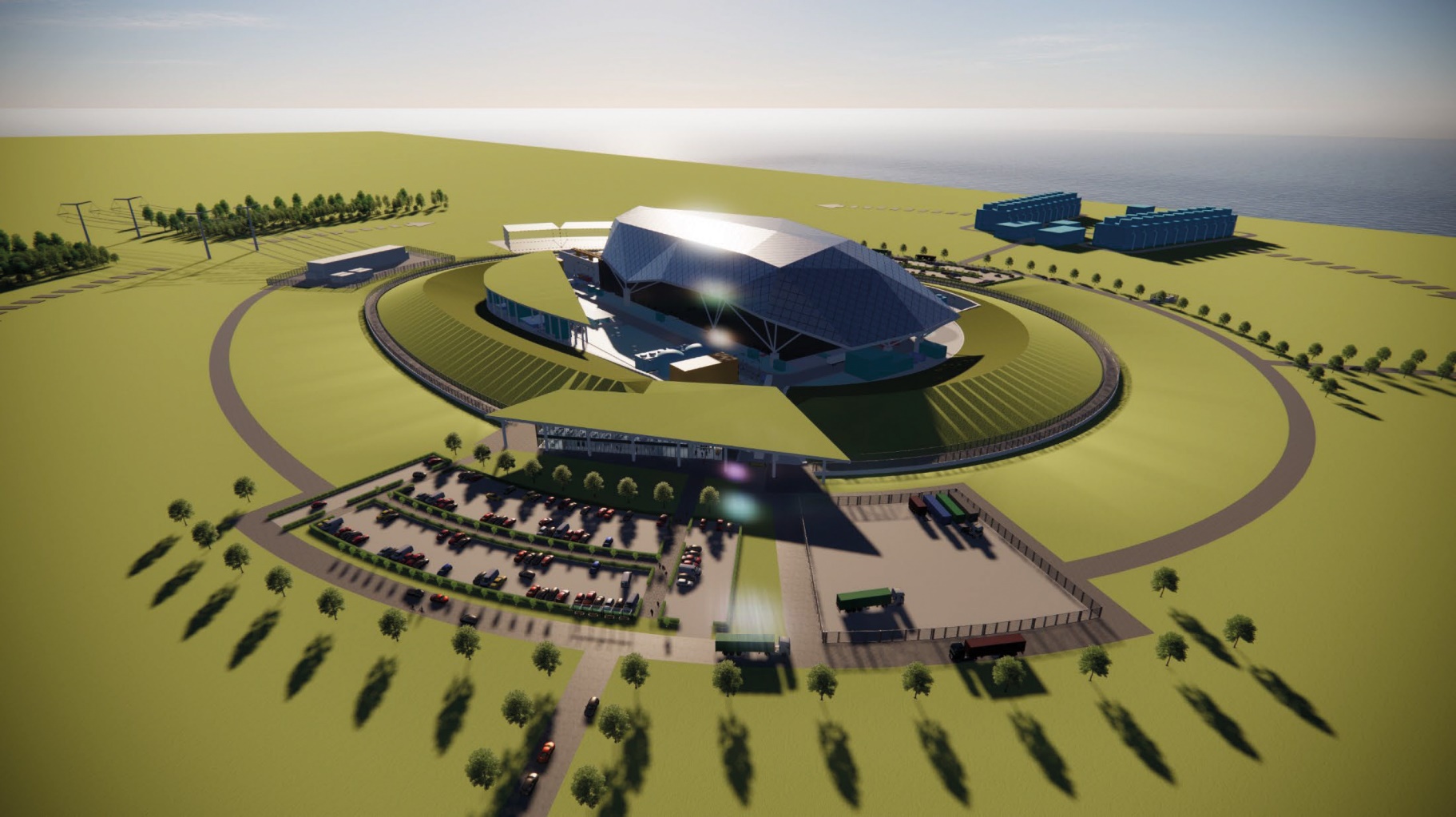
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| ONR Project Assessment Report  Generic Design Assessment of the Rolls-Royce SMR – Step 2 summary |





ONR Project Assessment Report

**Project Name**: Generic Design Assessment of the Rolls-Royce SMR

**Report Title**: Step 2 summary

**Dutyholder/ Applicant**: Rolls-Royce SMR Limited

**Authored by**: [Redacted]

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# Executive Summary

In April 2023, having successfully completed Step 1, the Office for Nuclear Regulation (ONR), the Environment Agency and Natural Resources Wales (NRW) announced that Rolls-Royce Small Modular Reactor (SMR) Limited's reactor design could progress to Step 2 of the Generic Design Assessment (GDA). During the last 16 months, we have undertaken an assessment focused on the adequacy of the design, and the safety, security and safeguard cases with the intent of identifying any fundamental shortfalls in meeting regulatory expectations. These activities are defined within our GDA guidance document, 'New Nuclear Power Plants: Generic Design Assessment Guidance to Requesting Parties’, ONR-GDA-GD-006 Revision 0, October 2019.

Rolls-Royce SMR Limited is the Requesting Party (RP) for the GDA. It was formally established in 2021 to design and build the Rolls-Royce SMR (although design work started within Rolls-Royce plc in 2015). Its design is a 470 MWe Pressurised Water Reactor (PWR) which uses well-established technology in operation all over the world. Innovation comes in the form of its modular approach to construction which would see many components built in factory conditions and assembled on site. Our assessment will be the first time that the design has been subject to regulatory scrutiny.

Rolls-Royce SMR Limited has confirmed that it intends to complete a three-step GDA with the objective of receiving a Design Acceptance Confirmation (DAC), if judged acceptable by ONR. The overall duration for GDA is expected to be 57 months, completing in December 2026. Step 3 is expected to take 29 months.

This report has been produced:

* To document the completion of and outcomes from Step 2;
* To summarise the activities undertaken by both Rolls-Royce SMR Limited and ONR during the step;
* To summarise ONR’s judgement on whether we have identified any fundamental shortfalls with the generic Rolls-Royce SMR design that could challenge future deployment in Great Britain;
* To summarise ONR’s judgement on whether the objectives for Step 2 have been met; and
* To document the basis for the decision on whether to proceed to Step 3, or not.

Our assessment considered all of ONR’s statutory purposes relevant to GDA (including nuclear safety, conventional health and safety, security and safeguards) across 21 technical topics. We used ONR’s standards and guidance as the basis for our assessments, and we also actively considered relevant International Atomic Energy Agency (IAEA) standards and requirements, given the RP’s objective to have an international standardised design. We targeted our assessment and used a sampling approach, based on significance, novelty or hazard potential as a means to determine an overall view on the adequacy of the design. Within Step 2, our sampling has been broad and high-level. We intend to use the intelligence gained from this assessment to feed into our more detailed assessments required post Step 2.

For our assessment, we have undertaken more than 250 interactions and sampled more than 900 submissions from across the safety, security, safeguards (and environmental) case (referred to as the ‘E3S’ case). The first version of the tier 1 E3S chapters were submitted at the start of Step 2, and lower-level tier 2 and 3 submissions were provided in accordance with the agreed submission schedule throughout the step. The information submitted met all the requirements from our guidance and demonstrated a good understanding of UK practice and regulatory expectations. We are satisfied that the foundations for further development are soundly based. At the end of Step 2 we received version 2 of the E3S chapters, which consolidates the information submitted during Step 2.

Rolls-Royce SMR Limited are using an integrated systems engineering and safety analysis approach, where the design and justifications inform and reinforce each other. We support the approach, which will bring benefits if delivered to the RP’s own high standards. We have seen this applied throughout the step, which has meant that both the design and associated E3S case have continued to mature and develop.

In December 2023 the RP declared its first Design Reference Point (DRP1), which represents a frozen design against which change control arrangements are now in place for GDA. For DRP1, the majority of Systems, Structures and Components (SSCs) included within the GDA scope have reached sufficient maturity to define the baseline design but further work is needed to complete the list of functional and non-functional requirements and demonstrate they are met by the design. Version 2 of the E3S case is aligned with the design defined in DRP1. Our regulatory judgements are therefore against an E3S case that reflects the maturity of both the design and supporting evidence at DRP1.

The summary findings from our assessment of the generic design and E3S case are:

* The foundation of the Rolls-Royce SMR design is established PWR technology in which we have extensive regulatory experience. This underpinning technology has been supplemented with passive safety features, which simplify the design and minimise the claims on support systems. The RP is also designing to achieve UK (and international) expectations and is using tools, standards and approaches we have seen applied in similar circumstances. We consider this to be a sound basis on which to substantiate the design, which gives us confidence that it can be achieved by the RP.
* To date, the RP has focused its analysis work on those aspects it considers most significant or where greater confidence was needed to inform the design. This is a sensible approach given the maturing and iterative nature of the RP’s work to date, and was sufficient for us to form a view on the adequacy of the main claims and whether the design is likely to fulfil these. Based on the representative or bounding analyses presented to us in Step 2, which are typically conservative and show suitable margins, and the approach, methodologies, codes and standards used, we have confidence that the building blocks to further develop the case are suitable.
* Key SSC architecture, functions and requirements have been presented during Step 2. We are satisfied that the design demonstrates application of important considerations to enable a safe and secure design, including matters such as inherent safety, fault tolerance, defence in depth and the hierarchy of controls, including consideration of matters such as common cause failure, segregation, redundancy and diversity. Future versions of the E3S case will need to provide the complete set of relevant design requirements and detailed supporting evidence to demonstrate that the design can deliver the credible claims made during Step 2.
* The approach to and examples of operational matters (such as operating rules and examination, inspection, maintenance and testing activities) were presented. We take confidence that the RP understands the importance and need to develop and justify these, and is actively considering these with plans to present those necessary to underpin the design during GDA.
* The preliminary radiological analysis for normal operations and faults gives confidence that ONR’s numerical targets are likely to be met. The RP has committed to document a comprehensive suite of analyses, based on the matured design, in a future version of the E3S case.
* We are satisfied that the RP’s approach to demonstrating safety risks are reduced to As Low As Reasonably Practicable (ALARP) is adequate, and this is inherent in its thinking. Whether the generic design achieves this requirement can only be judged once a matured design and E3S case are available. We are satisfied the RP is working towards this.

We have not identified any Regulatory Issues (RIs), which would represent a fundamental shortfall with the design, or any potential conflicts with relevant government policy. During our assessment we raised two Regulatory Observations (ROs), where we identified potential shortfalls that required further work from the RP to resolve. These relate to development of the E3S case and the Probabilistic Safety Analysis. We are content that both of these ROs will be resolvable by the RP, and good progress has been made.

The RP expects that it will need to produce at least two further versions of its E3S case during Step 3, corresponding to further declared DRPs, to incorporate changes to the design and additional supporting evidence. From our interactions during Step 2, we have confidence that the RP has credible plans to undertake this development, and has committed to do so on timescales compatible with GDA. To achieve its stated objective of a DAC will require:

* Further development of the generic design, to a level that demonstrates that the claims and arguments made for safety, security and safeguards can be fulfilled. We have seen evidence of the RP’s comprehensive plan to achieve this level of design maturity during GDA.
* A full scope safety analysis, covering deterministic and probabilistic analysis, the assessment of hazards and security risks, based upon the generic design and representative assumptions. The RP has outlined its intentions for producing this, as an iterative part of design development, on timescales compatible with its objectives for GDA. Based upon our assessments during Step 2 we are confident such a demonstration should be achievable.

In line with our guidance, the RP undertook a self-assessment and review of its own readiness to proceed to Step 3. The overall conclusion of the RP’s readiness review is that it considers itself ready to begin Step 3, which we agree with. As part of our own review of readiness to proceed to Step 3, we used the knowledge gained during Step 2 to inform our detailed planning within the 21 assessment plans we have developed for Step 3. We have agreed a submission schedule with the RP, which includes the submission of more than 1,000 documents. The RP has stated it has sufficient resource to deliver the identified submissions to the agreed schedule. The outcome from our readiness review was that we consider we are ready to proceed to Step 3 of GDA for the Rolls-Royce SMR.

In summary, based on the work carried out by ONR, we are satisfied that:

* The RP has completed all of the requirements for Step 2 from our guidance;
* Interactions with the RP throughout Step 2 have continued to be professional and constructive, and we have confidence that this will continue;
* The RP has matured significantly during the step, in developing its organisation and arrangements to support GDA, and has embraced continual learning and improvement;
* Those agreements that are necessary to undertake the GDA remain in place, and have been amended as necessary to reflect the project needs;
* The RP submitted a large body of quality information which demonstrated a good understanding of our regulatory expectations and has started to document the basis for how the generic design can be shown to fulfil the claims made in the E3S case;
* The RP has taken account of UK specific expectations and its methodologies and approaches align to our expectations and provide a sound basis for further development;
* Based on our assessment to date, and subject to the provision and assessment of suitable and sufficient supporting evidence, we have not identified any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the generic Rolls-Royce SMR design;
* The RP is aware of the significant efforts needed to mature the design and E3S case on timescales compatible with its stated objective of achieving a DAC at the end of Step 3, and has put in place credible plans to that end;
* We have continued to build our knowledge, and have used this to inform our planning for further assessment activities; and
* We, and the RP, are ready to proceed to Step 3 of the GDA.

During Step 3 we will continue to rigorously assess the RP’s submissions in line with our assessment plans, raising any matters of concern as they arise with the RP via interactions and using the established tools available to us, including ROs or RIs, as necessary.

We therefore recommend that:

* Recommendation 1: ONR should publish a Step 2 GDA Statement for the generic Rolls-Royce SMR design which indicates that, based upon our assessment to date, we have not identified any fundamental shortfalls with the design.
* Recommendation 2: ONR should proceed to Step 3 of the GDA for the generic Rolls-Royce SMR design.

