scope of the Radiological Protection and Criticality assessments focused on relevant risks that will arise during normal operation of the UK HPR1000 and to judge whether these have been, or are likely to be, reduced to ALARP. This included the justification for radiological doses to workers and the public, the adequacy of engineering controls (such as material selection or radiation shielding), and measures to control radioactive contamination. The use of OPEX from relevant existing plants was of key importance for the source term and radiological dose assessment for workers and members of the public. Fault sequences for the criticality safety of out-of-core nuclear fuel handling and storage activities were also considered. However, as previously stated, the main focus of the criticality assessment was on the approach to ensuring the safety of out-of-core nuclear fuel handling and storage activities, during normal operations.

204. The main themes considered by ONR's assessment were the RP's designation of radiation and contamination areas, use of operational experience for source terms, calculation of occupational and public radiation exposures, criticality safety for out-of-core nuclear fuel handling activities, and radiation shielding design. These fed into ONR's judgement of whether the generic UK HPR1000 design is capable of reducing relevant risks to ALARP, and how it compares with the expectations laid down in relevant UK standards and guidance.

205. Throughout GDA, the RP made significant improvements to its generic safety case and identified a number of improvements for the generic UK HPR1000 design, that further reduce doses to workers and the public to ALARP.

206. The conclusions of ONR's assessment, from a Radiological Protection and Criticality perspective, are:

- The RP has provided appropriate arguments and evidence to corroborate the claims made within the PCSR Chapter 22 'Radiological Protection'.
- The RP has provided appropriate arguments and evidence to corroborate the claims made within the PCSR Chapter 5 'Reactor Core'.
- The RP has provided appropriate arguments and evidence to corroborate the claims made within the PCSR Chapter 32 'Emergency Preparedness'.
- The RP meets the expectations of RGP.

207. Full details of ONR's assessment of this topic can be found in the Radiological Protection and Criticality Step 4 assessment report (Ref. 58). ONR recommends that from a Radiological Protection and Criticality perspective a DAC may be granted.

8.18 Radioactive Waste Management

208. Operation of the UK HPR1000 will result in the production of gaseous, liquid and solid radioactive wastes which are discharged or disposed of when they arise, or are stored awaiting the availability of disposal routes, in the case of some solid wastes. Whilst the designs of systems for gaseous and liquid radioactive wastes in the generic UK HPR1000 design is consistent with those used in the UK and internationally, the design of some systems for solid wastes differed significantly in the reference design (Fangchenggang NPP Unit 3). This reflected differing practices and infrastructure in China and the UK for solid radioactive waste management. During GDA, the RP made significant changes to strategies and SSCs for the management of some solid radioactive wastes to be consistent with UK Government policy, practices and infrastructure.

209. ONR's assessment was focused on the safe management of the highest hazard nuclear liabilities that will arise from operation and the radioactive waste systems where the hazards may be least well controlled. The highest hazard radioactive wastes are solid High Level Wastes (HLW) and Intermediate Level Wastes (ILW). The main themes addressed included radioactive waste management strategies (including compatibility with disposal routes), minimisation of the generation and accumulation of radioactive wastes, safe management of ILW and HLW non-fuel core components, including long-term on-site storage, and the control and containment of radioactive wastes.

210. The conclusions of ONR's assessment are:

- The radioactive waste inventory appears to be complete and is consistent with OPEX available from similar reactor technologies worldwide.
- The radioactive waste management strategies are consistent with UK Government policy and practices and take due account of the lifecycle of radioactive wastes from generation to disposal.
- The RP has identified and made effective use of national and international RGP and OPEX in radioactive waste management.
- The RP has adequately demonstrated the minimisation of generation and accumulation of radioactive waste.
- The RP has provided adequate evidence that it has considered the full range of options in developing the management strategy for the retrieval and

storage of waste in-core instrument assemblies, including the proposed winding operations.

- The RP has presented adequate evidence for the safe storage of HLW and ILW and has provided a conceptual design for the ILW interim storage facility consistent with RGP and OPEX. There are clear assumptions and requirements for SSCs to aid detailed design during site-specific stages.
- The RP has provided adequate evidence to demonstrate that the risks associated with radioactive waste management are reduced to ALARP, with the exception of some specified sub-systems in the solid waste treatment system where further work will be required from the licensee.

211. Full details of ONR's assessment of this topic can be found in the Radioactive Waste Management Step 4 assessment report (Ref. 59). ONR recommends that from a Radioactive Waste Management perspective a DAC may be granted.

8.19 Security

212. ONR has an expectation, within the scope of GDA, that the RP examines how security risks inherent in the design will be identified, assessed and addressed. ONR further expects that the RP will submit a GSR that explains, within the design, the categorisation of nuclear material and other radioactive material for both theft and sabotage and offers a conceptual security regime that meets ONR's expectations regarding risk management. This is considered by ONR under the Security technical discipline.

213. ONR's assessment focused on four aspects. First, the RP's submissions based on its GSR security case and supporting documents as they related to an application of selective SyAPs and the adoption of a 'secure by design' approach drawing on the Key Security Plan Principles (KSyPPs). Then how the RP had carried out categorisation for theft and sabotage through the characterisation of the design in scope. Concurrently, how the RP had carried out its characterisation of the design's technology as it related to cyber security risks. Lastly, the RP's high-level SyAPs aligned security regime concept that would inform a potential licensee in a future formulation of a security plan.

214. The conclusions of ONR's assessment are:

- The RP has demonstrated that it has adopted a SyAPs-based approach. Specifically, that it has addressed adequately the KSyPPs. The RP has applied a 'secure by design' methodology thereby identifying security risks and then addressed these through modifications. If modifications are not possible within GDA, the RP has made commitments for such mitigation in the site-specific stage. Where design changes cannot meet security expectations, or may not in the future, the RP has described a conceptual security framework to deliver a graded approach and one that offers adequate defence-in-depth to reflect the relative risk by location and magnitude.
- The RP has demonstrated that it has a workable methodology for assessing the risk posed by theft and sabotage against the design including the use of the UK design basis threat. The RP has applied that methodology effectively to shape its conceptual security regime.
- The RP has demonstrated that it has suitable assessment processes for evaluating the risk posed by malicious acts against Computer Based Systems Important to Safety (CBSIS) and has identified appropriate controls.
- The RP has used its risk analysis to inform a conceptual security regime. ONR considers the RP's conceptual regime as providing a licensee with a

framework that addressees the expectations within KSyPPs and would aid a licensee in developing a security plan for regulatory approval.

215. Full details of ONR's assessment of this topic can be found in the Security Step 4 assessment report (Ref. 40). ONR recommends that from a Security perspective a DAC may be granted.

8.20 Spent Fuel Interim Storage Facility

216. Consistent with UK Government guidance on the 'Funded Decommissioning Programme Guidance for New Nuclear Power Stations' (Ref. 47) and UK Government policy for new nuclear build, the generic UK HPR1000 design identifies the requirement to consider the on-site safe storage of spent fuel until a GDF becomes available. Chinese policy for managing spent nuclear fuel is different to the UK approach, therefore, the inclusion of a facility in the generic UK HPR1000 design represented a change to the UK HPR1000 reference design. For the generic UK HPR1000 design, the RP has decided to implement dry storage of spent fuel. ONR's assessment considered the adequacy of the conceptual design of the SFIS facility and the impact upon the existing infrastructure within the generic UK HPR1000 design.

217. The main theme within ONR's assessment was to consider whether the RP had adequately identified the impact that implementing dry storage of spent fuel has on the existing Fuel Building and the new SFIS facility. This included seeking evidence that relevant risks were capable of being reduced to ALARP.

