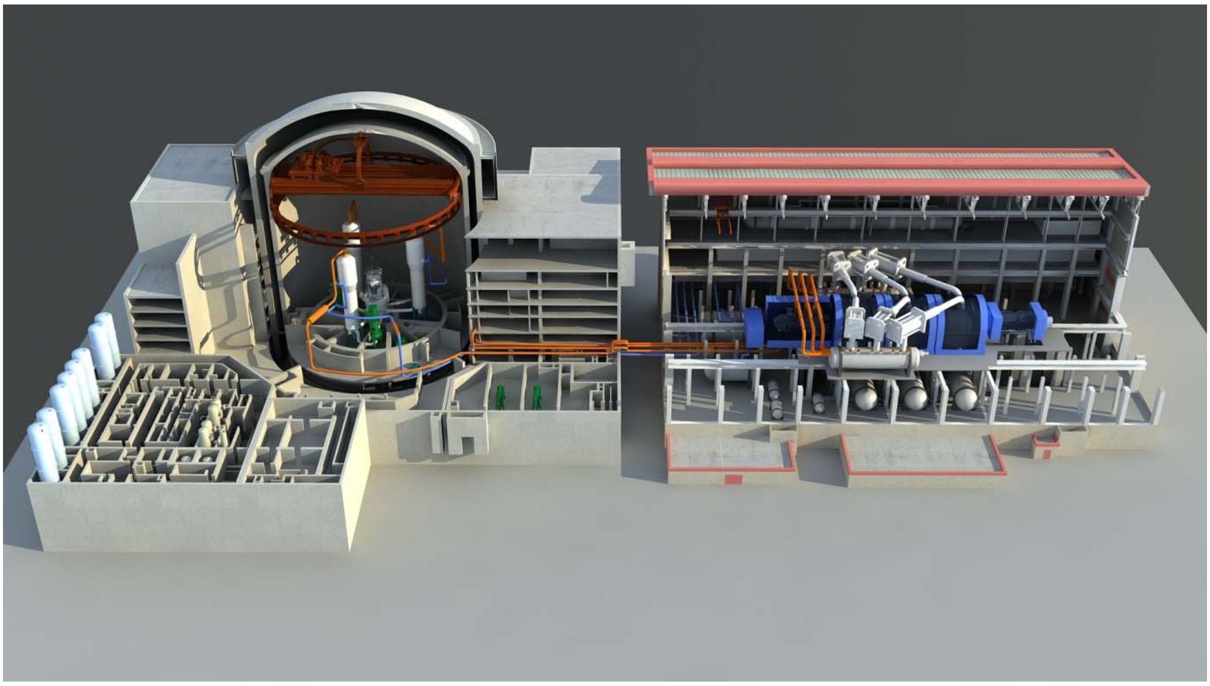
Office for Nuclear Regulation

New Reactor Division – Generic Design Assessment

Summary of the Step 2 Assessment of the UK HPR1000 Reactor



Picture courtesy of CGN

Project Assessment Report ONR-NR-PAR-18-007
Revision 0
November 2018

Published 11/18

EXECUTIVE SUMMARY

The mission of the Office for Nuclear Regulation (ONR) is to “provide efficient and effective regulation of the nuclear industry, holding it to account on behalf of the public”. In the context of new nuclear build in the UK, regulation is initially undertaken via the Generic Design Assessment (GDA) process. ONR and the Environment Agency (EA) developed the GDA process in 2006 in order to allow the nuclear regulators to assess reactor designs on a ‘generic’ basis, i.e. 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 issues, and hence early identification of required 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 power stations. However, the UK Government recognises that the approach is more efficient than the approach used prior to the existence of GDA and therefore expects reactor designers to follow the GDA process.

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 nuclear power plant. A prospective operator will have to obtain a nuclear site licence (NSL), and there is on-going regulation under the NSL throughout the life cycle of the plant.

To date, three reactor designs have been assessed under the GDA process and received Design Acceptance Confirmations (DAC) from ONR and Statements of Design Acceptability (SoDA) from the EA; 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 formally asked ONR and EA to begin the GDA of the UK HPR1000. The UK HPR1000 is a reactor design proposed for deployment at Bradwell-on-Sea, Essex. General Nuclear System LTD (GNS) is a UK-registered company that was established to implement the GDA on the UK HPR1000 reactor on behalf of three joint requesting parties, i.e. China General Nuclear Power Corporation (CGN), EDF and General Nuclear International (GNI).

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 1 of the UK HPR1000 GDA commenced in January 2017 and finished in November 2017. Step 1 of GDA is the preparatory step and, on completion, ONR issued a statement on the GDA joint regulators website that this step had been completed and that we were progressing to Step 2 of GDA.

Step 2 of GDA is the commencement of technical assessment and is focused on understanding and assessing the fundamental safety and security claims, and acceptability of the UK HPR1000 within the UK regulatory regime. During Step 2 of GDA ONR has considered the fundamental safety and security aspects of the design, and the EA has considered the environmental acceptability of the design, which is reported separately. This is ONR’s second report on the UK HPR1000 design and it evidences the conclusion of Step 2 of GDA.

Overall, the interactions with the RP throughout Step 2 of GDA have been constructive. The structure of the RP organisation is complex, with two very large companies, EDF and CGN, from different regulatory backgrounds cooperating in a new, technically challenging endeavour. GNS’s role in coordinating these activities has been challenging but GNS has worked consistently hard to ensure that UK regulatory expectations are met. We have also seen strong commitment from GNS, CGN and EDF to learn lessons from Steps 1 and 2 of GDA and to improve their working arrangements. The high level of expertise available within CGN and EDF will be essential when GDA moves into the detailed assessment stages.

During Step 2 of GDA we have undertaken the assessment work we had planned across 19 technical disciplines and we have also covered topics of a cross-cutting nature. Our assessment conducted to date has not identified any fundamental safety or security shortfalls that might prevent the issue of a DAC for the UK HPR1000 design. We have however identified a number of potential regulatory shortfalls and have raised Regulatory Observations to address those.

We can also confirm that both the RP and ONR have completed the preparatory work necessary to enable commencement of Step 3 of GDA.

There is a considerable amount of work to be undertaken by the RP going forward, requiring significant resource across all of the topic areas. ONR will continue to rigorously assess the safety and security submissions throughout Step 3 and Step 4 of GDA, and will address potential issues should they arise.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
ARN	(Argentina's) Autoridad Regulatoria Nuclear
AoF	Allocation of Function
BAT	Best Available Technique
BEIS	Department for Business, Energy and Industrial Strategy
BSI	British Standards Institution
BSL	Basic Safety Level (in SAPs)
BSO	Basic Safety Objective (in SAPs)
CCF	Common Cause Failure
CDM	Construction, Design and Management
CGN	China General Nuclear Power Corporation Ltd
DAC	Design Acceptance Confirmation
DBA	Design Basis Analysis
DEC	Design Extension Condition
DMGL	Delivery Management Group Lead
EA	Environment Agency
EMI	Electromagnetic Interaction
ENIQ	European Network for Inspection and Qualification
GDA	Generic Design Assessment
GNI	General Nuclear International Ltd
GNS	Generic Nuclear System Ltd
GSR	Generic Security Report
HBSC	Human Based Safety Claims
HF	Human Factors
HFI	Human Factors Integration
HIC	High Integrity Component
HRA	Human Reliability Analysis
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
iDAC	Interim Design Acceptance Confirmation
ISO	International Organisation for Standardisation
IVR	In-vessel Retention
JPO	(Regulators') Joint Programme Office
MDEP	Multinational Design Evaluation Programme (within OECD-NEA)
MDSL	Master Document Submission List

MSQA	Management of Safety and Quality Assurance
MW	Megawatts
NDT	Non-Destructive Testing
NEA	Nuclear Energy Agency (within OECD)
NNR	(South Africa’s) National Nuclear Regulator
NNSA	National Nuclear Safety Administration
NPP	Nuclear Power Plant
NSL	Nuclear Site Licence
OECD	Organisation for Economic Cooperation and Development
ONR	Office for Nuclear Regulation
PCER	Pre-construction Environmental Report
PCI	Pellet-Cladding Interaction
PCMI	Pellet-Cladding Mechanical Interaction
PCSR	Pre-construction Safety Report
PIE	Postulated Initiating Event
PSA	Probabilistic Safety Analysis
PSR	Preliminary Safety Report (includes security and environment)
PTI	Project Technical Inspector
PWR	Pressurised Water Reactor
RCP	Reactor Coolant Pump
RGP	Relevant Good Practice
RHWG	Reactor Harmonization Working Group (of WENRA)
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
SAA	Severe Accident Analysis
SAP(s)	Safety Assessment Principle(s)
SFAIRP	So Far As Is Reasonably Practicable
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SG	Steam Generator
SoDA	(Environment Agency’s) Statement of Design Acceptability
SSC	Structures, Systems and Components

SyAP(s)	Security Assessment Principle(s)
TAG	Technical Assessment Guide(s)
UKHPR1000WG	UK HPR1000 design specific Working Group (within MDEP)
WENRA	Western European Nuclear Regulators' Association

TABLE OF CONTENTS

Annexes

1 CONTEXT OF THIS PROJECT ASSESSMENT REPORT

1. In November 2017 the Office for Nuclear Regulation (ONR) and the Environment Agency (EA) announced that we were progressing to Step 2 of the Generic Design Assessment (GDA) of the UK HPR1000 reactor.

2. During the last 12 months ONR has completed the Step 2 assessment planned across 19 technical disciplines.

3. Noting that the regulators will only progress to Step 3 of the GDA following satisfactory outcomes from a series of readiness reviews undertaken by the regulators and the GDA Requesting Party (RP), this Project Assessment Report has been prepared as an input to ONR's decision on whether to progress to Step 3 of the UK HPR1000 GDA.

2 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 EA developed the GDA process in 2006. GDA allows the nuclear regulators to assess reactor designs on a 'generic' basis, i.e. 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 issues, and hence early identification of required 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 licensing regime for new power stations. However, the UK Government recognises that the approach is more efficient than the approach used prior to the existence of GDA and therefore expects reactor designers to follow the GDA process.

6. Three reactor designs have been assessed under the GDA process and received Design Acceptance Confirmations (DAC) from ONR and Statements of Design Acceptability (SoDA) from the EA; the UK EPR™ received its DAC and SoDA in December 2012, the AP1000® in March 2017 and UK ABWR in December 2017.

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

8. GNS is a UK-registered company that was established to implement the GDA of the UK HPR1000 reactor on behalf of three joint requesting parties, i.e. China General Nuclear Power Corporation (CGN), EDF and General Nuclear International (GNI). Although for practical purposes we have often referred to GNS as the UK HPR1000 GDA RP, it is important for the reader of this report to have a clear understanding of the actual composition and identity of the UK HPR1000 GDA RP.

9. During Step 1 of the UK HPR1000 GDA 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) containing the PSR and the means for the public to raise comments. The RP completed Step 1 of the GDA process in November 2017 and we immediately began the technical assessment work – Step 2 of GDA.

3 INTRODUCTION

10. 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.

11. Step 1 of the UK HPR1000 GDA commenced in January 2017 and finished in November 2017. Step 1 of GDA is the preparatory step and ONR did not undertake any technical assessment, however, the regulators did engage with the RP to ensure that regulatory expectations were understood. Thus, during Step 1 of the UK HPR1000 GDA ONR held extensive discussions with the RP (including technical discussions both in the UK and in 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 technology. In November 2017 we announced on our website that we were progressing to Step 2 of the UK HPR1000 GDA (Ref. 5).