Table 2: List of abbreviations

| Term/Acronym | Description |
| --- | --- |
| AC | Alternating Current |
| ALARP | As low As Reasonably Practicable |
| ASCE | Assurance and Safety Case Environment |
| ASF | Alternative Shutdown Function |
| ASME | American Society of Mechanical Engineers |
| BAT | Best Available Technique |
| BSL | Basic Safety Level |
| BSO | Basic Safety Objective |
| C&I | Control and Instrumentation |
| CAE | Claim, Argument and Evidence |
| CDF | Core Damage Frequency |
| CDM | Construction (Design and Management) Regulations 2015 |
| CR | Control Rod |
| CRDM | Control Rod Drive Mechanism |
| CSCS | Cold Shutdown Cooling System |
| DAC | Design Acceptance Confirmation |
| DBA | Design Basis Analysis |
| DBC | Design Basis Condition |
| DBT | Design Basis Threat |
| DC | Direct Current |
| DEC | Design Extension Condition |
| DiD | Defence in Depth |
| DPS | Diverse Protection System |
| DR | Design Reference |
| DRP | Design Reference Point |
| E3S | Environment, Safety, Security and Safeguards |
| EBI | Emergency Boron Injection |
| ECCS | Emergency Core Cooling System |
| EIMT | Examination, Inspection, Maintenance and Testing |
| ESWS | Essential Service Water System |
| FPCS | Fuel Pool Cooling System |
| GB | Great Britain |
| GDA | Generic Design Assessment |
| GSE | Generic Site Envelope |
| HPIS | High Pressure Injection System |
| HVAC | Heating, Ventilation and Air Conditioning |
| IAEA | The International Atomic Energy Agency |
| IMS | Integrated Management System |
| ISO | International Organization for Standardization |
| ISS | Integrated Security Solution |
| IVR | In-Vessel Retention |
| IWS | Integrated Waste Strategy |
| LOCA | Loss of Coolant Accident |
| LOOP | Loss of Offsite Power |
| LUHS | Local Ultimate Heatsink System |
| MEP | Mechanical, Electrical and Plumbing |
| MDSL | Master Document Submission List |
| MKoP | Modular Kit of Parts |
| NISR | Nuclear Industries Security (Amendment) Regulations 2017 |
| NPP | Nuclear Power Plant |
| NRW | Natural Resources Wales |
| ONMACS | ONR Nuclear Material Accountancy, Control, and Safeguards Assessment Principles |
| ONR | Office for Nuclear Regulation |
| OPEX | Operational Experience |
| PCC | Passive Containment Cooling |
| PDHR | Passive Decay Heat Removal |
| PIE | Potential Initiating Event |
| PSA | Probabilistic Safety Analysis |
| PSR | Preliminary Safety Report |
| PWR | Pressurised Water Reactor |
| RCCA | Rod Cluster Control Assembly |
| RCS | Reactor Coolant System |
| RD | Reference Design |
| RGP | Relevant Good Practice |
| RI | Regulatory Issue |
| RO | Regulatory Observation |
| RP | Requesting Party |
| RPS | Reactor Protection System |
| RPV | Reactor Pressure Vessel |
| RQ | Regulatory Query |
| SAP | Safety Assessment Principle |
| SbD | Secure by Design |
| SBO | Station Black Out |
| SFP | Spent Fuel Pool |
| SG | Steam Generator |
| SMR | Small Modular Reactor |
| SSC | Structure, System and Component |
| SyAP | Security Assessment Principle |
| TAG | Technical Assessment Guide |
| UK | United Kingdom |
| UKRI | UK Research and Innovation |
| VAI&C | Vital Area Identification and Categorisation |
| WENRA | Western European Nuclear Regulators Association |

Table of Contents

[Executive Summary 4](#_Toc169508447)

[1. Purpose 14](#_Toc169508448)

[2. Background 15](#_Toc169508449)

[3. Work carried out by ONR in consideration of this request 29](#_Toc169508461)

[4. Matters arising from ONR’s work 32](#_Toc169508470)

[5. Readiness for Step 3 65](#_Toc169508494)

[6. Conclusions 68](#_Toc169508498)

[7. Recommendations 70](#_Toc169508499)

[References 71](#_Toc169508500)

[Appendix 1 77](#_Toc169508501)

**Tables**

Table 1: Circulation (latest issue)

Table 2: List of abbreviations

Table 3: Step 2 requirements from Guidance to Requesting Parties

**Figures**

Figure 1: Rolls-Royce SMR layout

Figure 2: Plan of reactor island structures and areas

Figure 3: Cross-section of reactor island base isolation system

Figure 4: Reactor Coolant System (RCS) layout

Figure 5: Passive Decay Heat Removal (PDHR) system schematic (heat removal)

Figure 6: Emergency Core Cooling System (ECCS) schematic

Figure 7: Claim, Argument Evidence (CAE) structure within the E3S hierarchy

Figure 8: Evolution of the generic E3S case

Figure 9: Rolls-Royce SMR civil structures

Figure 10: Assembly of Modular Kit of Parts (MKoP) frames to clusters and blocks

Figure 11: Reactor Island pictorial view

# Purpose

1. In April 2023, having successfully completed Step 1, the Office for Nuclear Regulation (ONR), the Environment Agency and Natural Resources Wales (NRW) announced that Rolls-Royce Small Modular Reactor (SMR) Limited's reactor design could progress to Step 2 of the Generic Design Assessment (GDA). Rolls-Royce SMR Limited intends to complete a three-step GDA, with the objective of receiving a Design Acceptance Confirmation (DAC) from ONR.
2. During the last 16 months we have undertaken those activities identified for Step 2 within our GDA guidance document, Guidance to Requesting Parties (ref. [1]). The assessment focused on the adequacy of the design, and the safety, security and safeguard cases with the intent of identifying any fundamental shortfalls in meeting regulatory expectations. We have also undertaken those enabling activities required to proceed to Step 3, subject to the decision to do so.
3. This report has been produced:

* To document the completion of and outcomes from Step 2;
* To summarise the activities undertaken by both Rolls-Royce SMR Limited and ONR during the step;
* To summarise ONR’s judgement on whether we have identified any fundamental shortfalls with the generic Rolls-Royce SMR design;
* To summarise ONR’s judgement on whether the objectives for Step 2 have been met; and
* To document the basis for the decision on whether to proceed to Step 3, or not.

# Background

## Generic Design Assessment

1. ONR is the UK’s independent nuclear regulator, with the legal authority to regulate nuclear safety, civil nuclear security and safeguards, and conventional health and safety at the 36 licensed nuclear sites in Great Britain (GB). We also regulate the transport of civil nuclear and radioactive materials by road, rail and inland waterways. ONR’s mission is to protect society by securing safe nuclear operations.
2. The environment protection aspects of the generic design are assessed and reported separately (ref. [2]) by the environment agencies (the Environment Agency and NRW) whom we work with closely during GDA. Whilst we have independent responsibilities and regulate within our own legal frameworks, we recognise the benefits of building on our close working relationship to align our processes and regulatory positions when we can. The Environment Agency has published separate guidance on the process it follows (ref. [3]).
3. The GDA process was developed in response to the government's 2006 Energy Review; in particular lessons learnt from experience with new nuclear power plants (NPPs) indicated that the use of a standardised design, where the design and safety case are well developed much earlier in the project, would facilitate a reduction in the time for regulatory assessment as well as minimise any potential regulatory uncertainty for a future site licensee wishing to build such a design. Although GDA is not a mandatory process, because of its inherent benefits it is expected that it will usually be requested for new NPPs intended for construction in GB.
4. The objective for GDA is to provide confidence that the proposed design is capable of being constructed, operated and decommissioned in accordance with the standards of safety, security, safeguards and environmental protection required in GB. For the Requesting Party (RP), the organisation(s) who requested the GDA, this offers a reduction in uncertainty and project risk regarding the design and safety, security, safeguards and environmental cases so as to be an enabler to future licensing, permitting, construction and regulatory activities.
5. To fulfil this objective, GDA progresses in steps, with the regulatory assessments becoming increasingly detailed. The assessment considers the majority of ONR’s statutory purposes, using inspectors from the full range of technical topics (for example, fault studies, civil engineering or chemistry), as defined in Guidance to Requesting Parties (ref. [1]).
6. The GDA process has three steps, noting that earlier GDAs had four steps; a change that resulted from lessons learnt and efficiency improvements implemented in 2019. The overall intent is that:

* Step 1 is the initiation step where matters such as the scope and timescales are agreed, and ONR’s knowledge of the design and the RP’s safety, security and safeguards cases increases;
* Step 2 is the fundamental assessment of the generic design and safety, security and safeguards cases, to identify any potential ‘showstoppers’ that may preclude deployment of the design; and
* Step 3 is the detailed assessment of the generic safety, security and safeguards cases on a sampling basis.

1. The Rolls-Royce SMR Limited design is the seventh design to begin a GDA, and is both the first SMR to be assessed by ONR and the first to follow the revised three-step GDA process.
2. To date, we have completed GDAs for four designs: the EDF and AREVA UK EPR™, the Westinghouse AP1000®, the Hitachi-GE UK ABWR and the CGN/EDF/GNI UK HPR1000. These completed with the award of a DAC in 2012, 2017, 2017 and 2022 respectively. We have also recently started two-step GDAs for the Holtec International SMR-300 and the GE Hitachi BWRX-300 designs. Full details of completed and ongoing GDA projects are available on the joint regulators’ website (ref. [5]).

## Objectives for Step 2

1. Step 2 is the first substantive technical assessment step, and builds upon the work undertaken during Step 1. The focus of the assessment in this step is towards the fundamental adequacy of the design and safety, security or safeguards cases, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the generic design and cases.
2. The intent of the assessment is to identify any fundamental shortfalls in the generic design, based upon the submitted information, and to present a balanced, holistic view of the generic design when compared to regulatory expectations. A fundamental shortfall is defined as one that could prevent ONR permissioning the construction of a power station based upon that design; in effect where we judge that the generic design cannot meet regulatory expectations in such a manner that it cannot be operated safely, securely or to ensure safeguarding.
3. To ensure we undertook a holistic, balanced and proportionate assessment during Step 2 we mobilised all of our technical topics. In total we have performed assessments for 21 topics, and each of these is reported separately (refs [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23] and [24]). Further details of the outcome from these assessments is provided in Section 4.
4. Guidance to Requesting Parties (ref. [1]) provides details of what the RP is required to do and what ONR will do during Step 2. These are repeated in Table 3 of this report, in Appendix 1. Where we have made a judgement against a requirement placed on the RP from this guidance, these are specifically cited in the text of this report.
5. A number of the requirements on the RP are to submit information to ONR. These cover matters which are necessary for undertaking GDA (such as project management activities and demonstration of adequate resources) along with matters of a more technical or regulatory nature. They are targeted at ensuring that sufficient information is provided to allow ONR to form a judgement on the fundamental adequacy of the design during Step 2, and that both the RP and ONR are prepared for the more detailed assessment to be undertaken in later steps.

## Requesting Party

1. For the purposes of the GDA, Rolls-Royce SMR Limited is the RP, and therefore the point of contact for the regulators.
2. Rolls-Royce SMR Limited was formally established on 5 November 2021, as an independent company to draw upon the many decades of experience of nuclear design and engineering in the parent body to deliver the generic Rolls-Royce SMR design. It is backed by private shareholders, which include international investors and Constellation who are the largest US nuclear operator. Public funding has also been provided by UK Research and Innovation (UKRI). The majority shareholding remains with Rolls-Royce plc.
3. Rolls-Royce SMR Limited is the designer, responsible for undertaking all aspects of the design, analysis, engineering and production of the safety, security, safeguards and environmental submissions which justify the design.

## Rolls-Royce SMR design

### Design status

1. The generic Rolls-Royce SMR design is being developed as a complete NPP solution based on what the RP claims is an optimised and enhanced use of proven technologies. The RP has stated that the design adopts innovations where these are claimed to add value, focused on providing cost and build assurance while maintaining safety, security, safeguards and environmental standards. It claims this is achieved by using modularised build techniques and off-site manufacturing under factory conditions, both of which are not new approaches but have never been applied to this extent in the nuclear industry.
2. Rolls-Royce SMR Limited is the first RP to enter GDA with a design that is not built or under construction worldwide. This means that there is no “reference design” for the purposes of GDA, and the generic design will continue to be developed in parallel with our regulatory assessment.
3. Our assessment of the Rolls-Royce SMR is the first time that the design has been considered by regulatory bodies. While this represents an opportunity to ensure the design meets UK expectations from the outset, this does emphasise the need to have confidence in the RP’s controls and processes regarding design activities. Our work during Step 1 did start to examine these aspects and we have continued this during Step 2; see Section 4.
4. The RP has initiated an International Atomic Energy Agency (IAEA) technical safety review of their design, using relevant IAEA standards (ref. [25]). At the time of writing, this review remains on-going. We expect to follow up on the outcomes of this review later in GDA, as required. This meets requirement [2.2] from Guidance to Requesting Parties (ref. [1]).

### Design maturity

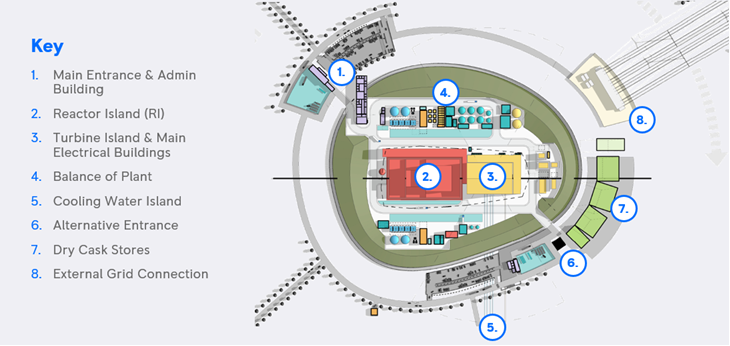
1. The RP’s development of the design began in the autumn of 2015 and it has continued to evolve since then. The RP specifically focused on maturing those aspects which it considers to be of environment, safety, security or safeguards significance during Step 2.
2. The RP has a structured process to baseline its design through a series of engineering milestones, termed “Reference Design” (RD) points. The design has continued to mature throughout GDA, from RD4 at the start of Step 1 through to RD7 which was achieved in November 2023.
3. During Step 2 we expect the RP to define a Design Reference (DR). This lists all the documents that define the design of the NPP that the GDA submissions refer to. We expect this to be ‘frozen’ at a specific date known as the Design Reference Point (DRP).
4. RD7 is significant for GDA as it is the design baseline against which both the first DRP, or DRP1, was declared and the current version of the generic Environment, Safety, Security and Safeguards (E3S) cases were written.
5. The RP expects that there will be further RDs declared throughout Step 3 in order to develop the design and supporting evidence needed to complete GDA. This will lead to further DRPs being declared. Further details of the RP’s design processes and design maturity are given in Section 4.