218. The conclusions of ONR's assessment are:

- The SFIS facility conceptual design includes adequate facilities for the safe management of spent fuel, with due consideration of factors which may impact upon the storage capacity.
- The RP has provided adequate evidence on the versatility of the generic UK HPR1000 design to safely accommodate the SFIS technology through consideration of the systems / services required; the bounding size of the SFIS equipment; and the space available within the Fuel Building, without unduly foreclosing options for the detailed design.
- The RP's generic UK HPR1000 safety case provides adequate evidence that the hazards and risks are understood, with engineered design features identified, which are consistent with RGP, to demonstrate that the SFIS technology SSCs are capable of reducing relevant risks to ALARP.
- The RP's strategy to co-store Rod Cluster Control Assemblies (RCCAs) / Stationary Core Control Assemblies (SCCAs) with Spent Fuel Assemblies (SFAs) in the spent fuel storage canister is consistent with the management strategy being proposed for similar radioactive waste items from other PWRs in operation or being constructed in the UK.
- The RP's generic UK HPR1000 safety case adequately acknowledges the requirement to define limits and conditions necessary in the interests of safety and the regime for EMIT of SSCs, as the detailed design of the SFIS technology progresses.
- The RP has sought advice from Radioactive Waste Management Limited (RWM) on the disposability of SFAs with RCCAs/SCCAs. RWM's assessment concludes that the disposal package, containing four SFAs and a single RCCA or SCCA, is compatible with a GDF.

219. Full details of ONR's assessment of this topic can be found in the Spent Fuel Interim Storage Step 4 assessment report (Ref. 60). ONR recommends that from a Spent Fuel Interim Storage perspective a DAC may be granted.

8.21 Severe Accident Analysis

220. Consistent with the principle of defence-in-depth, ONR has an expectation that events more severe than those considered within the design basis are managed through the provision of equipment and procedures that can control or mitigate the consequences. For GDA, this means that beyond design basis events, with plant damage states where the potential consequences are severe, should be considered in the safety case as a complementary mix of deterministic and probabilistic analysis. The Severe Accident Analysis topic area is primarily concerned with deterministic analysis that supports design of safety features used in severe accident management.

221. The main themes considered by ONR's assessment were whether the RP had adequately identified severe accident phenomena, safety features for severe accident management, the analyses used to substantiate whether the UK HPR1000 design would be effective and, overall, if relevant risks had been reduced to ALARP.

222. Throughout GDA, the RP made significant improvements to the severe accidents safety case and also identified a number of improvements to the generic UK HPR1000 design that further reduced the risks to ALARP.

223. The conclusions of ONR's assessment are:

- The RP has adequately identified severe accidents phenomena, severe accident scenarios and safety features for severe accident management.
- The RP has demonstrated that the UK HPR1000 safety features for severe accident management are effective through deterministic analysis and has provided appropriate verification and validation evidence for the codes used.
- The RP has demonstrated that appropriate engineering requirements have been derived and assigned to SSCs claimed for severe accident management.
- The RP has demonstrated that the UK HPR1000 supporting systems are adequate to support severe accident management.
- The RP has successfully demonstrated that early or large releases have been practically eliminated in the generic UK HPR1000 design.
- The RP's approach is aligned with both ONR and international expectations for severe accident analysis.
- For the purposes of GDA, the RP has demonstrated that the generic UK HPR1000 design has reduced the relevant risks to ALARP.

224. Full details of ONR's assessment of this topic can be found in the Severe Accident Analysis Step 4 assessment report (Ref. 61). ONR recommends that from a Severe Accident Analysis perspective a DAC may be granted.

8.22 Structural Integrity

225. ONR's Structural Integrity assessment covers the engineering assessment of the integrity of metallic and non-metallic structures and components. Structural integrity encompasses a number of technical areas including metallurgy, material properties and testing, ageing and degradation mechanisms, welding engineering, stress analysis, fracture mechanics and non-destructive testing techniques.

226. ONR expects that an adequate generic safety case can be provided for nuclear safety related metal pressure vessels, piping, other structural components and their supports, to ensure that the risk of failure is reduced to ALARP. In GDA, ONR sought confidence that the RP could provide a conservative demonstration of integrity for nuclear safety significant structures over the design life of the plant. This is particularly important for claims based on the likelihood of gross failure being so low that the consequences of gross failure can be discounted from the deterministic safety analysis, in other words, a highest reliability claim.

227. The main themes considered for demonstrating a robust structural integrity safety case for the generic UK HPR1000 design included:

- component design (including the use of adequate codes and standards); and
- adequacy of the structural integrity safety case including:
  - avoidance of fracture demonstration (where appropriate);
  - multidiscipline input to determine safety classification;
  - material selection, fabrication;
  - in-manufacture examination and testing;
  - analysis of structural integrity under normal load / faulted conditions (including fracture mechanics-based analyses); and
  - lifetime ageing of materials.

228. Throughout GDA, the RP made significant improvements to its structural integrity safety case. The RP also identified several improvements to the generic UK HPR1000 design, that further reduce the risk of failure to ALARP for metallic pressure retaining and structural components important to nuclear safety.

229. ONR concludes that the RP has:

- Developed an adequate safety case structure and methodology, which demonstrates how the risks associated with structural integrity of the plant are identified, assessed and reduced to ALARP.
- Demonstrated an adequate approach for the structural integrity classification of SSCs important for safety. This approach is commensurate with safety significance, with additional measures where claims of highest reliability are considered unavoidable.
- Provided adequate avoidance of fracture demonstrations based on conservative defect tolerance assessments including material properties and appropriate GDA technical justifications, which provide confidence in the future qualification of manufacturing inspections for highest reliability components in the UK HPR1000.
- Selected and applied relevant design and construction codes, with a basis for confidence that code compliance is achieved, based on conservative assumptions. This includes identifying and mitigating risks arising from combining codes and standards for certain safety significant components.
- Developed an adequate materials selection and testing strategy to underpin safety case claims of high-quality components and consideration of through life ageing and degradation.
- Presented sufficiently detailed proposals for Non-Destructive Examination (NDE) that support the structural integrity claims in the generic safety case, which will assist the licensee in demonstrating relevant risks will be reduced to ALARP. The RP has appropriately considered ‘design for inspectability’,

resulting in several design modifications of safety significant components to improve NDE reliability.
- For the purposes of GDA, demonstrated that the generic UK HPR1000 design has reduced relevant risks to ALARP, in terms of structural integrity classification, component design, design code selection and materials selection.

230. Full details of ONR's assessment of this topic can be found in the Structural Integrity Step 4 assessment report (Ref. 62). ONR recommends that from a Structural Integrity perspective a DAC may be granted.

8.23 Cross-Cutting Topics

During GDA, a number of cross-cutting topics, which were significant enough to warrant dedicated management focus, leadership and coordination, were identified by ONR. ONR's assessment for most of the cross-cutting topics is reported in the relevant discipline(s) assessment reports and summarised in Annex 1 of this report. However, several of the cross-cutting topics related to general arrangements and methodologies and those apply to the majority of the technical disciplines. Our assessment of those cross-cutting topics is reported in the cross-cutting assessment report (Ref. 22) and has focused on the following aspects of the generic UK HPR1000 safety case:

- The general safety and design principles described in Chapter 4 of the PCSR which are the Nuclear Safety Principles (NSPs) underpinning the generic UK HPR1000 design and safety case.
- The RP's approach to producing, developing and delivering the generic UK HPR1000 safety case throughout GDA, including the RP's organisational capability.
- The RP's commitments management process for identifying, capturing and managing commitments throughout GDA. This included the appropriate capture of post-GDA commitments to be considered by the licensee.
- The RP's arrangements for identifying and tracing requirements and assumptions throughout the safety case. This included a detailed sampling of the implementation of the RP's requirements management process.
- The RP's approach to developing and identifying operating rules within the generic UK HPR1000 safety case and its suitability for transfer to a licensee.
- The RP's demonstration of how OPEX is identified, captured, and used in the generic UK HPR1000 design and safety case.