12. Step 2 of the UK HPR1000 GDA commenced in November 2017 and is targeted for completion in November 2018. Step 2 of GDA is the commencement of technical assessment and is focused on understanding and assessing the fundamental safety and security claims, and the acceptability of the UK HPR1000 within the UK regulatory regime. Safety and security claims, or assertions, are those statements that describe the design and explain why the facility is safe and secure; they are normally presented within the PSR and its supporting references.

13. The key objective of Step 2 is to identify any fundamental safety or security issues that might prevent the issue of a DAC. It is important to note that our assessment during Step 2 focuses on high level descriptions of the design and its safety and security cases. As we progress our assessment in further steps of GDA, we go deeper into the documentation provided by the RP, and obtain the results of our own confirmatory analyses, significant issues may still be identified. We have GDA regulatory tools to deal with such issues. This Project Assessment Report describes our assessment during Step 2 and its outcome. It is underpinned by 19 technical assessment reports, which are published on our joint regulators' GDA website (Ref. 6).

14. During Step 3 of GDA ONR increases its regulatory scrutiny and undertakes a more detailed assessment of the design focusing on the methods and approaches used by the RP to meet the safety and security claims. These are normally described within the (generic) Pre-construction Safety Report (PCSR), and Generic Security Report (GSR) and their references. At the end of Step 3 ONR publishes a Summary Assessment Report on our joint regulators' GDA website (Ref. 6). The RP's target duration for Step 3 of the UK HPR1000 GDA is 13 months.

15. During Step 4 of GDA ONR conducts in-depth assessment of the evidence presented by the RP to support and form the basis of the safety and security cases. At the end of Step 4 ONR judges whether a DAC should be issued for the design. If there are generic technical issues that remain outstanding, and depending on their significance, ONR may issue an interim DAC (iDAC), or may judge that neither a DAC, nor an iDAC, are warranted. ONR publishes its Step 4 Assessment Reports

and a Summary Assessment Report on our joint regulators' GDA website (Ref. 6). The RP's target duration for Step 4 of the UK HPR1000 GDA is 25 months.

16. 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 nuclear power plant. A prospective operator will have to obtain a nuclear site licence (NSL), and there is on-going regulation under the NSL throughout the life cycle of the plant. In particular, a licensee will require ONR's formal consent before nuclear safety related construction can commence, for which it will need to develop and submit for regulatory assessment a site specific pre-construction safety case and a site security plan and demonstrate compliance in accordance with Nuclear Industry Security Regulations 2003 (as amended) (Ref.15). To enable these processes, our regulatory philosophy is that after obtaining a DAC, the RP should transfer the outputs from the GDA (including 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), to the licensee to be used to support the development of the site specific safety case and the site security plan. 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, 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.

17. In addition, 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 dossier.

3 ASSESSMENT STRATEGY

18. ONR's assessment of the RP's Step 2 safety and security submissions has been undertaken by specialist inspectors covering 19 technical disciplines. During Step 2 of GDA the inspectors working on the 19 topic areas were distributed in two groups reporting to two Delivery Management Group Leads (DMGLs) who have coordinated the assessments and provided strategic oversight.

19. The GDA Project Technical Inspector (PTI) is responsible for leading the assessment of the RP's arrangements for developing the safety and security cases and also for matters of a cross-cutting nature, which impact all disciplines and require coordination to ensure a consistent approach.

20. The DMGLs and PTI report to ONR's Head of HPR1000 Regulation who leads the regulatory activities related to HPR1000 within ONR's New Reactors Division.

21. ONR undertook thorough preparations for Step 2 during Step 1 of the GDA. As part of these preparations ONR's inspectors developed Step 2 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 2;
- Identified the assessment standards that would be used;

- Listed the documentation that the RP had planned to provide to supplement the specific chapter(s) of the PSR to serve as the basis for ONR's assessment; and
- Delineated the Step 2 timeline tailored for each specific area, including planned activity that would enable timely completion and documentation of the assessment in each technical area (e.g. meetings and workshops with the RP's specialists, or the Management for Safety and Quality Assurance (MSQA) Step 2 inspection, as appropriate).

The Step 2 Assessment Plans were shared with the RP to provide transparency.

22. Technical oversight and assurance throughout Step 2 have been provided by ONR's Professional Leads.

23. During our assessment we use 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.
- Regulatory Observations (RO). ROs are raised when we identify potential regulatory shortfalls requiring action and new work by the RP for them to be resolved.
- 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.

24. ONR works closely and coordinates its assessment activities with the EA which considers the environmental acceptability of the design. In particular, in Step 2 we have worked jointly with EA in the area of MSQA and we have maintained very close coordination in the areas of Radioactive Waste Management, Decommissioning and Spent Fuel Management. The EA reports its findings from GDA separately on its website (Ref. 7).

4 ASSESSMENT STANDARDS

25. ONR expects new nuclear reactors 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 health 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. As indicated above, the UK HPR1000 GDA RP has provided, for regulatory assessment during Step 2, preliminary safety and security cases in the form of a PSR with associated references.

26. The overriding legal requirement for any nuclear facility proposed for construction in Great Britain is that the level of risk is demonstrated to be as low as reasonably practicable (ALARP) when the facility starts operation and over its lifetime. In simple terms ALARP is a requirement to take all measures to reduce risk where it is reasonable to do so. Often, this is not done through explicit comparisons of costs and benefits, but rather by applying established relevant good practice (RGP).

27. We expect the RP's 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 and standards produced by organisations such as the British Standards Institution (BSI), the International

Organisation for Standardisation (ISO), 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 an industrial sector can also be considered RGP. ONR's guidance including our Safety Assessment Principles (SAPs) (Ref. 8) and Technical Assessment Guides (TAGs) (Ref. 9) inform our view of RGP.

28. 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 (Refs 10 and 11):

- 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.

29. In Step 2 of GDA the RP is required to provide its approach to ALARP, i.e. a description of the process being adopted to ensure that the risks to human health arising from the operation of a power station based on the proposed design are reduced to ALARP.

30. Our inspectors use ONR's SAPs (Ref. 8) and Security Assessment Principles (SyAPs) (Ref. 12) 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, it is important that the RP understands that neither the SAPs nor the SyAPs are intended, or sufficient, to be used as design standards.

31. Both the SAPs and the SyAPs are consistent with IAEA standards and guidance, and are supported by more detailed TAGs (Ref. 9).

32. Our expectations for GDA are detailed in ONR's GDA Guidance to RPs (Ref. 13). For clarity, the requirements for Step 2 of GDA are repeated in Annex 1 of this report.

5 MAIN FEATURES OF THE DESIGN AND SAFETY SYSTEMS

5.1 General Description

33. The HPR1000 technology is described in the UK HPR1000 PSR (Ref 4). The HPR1000 is a Pressurised Water Reactor (PWR) designed by CGN using the Chinese Hualong Technology. Its electric output is approximately 1180MW.

34. The HPR1000 has evolved from a sequence of reactors which 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

Nuclear Power Plant (NPP) Units 3 and 4, are under construction in China. Fangchenggang NPP Unit 3 is the reference plant for the UK HPR1000. Ref. 3 indicates that the HPR1000 is designed to have a lifetime of at least 60 years.

35. The HPR1000 is a three-loop PWR. Each loop consists of primary pipes going in and out of 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 is a vertical vessel the function of which 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, which is equivalent to approximately 150 times the atmospheric pressure.

36. 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 from the reactor moves along the hot legs and enters the primary side of each SG (bottom plenum first and then the tubes) where it transfers the heat to the water, at much lower pressure in the secondary side of the SGs, and produces steam. 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 in the SGs drives a turbine that, ultimately, via a generator produces electricity.

37. The RPV is a cylindrical steel vessel designed to withstand high temperatures and pressures. The RP documentation indicates that the number of welds between parts of the RPV is minimised as far as possible. 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 gauge pipe arranged 17x17. 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.

38. 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 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.

39. Three safeguards buildings adjacent to the reactor building house key safety systems. The main control room is located in one of the safeguards buildings. The fuel building is also adjacent to the reactor. It contains the fuel handling and short term storage facilities.

40. The UK HPR1000 PSR (Ref. 3) indicates that the reactor building, the fuel building and all three safeguards buildings are designed to withstand an earthquake of magnitude 0.3g. The PSR 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 containment building, safeguards buildings, fuel building and nuclear auxiliary building are key facilities in the area generally referred to as the nuclear island (Figure 1). The turbine building is the central part of the so called conventional island.

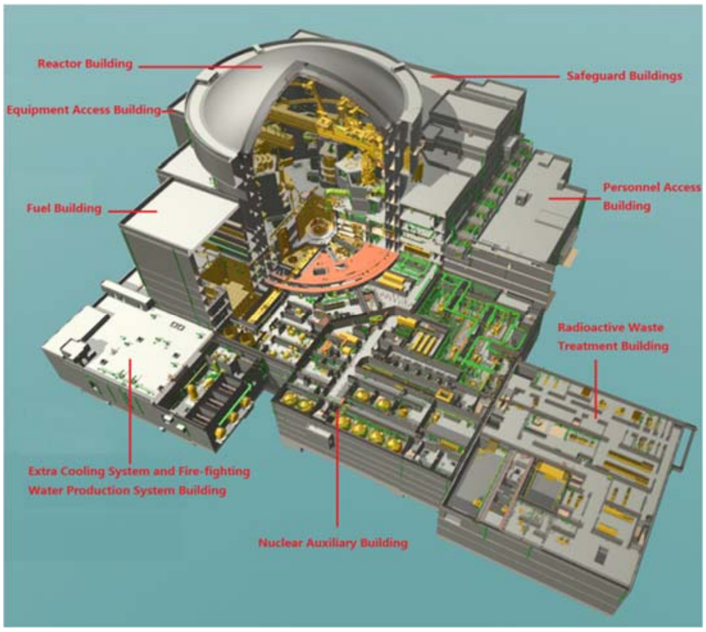


Figure 1 - Nuclear Island
(Picture courtesy of CGN)

5.2 Safety Systems

41. 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, i.e. to take the reactor to a safe and stable condition. Brief introductions to the HPR1000 safety systems can be found in chapter 2 of the PSR (Ref. 3) 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 HPR1000.

42. The design philosophy underpinning the HPR1000 reactor cooling safety function is based on three independent trains of engineered safety features physically separated in the three safeguards buildings discussed above. The RP claims that they offer 3x100% redundancy. Each safeguards building houses:

- One train of the (motor-pump driven) emergency feedwater system to feed water into the steam generators in case of loss of normal feedwater.
- One train of the safety injection system. The safety injection system has three sub-systems, i.e. 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).

43. Although the safety philosophy for the HPR1000 is mainly based on active systems, the HPR1000 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 auxiliary 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 2)

- The passive reactor cavity injection system supports the in-vessel retention function.

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 passive as well.

44. It is important to mention that, for the HPR1000, the design choice to manage severe accident scenarios where there is core degradation is based on retention of the molten debris inside the RPV via engineered means to externally flood the RPV. This strategy is called in-vessel retention (IVR).

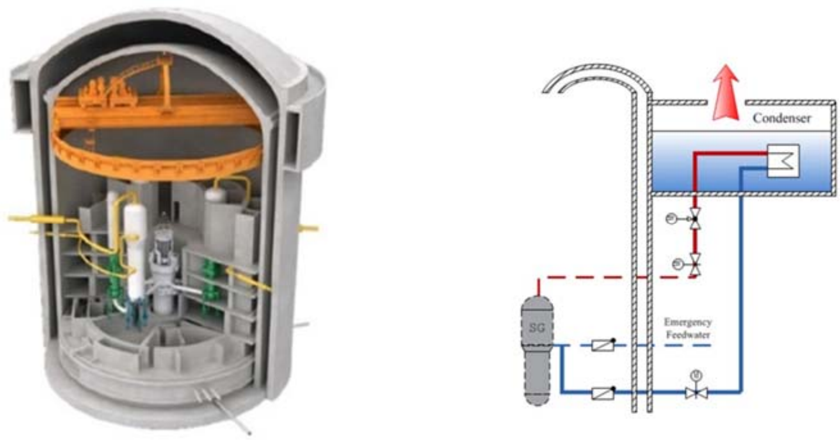


Figure 2 – Secondary Passive Residual Heat Removal System
(Pictures courtesy of CGN)

5.3 ONR's Familiarity with the Technology Used in HPR1000

ONR has extensive experience assessing PWR designs and is therefore familiar with the technologies presented. Our assessment moving forward, while addressing all aspects of the design, will pay special attention to the safety aspects that are unique to the HPR1000, such as the passive secondary heat removal system and how its effectiveness is demonstrated by the RP.