### Design overview

1. The Rolls-Royce SMR design has been developed by the RP based upon well-established Pressurised Water Reactor (PWR) technology, in use all over the world, but the modular approach adopted in the design will see the majority of the NPP built in factory conditions and assembled on site. In addition to commercial drivers, the RP claims that this approach will have benefits due to the more controlled environment for manufacture and commissioning.
2. The generic Rolls-Royce SMR design is a three loop PWR with a target electrical power output of 470 MWe (from a thermal power of 1,358 MWth) and a design life of 60 years for non-replaceable components.

#### Layout

1. The generic site layout is shown in Figure 1, noting that this diagram excludes the architectural shell which covers the reactor. The total site footprint is approximately 49,000m2.



**Figure 1: Rolls-Royce SMR layout** (ref. [26])

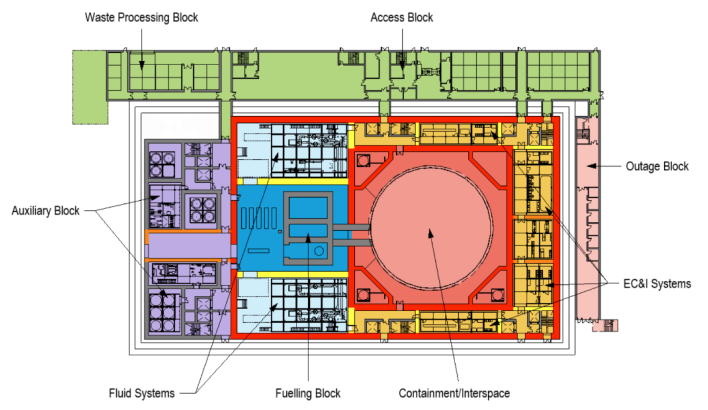
1. The design features a number of areas or ‘islands’ and includes:

* The reactor island which includes the Structures, Systems and Components (SSCs) that form the reactor, transfer and store new and used fuel, and any associated nuclear auxiliary systems. The purpose of the reactor island is to use the heat from a controlled nuclear fission reaction to generate steam, which is then passed to the turbine Island.
* The turbine island which provides the link between the reactor island where steam is generated, and the electrical connections where generated electricity is provided to the power grid. The main equipment in the turbine island is the steam turbine and generator arrangement, where the mechanical energy of steam is converted into electrical energy.
* The cooling water island provides the primary means of removing heat from the power station, passing it to the ultimate heat sink. This includes the various cooling water systems needed for operating the plant.
* The balance of plant island which provides a range of ancillary functions to enable the other systems across the power station to achieve their functions, such as the supply of demineralised water and chemicals. This includes the water supply, disposal, treatment system, auxiliary systems, storage systems and ancillary systems.

1. A range of electrical and Control and Instrumentation (C&I) systems, which span the design including systems relating to grid connection and intra-site electrical distribution, including emergency power supplies. It also includes nuclear and non-nuclear C&I systems which provide control, monitoring and protection functions.
2. The generic design for GDA utilises cooling towers at a coastal site to provide the main heat sink for the plant during normal operations.

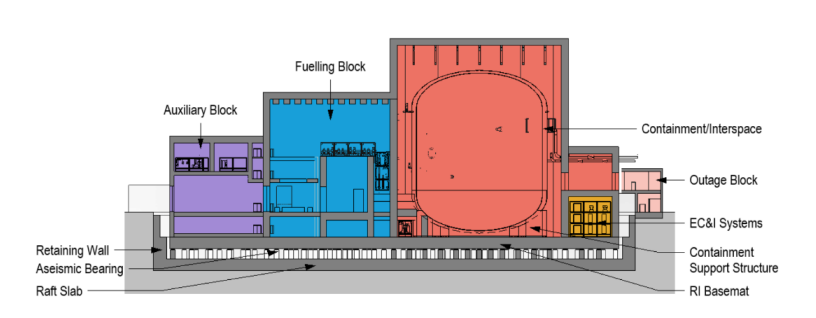
#### Structures

1. The main nuclear significant structures are associated with the reactor island. The reactor island is arranged into a series of “blocks” which contain the different process and safety systems needed for the plant. During Step 2 the layout of the reactor island was updated by the RP. This is claimed to optimise the arrangement of key systems and improve the resilience to internal hazards.
2. A plan view through the reactor island is shown in Figure 2.



**Figure 2: Plan of reactor island structures and areas** (ref. [27])

1. A hazard shield, consisting of a reinforced concrete wall and roof, is included in the Rolls-Royce SMR design to provide protection against a radioactive release due to external hazards. The bounding case for the hazard shield is based on an aircraft impact hazard, aiming to ensure confinement of fuel, prevention of criticality, protection of reactor shutdown and cooling systems and protection of monitoring systems. The hazard shield covers the containment, interspace, fuelling block, electrical, C&I systems and fluid systems blocks/zones to ensure all class 1 SSCs needed for these functions are protected (indicated by the red walls in Figure 2).
2. The generic Rolls-Royce SMR design also includes aseismic bearings for a base isolation system within the reactor island. The main benefit claimed of this system is that it allows the superstructure to be standardised, along with the equipment in the power station, regardless of site-specific seismicity. The base isolation system features concrete pedestals and elastomeric bearings that support the reactor island. This is shown in Figure 3. The arrangement allows for the decoupling between the ground and the superstructure, with a gap around the perimeter to allow for horizontal displacements. This is claimed to protect the supported structure from the damaging effects of horizontal earthquake shaking in a seismic event. The base isolation applies to both the containment and fuel and control buildings, which house the class 1 and 2 SSCs needed for post-earthquake functionality.

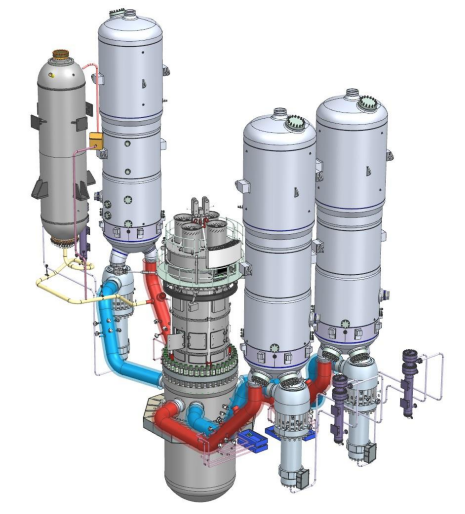


**Figure 3: Cross-section through reactor island** (ref. [27])

1. The containment/interspace holds a containment vessel that encloses the reactor, providing confinement of radiation sources and preventing release to the environment in accident conditions. The containment vessel is a large steel pressure vessel, designed and substantiated to the American Society of Mechanical Engineers (ASME) III specifications, which contains the components of the Reactor Coolant System (RCS). The vessel is cylindrical and includes a top and bottom dome. The vessel is approximately 34.5 m in diameter, 41.5 m in height with an internal free air volume of around 23,000 m3. The containment vessel can be seen in Figure 3.

#### Reactor

1. The RCS is shown in Figure 4. The RCS is in a three-loop close-coupled configuration, arranged to facilitate natural circulation when pumped flow is unavailable.
2. Each loop consists of primary pipes going into and out of the Reactor Pressure Vessel (RPV) (referred to as cold and hot leg respectively), one seal-less reactor coolant pump in the cold leg, and one vertical u-tube Steam Generator (SG). One of the loops contains the pressuriser connected to the hot leg, whose function is to maintain sub-cooled conditions and absorb volume changes during transients. The operational pressure of the primary circuit is 15.5 MPa abs.

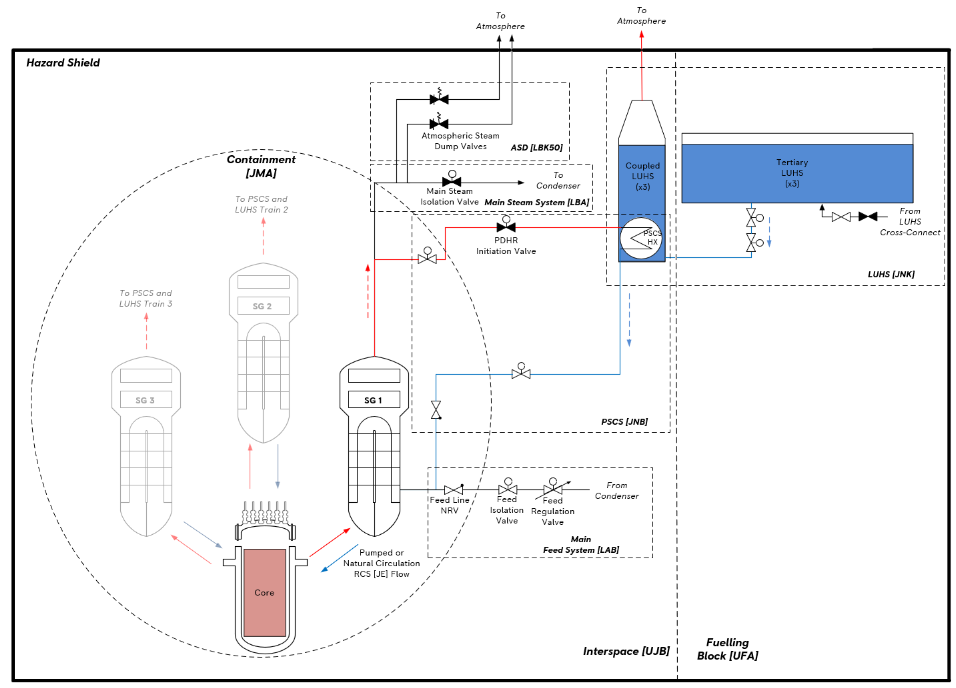


**Figure 4: Reactor Coolant System (RCS) layout** (ref. [28])

1. At the centre of the RCS is the RPV. The RPV is a cylindrical steel vessel designed to withstand the high temperatures, pressures and radiation of the reactor. The RPV houses the reactor core, in-core instrumentation and the reactor internals. The reactor core is made up of 121 fuel assemblies and 113 control rod assemblies. Each fuel assembly is arranged in a 17x17 array of fuel rods consisting of a metallic zirconium alloy cladding housing the nuclear fuel, which is in the form of small ceramic pellets, which contain up to 4.95% enriched uranium dioxide fuel. The hemispherical upper head of the RPV is removable to allow refuelling of the reactor every 18 months.
2. Water is used as the primary coolant, to extract the heat from the reactor, and as a moderator to maintain the nuclear reaction in the core. Hot water from the core outlet passes into the SGs, where it flows through thousands of heat exchange tubes which transfer the heat to the secondary coolant on the outside of the tubes, which is allowed to boil and produce steam. It is this steam produced in the secondary side of the SGs that drives a turbine that ultimately, via a generator, produces electricity. The primary coolant leaving the SGs, which is now at lower temperature, is then pumped back into the reactor via the cold legs. The flowrate of the primary coolant is such that the flow through each loop takes only a few seconds.
3. Unlike other commercial PWRs, the generic Rolls-Royce SMR design is designed to operate without soluble boron during normal operations. Rolls-Royce SMR Limited claim that, in addition to simplification of the design, this provides safety benefits including full shutdown margin delivered by the control rods and elimination of boron dilution faults.