231. The conclusions of ONR's assessment of the six cross-cutting topics are:

- The safety case for the above cross-cutting topics, which comprises chapters 4, 20 and 31 of the PCSR plus the supporting evidence, has been adequately developed by the RP for the purposes of GDA.
- The UK HPR1000 general safety and design principles are adequate for the purposes of GDA.
- The RP established and deployed suitable means to deliver, in a timely manner, a comprehensive safety case.
- The RP established adequate arrangements for capturing and implementing commitments during GDA. The RP has identified and captured post-GDA commitments for the licensee to consider.
- The RP's process for identifying and tracing requirements through the generic UK HPR1000 safety case is adequate for the purposes of GDA. This process

is at an early stage and it will need further development and implementation by the licensee.

- The RP's approach to defining operating rules underpinned by the safety case is sufficient for GDA and suitable for further development by a licensee.
- The RP has developed adequate arrangements for identifying, capturing and analysing OPEX, including a suitable and sufficient OPEX methodology.

232. Full details of ONR's assessment of the cross-cutting topics considered above can be found in the cross-cutting Step 4 assessment report (Ref. 22). ONR recommends that from the perspective of the topics reported in the cross-cutting Step 4 assessment report a DAC may be granted.

8.24 Overall Adequacy of the Generic UK HPR1000 Safety and Security Cases

233. ONR expects an RP to establish and deploy suitable means to deliver, in a timely manner, good quality and comprehensive safety and security cases (Ref. 16). Therefore, a significant amount of regulatory effort was put in place to assess the RP's generic safety and security cases against ONR's expectations (Ref. 16, Ref. 20, Ref. 27, Ref. 28). This included:

- Examining the adequacy of the RP's safety and security cases development strategies, the delivery programme and the organisational development to support the safety and security case development. This is reported in the cross-cutting Step 4 assessment report (Ref. 22).
- Conducting, early in Step 4 of GDA, an overall safety and security case health check covering the PCSR and GSR version 1 and supporting references. This was done holistically against ONR's safety case expectations (Ref. 20) which were also interpreted for, and applied to, our review of the security case. Feedback was provided to the RP on the outcome of the assessment. This has been reported in previous sub-sections of this report.
- Providing oversight of the RP's design reference documentation to maintain confidence that the DR remained aligned with the safety and security cases throughout GDA.
- Assessing that the information in the RP's generic safety case was suitable and sufficient to demonstrate that risks have been reduced to ALARP.
- Reviewing the consolidated generic safety and security cases to ensure that they reflect the final positions reached across all the technical disciplines capturing the results of the assessments carried out during GDA.
- Reviewing the RP's arrangements for transferring the safety case to a licensee.

234. The first two items above were key activities which enabled the RP to improve its safety and security cases. Those are reported in detail in the cross-cutting Step 4 assessment report (Ref. 22). The other items listed above are addressed in the following sub-sections.

8.24.1 Design Reference and Design Change Control

235. ONR expected the generic UK HPR1000 design and safety and security cases to evolve throughout GDA (Ref. 16), for example in response to ROs, to capture other regulatory outcomes from our assessment, or to capture the outcomes from the RP's own gap analyses. The RP developed a process to capture the changes in the design, assess them holistically and reflect them in the safety case and DR. An overview of how the DR evolved through GDA is provided in Section 7.

236. During Step 4 of GDA, as part of the MSQA assessment, ONR inspected the design change process implemented by the RP in detail and was satisfied with the RP’s approach (Ref. 55).

237. In addition, ONR developed a robust process to review and accept, or otherwise, the design changes proposed by the RP after the DRP. ONR maintained oversight of the design reference documentation by reviewing the different revisions of the ‘Design Reference Report’ to remain confident that the DR and the safety and security cases remained aligned throughout GDA.

238. As part of the safety and security case consolidation, the RP carried out additional checks (Ref. 63) to ensure alignment between the DR (Ref. 38) and the safety and security cases. DR3.0 is the final design reference for the generic UK HPR1000 design and it is aligned with version 2 of the PCSR and GSR.

239. Overall, the GDA of the UK HPR1000 has resulted in 95 modifications (from DR1.0 to DR3.0) to the generic UK HPR1000 design with respect to the Chinese reference design. The RP undertook a holistic review of the design modifications to check if the costs (in time, trouble and effort) were grossly disproportionate to the overall safety benefit to the plant, when all the changes were considered holistically. The RP concluded that "the design of UK HPR1000 has an appropriate balance between overall safety benefit and disbenefit (cost, complexity etc) when all modifications were considered as a whole" (Ref. 64).

8.24.2 UK HPR1000 ALARP Demonstration

240. To demonstrate the reduction of the UK HPR1000 risks to ALARP, early in GDA the RP developed an ALARP methodology based on ONR’s expectations for new reactors (Ref. 27). At the end of Step 2 we reported (Ref. 6) that the RP’s ALARP methodology broadly met our expectations, although we recognised that this was a high-level strategy document, and that the RP would still need to demonstrate its practical application. At the end of Step 3 we reported (Ref. 10) that the RP had been highly receptive to regulatory feedback and guidance on ALARP and that in the second half of Step 3 we had seen improvements in many of the submissions that justify that risks are reduced to ALARP.

241. The RP has supported the ALARP claims in the PCSR with ALARP demonstration reports, which were produced for each chapter of the PCSR. As already mentioned in sub-section 3.4, the RP also produced a ‘Holistic ALARP demonstration report’ (Ref. 29) that supported Chapter 33 of the PCSR ‘ALARP Evaluation’. ONR’s assessment of the RP's ALARP demonstration has been carried out at a technical discipline level. However, considering the risks holistically is fundamental and therefore our overall judgement is summarised here.

242. The RP’s ‘Holistic ALARP demonstration report’ supports the claim that the risk associated with the generic UK HPR1000 design has been reduced to ALARP. The arguments provided followed the RP’s ALARP methodology and were aligned with ONR’s expectations (Ref. 27, Ref. 28). In summary, the RP:

- Presented the rationale for the evolution of the generic UK HPR1000 design.
- Showed that relevant OPEX and RGP have been incorporated into the design, including presenting comparisons with national and international standards.
- Considered risk insights from safety analysis disciplines together with engineering principles.

- Proposed design modifications based on OPEX, RGP and risk insights. Those modifications followed a process supported by optioneering and reached an ALARP position in that no further reasonably practicable improvements were identified that could be implemented for the generic design.
- Presented a comparison of the generic UK HPR1000 design against numerical targets in the NSPs in the report to support the ALARP position.

243. We assessed the 'Holistic ALARP demonstration report' (Ref. 29) and together with ONR's assessment in each technical discipline, we are satisfied that for GDA the overall level of risk associated with the generic UK HPR1000 design has been or is capable of being reduced to ALARP. However, further work will be needed by a licensee to develop this evaluation for the detailed design and considering site-specific aspects.

8.24.3 Safety and Security Case Consolidation

244. The RP's consolidation of the generic safety and security cases was a significant undertaking that provides a further level of assurance of their adequacy. The consolidation was necessary to ensure that the final versions of the safety and security cases include any changes made during GDA, accurately reflect DR3.0 and are self-consistent. By virtue, this also means that ONR's assessments are consistent with the final safety and security cases produced during GDA.

245. ONR reviewed the consolidated generic safety and security cases, including PCSR and GSR version 2, and the outcome is reported in each of the Step 4 assessment reports (Ref. 65). Overall, ONR is satisfied that version 2 of the PCSR and GSR and their references reflect the consolidated final versions of the generic UK HPR1000 safety and security cases.

8.24.4 Arrangements for Transferring the Generic Safety and Security Cases to the Licensee

246. ONR has also considered the RP's arrangements for transferring the safety case to a licensee in our assessment of the RP's processes for managing safety case implementable requirements, GDA commitments, EMIT arrangements, and its approach to operating rules. The majority of those are reported in the cross-cutting Step 4 assessment report (Ref. 22) and the rest can be found in Annex 1. In summary, ONR considers that the RP has developed adequate arrangements for transferring the generic UK HPR1000 safety case to a licensee.