6 THE GDA REQUESTING PARTY

6.1 Organisation

45. CGN and EDF created GNS as a joint venture company to undertake the GDA for the UK HPR1000 reactor. GNS is owned by GNI (66.5%) and EDF Energy Holdings Limited (33.5%), the UK subsidiaries of CGN and EDF respectively. GNS acts on behalf of the three joint requesting parties, CGN, EDF and GNI. For practical purposes, during Steps 1 and 2 we have referred to GNS as the RP. However, our understanding of GNS's role has become clearer over the duration of these steps. This is discussed hereafter.

46. GNS is supported by its parent organisations, which have defined their roles in the PSR (Ref. 3):

- 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.
- EDF provides technical expertise to support the UK HPR1000 GDA project. This includes reviewing technical documentation, providing operating plant experience 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.

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

48. It is important to summarise, and note, that while CGN and EDF are two of the parties requesting the GDA, they are also formal service providers to GNS, making the structure of, and logistics within, the RP complex. This is discussed further below.

6.2 Interactions with the Requesting Party

49. CGN and EDF bring a wealth of experience to the UK HPR1000 GDA both as designers and operators of nuclear power stations. During our interactions with both organisations we have observed on multiple occasions the extensive technical expertise that resides within both organisations. Therefore, the partnership between these organisations brings important benefits to the GDA, particularly when considering the knowledge of the UK regulatory environment that EDF can offer.

50. However, the structure and organisation of the HPR1000 GDA RP is complex and the role of GNS, its capacity and capability to deliver this role and to coordinate the activities of CGN and EDF, as well as the decision-making mechanisms within the RP, have not always been clear. Lack of agility in the RP's response has brought challenges during Step 2.

51. The RP has undertaken work to learn lessons from the experience so far and has identified areas for improvement in relation to the interactions between the RP organisations as well as with ONR. GNS has also recognised that its capability and capacity have been stretched during Step 2 and is accelerating its recruitment plans. We have been reassured by the RP's hard work and commitment to ensuring that they are adequately prepared to progress through the next stages of GDA.

52. We have found the RP to be willing to engage with ONR. Although resource limitations at GNS have, at times, impacted its flexibility to facilitate meetings between the regulator and the design teams, we have had a high level of technical engagement across all assessment topics. We have also had the opportunity to engage directly with CGN's design teams in China. Our interactions have also included informative visits to Daya Bay and Fangchenggang NPPs and a range of research and manufacturing facilities that support the Chinese nuclear power industry.

53. During previous GDAs, RPs whose design teams are based overseas found it a challenge to understand some requirements that are specific to the UK regulatory regime; CGN has also recognised some of these challenges in its understanding of

ALARP and UK safety cases. CGN, GNS and EDF have worked together to develop training on these matters and, although a significant amount of work still needs to be done to further develop competence, the organisations have demonstrated commitment to further increasing their understanding.

7 COLLABORATION WITH OVERSEAS REGULATORS

54. ONR considers international cooperation important for 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.

55. When assessing new reactors we aim to take into account international good practice, international standards and the assessment undertaken by overseas regulators, and we also aim to work with overseas regulators to benefit from their work and experience where appropriate.

56. It is important to stress, however, that any cooperation with other nuclear regulators does not replace ONR conducting our own independent assessment, but can help to supplement it with additional valuable information and insights, making our own work more efficient. 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.

57. UK HPR1000 uses Chinese Hualong technology. The Reference Plant for the UK HPR1000 is Fangchenggang NPP Unit 3, which is under construction in China. Therefore establishing collaboration with the Chinese nuclear regulator, the National Nuclear Safety Administration (NNSA) was an early priority for ONR in the UK HPR1000 GDA.

58. Following initial discussions early in 2017, in September 2017 NNSA and ONR/EA launched a bilateral China/UK Regulatory Working Group with two key objectives:

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

59. A two-year work plan was established based on bilateral workshops covering the following topics:

- Safety review standards – held in September 2018.
- UK / China Civil nuclear security requirements – held in September 2018.
- Radioactive waste management – planned for 2019.
- Safety evaluations including independent regulatory analyses and studies on accident analyses (including severe accident analyses) – planned for 2019.

60. In addition, in September 2017 the Policy Group of the OECD-NEA Multinational Design Evaluation Programme (MDEP) approved the creation of the HPR1000 design specific Working Group (HPR1000WG). The members of this working group are NNSA, ONR, Argentina's Autoridad Regulatoria Nuclear (ARN) and South Africa's National Nuclear Regulator (NNR). The first meeting of the HPR1000WG took place in March 2018 in China and considered several topics including lessons learnt from the Fukushima accident, and unique HPR1000 design features affecting safety. The second meeting of the group held in September 2018 in France included a session on internal and external hazards.

8 GDA COMMENTS PROCESS

61. ONR's mission includes holding the nuclear industry to account on behalf of the public and places great importance on being open and transparent to ensure the public is informed of its work and its regulatory decisions, which will in turn improve and maintain their trust. Within GDA ONR does this by publishing, on the joint regulators GDA website (Ref. 6), our GDA guidance, the regulatory observations (ROs) and regulatory issues (RIs) raised during our assessment and corresponding RP's resolution plans, and our assessment reports documenting the outcomes of our assessment.

62. As part of the GDA process GNS publishes information on the reactor design as well as the technical submissions that we receive as part of the assessment process. GNS's website (Ref. 4) includes a comments process where the public can comment on any aspect of the HPR1000 reactor technology, design, safety, security and environmental features via the website or by post.

63. Since the start of the UK HPR1000 public comments process GNS has received a total of 29 comments (November 2017 – August 2018). Of the 29 comments:

- 16 comments relate to technical aspects of the reactor technology, design, safety, security and environmental features;
- One comment relates to the GDA process, specifically the public comments process and consultation; and
- 12 comments relate to other aspects not directly related to the reactor design or GDA process such as siting, policy and aesthetics of the design.

64. The RP has responded to all of the comments. Four comments were deemed to be out of scope of the public comments process and one of these was passed to the Bradwell B Community Relations team. All comments and responses have been shared with the regulators for consideration in the assessment process as appropriate. All the technical matters raised via the public comments received so far are or will be covered by our assessment.

9 SUMMARY OF ONR'S ASSESSMENT OUTCOMES

65. The following subsections summarise the assessment we have conducted during Step 2 of GDA across 19 technical disciplines. The sections are structured consistently; for each topic we first outline the key relevant aspects within the preliminary safety or security cases, we then highlight the areas of strength within the safety and security submissions, and those matters that require follow-up during Step 3 and beyond. A final conclusion on whether any fundamental safety or security shortfalls have been found is also included for each technical topic. For more information, the reader should refer to the 19 assessment reports published in the GDA joint regulators website (Ref. 6).

66. In addition to the 19 assessment summaries below, subsection 9.20 describes the regulatory activity in relation to matters of a cross-cutting nature that we have undertaken during Step 2 of GDA, and the key outcomes.

67. Our assessment conducted so far has not identified any fundamental safety or security shortfalls that might prevent the issue of a DAC for the UK HPR1000 design. We have however identified a number of potential regulatory shortfalls that require action and new work by the RP for them to be resolved. We have issued or are in the process of issuing ROs to address those shortfalls. At the time of writing this report

three ROs have been published in our GDA joint regulators website (Ref. 6) together with the RP's resolution plans:

- RO-UKHPR1000-001 "Diverse Actuation System Design Shortfalls".
- RO-UKHPR1000-002 "Demonstration that the UK HPR1000 Design is Suitably Aligned with the Generic Site Envelope".
- RO-UKHPR1000-003 "Suitable and Sufficient Severe Accident Analysis Safety Case".

68. During Step 2 we have also raised 152 RQs requesting the RP to provide clarification or additional information on safety and security matters. So far we have not raised an RI.

9.1 Chemistry

69. Key aspects of the UK HPR1000 preliminary safety case related to Chemistry, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Those areas where the Chemistry or chemistry control of a system is claimed as directly contributing to safety.
- Those areas where the Chemistry or chemistry control of a system is, by inference, significant to the availability or longevity of systems, structures and components important to safety.
- Those areas where the Chemistry or chemistry control of a system has an influence on the exposure, or potential exposure, of workers or the public to ionising radiation, this includes during fault or accident scenarios.

70. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Chemistry identified the following areas of strength:

- The proposed approach to materials selection for UK HPR1000 is to use materials that exhibit low susceptibility to certain degradation mechanisms, such as flow accelerated corrosion. We consider that for the RP to have stated this early in Step 2 demonstrates positive bias in favour of safety and we consider this to be an area of strength.
- The RP is proposing a systematic approach to the Chemistry of the UK HPR1000 and has laid this out in a strategy document.
- The RP has recognised the importance of considering the source term early and the benefit of considering factors contributing to the generation of radioactivity.
- The RP has responded well to challenge and has recognised that additional work will be required in a number of areas, e.g. the impact of IVR, zinc dosing.
- Overall, the RP has identified the operating Chemistry for many of the main safety related systems in UK HPR1000. While in some areas the claims are still at a high-level, we have no reason to suggest that they cannot be fully developed as the GDA of UK HPR1000 progresses.

71. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Chemistry identified areas that require follow-up, including:

- Identification and application of relevant codes and standards.
- Applicability of the Chemistry of the reference plant to UK HPR1000.
- Chemistry of the primary circuit.

- Accident Chemistry and the impact of IVR on accident progression and the evolution of volatile species.
- Combustible gas behaviour in containment and the effectiveness of passive autocatalytic recombiners.
- Chemistry of the secondary circuit and in particular the impact of and approach to management of chloride ingress.
- Spent fuel pool cleanup and temperature control systems.
- Chemistry and chemistry control of auxiliary systems.
- Chemistry aspects of the waste management systems.
- Practical application of the proposed materials selection methodology and its impact on operating Chemistry.
- Source term and radionuclide selection and how the actinide baseline will be established.

72. The Chemistry assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.2 Civil Engineering

73. Key aspects of the UK HPR1000 preliminary safety case related to Civil Engineering, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Demonstration that the methods of analysis and the determination of design parameters are applicable for the design of nuclear safety-related structures.
- Demonstration that the design methodology, load combinations and seismic design for UK HPR1000 will comply with RGP codes and standards.
- Demonstration that UK HPR1000 civil structures will adopt RGP codes and standards. In addition, a demonstration that the design will be compatible with UK construction practices and materials.
- Demonstration that nuclear safety-related structures can deliver safety functional requirements.
- Demonstration that the design of UK HPR1000 will consider applicable UK regulations relevant to Civil Engineering.
- Demonstration that the categorisation process and classification of UK HPR1000 nuclear safety-related structures will adopt RGP codes and standards.
- Demonstration that nuclear safety risks related to the design, procurement, construction, operation, maintenance and decommissioning of Civil Engineering structures have been reduced to ALARP.

74. In addition, Civil Engineering is responsible for the demonstration that the plant has sufficient resilience against non-accidental aircraft impact.

75. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Civil Engineering has identified the following areas of strength:

- The RP has developed a plan to deliver a clear and logical document hierarchy which includes analysis and design submissions to articulate the Civil Engineering safety case. Once completed, this should demonstrate the “golden thread” through the Civil Engineering safety case.
- The seismic categorisation process, of relevance to nuclear-safety related structures, is commensurate with relevant IAEA guidance.
- The RP will adopt the latest internationally recognised and accepted nuclear-specific codes and standards for the analysis and design of safety-related

nuclear structures. This should lead to a conservative analysis commensurate with the importance of the safety function(s) being performed and reflect RGP.
- The RP has established an Aircraft Impact Multi-Disciplinary Working Group to oversee and coordinate the activities required for the Aircraft Impact topic.

76. GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Civil Engineering has identified the following areas that require follow-up:

- Demonstration of the "golden thread" within the Civil Engineering safety case, including identification of safety functional requirements, engineering requirements and acceptance criteria for nuclear safety-related structures.
- Additional work to demonstrate that the Spent Fuel Pool (SFP) is capable of delivering the safety functional requirements to meet ONR expectations for defence in depth.
- Other civil structures, systems and components will be sampled to ensure that they are capable of delivering the claimed safety functional requirements (e.g. use of grouted tendons for pre-stressed inner containment).
- Application of nuclear safety categorisation and classification, and seismic categorisation to the design of civil structures.
- Ground parameters included in the Generic Site Envelope report.
- Barrier substantiation, in coordination with the Internal Hazards topic.
- Combining of codes and standards needs to be adequately justified and their mutual compatibility demonstrated, particularly when using British or European material parameters in American design codes.
- Evidence to demonstrate compliance with ONR expectations for Aircraft Impact.
- The RP has identified that two types of aircraft impact shell exist for the HPR1000. ONR considers this a novel concept for the UK and the implications for the Civil Engineering assessment and generic aircraft impact safety case need to be further explored.

77. The Civil Engineering assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.3 Control and Instrumentation (C&I)

78. Key aspects of the UK HPR1000 preliminary safety case related to C&I, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- The C&I architecture of the UK HPR1000 reference plant (Fangchenggang NPP Unit 3) consists of multiple interconnected C&I systems which are classified based upon their nuclear safety significance.
- C&I systems are provided to ensure effective reactivity control, heat removal and confinement of radioactive material.
- Reactor protection is performed by a dedicated reactor protection system (RPS) which is categorised as being of the highest safety classification, and this system is backed up by a diverse actuation system of lower safety classification.
- Reactor control under normal operating conditions is performed by a control system which is of a different design and which is claimed to act independently from those systems performing reactor protection functions.

79. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to C&I identified a number of areas of strength, including the following:

- The C&I systems are designed to provide five independent levels of defence in depth covering normal operation, accident mitigation, diverse accident mitigation, severe accidents and emergency response – this approach aligns with established UK RGP regarding defence-in-depth.
- The RPS has been allocated the highest level of safety classification and contains multiple levels of equipment redundancy, being of a four train design, and in this regard reflects UK RGP.

80. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to C&I identified the following areas that require follow-up:

- The contents of the PSR addressing C&I design were based upon the design of a reactor currently under construction in China (Fangchenggang NPP Unit 3) and a safety case based upon the UK design is to be provided later in GDA. In Steps 3 and 4 of GDA we will assess (against UK RGP) any significant differences between the UK design and the Fangchenggang NPP Unit 3 design which were not considered within this Step 2 assessment.
- We raised RO-UKHPR1000-001 concerning shortfalls in the design of the diverse actuation system. In response the RP produced a resolution plan which was judged to be credible and timely; we will review the RP's implementation of this plan later in the GDA process. The planned closure date for this RO is August 2019.
- The RP's safety case contained claims concerning the ability of the C&I equipment to support the overall station safety case, covering functional performance, reliability and design substantiation, but arguments and evidence to support these claims were not available for assessment within Step 2; we will assess these aspects later in the GDA process.
- The ability of C&I architecture to withstand potential Common Cause Failures (CCF) is a key aspect of the design, and as more safety case information becomes available we will consider this area in greater detail later in the GDA process.

81. The C&I assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.4 Conventional Fire Safety

82. Key aspects of the UK HPR1000 preliminary safety case related to Conventional Fire Safety, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- The PSR contains objectives which provide confidence that fire safety for the protection of people from the danger of fire will be adequately assessed, and risks reduced ALARP during the progress of the UK HPR1000 through the GDA process. Relevant objectives include:
    - The PSR identifies fire as a risk to life safety.
    - The principle of defence in depth is applied to fire protection arrangements.
    - There is an objective to "eliminate or reduce risk".

- There is recognition by the RP of the need to map the design against UK regulations for Conventional Fire Safety and determine a gap analysis.

83. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety claims related to Conventional Fire Safety identified the following areas of strength:

- The RP has produced a high level fire safety strategy which describes how the design of the UK HPR1000 will comply with legislative requirements and meet UK expectations for fire safety in the design of buildings to protect people from the danger of fire.
- A procedure has been developed, to identify those areas where the design departs from published guidance, and to consistently manage the ‘gaps’ in compliance with prescriptive codes of practice. The management process utilises fire engineering principles to provide an adequate level of safety which is achieved by implementing alternative fire protection measures to reduce fire risks in the final design to ALARP.

84. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety claims related to Conventional Fire Safety identified the following area that requires follow-up:

- The “Methodology for Gap Management in Conventional Fire Safety Area” will remain a live document during Step 3 and will require regular updates from lessons learnt, after the RP benchmarks its fire engineered design solutions against RGP.

85. The Conventional Fire Safety assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.5 Conventional Health and Safety

86. Key aspects of the UK HPR1000 preliminary safety case related to Conventional Health and Safety, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Confirmation of understanding in the preparation of the design of the UK HPR1000, that foreseeable Conventional Health and Safety risks should, so far as is reasonably practicable, be eliminated, or reduced, or controlled, to protect persons affected by the construction or operation of a nuclear power station based on the proposed design.
- Acknowledgement of the effect of the design on risks to health and safety of any person across the life cycle of the nuclear power station, including: construction, operation, maintenance and decommissioning.
- Appreciation by the RP of the need to identify by gap analysis early in GDA the potential legal differences between Chinese industrial safety and UK Conventional Health and Safety regulatory approaches, so they may be understood and addressed in the design of the UK HPR1000.
- Recognition of the Conventional Health and Safety interface with nuclear and environment design across GDA topic specialisms via appropriate cross-chapter reference.

87. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety claims related to Conventional Health and Safety identified the following areas of strength

- The RP will adopt recognised Conventional Health and Safety standards in the design of the UK HPR1000 applying general principles of prevention to ensure compliance with UK relevant statutory provisions.
- The Construction Design Management (CDM) Strategy, outlines how the RP determines that the UK HPR1000 GDA project will meet the key requirements of the Construction (Design and Management) Regulations 2015 (CDM 2015), (Ref. 16), and provides an essential and specific GDA reference basis to support CDM 2015 compliance.
- The RP's CDM Strategy clarifies roles, functions and responsibilities, with supporting arrangements to identify, eliminate, reduce or control foreseeable health and safety risks in design.
- The CDM Strategy outlines a design methodology approach, coordinating and monitoring the identification and assessment of health and safety risks, referencing risk assurance processes. The RP acknowledges that all GDA project designers must have an understanding of the UK context.

88. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Conventional Health and Safety identified the following areas that require follow-up:

- Chapter 25 of the PSR recognises the significant regulatory difference between Chinese and UK regulatory systems: RP gap analysis of Conventional Health and Safety law and standards commenced in Step 2 and is on-going. During Steps 3 and 4 assurance of accurate detail of difference in key design topic areas, and confirmation of UK HPR1000 Conventional Health and Safety design modifications arising will be pursued.
- We will seek assurance that UK HPR1000 designers, including the RP as CDM Principal Designer and as Designer, demonstrate the necessary UK statutory understanding to ensure in either their preparation or modification of the UK HPR1000 design the elimination, as far as reasonably practicable, of foreseeable risks; and where this not possible the reduction or control of conventional health and safety risks, so far as is reasonably practicable, in accordance with UK statutory requirements. Further, that management of significant and foreseeable risks is effectively coordinated throughout the design process, and, as necessary, supported by UK conventional health and safety skilled, knowledgeable and experienced persons.
- ONR will pursue confirmation that UK HPR1000 design preparation or modification appropriately records design information arising from gap analysis design review, including information about significant risks that cannot be eliminated, in a format that may be accessed and understood by those who will be implementing the design.

89. The Conventional Health and Safety assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.6 Electrical Engineering

90. Key aspects of the UK HPR1000 preliminary safety case related to Electrical Engineering, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- The electrical systems are designed so that the safety of the power plant is assured through the continuity of electrical power supplies, regardless of the initiating event or fault.

- The electrical systems provide power to ensure that, in the event of a loss of offsite power, the reactor can be shut down and the facilities safely cooled.
- Redundant Class 1 electrical systems are provided, which are to be physically separated and independent.

91. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Electrical Engineering identified the following areas of strength:

- The RP has presented high level claims that set out the principles by which the electrical system should be designed.
- The architecture of the electrical systems, with redundant divisions fed by multiple offsite and onsite power sources, should provide the basis of a design which should be capable of being demonstrated to meet international standards and ONR's expectations for redundancy and defence-in-depth.

92. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Electrical Engineering identified the following areas that require follow-up:

- Categorisation and classification of the electrical equipment: consistency between the assigned Class and the safety function(s) that the equipment supports.
- Requirements for diversity of the electrical equipment to address any issues identified in the CCF analysis of the architecture and equipment.

93. The Electrical Engineering assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.7 External Hazards

94. Key aspects of the UK HPR1000 preliminary safety case related to External Hazards, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- A Generic Site Envelope has been developed for the UK HPR1000 GDA, including external hazard values.
- The external hazards scope of the UK HPR1000 GDA has been developed, including screening of hazards.
- External hazard claims and methodologies have been developed for the major hazards in the GDA scope.

95. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to External Hazards identified the following areas of strength:

- Good progress has been made in the definition of GDA scope for external hazards.
- The claims and outline approach towards the external hazards safety case are well developed.
- An agreed resolution plan to the Regulatory Observation the RO issued in this area (RO-UKHPR1000-002) has been produced.

96. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to External Hazards identified the following areas that require follow-up:

- For site licensing external hazards which have been screened out of GDA scope, the RP should provide confidence that the design will, in principle, be able to consider and mitigate them to provide an ALARP design solution for these hazards. This may include protection concepts for the design.

- The suitability of the generic site envelope and UK HPR1000 design should be addressed through the resolution of RO-UKHPR1000-002. As further site characterisation information becomes available from Bradwell B the RP may wish to revisit the generic site envelope values to ensure that a suitable GDA is achieved by the UK HPR1000 design basis bounding the site values.
- The approach to combinations of hazards including those which the RP deems to be site-specific will need to be clarified and justified in future generic safety case submissions.
- The RP's approach to beyond design basis hazards should be developed and applied to external hazards systematically.
- The aircraft crash safety case approach will need to be clarified in future steps, including the hazard definition and Structures, Systems and Components (SSC) response.
- The RP's treatment of climate change in the meteorological external hazards should be clarified. The meteorological hazards which are subject to climate change should be clarified.
- Assessment of the categorisation and classification related to external hazards, including the seismic classification of SSCs should be undertaken when the categorisation and classification methodology is implemented on UK HPR1000.