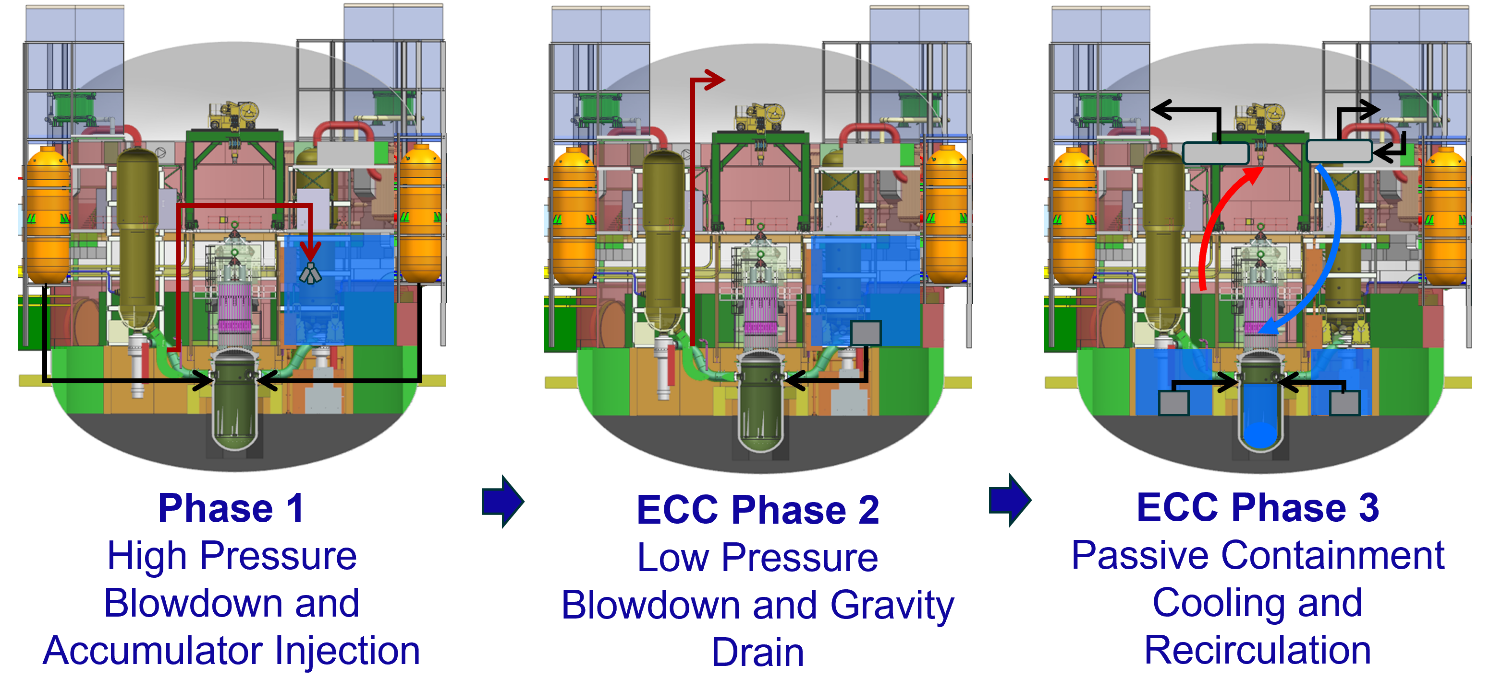
#### Safety systems

1. A range of safety measures are present in the Rolls-Royce SMR design to provide cooling, control criticality and contain radioactivity under fault conditions. Reflecting the RP’s design philosophy which prioritises use of passive safety features, active components and supporting electrical supply are claimed to be of relatively lower risk importance than passive ones. As such, hazards which render active systems unavailable, such as complete loss of electrical supplies (station blackout), are claimed to present very low risk. Similarly, failures of operator actions in delivery of safety functions are not claimed to be important. The RP's design philosophy is that no on-site mobile equipment is required within the first 3 days of accident management, and no off-site support is required for at least 7 days.
2. The Rolls-Royce SMR design employs both active and passive decay heat removal systems for heat removal during normal conditions, intact circuit faults and small break Loss of Coolant Accidents (LOCAs). Condenser decay heat removal utilises the SGs and the normal duty steam condenser to cool the RCS. Passive Decay Heat Removal (PDHR) is a dedicated safety measure that utilises the SGs and the Local Ultimate Heatsink System (LUHS) to cool the RCS. In the PDHR system decay heat is transferred to the LUHS water tanks via dedicated submerged heat exchangers. Boiling/evaporation of the LUHS water to atmosphere provides the ultimate heat sink via passive means which rely on natural circulation. This is shown in Figure 5.
3. To provide pressure support during small LOCAs, in addition to the duty systems which provide pressure support, the design includes a High-Pressure Injection System (HPIS).



**Figure 5: Passive Decay Heat Removal (PDHR) system schematic (heat removal)** (ref. [29])

1. In circumstances where the SGs are unavailable for decay heat removal or are unable to provide heat removal, for example in intermediate or large LOCA, the Emergency Core Cooling System (ECCS) is designed to provide a passive, redundant, diverse and segregated protective safety measure. This system provides core cooling in a sequence which involves controlled blowdown of the RCS to the containment through dedicated relief valves and spargers (if necessary), water injection from three accumulator tanks, gravity injection from the refuelling pool and any water that is collected in the sump from the RCS, followed by a longer term passive circulation from water accumulated within the containment sumps. This is shown in Figure 6.



**Figure 6: Emergency Core Cooling System (ECCS) schematic** (ref. [30])

1. Shutdown of the reactor in faults can be achieved using either the scram function or the Alternate Shutdown Function (ASF). The scram function isolates power to the Control Rod Drive Mechanisms (CRDM), causing the control rods to be rapidly inserted under gravity. The ASF is provided by the Emergency Boron Injection (EBI) system which delivers boron solution to the RCS, via the HPIS pumps. These safety functions are initiated by independent and diverse control and instrumentation systems.
2. During shutdown conditions, normal heat removal from the reactor is provided by the Cold Shutdown Cooling System (CSCS). Similarly, for the spent fuel pool, normal heat removal is provided by the Fuel Pool Cooling System (FPCS). The systems can be cross connected, and each can be used for cooling the shutdown reactor or the spent fuel pool. During certain operating modes PDHR/ECCS are unable to provide safety functions during accident conditions. In these plant states, if active heat removal is lost, heat removal is provided by evaporative cooling. A similar case is made for accident conditions in which active cooling cannot be provided to the spent fuel pool. Evaporative cooling is claimed to provide sufficient grace times to re-establish active cooling.
3. As described previously, a steel containment is provided to mitigate the release of fission products to the environment in accident conditions. The containment safety measure also incorporates features to minimise and mitigate postulated severe accident phenomena. These include passive hydrogen re-combiners to prevent high-energy hydrogen combustion that could challenge the containment, both active and passive containment heat removal systems, and severe accident depressurisation to avoid high-pressure melt ejection. The design also includes features to achieve In-Vessel Retention (IVR) of molten core material in a severe accident. This is achieved by externally cooling the RPV lower head by gravity flooding the reactor cavity pit with water and allowing this to evaporate, condense and return to the pit. Steam released into the containment throughout the transient is cooled by the LUHS Passive Containment Cooling (PCC) system heat exchangers.
4. The RP claims that the safety analysis informs the design and demonstrates there is suitable and sufficient Defence in Depth (DiD) to deliver the fundamental safety functions, and that nuclear safety risks to workers and the public are reduced to As Low As Reasonably Practicable (ALARP).
5. The RP have also set a design objective to demonstrate an overall Core Damage Frequency (CDF) of less than 10-7 per year of power operation through development and use of a comprehensive Probabilistic Safety Analysis (PSA).

## Safety, security and safeguards cases

1. During Step 1 the RP submitted information on its strategy and intentions to develop the generic E3S cases for the design, alongside a Preliminary Safety Report (PSR). These formed the basis of our assessment during Step 1.
2. During Step 2 these strategies were enacted and the RP submitted updated versions of the top level E3S case chapters and a range of supporting documents. Our views on these submissions are detailed further in Section 4, but an overview of the current status of the E3S case is summarised below.

### Approach

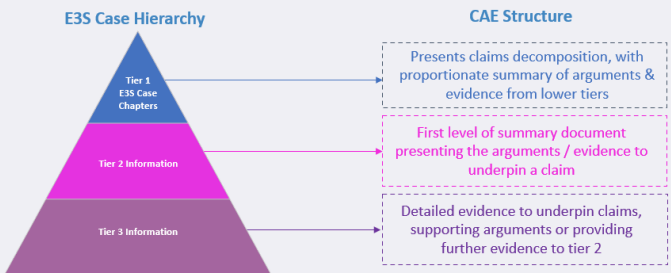
1. The stated fundamental objective of the Rolls-Royce SMR design is “to protect people and the environment from harm” and the E3S case is being developed to demonstrate that this can be achieved. This includes the RP demonstrating that risks are (or at this stage can be) reduced to ALARP, applying best available techniques (BAT), and ensuring secure by design (SbD) and safeguards by design.
2. Chapters 1 (ref. [26]) and 3 (ref. [31]) of the E3S case provide summary information on the RP’s approach to development of its E3S case. This approach has continued to evolve throughout Step 2. Several notable aspects of the RP’s approach are:

* The RP has chosen to develop its cases in a holistic manner across the E3S purposes, meaning evidence may be used to support multiple claims within the case;
* The use of a rigorous Claim, Arguments and Evidence (CAE) structure to define the “golden thread” for the case;
* A combined systems engineering and analysis approach;
* Derivation and management of functional and non-functional requirements; and
* Adoption of a range of digital tools to aid the production and control of the design and case, notably to manage requirements, the E3S case and any changes.

1. The approach adopted by the RP is ambitious, and would represent good practice in a number of areas if it can be delivered to the RP’s own high standards. Our assessment of the RP’s approach to development, governance and management of its E3S case is detailed in Section 4.

### Structure, scope and content

1. The E3S case is being developed using a three tier hierarchy and incorporating a CAE structure with the highest-level claims being derived from the RP’s own E3S principles. The highest level of the three tiers is the E3S chapters, with the lower tiers providing more detailed arguments and evidence. This is illustrated in Figure 7.

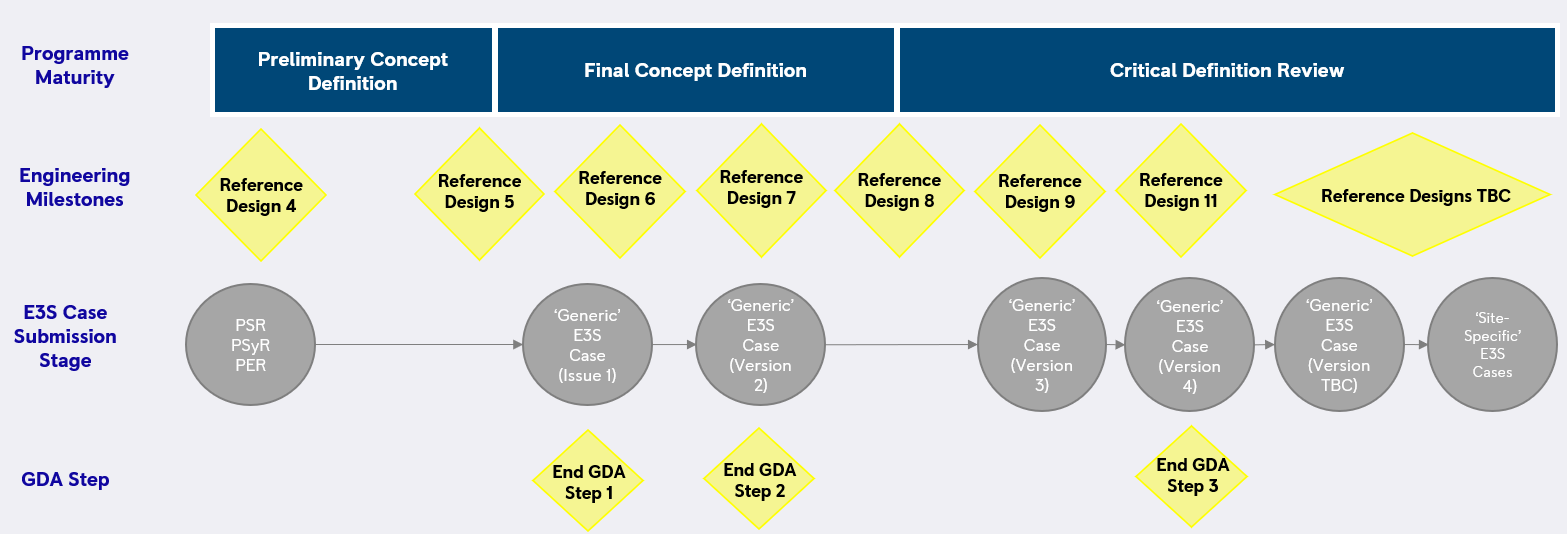


**Figure 7: Claim, Argument Evidence (CAE) structure within the E3S hierarchy** (ref. [26])

1. The structure of the tier 1 E3S case chapters largely aligns with the IAEA guidance for safety cases, SSG-61 (ref. [32]), supplemented to include UK specific expectations and expanded to include the other E3S purposes. This leads to 33 chapters. All of ONR’s technical topics, as defined in Guidance to Requesting Parties (ref. [1]), are within the scope of the E3S case, although some do not have a direct alignment to an individual chapter.
2. One artifact of the RP’s engineering process is the derivation and management of requirements which define what the design must deliver. The E3S requirements, comprising both safety functional (or equivalent for security, safeguards and environment) and non-functional requirements, are a sub-set of the requirements generated, and derive from the underpinning E3S analysis (or evidence). The requirements, and their substantiation, will therefore become a more prominent feature of the E3S case as it develops and will provide the ‘golden thread’ to the engineering substantiation.

### E3S case maturity

1. As with the design, the corresponding E3S case has continued to mature throughout Step 2. Version 1 of the tier 1 E3S chapters were submitted to the Regulators at the start of Step 2, and lower-level tier 2 and 3 submissions were provided in accordance with the agreed submission schedule throughout the step. These submissions formed the basis for our assessment in Step 2. When taken together, these documents represent the E3S case for the generic Rolls-Royce SMR design.
2. At the end of Step 2 we also received version 2 of the E3S chapters. These updated chapters were consolidated by the RP to include relevant information submitted during Step 2. As such version 2 of the chapters are consistent with the information we assessed. These are published on the RP’s GDA website (ref. [33])
3. As explained in Section 2.4.2, DRP1 is based on the RP’s RD7 engineering milestone. Whilst this RD does provide a definition for all SSCs declared within the DRP, there remains further analysis, justification and substantiation to be produced, which will impact on the E3S case. The E3S case therefore reflects the maturity of both the design and supporting evidence at that point in time and there remain aspects where further work will be required by the RP to achieve its objective of a DAC. Further details of DRP1, and our assessment of it, are provided in Section 4.
4. The RP expects that it will need to produce at least two further versions of its E3S case during Step 3, both corresponding to further declared DRPs. These will consolidate changes to the design and supporting evidence for the E3S case up to that point. The RP’s overall intent, the details of which may change, is illustrated in Figure 8.



**Figure 8: Evolution of the generic E3S case** (ref. [26])

# Work carried out by ONR in consideration of this request

1. Guidance to Requesting Parties (ref. [1]) details the activities that both ONR and the RP are expected to undertake. This provided the framework for ONR’s work during Step 2.
2. To ensure that ONR’s activities were coordinated and delivered, we produced a delivery strategy (ref. [34]) which outlines roles and responsibilities, key activities and assurance arrangements for the project. It also served as the overarching assessment plan for Step 2, including specifically identifying those activities which are undertaken at project or topic level. Importantly, given the breadth of assessment undertaken during Step 2, it defined how we coordinated across each of our technical topics.
3. During Step 1, each of the 21 assessment topics produced an assessment plan for Step 2. This defined the aspects each topic intended to assess to inform their overall judgements on adequacy. As part of these plans we explicitly consider how our targeted assessment activities support the delivery strategy (ref. [34]) and the objectives for Step 2, such that we produce a holistic, joined up assessment of the generic design and E3S case. These assessment plans formed the basis of the assessment undertaken by each topic.