247. In addition, and as we already indicated in sub-section 8.19, ONR considers that the RP's conceptual security regime provides a framework for a licensee to develop its site-specific security plan.

8.24.5 Adequacy of the Generic Safety and Security Cases - Summary

248. ONR's assessments across all the technical disciplines have considered the adequacy of the generic UK HPR1000 safety and security cases at a discipline level. All the assessments concurred on the adequacy of the generic UK HPR1000 safety and security cases.

249. The RP's holistic design and ALARP reviews have provided us with further confidence that our own regulatory work in GDA has contributed to improving the safety of the generic UK HPR1000 design without triggering disproportionate or unreasonable design changes.

250. ONR's assessment of the generic safety and security cases, as presented in version 2 of the PCSR (Ref. 13) and GSR (Ref. 14) and the supporting references (included within the MDSL (Ref. 37), has concluded that they are suitable and sufficient to support the granting of a DAC. The generic UK HPR1000 safety and security cases are also suitable for transfer to a licensee for further development during the detailed design and site-specific stages.

9 OUTCOMES FROM ONR's ASSESSMENT

251. ONR's guidance to RPs (Ref. 16) defines three possible outcomes from ONR's assessment:

- GDA Issue - This is a generic shortfall judged to be significant but resolvable. GDA Issues require resolution before ONR would consider issuing a DAC for the generic design.
- Assessment Finding – This is a matter considered significant enough to warrant ONR tracking to resolution but does not undermine ONR's confidence in being able to provide a DAC for the generic design.
- Minor Shortfalls – These are potential areas for improvement identified during ONR's assessment, but they are not considered significant enough to warrant ONR tracking to resolution.

252. Our GDA assessment has only identified Assessment Findings and minor shortfalls. No GDA Issues were raised by ONR or the Environment Agency.

253. Assessment Findings are primarily concerned with the provision of site-specific safety / security case evidence which will usually become available as the project progresses through the detailed design, construction and commissioning stages. They are for the licensee to resolve (Ref. 16).

254. A residual matter will generally be recorded as an Assessment Finding if one or more of the following apply (Ref. 16):

- To resolve this matter site-specific information is required.
- The resolution of this matter depends on licensee design choices.
- The matter raised is related to operator-specific features / aspects / choices.
- The resolution of this matter requires licensee choices on organisational matters.
- To resolve this matter the plant needs to be at some stage of construction / commissioning.
- To resolve this matter the level of detail of the design needs to be beyond what can reasonably be expected in GDA (for example, manufacturer / supplier input is required, or areas where the technology changes quickly, and so to avoid obsolescence of design).

255. The licensee's work to address the GDA Assessment Findings will be subject to proportionate regulatory oversight delivered through ONR's regulation of new NPP projects. The schedule for resolution of the GDA Assessment Findings will be determined by the licensee in accordance with its intended development / construction programme.

256. Clear identification of Assessment Findings in GDA allows licensees early visibility of design matters that it will need to address at an appropriate later stage. This enhances the certainty of regulatory expectations as the design enters the detailed design and construction phases, and it is one of the benefits of the GDA process.

257. ONR's Step 4 assessment of the generic UK HPR1000 design across 21 technical disciplines and cross-cutting topics has identified 243 Assessment Findings. These can be found in the relevant Step 4 assessment reports (Ref. 65) and in the consolidated list of Assessment Findings (Ref. 66). A schematic breakdown of these by technical discipline is shown in Figure 6. Minor shortfalls are identified in the relevant Step 4 assessment reports.

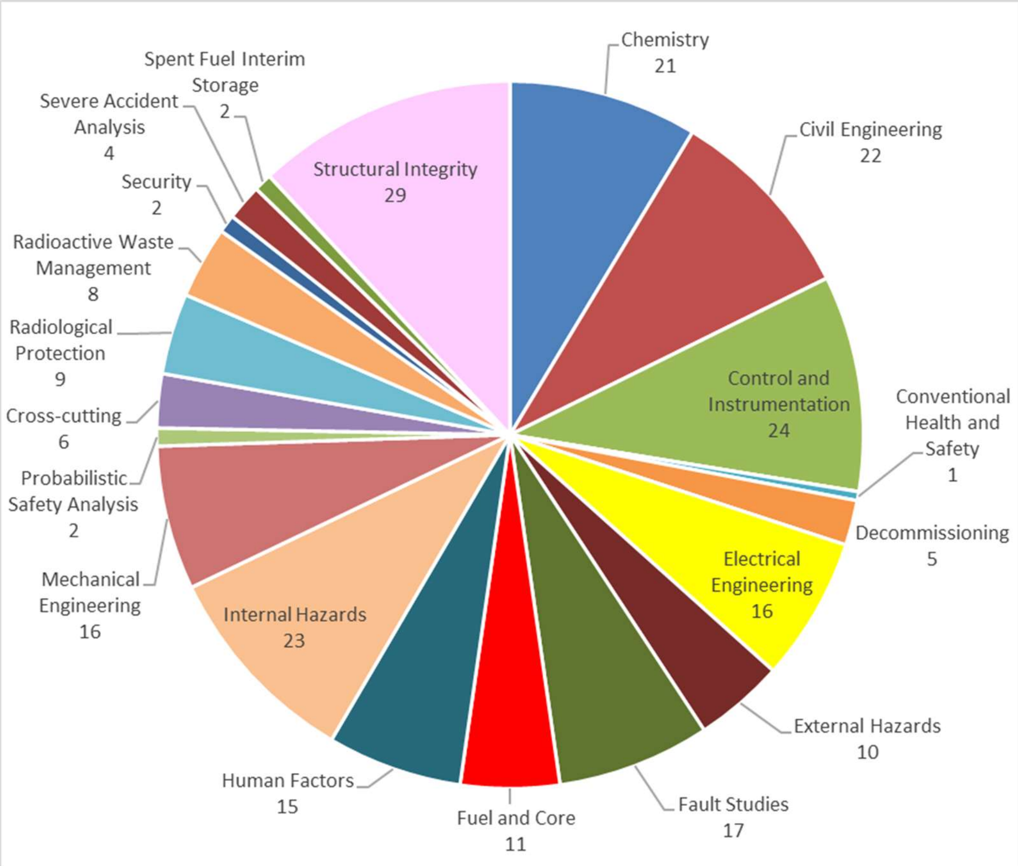


Figure 6: UK HPR1000 GDA Assessment Findings by Technical Discipline

10 CONCLUSIONS

258. This report is ONR's third public summary report on our assessment of the generic UK HPR1000 design, and it comes at the end of Step 4 of GDA. In this step we undertook a detailed assessment focusing on the evidence that substantiates the claims and arguments in the safety and security cases. Step 4 of GDA is the final step in the GDA process where ONR judges whether a DAC should be issued for the design.

259. Overall, our interactions with the RP throughout Step 4 have been constructive. The RP's organisational arrangements matured further with clear evidence of GNSL, CGN, and EDF SA capturing, and acting upon, learning from Step 3. Coordination between the three organisations improved and their working arrangements became embedded.

260. During Step 4 of GDA, the RP overcame the technical challenges identified during this step and the RP put effective measures in place to improve the areas highlighted by ONR's assessments and inspections.

261. During Step 4 of GDA, ONR has undertaken assessment work across 21 technical disciplines and cross-cutting topics. From our assessment we have concluded the following:

- All of the regulatory shortfalls identified throughout GDA, including those captured in the 56 ROs raised, have been adequately addressed by the RP, and the final position on those technical matters is reflected in the generic safety and security cases.
- Our assessment has identified 243 Assessment Findings for the licensee to resolve during the detail design and site-specific stages.
- Our assessment has not identified any fundamental safety or security shortfalls that might prevent the issue of a DAC for the generic UK HPR1000 design.
- The RP has demonstrated, for the purpose of GDA, that the overall level of risk associated with the generic UK HPR1000 design has been or is capable of being reduced to ALARP.
- ONR is satisfied that version 2 of the PCSR and GSR for the generic UK HPR1000 design, and the supporting submissions contained within the MDSL, are adequate for the purposes of issuing a DAC.
- Our assessments across all technical disciplines and cross-cutting topics have met the objectives of GDA (Ref. 16).