97. The External Hazards assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.8 Fault Studies

98. Key aspects of the UK HPR1000 preliminary safety case related to Fault Studies, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- All initiating faults with the potential to lead to significant radiation exposure or release of radioactive material will be identified in the Fault Schedule.
- The design basis analysis (DBA) will provide a robust demonstration of the fault tolerance of the engineering design and effectiveness of the safety measures.
- The UK HPR1000 design will be developed in an evolutionary manner using robust design processes, building on relevant good international practice, to achieve a strong safety and environmental performance.
- Design extension conditions (DEC) of type A (DEC-A events) that have the potential to lead to severe accidents will be systematically analysed.

99. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Fault Studies identified the following areas of strength:

- Development of a logical method and auditable trail for the list of postulated initiating events (PIE) for UK HPR1000.
- The PSR considers operating conditions in all possible conditions from full power operation to cold shutdown.
- The RP claims to have undertaken transient analysis for UK HPR1000 reference plant (Fangchenggang NPP Unit 3) with two sets of computer codes and that both demonstrate appropriate margins to relevant success criteria, in line with Chinese regulatory requirements.

- The RP appears to have a reasonable basis for the development of a safety case for fuel handling and storage operations.
- The RP intends to conduct deterministic analysis of DEC-A sequences but using more realistic assumptions than the conservative assumptions used in DBA, to show that the plant is tolerant without significant fault escalation and unacceptable consequences.
- The fault schedule template appears to be a sound basis for the RP to develop a suitable fault schedule which will contain the information expected by ONR's SAPs.
- The RP's approach to categorisation of safety functions and classification of structures, systems and components (SSC) is based upon guidance given in IAEA Safety Guide SSG-30, amended to recognise and address UK expectations.

100. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Fault Studies identified the following areas that require follow-up:

- Fault identification for support systems.
- Spurious C&I systems actuation.
- Demonstration of diverse protection against frequent faults.
- Treatment of maintenance assumptions within the design basis.
- Development of appropriate acceptance criteria for the DBA for fuel handling and storage operations.
- Scope of the fuel handling and storage operations safety case and the interfaces with the proposed spent fuel interim storage solution.
- Fault identification for fuel handling and fuel storage, particularly with respect to the identification of worker exposure (on-site risks).
- List of DEC-A sequences and confirmation that these have been assessed using appropriate methods. We will also consider the demonstration of the adequacy of the provisions made in the design to protect against these sequences.
- We intend to commission some independent confirmatory analysis of a sample of UK HPR1000 fault sequences. We will use the results of this analysis to inform our judgement on the adequacy of the RP's analysis codes and key assumptions.
- During Step 2 there has been considerable uncertainty as to what computer code(s) the RP will use to undertake the UK HPR1000 Fault Studies. The RP has now confirmed its choice of codes and during Step 3 we will follow-up how they are used, including the validation and verification of the codes, the results, and explanations of the differences observed, if any, with respect to the results of the Fault Studies for the reference plan, and how these differences may impact the UK HPR1000 design.
- The maturity of information within the fault schedule and links to supporting analysis within the safety case.
- Breakdown of safety functions to an appropriate level such that SSCs can be suitably classified.
- Application of the categorisation and classification methodology to the reactor systems and protective safety features.
- Application of the categorisation and classification methodology to areas away from the primary or front line reactor systems, such as the supporting systems and fuel route and fuel handling equipment.

101. The Fault Studies assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.9 Fuel and Core

102. Key aspects of the UK HPR1000 preliminary safety case related to Fuel and Core, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Description of the major design features of the Fuel and Core design for the UK HPR1000 reference plant (Fangchenggang NPP Unit 3).
- Definition of the most important functional requirements and design criteria applied in the Fangchenggang NPP Unit 3 design.
- Identification of the critical degradation mechanisms for the fuel and core SSCs.

103. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Fuel and Core identified the following main areas of strength:

- The safety functions, functional requirements and design criteria for Fuel and Core align with the design claims that the fuel and core are designed to provide safe operation in normal operation and fault conditions.
- The main degradation mechanisms for the fuel and core are appropriately identified.
- The safety functions and main functional requirements related to the spent fuel interim storage (SFIS) are correctly outlined.

104. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Fuel and Core identified the following main areas that require follow-up:

- The Fangchenggang NPP Unit 3 design features provide initial visibility; however, the actual assessment in GDA Step 3 can only progress when the details of the UK HPR1000 fuel and core design and safety justification have become available to ONR.
- The design criteria do not appear to meet ONR's requirements to maintain fuel integrity in frequent faults; protections against pellet-cladding interaction (PCI) and pellet-cladding mechanical interaction (PCMI) need to be demonstrated.
- Further detailed information on the models, computer codes, uncertainty and safety margins of the Fuel and Core analysis for the UK HPR1000 will need to be presented in Step 3.
- The SFIS design concept and safety justification will need to be presented in Step 3, once a decision on the storage technology to be used as the basis for the GDA is made by the RP.

105. The Fuel and Core assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.10 Human Factors

106. Key aspects of the UK HPR1000 preliminary safety case related to Human Factors, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- A description of the organisation and arrangements that will deliver adequate Human Factors Integration (HFI) into the UKHPR1000.
- Identification of the codes, standards, and methods that will be used to ensure that HFI is effectively delivered and that all relevant areas of the design meet relevant good practice, where reasonably practicable.

- A description of the process by which operator claims important for nuclear safety will be systematically identified and substantiated to ensure that the design is optimised and risks are reduced ALARP.
- A description of the design process, which will ensure that the UKHPR1000 is a balanced design in terms of allocation of protection.

107. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Human Factors identified the following areas of strength:

- The RP has made significant strides during Step 2 in understanding ONR's regulatory expectations. It has established a robust model of HFI, which should enable it to successfully deliver the human factors safety case within GDA. The HFI process is adequately underpinned by a suite of human factors process claims, which we consider to be credible. It has put in place measures to ensure that its organisational model will not be a barrier to widespread integration of human factors across disciplines.
- The RP has quickly established an appropriate supply chain to gain the necessary knowledge from the nuclear industry in Great Britain, along with developing a credible resource model, which will be needed to deliver the necessary human factors analysis to support the GDA. It has embarked upon a programme of training for all human factors and interfacing disciplines to facilitate the necessary understanding of regulatory expectations.
- The methods, codes and standards proposed generally meet RGP and establish a baseline for achieving a design where risks are ALARP.
- The Fangchenggang NPP Unit 3 baseline design is currently in build and is an evolution of the CPR1000, CPR1000+, and ACPR1000 designs. The Fangchenggang NPP Unit 3 baseline design has been designed, taking into account international and domestic evolutionary operational experience; key to which are the lessons learned from the Fukushima accident, which placed significant operational demands on the operator. Those pertinent to our human factors assessment include improvements to the main control room habitability and the incorporation of IVR capability to extend the operator's available times for emergency equipment preparation. The design also benefits from a development simulator that has been employed for user testing. We thus consider the likelihood of inadvertently introducing a sufficiently significant human factors issue during the evolutionary process – one that cannot be rectified during Steps 3 and 4 of GDA – to be acceptably low.

108. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Human Factors identified the following areas that require follow-up:

- The role that the operator plays in ensuring nuclear safety has not been adequately defined during Step 2. The RP will need to provide a more cogent and coherent description of this role for Step 3.
- The Human Based Safety Claims (HBSC) supplied at the end of Step 2 lack detail and context. This will need developing throughout GDA.
- It is unclear what the baseline human factors case is for the UK HPR1000 reference plant (Fangchenggang NPP Unit 3). This will need to be developed during Step 3 as it informs the forward work programme.
- The RP has indicated that the focus of human factors work on Fangchenggang NPP Unit 3 was mainly on control rooms. The expansion of HFI into other risk important areas of the plant will need to be monitored by ONR to ensure a proportionate and consistent approach.

- The approach to human reliability analysis (HRA), as described, broadly aligns with RGP. However, further discussion with the RP is needed to ensure that screening and modelling during Step 3 are appropriate. This assessment will be jointly carried out by ONR's Human Factors and Probabilistic Safety Analysis (PSA) inspectors.
- The RP's approach to allocation of function (AoF) is a sensible starting point but will require further modification to accommodate the subtleties of AoF for highly complex sociotechnical systems.
- Whilst the RP has made good progress with improving capability, it remains to be seen how effective this will be in delivering the GDA. The organisational capability of the RP will require monitoring to ensure it is delivering to schedule and quality.
- A targeted intervention on the application of the human factors design guidance across the UK HPR1000 design to ensure that claims of HFI are valid. This intervention will be jointly carried out by ONR inspectors covering a range of appropriate disciplines, e.g. Mechanical Engineering and MSQA.

109. The Human Factors assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.11 Internal Hazards

110. Key aspects of the UK HPR1000 preliminary safety case related to Internal Hazards, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- A design basis event internal hazard will be limited to one division by robust hazard barriers segregating redundant divisions of SSCs, such that will not prevent the delivery of the fundamental safety functions of:
    - Control of reactivity;
    - Removal of heat from the reactor and from fuel store; and
    - Confinement of radioactive material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases.
- In areas where segregation by hazard barriers is not feasible, spatial separation between the different divisions of SSCs, or local protection will be incorporated to ensure delivery of the fundamental safety functions.

111. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Internal Hazards identified the following areas of strength:

- The RP has adopted a reasonable approach in their internal hazards methodologies, which comprises: identification of internal hazards sources, identification of safety related SSCs, quantification of loads (hazard specific), identification of unmitigated consequences, identification of safety measures, assessment of safety measures, and production of a hazard schedule.
- The RP has undertaken an appropriate literature review to support its internal hazards identification study and has commenced its combined hazards identification work to identify credible hazard combinations.
- The RP responded positively to regulatory expectations on the analysis methodologies for high energy pipes failures. Firstly, the RP accepted the need for postulating gross failure in the analysis methodology; secondly, it identified all the pipes that have been excluded from analysis of the design of

the UK HPR1000 reference plant (Fangchenggang NPP Unit 3) under the leak before break criteria and containment penetration rupture exclusion rules, and made a commitment to consider them in GDA.

- During interactions with the RP, the RP presented examples of the consequences analysis undertaken for Fangchenggang NPP Unit 3 for some internal hazards, and demonstrated reasonable understanding of what is expected in GDA.

112. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Internal Hazards identified the following areas that require follow-up:

- Development of suitable and sufficient claims for all internal hazards including electromagnetic interactions (EMI), toxic and corrosive material and gases, vehicular impact and combined hazards.
- Development of the hazard barriers claims further to include all penetrations on hazard barriers including doors, access hatches, ventilation ducts and others.
- Demonstration that the UK HPR1000 plant layout is optimised against all internal hazards for all building and plant states and reflecting the competing needs from other technical disciplines as appropriate.
- Identification of all exceptions to segregation areas for all buildings and plant states, and development of suitable internal hazards consequence analysis for those areas. Demonstration that segregation of redundant SSCs is provided wherever it is reasonably practicable to do so.
- Demonstration that the revised identification and screening process of internal hazards captures the technical gaps that ONR identified in its assessment.
- Demonstration that the combined hazards identification, screening and analysis methodology captures regulatory expectations in the derivation of credible combined hazards, and that the derived combined hazards are relevant to the UK HPR1000 design.
- Demonstration that the revised general requirements of protection design against internal hazards captures the technical gaps identified in ONR's assessment.
- Demonstration that all internal hazards analysis methodologies are in line with ONR's expectations and have adequately addressed the technical gaps identified in Step 2.
- Application of the methodology of safety categorisation and classification to the engineering measures delivering the internal hazards safety claims.
- Demonstration that the risk from internal hazards is reduced ALARP.