## Assessment of submissions

1. The RP submitted more than 900 documents to ONR during Step 2, which have been the basis for our assessment. This included a range of documents, at all tiers within the RP’s E3S case and across all of our technical topics.
2. The primary objective for the assessment was to enable a judgement to be made regarding the adequacy of the generic design and E3S case, in line with the objectives for Step 2.
3. The assessment was undertaken against the expectations in relevant standards and guidance, most notably our Safety Assessment Principles (SAPs) (ref. [35]), Security Assessment Principles (SyAPs) (ref. [36]) or ONR Nuclear Material Accountancy, Control, and Safeguards Assessment Principles (ONMACS) (ref. [37]). We have also made use of international guidance from the IAEA (refs [38] and [39]) and Western European Nuclear Regulators Association (WENRA) (refs [40] and [41]), where relevant.
4. In addition, Appendix 2 of Guidance to Requesting Parties (ref. [1]) sets requirements on the RP for information to be submitted during Step 2. The requirements are summarised in Table 3 of this report along with reference to where they are documented in this report, as appropriate. Our assessment also determined whether these requirements had been met.
5. The main deliverable produced from each of ONR’s technical topics are the Step 2 Assessment Reports (refs [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23] and [24]). These record the scope of regulatory assessment undertaken, the areas that have been targeted and the judgements made based on the submissions to date.
6. Key aspects of ONR’s assessment of these submission is summarised in Section 4.

## Interactions with the requesting party

1. During the 16 months of Step 2 we held more than 250 interactions with the RP, both at the project level and across the 21 individual technical topics. These proved an efficient and effective way to facilitate our assessment. This included a number of workshops and briefings provided by the RP to continue to improve our understanding of the design and its arrangements and processes, and a number of specific targeted interventions to look at the RP’s arrangements and capability to support the GDA.
2. Overall, the purpose of these interactions was to enable our assessment during the step, and to maintain oversight of ongoing activities and aid future interactions. These interactions were positive and we found the RP to be professional, responsive and open throughout and to have an appropriate focus on safety, security and safeguards. We have confidence that this constructive working relationship will continue throughout GDA.
3. The outcomes from these interactions are discussed in Section 4.

## Step 3 assessment plans and submission schedule

1. As part of the enabling activities necessary to progress to Step 3, each topic area has also produced an assessment plan for Step 3. These outline the areas we would expect to sample to inform the judgment on the overall adequacy of the generic design and E3S case at the completion of GDA. These have been informed by the findings of our assessment in Step 2, the delivery strategy (ref. [34]) and the overall objectives for Step 3.
2. To inform these plans, we agreed with the RP a submission schedule which defines all of the documents we expect to receive throughout Step 3 (ref. [42]). This schedule lists over 1,000 submissions spread across all 21 technical topics. This meets requirements [2.13] and [2.14] from Guidance to Requesting Parties (ref. [1]). This schedule will be maintained as live by the RP throughout GDA.

## Readiness reviews

1. As required by Guidance to Requesting Parties (ref. [1]) we undertook a readiness review to determine if the RP should proceed to Step 3. This included a review of our own readiness, but also considered the evidence provided by the RP of its readiness to proceed. The details of these reviews are provided in Section 5.

## Joint working with the Environment Agency and Natural Resources Wales

1. As a joint project, we have worked collaboratively with both the Environment Agency and NRW during Step 2, as appropriate. This included joint interactions on matters of regulatory interest to each regulator, particularly for quality assurance and aspects of radioactive waste management. We expect this joint working to continue and deepen for the remainder of the GDA.
2. The Environment Agency assessment of the environmental aspects of the generic Rolls-Royce SMR design are reported separately (ref. [2]).

## International collaboration

1. We are the first, and currently the only, nuclear regulator to assess the Rolls-Royce SMR design. This meant we have not had the opportunity to collaborate with any other international regulators, or leverage assessments performed by others, during Step 2. We are open to and will seek to strengthen international collaboration where possible.
2. We are encouraged that the RP has facilitated the observation of GDA interactions by five European regulators, seeks input from the US nuclear operator Constellation and has commissioned the IAEA review outlined in Section 2.4.1.

## Use of Technical Support Contractors

1. During Step 2 we procured technical support to inform our assessment. Three packages of work were completed relating to civil engineering, modularisation and verification and validation of computer codes. The outputs from these contracts are factored into our assessment described in Section 4.
2. We also let a longer term contract which will support our independent confirmatory analysis of the RP’s transient analysis. This will deliver during Step 3.

## Public comments

1. In accordance with requirement [2.24] from Guidance to Requesting Parties (ref. [1]), the RP has enabled a public comments process. We are satisfied the RP is meeting the expectations of this requirement.
2. At the time of writing, a total of 40 comments had been received for Rolls-Royce SMR Limited to consider. None of the comments directly affected our assessment or our GDA process.

# Matters arising from ONR’s work

1. This section provides an overview of ONR’s assessment of key aspects of the Rolls-Royce SMR design and associated E3S case.
2. Our assessment considered all of ONR’s statutory purposes relevant to GDA, including nuclear safety, conventional health and safety, security and safeguards. As is normal we have used ONR’s standards and guidance as the basis for our assessment (SAPs (ref. [35]), SyAPs (ref. [36]) or ONMACS (ref. [37]), and associated Technical Assessment Guides (TAGs) (ref. [43])). We have also actively considered relevant IAEA standards and requirements as part of our assessment, given the RP’s objective to have an international standardised design, informed by the applicability described in the IAEA’s Safety Report Series No. 123 (ref. [44]).
3. In accordance with Guidance to Requesting Parties (ref. [1]), our assessment has focused on the fundamental adequacy of the design and safety, security and safeguards cases, and the suitability of the methodologies, approaches, codes, standards and philosophies which form the building blocks for the design and generic cases. Notable shortfalls or gaps against our expectations for this step of GDA have been noted in this report (along with their significance), with further details available within the individual topic assessment reports.
4. In accordance with ONR guidance on assessment (ref. [45]), we have targeted our assessment and used a sampling approach, based on significance, novelty or hazard potential as a means to determine an overall view on the adequacy of the design. Within Step 2, our sampling has been broad and high-level. We intend to use the intelligence gained from this assessment to feed into our more detailed assessments required post Step 2.
5. As a summary, this report does not capture all aspects of the assessments undertaken, which are detailed in the topic assessment reports (refs [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23] and [24]). It does however provide a view on those aspects we consider most significant, novel or pertinent to support our overall view on the adequacy of the design.
6. This section is composed of four main sub-sections. The first two provide a summary of the RP’s arrangements for undertaking the GDA and the definition of the generic design, which are both important enablers for undertaking the assessment of the design and E3S case. It then details the overall approach to development of the E3S case, before presenting a summary of our view on the fundamental adequacy of the generic design.

## RP’s arrangements for undertaking GDA

1. In order to successfully undertake and deliver a GDA, the RP needs to have adequate arrangements in place to produce the generic design and supporting safety, security and safeguarding documents. Some of these arrangements are directly necessary to deliver GDA specific requirements, such as for the management of regulatory questions, but for others we need confidence in the RP’s processes that are a part of its own business arrangements. A number of the requirements from Guidance to Requesting Parties (ref. [1]) directly relate to these.
2. During Step 1, a particular focus of our assessment was on gaining assurance on the adequacy of these arrangements as an enabler for our more detailed assessment. For Step 2 we considered the implementation and continued development of these.

### Management system

1. Rolls-Royce SMR Limited’s development of its Integrated Management System (IMS) has continued throughout Step 2, building upon the solid foundations assessed during Step 1. This included updates to individual processes, but also the overall project quality management plan. The RP has aligned the IMS and its development to relevant management system standards, including International Organization for Standardization (ISO) 9001: 2015 – Quality Management Systems, ISO 14001: 2015 – Environmental Management Systems and IAEA GSR Part 2 – Leadership and Management for Safety (ref. [46]). Of particular note is that the RP achieved independent third party accreditation of the IMS for ISO 9001 in 2023, and continues to work towards further accreditation.
2. Our assessment concluded that there is good alignment to the standards and criteria we expect including for the RP’s quality organisation, process control and ownership, process interfaces, control of information, ease of use, monitoring and measuring. We are satisfied that the IMS is adequate for this stage of the GDA and have confidence that this will continue.

### Document control

1. Many documents are produced, updated and exchanged with the regulators during the course of a GDA which puts onus on the RP’s arrangements for control of documents.
2. There are a number of GDA specific requirements for document control, including those related to how we exchange documents between us and the RP, production and control of the Master Document Submission List (MDSL) and responding to regulatory questions (Regulatory Queries (RQs), Regulatory Observations (ROs) and Regulatory Issues (RIs)). We assessed the RP’s arrangements for each of these during Step 1. In Step 2 the RP has applied these arrangements effectively to deliver the needs of the GDA, including adapting to learn lessons and make improvements, and we are content that this will continue. The working interface between the RP’s Regulatory Interface Office and the regulator’s Joint Programme Office has proved to be efficient and effective. This is further evidenced by:

* We did not identify any concerns regarding the quality of submitted information in terms of its assessability (e.g. whether it is legible, complete, configured etc. as opposed to the adequacy or otherwise of the content),
* We received 13 issues of the MDSL during Step 2 (ref. [47]), the content of which correctly identifies the submissions made for our assessment;
* We issued and received responses to 208 RQs during the step (ref. [48]); and
* We issued and received resolution plans and submissions in response to the two ROs we raised during Step 2 (further details of which are provide in later sections).

1. We are content that the RP’s arrangements for document control are sufficient for GDA. This fulfils requirement [2.15] from Guidance to Requesting Parties (ref. [1]).

### Design reference and change control

1. It is important that the generic design assessed under GDA is fixed, and any changes to it are subject to appropriate controls. The mechanisms to achieve this are specified in Guidance to Requesting Parties (ref. [1]) via the RP setting a Design Reference (DR) and adopting change management arrangements.
2. In line with requirement [2.16] of Guidance to Requesting Parties, Rolls-Royce SMR Limited submitted the DR report during Step 2 (ref. [49]). This report lists all the documents that define the design of the NPP that the GDA submissions refer to, in addition to giving wider context to the design and showing alignment to other GDA aspects, such as development of the E3S case and the RP’s overall engineering processes. It also indicates further updates to the DR will be made throughout GDA. Overall, the approach and scope of the DR provided by the RP is considered adequate. The content of the DR is considered in Section 4.2.3., in terms of the first fixed DR or DRP for GDA.
3. Change management is covered by a specific process within the RP’s IMS, which was adapted to include GDA specific needs, including inclusion of changes to the E3S case. The process and associated guidance are comprehensive and we are confident that the RP understands the need to have robust arrangements. From our assessment we are content that the arrangements implement:

* a categorisation process reflecting the potential E3S impact of the change;
* change control governance to oversee the categorisation of the proposed changes and the overall running of the process; and
* a method for alerting ONR to the more significant changes to the E3S case, and seeking our agreement for their inclusion within the GDA.

1. During Step 2, given the timing of setting the DRP (in December 2023), there have not been any changes proposed by the RP, and therefore we have not determined the suitability of this process. However, we have been given confidence using examples proposed by the RP and will maintain oversight. This fulfils requirement [2.18] from Guidance to Requesting Parties (ref. [1]).

### Capturing requirements, assumptions and commitments

1. The production of a design and associated E3S case will generate requirements, assumptions and commitments. These will need to be fulfilled by the RP whilst it continues to control the design and E3S case or by the future licensee. Our expectation is that Rolls-Royce SMR Limited will have suitable and sufficient arrangements in place to capture and control these, both for its own activities during GDA but also as an output from the generic E3S case. During Step 2 our focus has been on the former, and assurance that the RP is effectively managing commitments that the RP itself will need to fulfil throughout GDA, in particular those made in responses to regulatory questions. We expect to turn to the latter aspects in Step 3.
2. The RP’s approach is summarised in its E3S management arrangements. This uses Adelard’s Assurance and Safety Case Environment (ASCE) software to create registers, or action tracking systems. This is supported by project operating instructions for regulatory questions and commitments on a future licensee. We have started to see evidence of the RP identifying such matters, and we have seen evidence that commitments made in response to RQs are indeed being managed effectively. We consider that further work is needed to fully embed these arrangements but we remain content that this is adequate for Step 2. This fulfils requirement [2.17] from Guidance to Requesting Parties (ref. [1]).

## Definition of the generic design

1. To undertake a GDA it is vital that we have clarity over both the design that is being assessed and what aspects of that design are included within the GDA scope, in line with the requirements of Guidance to Requesting Parties (ref. [1]).

### GDA scope

1. During Step 1, the RP documented the agreed GDA scope (ref. [50]). This report describes the physical and functional scope of the power station that is proposed for consideration in the GDA. This includes all SSCs identified as being important the safety, security and safeguards, all modes of operation and all stages of the plant lifecycle. As would be expected, a number of exclusions have been declared from the GDA scope by the RP, all of which we consider to be reasonable.
2. Rolls-Royce SMR Limited has maintained that it intends to complete a three-step GDA, with the objective of receiving a DAC from ONR. During Step 2 the schedule was amended to reflect a 29 month Step 3, based upon more detailed planning activities undertaken by the RP. This would correspond to a total duration of GDA of 57 months from April 2022 to December 2026. The GDA scope remains aligned to this objective. This meets requirement [2.2] from Guidance to Requesting Parties (ref. [1]).
3. Whilst an updated version of the scope document is planned prior to completion of Step 2, the changes are editorial and terminology and do not impact the declared GDA scope. In accordance with requirement [2.1] of Guidance to Requesting Parties (ref. [1]) the RP maintained the GDA scope up to date throughout Step 2. We are content this meets this requirement and the declared GDA scope remains fit for purpose.