262. Therefore, in ONR's opinion, the UK HPR1000 design could be built and operated in GB, on a site bounded by the GSE, in a way that is acceptably safe and secure, subject to:

- site-specific assessment, licensing and permissioning; and
- resolution of the 243 Assessment Findings

11 RECOMMENDATIONS

263. It is recommended that:

- ONR issues a DAC to the UK HPR1000 GDA RP for the UK HPR1000 design.
- Annex 1 of the DAC defines the boundaries of the assessment undertaken, and to which the DAC therefore applies, by reference to the following documents:
    - (Generic) Pre-Construction Safety Report, HPR/GDA/PCSR/0001 to HPR/GDA/PCSR/0033, Revision 002, dated 29th September 2021;
    - Generic Security Report, HPR/GDA/GSR/0001, Revision 002, dated 29th September 2021;
    - UK HPR1000 Design Reference Report, NE15BW-X-GL-0000-000047 Revision I, dated 10th September 2021; and
    - Master Document Submission List, HPR-GDA-REPO-0197, Revision 001, dated 19th November 2021.

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Annex 1

CROSS-CUTTING TOPICS

264. This annex summarises, and provides visibility on, how ONR has managed assessment of the following cross-cutting topics:

- Categorisation of safety functions and classification of safety measures.
- Comparison against the numerical targets in ONR's SAPs.
- Adequacy of the safety case for the UK HPR1000 fuel route in the Fuel Building.
- Demonstration of the defence-in-depth and diversity in the UK HPR1000 design.
- Approach to EMIT for the UK HPR1000.
- Adequacy of the SFIS facility safety case
- Radioactive waste safety case for the UK HPR1000.
- Holistic assessment of the HVAC system.
- Source term assessment for normal operations and fault / accident conditions.
- Assessment of the generic UK HPR1000 design against space weather hazards.
- Cyber security.
- Overview of ONR's assessment of the generic UK HPR1000 layout design.
- Grid code compliance of the generic UK HPR1000 design.

265. Each summary below provides an overview of the topic, the technical disciplines that have contributed to the assessment and where further information can be found. They also conclude on the adequacy of the UK HPR1000 design and the generic safety case regarding the cross-cutting topic.

266. It should be noted that the overall list of cross-cutting topics, for which ONR established a specific management strategy as discussed in sub-section 3.2.1, also includes 'demonstration of ALARP', 'GDA scope', 'design control' and 'security and safety case interactions'. The first three are reported in the main body of this report and the 'security and safety case interactions' is reported in the Security Step 4 assessment report (Ref. 40). Therefore, those four cross-cutting topics are not included in this Annex.

Categorisation of Safety Functions and Classification of Safety Measures

267. The generic UK HPR1000 safety case includes a method for the identification and categorisation of safety functions, and the classification of safety measures (comprising operator actions and/or SSCs that deliver those functions) (Ref. 67). Within each discipline, the RP provided additional information on the application of this classification methodology to that discipline. This methodology was based on the reference design but was produced to account for the regulatory approach and expectations in the UK. ONR's assessment concluded that the methodology was consistent with ONR and relevant international guidance. In producing and applying that methodology, the RP identified some instances where the classification of operator actions and SSCs for the generic UK HPR1000 design was not consistent with the methodology.

268. ONR's assessment of the methodology was led by the Fault Studies discipline, which considered the safety functions and whether these had been appropriately categorised. The assessment of the adequacy of the classification of safety

measures was coordinated between Fault Studies, Human Factors and relevant engineering disciplines. ONR's focus was on ensuring the adequacy of the methodology and the consistent application of this to the safety measures, along with gaining confidence that the safety measures can deliver the safety functions required of them.

269. In response to ONR's assessments, the RP has reviewed and, in some cases, revised the classification of some SSCs to ensure that they are consistent with the methodology (Ref. 67). Such revisions have resulted in modifications which have been integrated into the generic UK HPR1000 design and safety case.

270. Full details of ONR's assessment of the RP's methodology can be found in the Fault Studies Step 4 assessment report (Ref. 51). The broad nature of this topic means that most of ONR's assessments considered the application of this methodology within their disciplines.

271. Following several modifications to the design and safety case, ONR's assessment has concluded that, in general, the RP has appropriately classified the safety measures within the generic UK HPR1000 design for GDA.

Comparison Against the Numerical Targets in ONR's SAPs

272. The numerical targets are an important part of the SAPs and provide guidance to ONR to assist in making regulatory judgements on whether radiological hazards are being adequately controlled and risks reduced to ALARP. Each target defines a set of BSLs and BSOs and it is ONR's policy that a new facility should at least meet the BSLs. Separate targets are defined for normal operations (Target 1 to 3), design basis fault sequences (Target 4), individual risk from accidents (Targets 5 and 7), frequency dose targets for accidents (Targets 6 and 8) and societal risk (Target 9). Further details are provided in the SAPs.

273. During GDA, the RP defined a set of Radiological Protection Targets (RPTs) and provided numerical risk estimates for the UK HPR1000 for normal operation and accident conditions for comparison against these targets. These RPTs are identical to the BSLs and BSOs defined by the numerical targets in the SAPs. ONR's assessment was coordinated primarily amongst the Radiological Protection, Fault Studies, PSA and Severe Accidents Analysis disciplines although many disciplines considered the targets as part of their assessments. The comparison to the SAPs numerical targets has been used to indicate where additional or strengthened safety measures may need to be considered in the design and to help ONR judge whether risks have been reduced to ALARP.

274. Overall, the comparison of the RP's numerical risks showed that the generic UK HPR1000 design broadly meets the expectations given in the SAPs. For some specific operations, faults and accidents considered, the RP identified improvements were necessary to further reduce the risks based on its numerical estimates. This resulted in a number of safety case and design changes.

275. Full details of ONR's assessments can be found in the Radiological Protection, Fault Studies, PSA and Severe Accidents Analysis Step 4 assessment reports (Ref. 58, Ref. 51, Ref. 61, Ref. 57).

276. Although further work will be needed in the site-specific phases, ONR's assessment has concluded that the relevant risks were reduced to ALARP based on the generic UK HPR1000 design and safety case.

Adequacy of the Safety Case for the UK HPR1000 Fuel Route in the Fuel Building

277. New and used fuel needs to be safely moved and stored during operations, including during refuelling of the reactor and the transfer of used fuel for long term storage. The generic UK HPR1000 design includes a range of fuel handling equipment for this purpose. ONR's assessment identified several shortfalls in meeting regulatory expectations, associated with the safety case for the equipment used to handle spent nuclear fuel in the spent fuel pool and the risks associated with handling loaded spent fuel casks in the Fuel Building. Overall, the safety case for the UK HPR1000 fuel route in the Fuel Building did not demonstrate that relevant risks had been reduced to ALARP. This led to RO-UKHPR1000-0056 (Ref. 23) being raised.

278. This assessment was coordinated primarily amongst the Fault Studies, Mechanical Engineering, C&I and Conventional Health and Safety disciplines, which considered the safety analysis and engineering substantiation in a holistic manner. ONR's assessment focus was towards ensuring the underlying adequacy of the safety case and gaining confidence that it was feasible for the generic design to deliver the requirements placed upon it, as part of detailed design of the equipment during the site-specific stages.

279. In response to ONR's assessments, the RP revised its safety case and identified that a modification to the design was also needed to reduce risks to ALARP. This changed the spent fuel crane design, amongst other consequential modifications. Collectively, this improved the safety justification, eliminated several significant faults from the design and demonstrated that it could be feasible for a licensee to complete the substantiation of the detailed design.