113. The Internal Hazards assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.12 Management of Safety and Quality Assurance (MSQA)

114. Key aspects of the UK HPR1000 preliminary safety case related to MSQA, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, describe the RP's GDA MSQA arrangements, its service providers' (CGN and EDF) MSQA arrangements and GNS's GDA project management arrangements.

115. In addition to assessing this documentation, we have also undertaken MSQA inspections at the headquarters of the RP and its service providers to ensure that the documented systems are adequately applied in practice.

116. The GDA Step 2 MSQA assessment identified the following areas of strength:

- The RP with its service providers have developed specific management system arrangements for the GDA project, to provide control for the development, verification, validation and review of the safety, security and environmental submissions.
- Project arrangements are in place to allow each entity to perform their identified responsibilities.
- Regular project interfacing occurs between all three entities used for overall project coordination.
- Escalation routes are available at all three parties for the resolution of technical concerns.
- There is reinforcing and building of GDA competency within the service providers by using in-house staff that had prior GDA experience and / or gaining the understanding to satisfy GDA requirements via training and GDA specialist support.
- The development of a 'common working platform' between the RP and service providers to aid organisational cooperation.
- A strong culture exists with respect to safety and learning from experience.

117. From the evidence sampled at the RP and service providers headquarters, we judged that the MSQA arrangements broadly satisfy regulatory expectations for this stage of the project.

118. The GDA Step 2 MSQA assessment identified the following areas of focus during Step 3:

- Practical application of the process for making fundamental safety decisions and design modification decisions.
- Arrangements for developing and controlling the GDA master document submission list (MDSL) and the (overall) document list.
- Resource planning and technical competency implementation.
- Arrangements for design change control, configuration management and associated training requirements.
- Safety case management including work planning, coordination and the application of the ALARP methodologies.

119. The MSQA assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.13 Mechanical Engineering

120. Important mechanical engineering aspects of the RP's UK HPR1000 preliminary safety case, as presented in the PSR and its supporting documents, provide:

- An outline of the mechanical engineering reactor equipment and supporting structures, based on the reference design.
- The mechanical engineering codes and standards applied in the design.
- Work to understand UK Relevant Good Practice (RGP) relative to mechanical engineering.
- An initial safety categorisation and classification methodology.
- An approach to undertaking ALARP judgements.
- A preliminary GDA mechanical engineering scope.
- A mechanical engineering safety case strategy to progress to Step 3.

121. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Mechanical Engineering identified the following areas of good practice:

- Development of a sample list of mechanical engineering SSC's for later GDA.
- Identification of main design characteristics differences between the reference design and the generic UK site envelope.
- Willingness to develop the generic safety case to align with UK expectation.
- Development of a technical risk register to manage gaps against UK relevant good practice.
- Review of previous GDA's, SAPs, TAGs and ONR's mechanical engineering assessment strategy.

122. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Mechanical Engineering identified the following areas requiring follow up:

- Mechanical engineering GDA scope.
- Generic safety case architecture.
- Alignment of the design with the generic site envelope.
- Proposals to link, through an engineering schedule, the safety analysis and the engineering SSCs.
- Management of gaps in RGP between the reference plant (Fangchenggang NPP Unit 3) and UK HPR1000 (including application of ALARP principles).
- Approach to design development (i.e. continuous improvement).
- Approach to design assurance.
- Approach to asset management (i.e. safeguarding safety of assets through life).
- Codes, standards and regulations.
- Approach to insulating the primary circuit components.
- Design of the heating, ventilation and air conditioning (HVAC) systems.
- Approach to undertaking nuclear lifts.
- Application of the safety categorisation and classification methodology.

123. The Mechanical Engineering assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.14 Probabilistic Safety Analysis (PSA)

124. Key aspects of the UK HPR1000 preliminary safety case related to PSA, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- The PSA for the UK HPR1000 reference plant (Fangchenggang NPP Unit 3) includes level 1 PSA for operation modes at power, shutdown and low power, spent fuel pool PSA, internal fire PSA, internal flooding PSA and level 2 PSA. The PSA uses methods that appear to meet ONR's expectations. The UK HPR1000 PSA is expected to follow similar methods and have a similar scope.
- The Fangchenggang NPP Unit 3 PSA results indicate that the risks of the Fangchenggang NPP Unit 3 design are understood and the ONR numerical targets would be met. As the UK HPR1000 design is based on the Fangchenggang NPP Unit 3 design, the RP claims that it has confidence that the UK HPR1000 PSA will similarly demonstrate the risk to the public associated from the design and that ONR's numerical targets are met.
- The Fangchenggang NPP Unit 3 PSA has been used to understand the risks from the design and to modify the design where necessary to lower the level

of risk. The RP has established an approach whereby the UK HPR1000 PSA will be used to support the design of the UK HPR1000 and where necessary to help justify modifications to the design to lower the level of risk.

- Although the UK HPR1000 PSA model has not been submitted during Step 2 of GDA, the Fangchenggang NPP Unit 3 PSA results were submitted to underpin the RP's claims in this area, as the UK HPR1000 design will be based on the reference plant.

125. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to PSA identified the following areas of strength:

- The RP has established a strategy and programme to develop a full scope level 1 and level 2 PSA for the UK HPR1000 aligned to UK regulatory expectations.
- The Fangchenggang NPP Unit 3 PSA appears to follow international good practices. Although we have not assessed this in detail as part of our assessment, this provides confidence moving forward in GDA.
- The RP's PSA team have demonstrated a good understanding of what will be required to produce a PSA that meets UK regulatory expectations.
- The Fangchenggang NPP Unit 3 PSA results show that the level of risk presented by the reference design is low, although further evidence will be needed to substantiate this. As the design of the UK HPR1000 is similar to the reference plant we expect that the RP will be able to demonstrate that the level of risk presented by the UK HPR1000 design is similarly low.

126. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to PSA identified the following areas that require follow-up:

- Applicability of the Chinese nuclear power plant operational experience for use in the UK HPR1000 PSA.
- RP's approach to the screening, bounding and grouping of initiating events.
- RP's screening methodology for hazards.
- HRA screening methodology to be applied for the UK HPR1000 PSA.
- Approach, content and timeframe for submission of the seismic PSA.
- Scope of external flooding PSA to be provided for the UK HPR1000 during GDA.
- Scope of the level 3 PSA to be submitted for the UK HPR1000, or alternatively how the RP intends to demonstrate the risks to the public and to compare the results of the UK HPR1000 PSA against the numerical targets in ONR's SAPs.
- Implementation of the approach developed by the RP to use PSA to support the UK HPR1000 design process.
- In addition, during Step 2 there has been considerable uncertainty as to what severe accident progression computer code(s) the RP will use to support the UK HPR1000 level 2 PSA. The RP has now confirmed its choice of codes and during Step 3 we will seek clarity regarding how they will be used, the validation and verification of the codes, the results, and explanation of the differences observed, if any, with respect to the results of the PSA for the reference plant, and how these differences may impact the design or operation of the UK HPR1000.

127. The PSA assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.15 Radiological Protection

128. Key aspects of the UK HPR1000 preliminary safety case claims related to Radiological Protection, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- Chinese regulations that the UK HPR1000 reference plant (Fangchenggang NPP Unit 3) has been assessed against as well as UK guidelines and requirements for radiological protection are both derived from international recommendations.
- ALARP principles and the design considerations for ALARP will be implemented in the UK HPR1000 design.
- Source terms associated with radiation protection have been adequately considered.
- Adequate radiation protection measures against exposure to radiation and radioactive substances will be provided during normal operation and fault or accident conditions.
- Proposed dose optimisation process aiming at reducing the potential doses received by workers to ALARP levels will be considered in UK HPR1000 design.
- Radiological risk fault and accident conditions will be adequately considered.

129. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radiological Protection identified the following areas of strength:

- The RP has demonstrated awareness of UK legislative requirements, along with a more detailed understanding of requirements related to demonstrating that relevant risks are reduced to levels that are ALARP.
- The PSR provides high-level examples of how the facility layout and equipment are designed with ALARP considerations in mind and demonstrates the application of lessons learned from the operation of predecessor plants.
- The RP's documentation provides a useful high level introduction to how the source terms will be defined. The RP has identified the UK HPR1000 systems for which it is developing source terms and outlined its approach for deriving them. We consider that this provides a suitable basis to develop the UK HPR1000 specific source terms in future submissions.
- A radiation and contamination zoning system is described which will adopt a graded approach, in line with RGP.
- The PSR considers optimisation of the collective dose based on operational experience feedback and RGP.

130. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radiological Protection identified the following among the areas that require follow-up:

- A broader examination of the requirements of IRR 17 (Ref. 14) needs to be carried out in Step 3 of GDA, looking at requirements that may affect the generic design.
- Further information is required to demonstrate how radioactivity within the reactor design has been reduced to ALARP through material choices, operating practices and chemistry control. As GDA progresses, I will expect the RP to provide suitable and sufficient evidence to demonstrate how operational practices and procedural controls which directly affect the source

term have been adequately considered, to ensure radioactivity is reduced to ALARP.

- The outlined approach to developing the Fangchenggang NPP Unit 3 source terms does not include actinides in the main radionuclide groups, on the basis that actinide concentration will be negligible. The evidence underpinning this has yet to be provided and will be required in Step 3 of GDA.
- The RP has not yet defined source terms that can be shown to be applicable to the UK design. Development of the UK HPR1000 source term will be required in Step 3 of GDA, including definition of the assumptions used to adapt the Fangchenggang NPP Unit 3 source term and further information on the RGP used to define and justify the source term.
- The RP should clearly demonstrate how the hierarchy of control measures has been applied to the design, with a focus on using engineering controls in the first instance.
- The RP's ALARP methodology is high-level and general. More detail will be required in Step 3 of GDA on the application of ALARP to occupational exposure.
- A collective dose target, and other dose metrics as appropriate, should be developed for the UK HPR1000 and it should be demonstrated that these are broadly comparable to leading operational PWRs of a similar design.
- When the UK HPR1000 source term is fully developed and justified, the direct radiation dose estimate to the most exposed member of the public needs to be calculated using a more representative and precise methodology to ensure that direct radiation doses to the public are well characterised, reduced to ALARP and can be compared with the relevant BSO (in ONR's SAPs).

131. The Radiological Protection assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.16 Radioactive Waste Management, Decommissioning and Spent Fuel Management

132. Key aspects of the UK HPR1000 preliminary safety case related to Radioactive Waste Management, Decommissioning and Spent Fuel Management, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

Radioactive Waste Management

- Application of the principles of prevention and minimisation of the generation of radioactive waste in the design, based on RGP for PWRs and consideration of the waste hierarchy.
- Definition of systems in the design for the management of gaseous, liquid and solid wastes based on the principle of segregation of wastes, taking account of the physical, chemical and radiological characteristics of the waste streams that will arise as a result of operation of the UK HPR1000.
- The RP's plan to produce a radioactive waste management strategy during Step 3 of GDA, which will cover the lifecycle of radioactive wastes from generation to disposal.

Decommissioning

- The design of the UK HPR1000 is intended to facilitate safe decommissioning at the end of its operational life.

- Initial definition of a decommissioning strategy consistent with UK Government policy and regulatory expectations.
- RP's plan to produce a preliminary decommissioning plan during Step 3.

Spent Fuel Management

- Recognition of the key safety functional requirements for a SFIS facility, namely decay heat removal, reactivity (criticality control), containment and shielding, and the commitment to reduce risks associated with spent fuel management to ALARP.
- Recognition of the need to package and store spent fuel in a way that does not foreclose its final disposal, a key difference from Chinese practice where fuel is reprocessed. This is consistent with UK Government policy.
- Preliminary identification of different technology options for the SFIS, noting selection of a preferred option will take place in a later step of the GDA process.

133. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radioactive Waste Management, Decommissioning and Spent Fuel Management identified the following areas of strength:

Radioactive Waste Management

- Recognition of the need to manage radioactive wastes across their lifecycle.
- Useful preliminary information on the prevention and minimisation of radioactive waste in areas such as fuel design and use, minimisation of radioactivity in the reactor core, materials selection and control of water chemistry in the primary circuit.

Decommissioning

- Good awareness of international guidance and the need to draw on operational experience and good practice from similar reactors.
- Explicit recognition of the need for the design to facilitate safe decommissioning to reduce risks to ALARP.

Spent Fuel Management

- Preliminary consideration of the benefits and detriments of the main technology options for the SFIS facility, in the context of the need to demonstrate that relevant risks are reduced to ALARP at the appropriate stage of its development.
- Good awareness of international practices in long term management of spent fuel.

134. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Radioactive Waste Management, Decommissioning and Spent Fuel Management identified the following areas that require follow-up:

- The design of the UK HPR1000 reference plant (Fangchenggang NPP Unit 3) described in the PSR does not fully align with UK practices for radioactive waste management, particularly in respect of solid wastes. Whilst the RP has identified differences or gaps between UK and Chinese practices, there is a lack of clarity on the work that will be carried out to address them, which needs to be addressed in a robust underpinned radioactive waste management strategy. The RP needs to provide further information on this strategy and the impact of any changes necessary on the generic design of the UK HPR1000 in terms of systems, processes and facilities/buildings. The RP also needs to provide a clear demonstration that the risks associated with radioactive waste management will be ALARP. At the time of writing this report we are preparing a RO to follow this up in Steps 3 and 4 of the GDA process.

135. The Radioactive Waste Management, Decommissioning and Spent Fuel Management assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.17 Security

136. Key security aspects of the UK HPR1000 are presented in the PSR, and the supplementary documents submitted by the RP. These can be summarised as follows:

- The security case and its supporting annexes detailing the RP’s security objectives, claims and arguments.
- The security risk management approach.
- The vital area identification (VAI) methodology, which includes the RP’s proposed cyber risk assessment process.

137. The GDA Step 2 assessment of the security arrangements for the UK HPR1000 identified the following areas of strength:

- An adequate VAI methodology has been prepared. This will allow the RP to focus the security arrangements on the areas of highest risk.
- The RP has been proactive in determining a process by which the significant risks to the cyber security of the proposed design can be identified.
- The RP has demonstrated an adequate understanding of the basic security principles and how these can be applied throughout the GDA process.

138. The GDA Step 2 assessment of the proposed security arrangements for the UK HPR1000 identified the following areas which will require further consideration by the RP during Step 3:

- The RP will need to develop clear arguments to support its claim of influencing the design following the VAI and cyber risk assessment process, and describe how this will be achieved.
- The RP has presented a holistic security picture which, in our opinion, will be of value to a future operator throughout the lifetime of the proposed reactor. During the future steps of the GDA, the RP will need to develop clear arguments about what is in the scope of the GDA, and how the claims detailed in Step 2 of the GDA, can be achieved.

139. The Security assessment did not identify any fundamental shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.18 Severe Accident Analysis (SAA)

140. Key aspects of the UK HPR1000 preliminary safety case related to SAA, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- The RP has conducted SAA for the UK HPR1000 reference plant, Fangchenggang NPP Unit 3. The RP intends to perform SAA with a similar approach and scope for the UK HPR1000.
- For the UK HPR1000, the RP intends to practically eliminate core melting sequences which could lead to large early release and to prevent radioactive release (including containment bypass and core melting sequences) which exceed safety objectives. To achieve these objectives, the basic SAA strategy is to maintain the integrity of the RPV and the containment in both short and long term as far as possible.
- The RP has prepared a programme to schedule the development of the SAA modelling and safety case documentation through GDA.

141. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to SAA identified the following areas of strength:

- The RP has presented a SAA work programme whereby it is likely that enough SAA will be completed to allow for meaningful assessment during GDA timescales.
- The RP's list of severe accident phenomena to be considered largely meets UK expectations;
- The RP has provided preliminary design descriptions of the severe accident systems and high level information describing how these systems would be used during a severe accident.
- The RP has considered lessons learnt from the Fukushima accident and has made changes to the design that it deems appropriate and practicable.
- The RP has provided an overview of the general approaches that are proposed to be used to model the progression of the severe accident sequences, the behaviour of fission products and to optimise the SAA engineered measures.
- The proposed approaches for SAA generally meet ONR's expectations.
- The RP has provided a list of typical radionuclide behaviours.
- The RP has also demonstrated that the severe accident engineered features have been included due to learning from international modern nuclear power plant design.

142. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to SAA identified regulatory shortfalls. To address these in June 2018 we issued RO-UKHPR1000-003 "Suitable and sufficient severe accident analysis safety case". The RP developed a credible resolution plan to respond to this RO. Both the RO and the resolution plan are published in our GDA joint regulators webpage (Ref. 3). Specific examples of areas that we will follow up during Step 3 are:

- During Step 2 there has been considerable uncertainty as to what severe accident analysis computer code(s) the RP will use to support the UK HPR1000 SAA. The RP has now confirmed its choice of codes and during Step 3 we will seek clarity regarding how they will be used, the validation and verification of the codes, the results, and explanation of the differences observed, if any, with respect to the results of the SAA for the reference plant, and how these differences may impact the severe accident management strategies and features for UK HPR1000.
- Further development of the proposed approaches for all aspects of SAA.
- Improved descriptions of the severe accident phenomena with specific application to the UK HPR1000 design.
- Further details of the intent, application and justification for the use of 'practical elimination' as part of the safety case.

- Further justification for exclusion of analysis of in-vessel steam explosion and recriticality.
- Improved descriptions of severe accident engineered features, strategies and procedures with specific application to the UK HPR1000 design.
- Expanded information regarding the RPs' intent for performing SAA in the SFP building.
- Improved information regarding the use of filtered containment venting.
- Further justification in the completeness of the list of areas that were considered in light of lessons learnt from the Fukushima accident.
- Improved descriptions of the changes made to the design as a result of lessons learnt from Fukushima.
- Improved description of the deterministic approach for screening of the severe accident sequences.
- Expanded descriptions of the fission product behaviour with specific application to the UK HPR1000 design.
- Improved demonstration that optioneering studies have been used to justify the claim that there are no further reasonably practicable improvements within any of the individual severe accident mitigation measures or accident management strategies.

143. The SAA assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.19 Structural Integrity

144. Key aspects of the UK HPR1000 preliminary safety case related to Structural Integrity, as presented in the PSR, its supporting references and the supplementary documents submitted by the RP, can be summarised as follows:

- An outline of the overall approach to structural integrity, including key interactions with other technical disciplines.
- The basis for the structural integrity classification including the identification of those structures and components needing a highest reliability claim (referred to as high integrity components (HIC)).
- An outline of the applicable codes and standards.
- The structural integrity safety case strategy, including the approach to providing beyond design code compliance justifications for highest reliability claims.
- The basis for an avoidance of fracture justification in support of highest reliability claims.
- Design summaries for the main metallic components in the reactor plant.
- An overview of the principles for material selection along with the identification and an outline of the mitigation strategies to underpin the 60 year design life.
- ALARP considerations for structural integrity.

145. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Structural Integrity identified the following areas of strength:

- The RP recognises the importance of structural integrity to the overall plant safety case by including a PSR chapter dedicated to structural integrity.
- The RP has proposed a structural integrity classification scheme that identifies the claims needed to support the overall safety case along with the need to separately classify structures and components for which highest reliability claims are invoked.

- The structural integrity claims for the design, construction and operation of the UK HPR1000 are based on established nuclear codes. The RP has recognised the need for additional measures beyond code to underpin highest reliability claims.
- The RP is developing an understanding of the means for demonstrating the 'avoidance of fracture' of HICs that aligns with ONR's SAPs, for example, the application of defect tolerance assessment using the R6 fracture mechanics methodology and proposals to qualify the manufacturing non-destructive testing (NDT) that is qualified using the European Network for Inspection and Qualification (ENIQ) methodology.
- The design summaries show that the main structures and components of the reactor plant are generally based on conventional PWR technology, giving a basis for confidence that the UK HPR1000 is likely to comply with modern PWR standards; there are also some design features that ONR judges to be beneficial to structural integrity.
- The RP is developing an understanding of ALARP and committed to consider and implement additional measures for structural integrity to reduce relevant risks, where reasonably practicable.

146. The GDA Step 2 assessment of the UK HPR1000 aspects of the safety case related to Structural Integrity identified the following areas that require follow-up:

- There are some structures and components that the RP has identified as HIC candidates with limited descriptions of the reasons. These candidates may be speculative at this stage, but where appropriate, ONR will seek assurances from the RP that ALARP measures are taken to minimise the number of HICs. In particular, ONR will issue a RO for the RP to justify the classification of the main coolant line.
- ONR considers that there may still be opportunities to optimise certain aspects of the UK HPR1000 design, from a structural integrity perspective. For example, by increasing the use of integrated forgings to reduce welded regions. ONR expects the RP to consider all available operational experience and potential options, and where relevant, to provide robust and proportionate ALARP justifications as part of the generic safety case.
- The RP is considering several options with regard to the nuclear codes to be applied for the SGs. ONR will formally assess the RP's SG ALARP justification covering codes and standards to determine whether a robust process has been applied, to underpin a defensible decision.
- There did not appear to be a clear link between the avoidance of fracture demonstration and the overall structural integrity claims for HICs. In addition, the RP needs to further develop arrangements to ensure that an integrated approach to develop the avoidance of fracture demonstration is adopted within the structural integrity discipline. ONR will issue a RO to seek the necessary improvements in this area.
- The RP's approach to ranking areas for detailed defect tolerance and NDT assessment during GDA had only been applied to the RPV. ONR needs to be satisfied that the RP has a programme of work that is adequately resourced and prioritised.
- The RP claimed that, in general terms, the UK HPR1000 is designed to facilitate NDT. ONR will seek more detailed evidence of sound design and design for inspectability.

147. The Structural Integrity assessment did not identify any fundamental safety shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

9.20 Cross-Cutting Topics

148. ONR considers cross-cutting topics to be those matters that relate to technical processes and have a substantive impact on the development of the safety case across all technical disciplines. Within ONR, assessment of these topics is coordinated by the PTI to ensure that a consistent approach is taken by both the RP in its development of submissions and ONR in its undertaking of assessments.

149. During Step 2, the RP has provided information regarding its approach to the following cross-cutting topics:

- Methodology for optioneering and decision making for ALARP.
- Methodology for categorisation of safety functions and classification of SSCs.
- Scope of GDA.
- Development of the UK HPR1000 safety case.

150. Engagement with the RP on cross-cutting topics has been slow during Step 2, while the RP and its supporting organisations agreed their approach on these matters. This meant that ONR had little visibility on the RP's planned approach before the methodologies for ALARP and categorisation and classification were submitted to us. We have conducted an initial review of these two methodologies and have concluded that they broadly meet our expectations at this stage. However, we recognise that they are high-level strategy documents which will need to be supported by working-level procedures and training to provide detailed guidance to RP staff involved in the production of the UK HPR1000 safety case. During Step 3 ONR will focus our attention on how the arrangements are applied in practice and will assess the quality of safety submissions to confirm that an adequate and consistent approach is being applied. Our expectation is that the RP will increase its engagement on these topics via multi-disciplinary workshops so that ONR can gain confidence that arrangements are adequate and being effectively applied.

151. Specific discussions in relation to the proposed scope of GDA are conducted within each individual discipline, as the scope and level of detail expected in GDA is dependent on the nature of each topic. This matter will be further progressed in Step 3 of GDA when the RP submits the PCSR, GSR and their supporting references, providing further details on the proposed scope and depth of the UK HPR1000 design. It is possible that gaps in the proposed GDA scope may be identified as our assessment progresses and we have a better understanding of how the SSCs contribute to, and interact within, the HPR1000 safety and security cases.