### Generic Site Envelope

1. The RP updated its Generic Site Envelope (GSE) (ref. [51]) during Step 2, largely to further refine what was presented during Step 1. The GSE report documents the site characteristics within which the generic Rolls-Royce SMR is capable of being built and operated. Overall we are content that the definition and use of the GSE is adequate, noting that further refinements would be normal business.
2. During Step 2 we have started a more detailed assessment of the GSE. From these we are content that:

* The defined ultimate heat sink is consistent with the generic design. Three means are provided to remove heat from the plant all of which utilise the atmosphere as the heat sink; mechanical draft cooling towers used to cool the main condenser, separate cooling towers to cool the Essential Service Water System (ESWS) used to cool the reactor systems, and ECCS which uses the LUHS tank for decay heat removal. The adequacy of these cooling provisions formed part of our assessment.
* The generic design includes provision of two offsite transmission system connections supplying three main electrical switchboards. These two offsite connections provide a significant role in deducing the claims on the onsite power sources and the risk of a Loss of Off-site Power (LOOP) event.
* The RP has assumed local density and distribution of population consistent with existing potential GB sites. This is a reasonable assumption for GDA.
* The identification of external hazards and their subsequent screening in the GSE is sufficiently comprehensive. The values proposed by the RP in the GSE are likely to be conservative, but more detail will be needed of their underpinning.
* The RP has estimated, using a conservative site boundary, that doses to the public would be below the SAPs Target 3 Basic Safety Limit (BSL) (ref. [35]).
* The RP’s analysis of climate change in the GSE is based upon Relevant Good Practice (RGP), and proposes a managed adaptive approach whereby the plant design will facilitate modification to adapt in response to climate change. This is valid in principle, but the RP will need to ensure sufficient space for future adaptions.

1. The GSE provides parameters that are intended to bound UK seismicity, based upon existing potential GB sites, defined in EN-6 (ref. [52]). Our assessment has highlighted that the values do not fully bound these sites, namely those which are very hard rock. Whilst the RP has used the values defined within the GSE to inform its civil design, further work may be required to address this should the Rolls-Royce SMR design be deployed at such a site.

### Design Reference Point

1. The DR report (ref. [49]) defines the first DRP for the Rolls-Royce SMR design. It includes a range of design, layout, engineering and analysis information which collectively defines the generic design. This is a subset of the RP’s own design definition processes, and integrates the GDA requirements into the RP’s established engineering processes, which we recognise as beneficial. The DRP aligns well with the GDA scope (ref. [50]), aside from a small number of SSCs which are not yet of sufficient maturity to be included in the DRP. We consider this reasonable at this point in GDA. All of our topic assessments have confirmed that the design defined in the DRP is consistent with their assessment during Step 2.
2. We therefore conclude that the DRP is adequate. This meets requirement [2.16] from Guidance to Requesting Parties (ref. [1]).

## Safety, security and safeguards cases

### Development of the E3S case

1. During Step 1 we assessed the RP’s strategy and intentions regarding the development of its E3S case, as described in Section 2.5.1. We were satisfied that the proposed E3S approach was logical, suitably structured and would give the RP means to direct the development of its design. The early production of clear strategies and the holistic approach were cited as good practices adopted by the RP.
2. In August 2023, based on assessment of the first issue of the E3S chapters and submissions, and interactions with the RP to date, we did not have sufficient confidence that the RP had fully developed and implemented suitable and sufficient procedures and controls to develop an E3S case which will meet UK and international regulatory expectations, and will be an enabler for future regulatory activities. Our judgement was that if the RP was to achieve its ambitions for its E3S case, it would need to develop a clearer understanding of the strategy, objectives, scope and plan for development of the case and embed this fully within the RP’s organisation and arrangements. As a consequence Regulatory Observation RO-RRSMR-001 was raised (ref. [53]).
3. This RO detailed a number of related aspects where further work was required, summarised into two Actions regarding documenting the development arrangements and embedding the arrangements for oversight, control and governance. The RP’s resolution plan (ref. [54]) identified newly produced arrangements for the development of the E3S case, internal training and an inspection by its own assurance function. In addition to assessment of these submissions, we also undertook a multidisciplinary intervention to review the effectiveness of implementation and have undertaken two separate reviews of the E3S case against the characteristics defined in our TAG on safety cases, NS-TAST-GD-051 (ref. [55]).
4. Resolution of the Actions raised under this RO remain on-going. The current status is summarised as:

* The Rolls-Royce SMR design originated as a design and engineering activity, and a significant focus of the RP remains to deliver this. The E3S case started as a parallel task, and the RP has worked hard to better integrate this across its organisation. This has been partially successful to date and we expect to see further evidence of progress to enable closure of the RO in due course.
* The RP’s approach to development of the E3S case is ambitious, and if achieved would represent several areas of good practice. At the start of Step 2, appreciation of this approach resided with a small number of individuals within the E3S team, and was less prominent to others, including the engineering team designing the plant. The RP has made some good progress in documenting and developing its arrangements, including the use of a number of digital tools, and rolling these out within the wider organisation. Despite this we judge that there remains work to do to fully document the enablers for the E3S case, to ensure consistency and clarity across all the purposes and topics. This is particularly the case for the CAE approach, use of requirements and the IBM DOORS (requirement management software) tool to inform the case, and the intent for how the “golden thread” will be documented.

1. We do note that the arrangements produced in response to this RO provide details of how the RP intends for its GDA E3S case to evolve into a site-specific case. This is preliminary, but we are content that the RP recognises and has considered early how this may be achieved. This meets requirements [2.19] and [2.20] from Guidance to Requesting Parties (ref. [1]).
2. Overall, we are content that good progress has been made throughout Step 2, and some of the matters raised by the RO have been resolved. There does remain further work needed by the RP to fully resolve the RO. We will seek resolution of this as soon as possible, but are confident that the RP can achieve this in a timely manner during Step 3 in order to effectively support its continued development of the design and E3S case.

### Design assurance

1. During Step 1 we sought confidence in the RP’s arrangements for control of its design and engineering activities. These arrangements are summarised within the Engineering Management Plan (ref. [56]). During Step 2, our assessment tested the implementation of these arrangements by the RP, specifically whether they give appropriate recognition of E3S related matters. Design assurance is multi-faced, and for Step 2 our assessment included consideration of requirements management, optioneering and governance. Given the ongoing maturing of the design and E3S case, much of our sample was historic, but was sufficient for our purposes for Step 2. Other relevant aspects are also reported in Sections 4.3.1 (requirements) and 4.4.7 (ALARP).
2. We remain content that the RP has a documented, structured approach to design development built upon its previous experience and relevant good practice. Whilst we have identified some areas where we expect to seek further information, we are content that the substantive aspects of the RP’s approaches are satisfactory. Overall, we recognise that the RP gives prominence to safety, security and safeguards considerations as part of its design activities. We are content that these do have a strong influence on the design however these are not yet as prominent in the E3S case documentation as we would expect.

## Adequacy of the generic design

1. As part of the assessment described here we considered the submissions provided by the RP in response to requirements [2.6], [2.7], [2.9] and [2.11] from Guidance to Requesting Parties (ref. [1]).

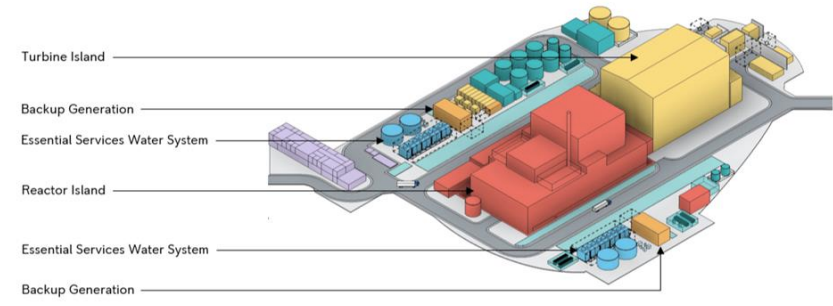
### Design parameters

1. The major technical parameters of the generic Rolls-Royce SMR design are defined within the E3S case (Table 1.5-1 of ref. [26]) and GDA scope (ref. [50]). These are characteristic for a PWR of this output. We have seen evidence that these are consistent throughout the design and E3S case, including the decomposition from these to the more detailed requirements that inform individual SSCs; for example the amounts of decay heat to be removed or the sizing of the containment to accommodate the pressure and temperature transients during faults. This includes the architecture and sizing of key SSCs that perform the fundamental safety functions of cooling, criticality and containment.
2. There is more work needed to substantiate and underpin these parameters as the design and analysis matures, and to demonstrate the traceability from the key parameter to the design. We are content that the foundations for this are soundly based and the RP has plans to do so.

### Structures and plant layout

**Civil structures**

1. The main civil structures associated with the generic Roll-Royce SMR are illustrated in Figure 9 (excluding the architectural shell). Those within the GDA scope are the reactor island, essential service waster system structures and back-up generation structures, plus any others whose failure would impact on class 1 and 2 structures. The design, functions and impact of the architectural shell, which covers the reactor and turbine islands, are not yet decided or analysed by the RP.



**Figure 9: Rolls-Royce SMR civil structures** (ref. [27])

1. During Step 2 our assessments have considered the RP’s approaches and methodologies to design, analyse, construct and maintain these. This has implicitly considered modularisation as applied to the civil design. In summary, whilst there are some areas where further details are sought or where additional information will be necessary as GDA progresses, we are content that:

* For those aspects of the design that were sampled during Step 2 these were generally found to be consistent with existing NPP designs. Some areas of novelty were identified as described more fully below.
* The overall adoption of relevant civil engineering codes and standards within the design is considered satisfactory.
* The safety classification of the civil structures is reasonable, as are the associated safety functional requirement allocations. Similarly the seismic classification is generally acceptable, however some areas where further justification will be required were identified.
* The analysis and modelling methodologies proposed are largely consistent with RGP, although some aspects were found to be less well developed than would be expected for this stage in design.

#### Seismic isolation

1. The Rolls-Royce SMR uses a base isolation system to reduce the seismic demand to the majority of reactor island structures, including the reactor and spent fuel pool (the extent of this systems is shown in Figure 3). By means of an aseismic bearing, the base isolation provides attenuation of the horizontal seismic ground motion to limit the peak acceleration transmitted to the structures located above it. The overall seismic case and seismic classification of SSCs takes credit for the seismic isolation system. Such an approach has not been used for an NPP in the UK before but has been used in a small number of large scale PWRs worldwide and the use for conventional buildings is well established. This has been considered as part of our assessment. We are content that it should be feasible to demonstrate that use of such a system is acceptable.
2. The exact number of bearings and their layout will need to be determined on a site-specific basis, but the generic design currently includes approximately 480 such bearings. The extent of SSCs that are mounted on the base isolation system is demonstrably informed by their safety significance and we expect supporting safety analysis to be available for detailed examination in the next step of GDA. The RP has further work planned to substantiate this design, including demonstration of redundancy and the avoidance of cliff-edge effects in beyond design basis events. Consideration has been given to maintenance and replacement in terms of space provisions, but detailed Examination, Inspection, Maintenance and Test (EIMT) activities have not yet been defined and justified. We are content with this position for Step 2.
3. The approach to seismic isolation has implications on other areas of the generic design and E3S case. The RP is aware of this, and recognises that it needs to provide further substantiation to claims made in the E3S case as the design matures. Notable are:

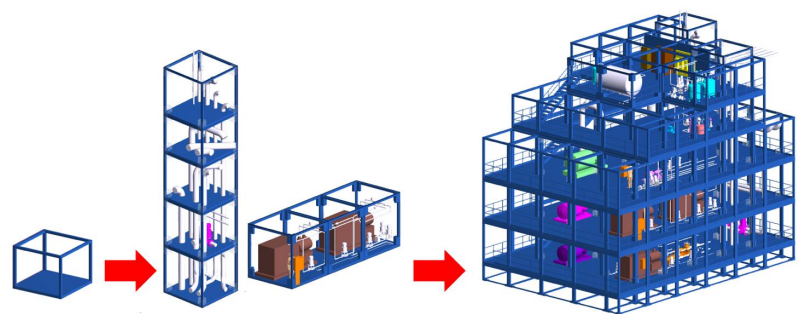
* Analysis of the plant motions during a seismic event will be more complex, including for SSCs where acceleration may be reduced but displacements increased, or where impacts may occur. Any credit taken for the seismic isolation system on the design of SSCs will require substantiation as the design matures.
* SSCs which span across seismic isolated and non-isolated areas of the plant will require justification. Whilst the overall claim made by the RP is that safety systems needed in the event of a seismic event are located entirely within the isolated portions of the plant, the impact needs demonstrating.
* The retaining wall which surrounds the reactor island will act as a ‘stop’ to prevent excessive horizontal displacement. In a beyond design basis event, the impact of the forces generated on the retaining wall will need further consideration, in addition to a demonstration that there will be no such impacts on the ‘stop’ under design basis conditions.
* The current assumption is that the isolation system is protected from relevant internal and external hazards. A number of design features are under development to facilitate this. The case to substantiate the protection and impact of hazards on this system has yet to be provided.

**Hazard shield**

1. The hazard shield sits atop the basemat which is supported by the aseismic bearings and is formed from reinforced concrete walls and slabs. Internal reinforced concrete walls provide lateral stability as well as segregation between the various blocks. The construction methodology proposes to make use of in-situ concrete walls between pre-cast (modular) units (e.g. corners), but is otherwise fairly standard for this type of structure.
2. The hazard shield covers the containment internal structures, interspace, fuelling block, and all class 1 SSCs needed for safety functions are protected (indicated by the red walls in Figure 2). The bounding case for the hazard shield is based on an aircraft impact. The RP’s proposed aircraft impact assessment methodology and philosophy was assessed during Step 2 and we found it to be consistent with UK expectations, albeit there are some shortfalls in the completeness of the information provided to date which will need to be resolved.
3. There are various openings in the hazard shield for personnel, piping and other plant access (e.g. fuel handling). The RP is developing the design solutions to ensure these are suitably protected. The approach, principles and options under consideration are considered reasonable and provide confidence that an adequate demonstration can be provided.
4. EIMT activities for the hazard shield itself have yet to be fully defined, but Rolls-Royce SMR Limited are committed to further work to develop these. Decisions still need to be made by the RP regarding the capability to remove very large equipment (such as steam generators), but the current assumption in the generic case is that this will need to be taken through the hazard shield roof. Creating such an opening, and the subsequent reinstatement of the roof, would be a significant undertaking. We will be seeking further justification for the approach the RP intends for these rare but potentially foreseeable activities over the lifetime of a fleet of Roll-Royce SMRs, covering impacts wider than to the hazard shield, to ensure risks are reduced to ALARP.