280. Full details of ONR's assessments can be found in the C&I, Conventional Health and Safety, Fault Studies and Mechanical Engineering Step 4 assessment reports (Ref. 43, Ref. 46, Ref. 51, Ref. 56).

281. ONR was satisfied that the improvements identified by the RP were sufficient to resolve the identified shortfalls for GDA.

Demonstration of the Defence-in-Depth and Diversity in the UK HPR1000 Design

282. Nuclear facilities should be designed and operated so that defence-in-depth against potentially significant faults or failures is achieved by the provision of multiple independent barriers to fault progression. Defence-in-depth should prevent faults, or if prevention fails should ensure detection, limit the potential consequences and stop escalation.

283. Based upon the submissions made by the RP during GDA, ONR judged there to be potential regulatory shortfalls associated with two aspects of the demonstration of defence-in-depth. The first potential regulatory shortfall related to the demonstration of diverse protection for frequent faults. This is a well-established expectation within UK safety cases for power reactors that was recognised by the RP early in GDA. This led to RO-UKHPR1000-0023 (Ref. 23) being raised. The second potential regulatory shortfall was associated with independence between different C&I systems, which presented a risk that common cause failure could simultaneously affect multiple systems across different levels of defence-in-depth. ONR raised RO-UKHPR1000-0017 in respect of this shortfall (Ref. 23).

284. The assessment of the responses to these ROs was led by the Fault Studies and C&I disciplines respectively which coordinated assessment with other disciplines, mainly Mechanical Engineering and Electrical Engineering.

285. ONR's assessment considered the way in which the RP's methods for the categorisation of safety functions and classification of safety measures support the demonstration of defence-in-depth. ONR is satisfied that the RP has considered defence-in-depth as a fundamental part of this methodology, which is based on international and GB good practice. Appropriate classification of equipment is fundamental to the requirements for the engineering design of SSCs.

286. To address the expectation of RO-UKHPR1000-0023 the RP has, consistent with good practice, identified diverse and independent safety measures for delivering the necessary safety functions following frequent faults. These safety measures have been classified in accordance with the RP's methodology and their effectiveness has been demonstrated by transient analysis which show that their operation can ensure that the acceptance criteria are met. Through this work, the RP identified several areas where further investigation was required to demonstrate the required diversity. From these investigations and subsequent optioneering the RP identified and implemented several design changes that it considers to be reasonably practicable.

287. To address the expectations of the RO-UKHPR1000-0017 the RP provided a demonstration of how the independence within the C&I architecture reduces the risk of common cause failures affecting multiple systems across different layers of defence-in-depth. This included a systematic review of equipment shared between C&I systems, including that involved in safety functions delivered by the Protection System (RPS [PS]) and Diverse Actuation System (KDS [DAS]). As a result of this review the RP identified and implemented a number of design modifications to introduce improved diversity within the C&I architecture, most notably the implementation of diverse component interface module and signal pre-processing module designs to reduce the risk that a failure of those components will simultaneously affect multiple levels of defence-in-depth.

288. Full details of ONR's assessments can be found in the Step 4 assessment reports of C&I and Fault Studies (Ref. 43, Ref. 51).

289. ONR was satisfied that the improvements identified by the RP were sufficient to resolve the identified shortfalls for GDA.

Approach to Examination, Maintenance, Inspection and Testing for the UK HPR1000

290. EMIT activities are vital to ensure a nuclear plant remains safe during operations and is an important part of safeguarding the reliability, operability, and availability of safety functions. During GDA, ONR sought assurance that the generic UK HPR1000 design was compatible with the expected EMIT activities. For the generic UK HPR1000 design, this included consideration of how EMIT of three-train safety systems would be managed to ensure the required system availabilities, and any differences from UK requirements and expectations.

291. In the early stage of GDA, the submissions received had not provided sufficient confidence in this regard and the scope, breadth and depth of information was inconsistent between technical topics. Often the information received was at the level of general principles, was ambiguous, and unclear as to what was proposed to be completed during GDA. Importantly, it was unclear how the RP intended to identify the permitted combinations of equipment unavailability for each permitted operating

state. Additionally, the safety case links between the EMIT requirements and the availability requirements set by the safety analysis needed to be demonstrated. This led to RO-UKHPR1000-0021 (Ref. 23) being raised.

292. This assessment was coordinated primarily amongst the Fault Studies, PSA, Mechanical Engineering, C&I, Electrical Engineering and Radiation Protection disciplines. ONR's assessment focus was ensuring the underlying adequacy of the EMIT aspects of the safety case and gaining confidence that it was feasible for the design to deliver the EMIT requirements placed upon it and to enable the licensee to develop a maintenance schedule and outage schedule during the site-specific stages.

293. In response to ONR's assessments, the RP revised and enhanced its EMIT safety case. This demonstrated that the design was largely compatible with the EMIT and system availability requirements, but also identified a number of modifications to the design that were needed to ensure that the design and safety case are consistent with UK legal requirements and regulatory expectations. Collectively, this improved the safety justification and demonstrated that it could be feasible for a licensee to complete the substantiation of the detailed design and develop a detailed maintenance schedule and outage schedule.

294. Full details of ONR's assessments can be found in the Step 4 assessment reports of the disciplines involved (Ref. 51, Ref. 43, Ref. 49, Ref. 57, Ref. 56, Ref. 58).

295. ONR's assessments were satisfied that the improvements to the safety case and engineering designs by the RP were sufficient to resolve the identified shortfalls for GDA.

Adequacy of the Spent Fuel Interim Storage Facility Safety Case

296. During Step 4 of the GDA, shortfalls were identified in the RP's ALARP demonstration for the selected SFIS technology. This led to RO-UKHPR1000-0050 (Ref. 23) being raised.

297. The SFIS technical topic primarily considered, and coordinated, relevant parts of the assessments undertaken by the ONR Fuel and Core, Fault Studies, PSA, Mechanical Engineering, Radiological Protection, SFIS and Conventional Health and Safety specialist inspectors. Taking into consideration the regulatory expectations outlined in the GDA scope for SFIS (Ref. 68), ONR's assessment focus was on:

- ensuring the RP identified the risks / hazards associated with the implementation of the SFIS technology in normal operations and fault / accident conditions; and
- that the generic design is sufficiently versatile to accommodate the detailed design of the relevant SSCs at the site-specific stages.

298. The assessment also involved working closely with the Environment Agency.

299. ONR assessed the RP's generic UK HPR1000 safety case, which incorporated a number of changes to support the implementation of the SFIS facility. In response to ONR's assessments, the RP reworked its generic safety case, providing a qualitative risk assessment which adequately identified preventative and mitigation safety measures, proportionate to the level of design detail available at GDA. The RP's generic safety case also identified fuel criteria relevant to the passive safe storage of spent fuel in the SFIS facility, which ONR judged to be satisfactory for GDA.

However, the detail design of the SFIS facility will be developed by the licensee as the design detail progresses during site-specific stages.

300. Full details of ONR's assessment can be found in the relevant Step 4 assessment reports (Ref. 44, Ref. 52, Ref. 51, Ref. 56, Ref. 57, Ref. 58, Ref. 60).

301. Overall, ONR's inspectors were satisfied that the RP's generic safety case for the SFIS technical topic resolved the shortfalls identified. This included the provision of adequate evidence to demonstrate the versatility of the generic design to accommodate the detailed design of the relevant SSCs and any changes required in the fuel criteria parameters.

Radioactive Waste Management Safety Case for the UK HPR1000

302. The radioactive waste management safety case cross-cutting topic addressed the safety (normal operations and fault / accident conditions) of systems and structures designed to manage gaseous, liquid and solid radioactive wastes that will arise during the operation of the UK HPR1000.The scope also encompassed the minimisation of radioactive wastes and strategies for radioactive waste management as part of overall regulatory expectations for this technical topic.