152. Engagement with the RP on the development of the UK HPR1000 safety case has also been slow during Step 2, with the first workshop on this important topic only held in May 2018. Following the workshop, we issued an RQ requesting further clarity on the RP's arrangements for safety case development. We considered that the RP's response revealed a number of potential shortfalls related to the status of the safety case planning and arrangements (including organisational).

153. ONR expects the RP to have adequate processes and controls in place to ensure that a generic safety case for UK HPR1000, that is coherent, cogent, consistent and complete, will be developed in GDA. However, production of a safety case can be complex and time consuming. It therefore requires forethought to be given right through the safety case production and development process. A safety case development strategy, safety case development programme and suitable organisational arrangements are key contributors to timely delivery of a high quality, comprehensive safety case, which is essential for the completion of GDA. Furthermore, oversight of the development of the safety case needs to be provided

by individuals with authority, expertise, and a clear vision for what the safety case is trying to achieve.

154. It is mentioned earlier in the report, but it is important to stress that the GDA safety case must be suitable for implementation as part of an operating regime, with any assumptions, requirements or commitments in the safety case being identified, captured and transferred to the future licensee. We encourage RPs to seek involvement of future operators in developing those arrangements and the safety case itself. This is to ensure that operational considerations are included and that the safety case will be of practical use during the site specific phase.

155. In summary, ONR identified potential shortfall in the arrangements of the RP for meeting the above expectations, in particular regarding the RP's safety case development strategy, programme and organisation, and its approach to capturing assumptions, requirements and commitments from the safety case. We have issued RO-UKHPR1000-004 to capture these potential shortfalls and ensure that the RP clearly understands the actions it needs to take to meet our expectations. We are currently discussing the RP's plans to respond to the RO. The RO and RP's resolution plan will be published in our joint regulators website (Ref. 3) in due course.

10 CONCLUSIONS

156. This report is ONR's second public report on the UK HPR1000 and it comes at the end of Step 2. We have considered the fundamental safety and security aspects of the design, and the EA has considered the environmental acceptability of the design, which is reported on separately.

157. Overall, the interactions with the RP throughout Step 2 have been constructive. The structure of the RP organisation is complex, with two very large companies, EDF and CGN, from different regulatory backgrounds cooperating in a new, technically challenging endeavour. GNS's role in coordinating these activities has been challenging but GNS has worked consistently hard to ensure that UK regulatory expectations are met. We have also seen strong commitment from GNS, CGN and EDF to learn lessons from Steps 1 and 2 of GDA and to improve their working arrangements. The high level of expertise available within CGN and EDF will undoubtedly prove to be an asset when GDA moves into the detailed assessment stages.

158. During Step 2 of GDA we have undertaken the assessment work we had planned across 19 technical disciplines and we have also covered cross-cutting topics. Our assessment conducted to date has not identified any fundamental safety or security shortfalls that might prevent the issue of a DAC for the UK HPR1000 design.

159. We can also confirm that both the RP and ONR have completed the preparatory work necessary to enable commencement of Step 3 of GDA.

160. Moving forward to Steps 3 and 4, the timely provision of information will be vital to ensuring that ONR has suitable and sufficient documentation to undertake a meaningful assessment.

161. There is a considerable amount of work to be undertaken by the RP going forward, requiring significant resource across all of the topic areas. ONR will continue to rigorously assess the safety and security submissions throughout Step 3 and Step 4 of GDA, and will address potential issues should they arise. As GDA progresses ONR will also review the arrangements developed by the RP to produce a holistic UK

HPR1000 safety case that recognises the dependencies between the individual technical topics.

11 REFERENCES

1. *UK HPR1000 Generic Design Assessment (GDA) – Assessment of the readiness of the GDA Requesting party (RP) and ONR to commence GDA.* ONR. October 2016. http://www.onr.org.uk/pars/2017/uk-hpr1000-16-005.pdf

2. *UK HPR1000 Reactor: Written statement - HCWS398*. BEIS. January 2017. https://www.parliament.uk/business/publications/written-questions-answers-statements/written-statement/Commons/2017-01-10/HCWS398/

3. *UK HPR1000 Preliminary Safety Report.* GNS. *http://www.ukhpr1000.co.uk/documents-library/step-2/*

4. *UK HPR1000 Generic Design Assessment (GDA) Website.* GNS. http://www.ukhpr1000.co.uk/

5. *Regulators begin Step 2 of nuclear reactor assessment.* ONR and EA. November 2017. http://news.onr.org.uk/2017/11/regulators-begin-step-2-of-assessment-of-new-nuclear-reactor/

6. *Generic Design Assessment Joint Regulators Website (HPR1000).* ONR and EA. http://www.onr.org.uk/new-reactors/uk-hpr1000/index.htm

7. *Environmental management – Nuclear regulation*. EA. https://www.gov.uk/topic/environmental-management/nuclear-regulation

8. *Safety Assessment Principles for Nuclear Facilities*. ONR. 2014 Edition Revision 0. ONR. November 2014. http://www.onr.org.uk/saps/saps2014.pdf

9. *Office for Nuclear Regulation (ONR) Permissioning inspection – Technical Assessment Guides.* http://www.onr.org.uk/operational/tech_asst_guides/index.htm

10. *Risk informed regulatory decision making.* ONR. June 2017. http://www.onr.org.uk/documents/2017/risk-informed-regulatory-decision-making.pdf

11. *Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable).* ONR. March 2018. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-005.pdf

12. *Security Assessment principles for the Civil Nuclear Industry*. 2017 Edition. ONR. March 2017. http://www.onr.org.uk/syaps/security-assessment-principles-2017.pdf

13. *Generic Design Assessment Guidance to Requesting Parties.* ONR. September 2016. http://www.onr.org.uk/new-reactors/ngn03.pdf

14. *The Ionising Radiations Regulations 2017 and Approved Code of Practice (ACOP) and guidance, L121, second edition*. HSE. 2018. www.legislation.gov.uk

15. Nuclear Industry Security Regulations 2003 (as amended), www.legislation.gov.uk

16. Construction (Design and Management) Regulations 2015, www.legislation.gov.uk

Annex 1

STEP 2: FUNDAMENTAL DESIGN, SAFETY CASE AND SECURITY CLAIMS OVERVIEW

http://www.onr.org.uk/new-reactors/ngn03.pdf

Description and aims

Step 2 is primarily an overview of the acceptability, in accordance with the regulatory regime of Great Britain, of the design fundamentals, including review of key safety and security claims (or ‘assertions’).

The aim of this step is to assess the key claims and identify any fundamental safety or security shortfalls that could prevent ONR permitting the construction of a power station based on the design.

A related aim is that the RP will come to fully understand the regulatory approach used in Great Britain and thus ensure that adequate safety and security documentation will be developed for Steps 3 and 4.

It will also introduce ONR inspectors to the fundamentals of the design and provide a basis for planning subsequent, more detailed, assessment.

This step may take around 6 to 8 months, assuming the RP is able to provide quality and timely submissions and responses to regulatory concerns.

Exceptionally, in the event that the RP is not able to provide the information necessary for ONR to complete the step in the indicative time period, there is scope for the step to be extended for an agreed, limited period to allow the requisite documentation to be developed, submitted and assessed. Agreement to such an extension would be dependent on the availability of ONR’s specialist resources during the proposed extension period. ONR will still aim to achieve the original planned overall timescale for completing GDA, for instance by seeking to shorten the next step.

The RP is required to:

Provide documentation in the form of a Preliminary Safety Report (PSR) and Preliminary Security Report, that includes sufficient information for ONR’s Step 2 assessment, in particular:

- A statement of the design philosophy and a description of the design sufficient to allow identification of the main nuclear safety claims including identification of hazards, control measures and protection systems.
- A description of the process being adopted by the RP to demonstrate compliance with the legal duty in Great Britain to ensure that the risks to human health arising from the operation of a power station based on the proposed design are reduced ‘So Far As Is Reasonably Practicable’ (SFAIRP). For ONR's assessment purposes the terms ALARP (As Low As Reasonably Practicable) and SFAIRP are interchangeable and require the same tests to be applied (refer to Section 5 below for further information).
- Details of the safety principles and criteria that have been applied in the RP’s own assessment processes, including the control of risks to workers

and the public.

- A broad demonstration that the RP’s safety principles and criteria are likely to be achieved by the design.
- An overview of the approach, scope, criteria and output of the deterministic safety analyses.
- An overview of the approach, scope, criteria and output of the probabilistic safety analyses.
- Specification of the site characteristics to be used as the basis for the safety analysis (the 'generic site envelope').
- Explicit references to standards and design codes used, justification of their applicability, and that they represent relevant good practice, and a broad demonstration that they have been met (or exceptions justified).
- Information on the quality management arrangements for the design, including design controls, control of standards, verification and validation, and the interface between design and safety.
- Details of the safety case development process, including peer review arrangements, and how this gives assurance that nuclear risks are identified and managed.
- Information on the quality management system for the safety case production.
- Identification and explanation of any novel or complex features, including their importance to safety.
- Identification and explanation of any deviations from modern, international good practices.
- Sufficient detail for ONR to satisfy itself that relevant Safety Assessment Principles (SAP) are likely to be satisfied.
- Bring to ONR’s attention any relevant information about assessments undertaken by regulators outside Great Britain.
- Identification of outstanding information that remains to be developed and its significance.
- Information on radioactive waste and spent fuel management, and on decommissioning.
- Information about the Reference Design (or designs) on which the PSR is based, and when the RP intends to ‘freeze’ the generic safety and security submissions.
- Security related information covering the reactor technology concept.
- A methodology to be adopted for the identification of Vital Areas.
- Sufficient detail for ONR to satisfy itself that “defence in depth” principles

have been applied to the design to prevent both internal "insider" and external threats from carrying out acts of sabotage or theft i.e. a Concept of Security Operations.

- Suitable cyber risk methodology has been adopted.

At the end of Step 2, undertake a review of its readiness to move to Step 3 and report on the outcome of this review to ONR.

The RP will also be required to provide the first Master Document Submission List.

In addition, the RP will be required to respond to matters raised by ONR during its assessment, and to issues arising from public comments.

Step 2: ONR will:

Undertake an assessment directed at reviewing design concepts and claims. This will include:

- The design safety philosophy, standards and criteria used.
- The approach to ALARP.
- The fault study approach including Design Basis Analysis (DBA) and Severe Accident management.
- The probabilistic safety analysis (PSA) approach.
- The overall safety case scope and extent.
- An overview of the claims in safety analysis and engineering design across a wide range of technical areas.
- The generic site envelope and its relevance to the safety case.
- The proposals for nuclear security including the general concept of security operations.
- The proposals for the Design Reference and safety submission freeze, including proposals for management of design changes during GDA.
- Identification of any matters that might be in conflict with Government policy.
- Identification of any significant issues that may prevent ONR from issuing a DAC.
- Consideration of relevant issues identified through the public involvement process.
- Undertaking a review of its readiness to move to Step 3.
- Assessing the VA Identification methodology
- Assessing the Cyber Risk Assessment

Where necessary, the RP should update the safety documentation on their website (removing commercial information, and security sensitive information) to reflect additional details provided during the step.

Step 2: ONR output

Publication of:

- A statement on whether any fundamental safety or security issues have been identified that might prevent the issue of a DAC or which would need to be addressed in order to acquire one.
- A summary report to support this statement, plus the ONR assessment reports, along with any other reports relevant to Step 2.
- A statement on whether the design assessment can progress to Step 3.