**Modularisation**

1. One of the RP’s main drivers in development of the Rolls-Royce SMR design is to provide build certainty, providing confidence in the build schedule and costs. The adoption of modularisation is a key enabler for this. Modularisation allows the RP to make use of volume manufacturing processes as opposed to site build which is more conventionally used for such large infrastructure. The RP’s intention is that components and systems will be manufactured in dedicated factories, before being transported to site and assembled, within sizing limits imposed by road transport. While commercial, transport and construction considerations are largely outside the assessment for the GDA, the implications on the generic design are not.
2. Modularisation as a concept is applied throughout the design and the RP aims to maximise its adoption. This results in four methods; the Modular Kit of Parts (MKoP), a corresponding civil kit of parts, original equipment modules, and bespoke modules. The MKoP is the most novel, widespread and E3S significant aspect, with the others less important, or considered normal business for our assessments (noting that the civil aspects of modularisation are inherent in the civil design). For Step 2 we have therefore concentrated on the overall approach to modularisation, including development of the E3S case, and the MKoP.
3. The MKoP is used mainly within the Reactor Island to house the Mechanical, Electrical and Plumbing (MEP) systems and consists of structural frames, and barriers and fittings for those frames. The frames tesselate on a standard grid to form larger clusters. Clusters are combined to form the various blocks within the reactor island. Such assemblies are illustrated in Figure 10. The blocks are surrounded by concrete walls (as illustrated in Figure 2), and anchored to the base. The RP’s intention is to use standardised designs for the frames, barriers and fittings (wherever possible) which will be designed to meet bounding requirements.



**Figure 10: Assembly of Modular Kit of Parts (MKoP) frames to clusters and blocks** (ref. [57])

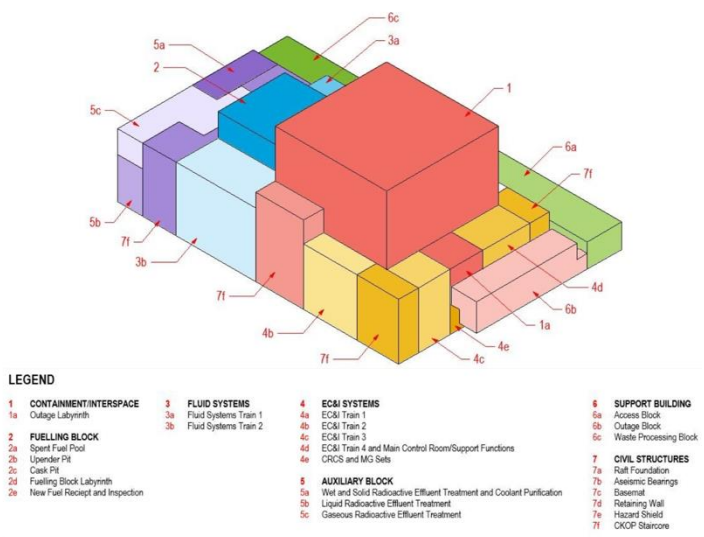
1. During Step 2 the RP developed its approach and documentation regarding modularisation, and the MKoP in particular, to include strategy and engineering documents. This has provided much improved clarity of the intentions, as well as the methodologies used both in the design and in producing the E3S justifications. Given the close interactions with layout, the RP has enhanced its working practices and organisation and there is now much closer integration between these two areas of design. We are therefore encouraged by the significant progress made by the RP during Step 2.
2. We do expect modularisation to continue to be an area of focus for the RP and us into step 3. Based on our assessment to date we consider:

* The degree to which the RP is applying modularisation, and the specifics of its application, are novel, not the concept in itself. Modularisation has been applied for many years outside the nuclear industry and at varying levels within the nuclear industry. A wealth of relevant Operational Experience (OPEX) exists for the RP to draw upon.
* The ambitious application of modularisation proposed by the RP will likely create challenges. Largely we would expect these to be similar to those seen in other new build projects. We are therefore content that these are normal business as part of design development and are confident that the RP should be able to resolve these satisfactorily.
* There remains a large amount of substantiation work to underpin the use of the MKoP. This includes matters relating to structural performance, seismic withstand, hazard barrier justification, management of interfaces and connections, and EIMT. Given this is integral to many areas of the E3S case the RP will need to ensure it has appropriate control and oversight, and close working practices embedded. The RP recognises this, has plans in place to do so and has provided reassurances that this can be achieved.
* Improvements will be necessary to the E3S case for modularisation, to justify the relevant impacts, and to focus on the E3S implications including the overall justification and ALARP demonstration. We have seen progress on this during Step 2, and we have confidence this will continue.

1. Overall, based on our assessment to date, we judge that the RP should be able to demonstrate that modularisation of the generic design will be compatible with maintaining adequate safety, security and safeguards. The RP has also highlighted a number of potential benefits in its approach from an E3S case perspective which, if they can be substantiated, would provide strong justifications for the adoption of modularisation.

**Layout**

1. The generic Rolls-Royce SMR design is intended to have a smaller physical footprint than is typical for a large scale NPP. The use of modularisation, in particular adoption of the MKoP frames to form the various blocks, directly impacts on plant layout. Combined with maturing the design, during Step 2 the RP has worked to develop and justify its plant layout. As such, our assessments have sought to understand how the layout has been informed by the various requirements that are placed upon it, across each of the E3S purposes. Our consideration spans from the site level layout, through to where individual SSCs may be located. Our main focus has been on the RP’s approach and potential hazards which may affect radiological safety, compliance with life fire safety and security requirements.
2. The RP’s design process for layout employs a decision hierarchy, with work focused on the most significant aspects first, starting at the site-level. This is a sensible approach for a developing design. It does mean that, for Step 2, the information presented is most mature at the site and reactor island level, but less so at the SSC level. The RP has clear plans to continue this development during step 3 of the GDA.
3. The RP submitted a suite of reports, aligned to the DRP, to provide detailed layout information for the reactor island. These also describe the layout design process including the decision making and governance processes. These provide evidence of a holistic approach to develop the layout and the rationale for design decisions. We are satisfied that this demonstrates clear logic, and considers relevant factors across all purposes. More work will be needed to fully develop these submissions as an integral part of the E3S case.
4. During Step 2 the layout of the reactor island was updated to optimise the arrangement of key systems and improve the resilience to hazards. This is shown in Figure 11. The main changes are to explicitly segregate the different blocks and safety trains, considering operational factors. The civil walls and structures are used as the principle barriers. We consider this represents an improvement on the previous iteration submitted at the start of GDA, and demonstrates the validity of the RP’s design processes.



**Figure 11: Reactor Island pictorial view** (ref. [58])

1. The RP’s standards and methodologies that describe how the layout will be assessed for the various purposes present an adequate basis for the development of the design and E3S case. We are also content that the strategies for minimising hazards and providing protection against them are credible, although substantiation evidence will need to be provided to support the claims made in the E3S case. Some of the analysis that has been submitted in Step 2 was based on an earlier version of the layout and, while this will need to be reviewed and updated, we are content that it provides confidence that the layout is suitably informed by consideration of nuclear safety, security and safeguards.
2. To date, limited evidence has been submitted to substantiate the layout of other buildings and areas of the Rolls-Royce SMR design. Based on the confidence gained through our assessment of the reactor island we are content that the RP can develop an E3S case for these other areas.

### Approach to defence in depth

1. International consensus is that the appropriate strategy for achieving the overall safety objective is through the application of DiD. The design should provide a series of independent barriers (inherent features, equipment and procedures) aimed at preventing faults in the first instance, and ensuring appropriate protection or mitigation of accidents in the event that prevention fails. During Step 2, we have considered both the RP’s approach to DiD and its application within the design.
2. The E3S case sets out how the RP has implemented DiD through the provision of independent systems for normal and accident conditions. The generic Rolls-Royce SMR is designed to achieve DiD against postulated initiating events (PIEs) through the provision of consecutive and practicable independent measures over five DiD levels, which would have to fail before harmful effects could be caused to people or to the environment. This approach meets with our, and international, expectations.
3. Our assessment of safety during normal operations, covering DiD levels 1 & 2, has included the full range of our engineering and operational topics. DiD levels 3 and 4, relating to the response to fault conditions has been the focus of our safety analysis topics, with engineering support. Level 5, related to off-site emergency actions, is out of scope of GDA as it the arrangements will be site specific and a matter for a future licensee and local authority. A summary of the RP’s approach is given in this section.
4. The RP has chosen to adopt an approach with is consistent with traditional UK approaches to safety cases, with frequent and infrequent faults being identified and a minimum of two or one safety measures provided respectively. For frequent faults these measures are claimed to be practicably independent and diverse.
5. We are content that the RP has defined an appropriate set of plant states which are the basis for the analysis of normal operations and fault conditions. The RP use the terminology Design Basis Conditions (DBC), and Design Extension Conditions (DEC) to categorise these plants states. The RP’s definition of DBCs is closely aligned with UK approaches to design basis. DEC-A includes beyond design basis accidents without core melt, and DEC-B covers severe accident conditions. The RP has also defined key requirements on SSCs and operators to deliver the safety functions during these plant conditions, but further work is required to ensure that these requirements are complete.
6. The RP has not submitted a complete set of safety analysis in Step 2, instead it has prioritised analysis of the most significant reactor DBCs (at power) and DEC-Bs, and the relevant safety measures to demonstrate their effectiveness (see Section 4.4.5). Analysis of DEC-As and DBCs arising in other operational modes and areas of the plant, including the fuel route and turbine island are yet to be provided. Whilst this has been sufficient for our assessment during Step 2, future submissions proposed for Step 3 will need to provide a more complete set of analysis.
7. The RP acknowledge the expectation to demonstrate practical elimination of a large or early release in fault conditions, but this has yet to be provided. Our expectation is that this should be based on both probabilistic and deterministic arguments and also considers the lower levels of DiD that contribute to preventing severe accidents or challenges to containment. Based on our assessment in Step 2 we have not identified any reason that a demonstration of practical elimination cannot be made for the design.
8. Overall, we are satisfied with the approach to DiD based on the submissions to date. This meets requirement [2.8] from Guidance to Requesting Parties (ref. [1]).

### Duty systems

1. Our assessment sampled a range of duty systems that support operation of the reactor during normal operations. Key aspects are summarised below, given their significance and based on learning from previous GDA assessments.

**Electrical power**

1. Electrical power is required for the reactor and spent fuel storage, during both normal operations and fault conditions. As the Rolls-Royce SMR design utilises passive means for some nuclear safety functions, the requirements for electrical power are different to those typical of a PWR. The design includes both Alternating Current (AC) and Direct Current (DC) sub-systems which are claimed to provide:

* independent electrical systems to support safety functions at multiple levels of DiD;
* power to ensure that during a LOOP event, the reactor can be shutdown and the facilities safely cooled; and
* redundant class 1 electrical systems, which are physically separated and independent, to meet the expectations of the single failure criterion.

1. We are satisfied that the proposed architecture of the electrical systems, with redundant divisions fed by multiple offsite and onsite power sources, should provide the basis of a design capable of meeting international guidance and ONR’s expectations for redundancy and DiD. We have also noted the potential benefit that using DC power supported passive safety measures could reduce the reliance on standby AC onsite power sources.
2. Further evidence will need to be generated by the RP to fully substantiate this design, including in relation to autonomy times for onsite power during a loss of offsite power event and cooling provisions provided by the Heating, Ventilation and Air Conditioning (HVAC) system. We are content that the RP can do this if it progresses to Step 3.

**Control and Instrumentation**

1. The C&I for the Rolls-Royce SMR comprises a number of control and monitoring systems for normal operations and a Reactor Protection System (RPS), Diverse Protection System (DPS) and an accident managements system. These are independent systems with the capability to detect and respond to reactor fault conditions.
2. We are content that the RP has used relevant codes and standards in developing its design. We are also satisfied that the RP has identified an appropriate set of reactor C&I safety systems based on the current design information, with system integrity targets consistent with their classes. We do note that the reliability claims made on software based class 2 systems are at the upper end of what may be substantiated by compliance with the normally applied standards and may will require additional substantiation. We are satisfied that the use of a hardwired class 1 DPS should provide an effective means of achieving independence from the class 2 RPS for DiD.
3. The RP has explained how it intends to demonstrate the effectiveness of the C&I systems to deliver their safety functions. These plans are incomplete but show good awareness of RGP and present a credible initial framework. We expect this will be much of the RP’s focus during Step 3.
4. Supporting system (namely electrical power supplies and HVAC) requirements and high-level architecture are adequate given the current design maturity. Substantiation of these requirements has yet to be submitted.
5. We are content that the RP has demonstrated that its approach to identification, assessment and mitigation of cyber risks to the design is consistent with RGP. We assessed the methodology, an analysis of a selected area of the design and an overall summary report. The RP’s methodology is informed by the principles of SbD, the identified threat and is capable of demonstrating security outcomes via application of a graded approach. Whilst analysis of the design to date is limited, our sample has provided confidence in the underlying approach and the RP has committed to widen the application and to use continual improvement. We are content the RP has integrated this within its design development arrangements and this presents the opportunity to build resilience into the developing design. This meets requirement [2.10] from Guidance to Requesting Parties (ref. [1]).

**Heating, Ventilation and Air Conditioning**

1. The HVAC systems ensure air is circulated for personnel, radiological control or cooling purposes. The HVAC systems are still under development, and were one of the aspects to mature later in Step 2. Our assessment therefore focused on understanding the RP’s intent and philosophy for its HVAC system designs.
2. The generic design includes various HVAC sub-systems that serve different areas of the reactor island. The design features, requirements and functions the RP has associated with the HVAC systems are typical for NPPs, although given the passive nature of other elements of the design the reliance and claims made on HVAC are expected to be lesser. A fault schedule is yet to be prepared covering the HVAC systems. However, based on the information submitted to date there are two features of the design which appear novel, and are also likely to be some of the most safety significant:

* To improve resilience and minimise the impact of support system faults the design includes a number of local cooling units. These are supported by ice stores and DC pumps, and remove heat from safety related C&I and electrical systems and the control rooms. This technology is not new, but we have not seen it used in this context. We welcome the intent behind this approach and will consider the implications further as the design matures.
* The design includes an emergency habitability system for the main control room designed to enable sealing of the room for 3 days. This includes two trains of carbon dioxide scrubbers and compressed air supplies. We expect that this approach will need substantiation.