303. ONR recognised the need for the RP to address gaps / differences in policy, practices and infrastructure for radioactive waste management between the UK and China in the design of the UK HPR1000. Several ROs (RO-UKHPR1000-0005, RO-UKHPR1000-0026, RO-UKHPR1000-0037, RO-UKHPR1000-0040 and RO-UKHPR1000-0042) (Ref. 23) were raised during Step 2 and Step 3 of GDA regarding the radioactive waste management for the generic UK HPR1000 safety case.

304. This cross-cutting topic involved the coordination of relevant assessment activities across a number of ONR's technical disciplines and relevant assessors in the Environment Agency. The main ONR disciplines involved were Radioactive Waste Management, Decommissioning, Radiological Protection, Mechanical Engineering, Chemistry, Fault Studies, Fuel and Core, SFIS and Conventional Health and Safety. ONR's assessment was focused on ensuring the adequacy of the generic safety case and the demonstration that relevant risks are reduced to ALARP. Another aspect of focus was gaining confidence that the RP had adequately defined safety requirements for SSCs for those radioactive waste management facilities at the conceptual design stage, in order to ensure the detailed designs will capture and fulfil these requirements.

305. ONR assessed the RP's generic safety case for the modified design of the UK HPR1000, which incorporated a number of changes to address gaps / differences against UK policy, practices and infrastructure for solid radioactive waste management. In addition, the RP had implemented a number of modifications in the design to reduce risks to ALARP. For example, the incorporation of additional isolation valves in gaseous and liquid waste management systems to reduce radiation doses during maintenance, and installation of an additional storage tank to reduce doses during later waste packaging as a result of radioactive decay. The RP also provided adequate evidence that the generation and accumulation of radioactive wastes will be minimised and that the radioactive waste management strategies met relevant regulatory expectations.

306. Full details of ONR's assessments can be found in the relevant assessment reports (Ref. 41, Ref. 46, Ref. 48, Ref. 52, Ref. 56, Ref. 58, Ref. 59).

307. ONR's inspectors were satisfied that the RP's safety case for radioactive waste management resolved the shortfalls identified and provided an adequate demonstration that relevant risks have been reduced to ALARP, raising Assessment Findings as appropriate.

Holistic Assessment of the Heating, Ventilation and Air Conditioning System

308. NPPs typically include a variety of HVAC systems that deliver important safety functions, including, but not limited to:

- a support function by maintaining suitable environmental conditions in buildings and rooms containing safety systems and/or components, to ensure that they deliver their required safety function(s); and/or
- confinement of radioactive materials.

309. Failure of a HVAC system in a NPP can potentially affect safety systems within more than one layer of protection and compromise the defence-in-depth provided by the design. Given the significance of the safety functions delivered by HVAC systems, ONR initiated this cross-cutting topic to ensure that a coordinated and proportionate regulatory assessment was undertaken of safety significant HVAC systems in the generic UK HPR1000 design. This assessment was coordinated primarily between the following ONR technical disciplines:

- Engineering disciplines (including Mechanical Engineering, Electrical Engineering and C&I)
- Fault Analysis (including Fault Studies and PSA)
- Hazards (External and Internal Hazards)
- Human Factors
- Radiological Protection
- Conventional Fire Safety

310. ONR's inspectors also engaged with the Environment Agency to ensure a collaborative assessment of HVAC systems.

311. ONR's assessment focused on ensuring that:

- All necessary safety functions were identified.
- The generic UK HPR1000 safety case provides an adequate analysis that demonstrates HVAC performance against frequent faults and bounding fault / accident scenarios.
- The design of HVAC systems reduces relevant risks to ALARP.

312. In response to the ONR and Environment Agency assessment, and relevant ROs raised (RO-UKHPR1000-0002, RO-UKHPR1000-0021, RO-UKHPR1000-0023, RO-UKHPR1000-0035, RO-UKHPR1000-0036 and RO-UKHPR1000-0039) (Ref. 23), the RP provided additional analysis of HVAC system performance and updated its generic UK HPR1000 safety case. This work showed that several modifications were needed to the generic UK HPR1000 design to ensure that relevant risks will be reduced to ALARP. These modifications included:

- additional measures to improve the resilience and diversity of HVAC systems against frequent faults; and
- measures to improve HVAC performance against bounding fault scenarios and environmental conditions.

313. Collectively, these modifications have improved the safety justification for HVAC systems, and enhanced the generic UK HPR1000 design's resilience against frequent faults and accident conditions. Further work is needed during site-specific phases by the licensee to complete the substantiation of HVAC systems and demonstrate that relevant risks are reduced to ALARP.

314. Full details of the ONR's assessment can be found in relevant Step 4 assessment reports (Ref. 43, Ref. 46, Ref. 49, Ref. 50, Ref. 51, Ref. 53, Ref. 54, Ref. 56, Ref. 57, Ref. 58).

315. ONR's inspectors were satisfied that the improvements implemented by the RP were sufficient to address the ROs and associated potential regulatory shortfalls identified during GDA reducing the risks to ALARP. Further work is needed during site-specific stages to demonstrate the detailed design of HVAC systems reduces relevant risks to ALARP.

Source Term Assessment for Normal Operations and Fault Accident Conditions

316. ONR's assessment of the source term cross-cutting topic covers normal operations and fault and accident conditions. The normal operation source term is defined as: "the types, quantities and physical and chemical forms of radionuclides present in a nuclear facility, that have the potential to give rise to exposure to radiation, radioactive waste, or discharges to the environment".

317. ONR's assessment of the normal operation source term included considering the suitability and sufficiency of the evidence provided by the RP to substantiate its quantification of the source term for the primary circuit and other systems. It also included how that analysis was presented for use in making other parts of the safety case for the generic UK HPR1000 design. A fundamental part of providing an adequate justification for the normal operation source term is a demonstration that radioactivity has been reduced to ALARP. This was the subject of a Chemistry-led RO, RO-UKHPR1000-0026 (Ref. 23).

318. Assessment activities were coordinated amongst the Chemistry, Radiological Protection, Radioactive Waste Management and Decommissioning disciplines, and the Environment Agency. The overall assessment was led by Chemistry, whilst Radiological Protection assessed the suitability and sufficiency of the evidence provided by the RP to substantiate its quantification of the normal operation source term; the output of which was used by the other disciplines involved in the assessment. ONR's assessment focus was on the RP's assumptions, methods and OPEX used to develop a source term that was adequate and representative of the generic UK HPR1000 design, and how the information was documented in the generic safety case.

319. The source term assessment also covered the RP's approach to defining and analysing accident source terms (covering both design basis and severe accidents). It included assessing the adequacy of the RP's underlying assumptions and how this work feeds more widely into the radiological consequence assessments used in the analysis of fault / accident conditions. This assessment was coordinated amongst the Chemistry, Fault Studies and Severe Accident Analysis disciplines. ONR's assessment focus was on the RP's assumptions, the basis of the accident source term(s) and the implications this had on the safety analysis / UK HPR1000 generic design.

320. In response to ONR's assessments, the RP reworked certain aspects of its generic safety case to clearly demonstrate that the generation, transport and deposition of radioactivity during normal operations, will be reduced to ALARP. An adequate source term was produced by the RP for both normal operations and fault and accident conditions.

321. Full details of ONR's assessments can be found in the Chemistry, Decommissioning, Radiological Protection and Radioactive Waste Management Step 4 assessment reports (Ref. 41, Ref. 48, Ref. 58, Ref. 59).

322. ONR's assessments concluded that the improvements identified by the RP were sufficient to resolve the shortfalls for GDA.

Assessment of the Generic UK HPR1000 Design Against Space Weather Hazards

323. The sun is a source of electromagnetic interference and other radiation, which can impact the performance and reliability of ground based technological systems. Collectively, these solar phenomena are known as space weather hazards. NPP safety systems and other associated infrastructure (for example the electric grid) may include components that are susceptible to space weather hazards. Safety functions delivered by these systems could be affected during a space weather event. Therefore, it is important that these hazards are considered in the generic UK HPR1000 design and the associated risks are reduced to ALARP. ONR's assessment identified a potential regulatory shortfall in the safety demonstration of the generic UK HPR1000 design against space weather hazards, which was included in the RO-UKHPR1000-0002 raised on the demonstration of alignment of the UK HPR1000 design with the GSE (Ref. 23).

324. The assessment of this technical topic was coordinated primarily between the External Hazards, C&I and Electrical Engineering disciplines. ONR initiated this technical topic to ensure that a coordinated and proportionate regulatory assessment was undertaken of space weather hazards and their effects on the generic UK HPR1000 design. ONR's assessment has focused on ensuring that the RP's generic UK HPR1000 safety case has demonstrated that:

- space weather hazards are identified and screened, and, where appropriate, characterised;
- an evaluation of the design is provided against space weather hazards; and
- the generic UK HPR1000 design reduces risks from space weather hazards to ALARP.

325. ONR assessed the RP's submissions relevant to space weather hazards and raised additional RQs, where needed. In response to ONR's assessment, the RP has provided additional analysis of the generic UK HPR1000 design against space weather hazards and updated its generic UK HPR1000 safety case. The RP's analysis:

- identified space weather hazards, screened them and, where appropriate, characterised them;
- identified potentially vulnerable systems;
- developed a range of strategies and plans for enhancing the generic UK HPR1000 design's resilience against space weather hazards; and
- identified potential modifications that would protect against or mitigate the hazard effects and improve the diversity and resilience of the safety systems.

326. This work has collectively improved the safety justification of the generic UK HPR1000 design against space weather hazards. The identified strategies and modifications will be implemented post-GDA during detailed design of the relevant systems. The licensee will need to demonstrate that relevant risks are reduced to ALARP.

327. Full details of ONR's assessment of space weather hazards is provided in the C&I, Electrical Engineering and External Hazards Step 4 assessment reports (Ref. 43, Ref. 49, Ref. 50).

328. ONR's inspectors were satisfied that the RP provided a proportionate analysis of the design against space weather hazards, developed appropriate mitigation strategies and identified relevant modifications that can be implemented during detailed design of the relevant systems.

Cyber Security

329. ONR's regulatory expectation for GDA is that an assessment of cyber security risks should be undertaken. The scope of this risk assessment should include both CBSIS and Computer-Based Security (CBSy) systems. During GDA Step 4 ONR's C&I and Security inspectors collaborated on the assessment of cyber security of CBSIS and CBSy systems. The assessment aligned two of ONR's purposes and was undertaken against both ONR's SyAPs, in particular SyDP 7.1, SyDP 7.3 and SyDP 7.5, and the SAPs, in particular ESS.27. The objectives of the assessment were:

- To seek confidence in the RP's assessment of cyber security risk and the identification of practicable design modifications to address vulnerabilities.
- To seek confidence that the RP's generic design for the UK HPR1000 can address the design basis threat.
- To review evidence that demonstrates the extent to which cyber security is taken into account in engineering practices used to develop the C&I platforms and systems for the UK HPR1000.
- To understand the strategy for undertaking independent assurance of cyber security through the system design and build phases.

330. The RP developed a methodology for undertaking cyber security risk assessment (CSRA) and implemented it on the centralised CBSIS in GDA Step 4. The RP developed a set of cyber security design requirements, which set out how the control sets identified in the cyber security risk assessments will be implemented in the design of CBSIS. ONR's assessment concluded that the CBSIS design process has given adequate consideration to cyber security and that it is possible to trace the outcomes of the CSRA through to the design documentation.

331. The cyber security risk assessments identified a number of vulnerabilities in the initial design of CBSIS and the design modifications required to resolve these vulnerabilities.

332. The RP also developed a strategy for undertaking independent assurance of cyber security as the detailed design of CBSIS progresses. This set out a graded approach, based on a system's security and safety significance, to selection of assurance activities and the independence required in their implementation.

333. During GDA Step 4, the RP also developed a strategy for cyber security risk assessment and deployment of CBSy. This was developed to a sufficient level of detail that ONR has confidence in the future development of a site-specific CBSy

system. The RP has also demonstrated due diligence for CBSy sufficiently to provide confidence that the relevant outcomes stated in SyAPs can be met.

334. Full details of the assessments can be found in the Security and C&I Step 4 assessment reports (Ref. 40, Ref. 43).

335. ONR's assessments concluded that the RP had provided sufficient confidence that the risks associated with cybersecurity of C&I systems had been adequately assessed for GDA, that strategies are in place to control these risks, and that regulatory expectations have been satisfactorily met.

Overview of ONR's Assessment of the Generic UK HPR1000 Layout Design

336. The UK HPR1000 layout cross-cutting topic focuses on the safety related aspects of the location of individual buildings, the positioning of the plant and the routing of services within those buildings. This includes:

- the size of the buildings and their location relative to each other;
- the division of the buildings by floors, separation barriers and rooms;
- the location of plant items within these buildings;
- the routes of pipes, cables and services between plant items; and
- access routes to permit installation and EMIT.

337. The nuclear safety aspects that ONR assessed in this cross-cutting topic are:

- Nuclear safety SSCs should feature redundancy, segregation and protective barriers to mitigate the risk of common cause failures.
- Safety zones: zones should be established for radiation, contamination and fire control.
- Personnel safety: the access routes should ensure safe personnel access and escape routes.
- Access: the plant and equipment should be capable of safe installation, operation and maintenance.

338. This assessment (Ref. 69) was coordinated between the following ONR technical disciplines to ensure that all nuclear safety aspects related to the layout design were considered:

- Civil Engineering
- C&I
- Conventional Fire Safety
- Conventional Health and Safety
- Electrical Engineering
- External Hazards
- Internal Hazards
- Mechanical Engineering
- Radiological Protection
- Security

339. Full details of ONR's assessment of the nuclear safety aspects of the generic UK HPR1000 layout design are provided in the relevant Step 4 assessment reports (Ref. 42, Ref. 43, Ref. 44, Ref. 46, Ref. 49, Ref. 50, Ref. 54, Ref. 56, Ref. 58, Ref. 40).

340. ONR was satisfied that all relevant aspects of the generic UK HPR1000 layout design were considered by the technical disciplines.

Grid Code Compliance of the Generic UK HPR1000 Design

341. The ability to connect a power plant to the GB transmission system is important both from a commercial perspective through the export of electrical power but also from the ability of the transmission system to provide power to the safety systems necessary to bring the NPP to a controlled and then safe shutdown state.

342. 'The Grid Code' (Ref. 70) defines the requirements for generating plants to connect to the GB transmission system and compliance with the grid code is a requirement for connection to the grid. In order to protect the integrity of the grid, requirements are defined in the grid code for generating stations to remain connected to the grid following defined voltage and frequency disturbances.

343. Whilst establishment of a grid connection agreement is a matter for a licensee, ONR's expectation is that the RP should demonstrate during GDA a full understanding of the requirements of the grid code and demonstrate the feasibility of a generic design to facilitate that connection. These demonstrations require support from a range of specialist areas within the RP organisation, including Electrical Engineering, Structural Integrity, Fault Studies and Fuel and Core. Similarly, ONR's assessment requires support from the same specialist areas.

344. In response to ONR's assessments, the RP presented several submissions to revise the generic UK HPR1000 design in order to comply with the grid code. Following assessment of the revised design by ONR's Electrical Engineering, Structural Integrity and Fuel and Core inspectors, the RP's solution was judged by ONR to be feasible for GDA. However, it was recognised that a licensee will need to undertake further analysis as the detailed design is developed.

345. Full details of ONR's assessments can be found in the Electrical Engineering, Fuel and Core Design and Structural Integrity Step 4 assessment reports (Ref. 49, Ref. 52, Ref. 62).

ONR's inspectors are satisfied that the RP has demonstrated a feasible option for complying with the grid code and at the same time ensuring that the fuel and core and structural integrity expectations are met.