1. Overall, we consider the intent and philosophy behind the HVAC design to be reasonable. The likely duties on the HVAC systems are consistent with other designs, noting some novelty in the Rolls-Royce SMR design, and we have confidence that the RP understands what is needed to produce a suitable design and E3S case.

### Safety measures

1. As described in Section 2.4.3, the generic Rolls-Royce SMR design has a number of safety measures and a fault schedule has been submitted which links faults, fault sequences and safety measures. This schedule is not yet complete, reflecting the maturity of the design and E3S case, but demonstrates the approach and intent. While the list of PIEs is relatively mature, the claimed safety measures are incomplete, notably for Spent Fuel Pool (SFP), refuelling and fuel handling faults. The RP recognises the further work necessary to develop the complete fault schedule.
2. Generally, based on our assessment, we are content that the RP has appropriate approaches to support its claims on the effectiveness of the principal safety measures. Of specific note are the following aspects.

**Passive safety**

1. The Rolls-Royce SMR design utilises a number of passive safety measures to deliver safety functions in fault conditions. During Step 2, we have sought to understand the safety claims on these systems and to gain confidence in their performance and substantiation.
2. The principal and significant means of controlling fuel temperature in faults are both passive. The RP makes claims on passive heat removal in both intact circuit faults and during Loss of Coolant Accidents (LOCAs), something which is relatively novel. The ECCS and PDHR systems provide decay heat removal in response to fault conditions, each with internal redundancy, and with no claimed reliance on essential services supplied from on-site mobile equipment for 3 days or from off-site for 7 days. These rely on battery-backed DC systems for the first 3 days. Two trains of back-up AC power are provided for the class 2 and 3 active systems.
3. During Step 2 we have established that, while the PDHR system can deliver its safety functions after initiation without active elements for some fault conditions, in other fault conditions the active HPIS (and associated supporting systems) is required to maintain primary circuit pressure. We will therefore seek evidence in Step 3 that these active components are able to deliver their safety functions in all relevant fault conditions.
4. We have assessed the safety analysis submitted by the RP and we are content that this shows margin to safety criteria in faults where ECCS and PDHR are claimed. Furthermore, the PDHR system is also shown to be effective in the Station Blackout (SBO) sequence. Whilst our view is based on a preliminary set of prioritised reactor faults, this provides confidence that a demonstration of effectiveness for all faults could be made in the future.
5. In the unlikely event that the design basis safety measures fail to prevent the core exceeding its design limits, the Rolls-Royce SMR includes several severe accident safety features. During Step 2 we have examined the E3S case supporting the design of the IVR strategy, hydrogen removal, severe accident depressurisation and containment heat removal. The RP has performed deterministic analysis to determine whether its proposed severe accident management strategies will be effective, with sensitivity analyses to accommodates the uncertainties that exist in the design. Whilst more refined analysis will be required during Step 3, the RP’s work to date provides us with confidence in the approach to analysing severe accident sequences and the demonstration of the effectiveness of the severe accident safety features.
6. The RP has documented a validation strategy for the computer codes it will use for its safety analysis. The strategy involves maximising the use of existing publicly available test data for validation evidence, supplemented by specific data obtained from new, bespoke test rigs. We are satisfied that, whilst a significant amount of additional work is required by the RP in Step 3 (and beyond) to validate its codes and methods, the information submitted to date is consistent with UK and international RGP and provides confidence in the approach adopted.

**Redundancy**

1. The RP has chosen to the follow the established UK approach to design basis analysis of demonstrating through conservative analysis that there are effective diverse safety measures for frequent faults, including penalising assumptions regarding failures, operating conditions and EIMT to all fault sequences with a frequency cut off of 1 x10-7 pa.
2. We are content that the RP has established a set of principles which outline the intent to design the safety measures to meet these expectations. The RP has also set general design basis assumptions for the plant performance analysis for common cause failures, consequential failures, loss of offsite power, preventative maintenance and single failure.
3. The principal safety measures of the generic Rolls-Royce SMR design, and the essential support services that enable these to operate (i.e., all class 1 SSCs), incorporate three-fold redundancy. We are content that, as the RP has stated that class 1 safety measures will not undergo online maintenance while the reactor is at power, these provide sufficient redundancy to meet the RP’s own design basis rules. Further work is required by the RP to demonstrate that these design basis rules are also met for all class 2 systems as these may also require controls over when systems are released for maintenance, noting that EIMT activities are yet to be developed.
4. Active class 2 safety measures, such as the CSCS and FPCS are the primary means of protection during some shutdown modes of operation. We have identified an area where the RP may not be able to demonstrate compliance with its own design basis rules for any systems which incorporate two-fold redundancy (e.g. emergency diesel generators and switchboards); the RP will need to demonstrate that there is sufficient protection against any initiating faults which affects one train while the other is unavailable due to maintenance.

**Containment**

1. The Rolls-Royce SMR design includes a separate steel containment vessel. Based upon our assessment we note that:

* The containment vessel design is based on an established nuclear code, which at a high level, meets ONR expectations. The detailed substantiation of structural integrity controls requires further consideration including the use of code cases.
* The RP have performed analysis to demonstrate that the containment vessel is sized to withstand the potential energy that may be released in fault conditions. We are satisfied that this analysis is adequate, although evidence will need to be submitted to demonstrate that bounding conditions have been analysed. The size is also limited by structural integrity considerations and the desire to avoid additional weld treatments. However, limiting the size of the containment has implications on other aspects of the design (such as handling equipment), conducting routine EIMT activities and the consequences of potential internal hazards. Further evidence will be needed to demonstrate the optimisation of these considerations in the design.
* The containment vessel is supported using a concrete support plinth. Details of how this will be attached to the containment is under development, but the approach is reasonable.
* The accumulators which form part of the ECCS are located outside of the containment vessel. This has the benefit of removing a potentially significant hazard source from inside containment but requires additional penetrations through the vessel.
* The RP has chosen not to include a means to filter any containment leakage. This is argued on the basis that the steel vessel will have lower levels of leakage (compared to larger, steel lined concrete containments). This may have implications for the RP’s analysis of radiological consequences and the PSA, and we will follow up these implications in Step 3.
* It is important that the containment is completely isolated for the passive ECCS to function effectively and efficiently. Further evidence will be needed to show this can be achieved, and the safety impact if not.

1. Whilst further work is needed, based on our assessment during Step 2 we are satisfied that a suitable case could be made for the containment design.

**Mitigation of releases**

1. A suitable strategy has been developed by the RP through which it will seek to demonstrate that the effects of chemistry during fault conditions are understood and that releases are minimised. In general the phenomena and behaviour expected for the Rolls-Royce SMR design will be consistent with existing PWR plants.
2. Despite these similarities, we have noted that the design does not include a means for controlling the pH of the sump during relevant fault conditions. Other designs include this control to directly minimise the amount of volatile iodine released. We consider this to be RGP, and have not been provided with an adequate justification for why this does not apply to the generic Rolls-Royce SMR design. Evidence will be needed to support this design choice.

### Operational matters

**Examination, Inspection, Maintenance and Testing**

1. Effective EIMT ensures that the claimed reliability of SSCs is maintained in line with requirements defined in the E3S case. During Step 2 we have sought to understand how the RP is developing the EIMT requirements for the generic Rolls-Royce SMR. The RP submitted its documented strategy for development of EIMT activities which defines the derivation, documentation and E3S coordination of EIMT, including how this informs and is itself informed by the design. We consider this strategy comprehensive, and consistent with our general expectations.
2. This strategy has only been applied to a limited extent during Step 2, given the evolving design maturity, and the RP acknowledges that further work is needed to define the periodicity and nature of EIMT required. Our assessment sampled some aspects of EIMT within the design and from these we have identified some area of additional focus for our assessment in Step 3:

* Redundancy for EIMT in safety systems, as detailed earlier (para. 179);
* The use of online maintenance activities;
* The impact of the MKoP and layout on EIMT activities; and
* Personnel safety and radiation exposure during EIMT activities.

1. We are content that Rolls-Royce SMR Limited have demonstrated an understanding of the requirements for EIMT, and have plans to develop these aspects of the E3S case further as the design matures.

**Operating Rules**

1. At this time, the operating rules, which will define the safe operating envelope for the plant consistent with the E3S case, are still in development. During our assessment we noted examples of developing operating rules in the E3S case, which appeared reasonable albeit they are often not declared as such, nor fully traceable. The approach, intentions and scope described by the RP for defining these is high-level, but does recognise the main aspects necessary. We are satisfied that operating rules can be developed as the design matures.

**Boron-free operating chemistry**

1. Rolls-Royce SMR Limited have chosen to design the plant to operate without soluble boron in the primary coolant. This is claimed to allow for a simplified design with a reduction in human error induced faults, and eliminates risks associated with boric acid, boron dilution faults, and the environmental impact of boron discharge. The RP has also chosen to use potassium hydroxide (KOH) as the alkalising agent (rather than lithium hydroxide (LiOH) that is used in other PWRs) which is claimed to offer benefits such as reducing primary circuit and fuel cladding corrosion and minimising the production of tritium. Whilst each of these changes has individually been implemented in civil PWRs worldwide, the combination of the two has not.
2. The chemistry implications of adopting this operating regime feature prominently in the E3S case submitted during Step 2, and the RP has clearly devoted considerable efforts to determining the adequacy of this approach. The RP claims that, as a minimum, equivalence to the common soluble boron and LiOH regime can be demonstrated and that there are no significant detriments from this choice. Most of the arguments presented are based on OPEX or extrapolations from experimental data, and appear supportive of the intent. The RP has recognised there are weaknesses in this approach, and key aspects of the full substantiation will be reliant on the results of a laboratory test programme which the RP has stated will be available during Step 3. Based on the case presented to date we are confident that the RP is progressing this matter satisfactorily and we will assess the evidence as it become available.
3. The implications of this chemistry choice also needs to take into account other modes of operation. In PWRs, when the reactor is shutdown the chemistry regime is used for removing fuel deposit that have built up during operations, trapping these within filters and ion exchange media. This involves a controlled change in the coolant chemistry, which would not be possible for the Rolls-Royce SMR. The assumption in the E3S case is that an alternative (as yet undefined) approach would be used.
4. If deposits are still present on the fuel this may lead to the need to clean the fuel during its removal for refuelling and provisions have been made in the SFP design for ultrasonic cleaning equipment to be deployed. To date, no details have been provided on the extent of fuel deposits expected, the efficacy of any shutdown chemistry approach to remove them, nor the need, frequency or safety performance of any fuel cleaning required. The management of corrosion and deposit within the primary circuit and in particular on the fuel pin heat transfer surfaces will require further work by the RP to justify safety, including consequential effects such as the treatment of any waste produced.

**Reactivity control**

1. Due to the choice of a boron-free coolant the full reactor shutdown margin is provided by Control Rods (CR) alone. There are 89 Rod Cluster Control Assemblies (RCCA) made up of a mixture of boron carbide, silver-indium-cadmium and stainless-steel CRs. This is more than would be necessary if soluble boron was used, but the RP has worked to optimise the number of CRs and the core design.
2. The CRs are operated in banks to manage through life reactivity control and core depletion. This approach has been informed by boiling water reactors which also operate boron-free. The impacts on power peaking has been considered by the RP in Step 2 by demonstrating compliance with fuel performance design criteria and by showing that relevant criteria, such as avoiding film boiling on the fuel surfaces, have been met. This does demonstrate adequate performance. However, the full analysis will need to be performed to understand the extent of available margin and the cores sensitivity to power peaking.
3. For planned shutdowns and for scram, analysis presented by the RP showed adequate shutdown margin, including with one-stuck rod, demonstrating single failure tolerance. This also provides a demonstration of hold down. A full suite of performance assessment for all faults for scram and ASF will need to be performed by the RP, which it has committed to complete during Step 3. This includes a demonstration that insertion of CRs will not be impeded in operational states and in accident conditions, other than severe accidents.
4. The number of CRs means that there is a corresponding increase in CRDMs and their penetrations through the RPV head. The RPV head is a very high integrity component. The CRDMs are of similar design and pedigree to existing PWRs. We expect evidence of the EIMT of the penetrations and CRDMs to be provided during Step 3.

**Minimisation and management of radioactivity, operator doses and waste**

1. Radioactivity is an inevitable byproduct of operating any nuclear reactor and we would expect this to be minimised to ALARP and appropriately managed. This would also have benefits to downstream impacts such as operator doses, production of radwaste and decommissioning. During Step 2 we have assessed the RP’s case for these aspects, including the generation, behaviour and management of radioactivity. Of note from our assessment are:

* The RP has developed estimates of the expected amounts of radioactivity that will be generated and distributed throughout the plant for use within the E3S case. This will be refined using relevant plant OPEX and expanded to cover all SSCs during Step 3 including modifying to account for the specifics of the Rolls-Royce SMR design. We consider that this strategy is in line with RGP.
* Whilst appropriate chemistry controls have been identified to minimise the generation and transport of radioactivity in the primary circuit, further evidence is required in Step 3 to support the proposed operating ranges for the design.
* Stellite or other high cobalt hard-facing materials are employed within the design. The RP recognises that these materials can be a significant radioactivity source, and has restricted their use, but has not yet provided a convincing argument for their continued use in some components.
* As described in Section 4.4.7., the RP’s estimated doses to operators have been shown to meet the SAPs Target 1 Basic Safety Level (BSL). Whilst only estimates at this stage, we consider this analysis is likely to be conservative, and expect it will reduce as the design and analysis matures. Other improvements to minimise and manage radioactivity, which the RP has committed to, will also be beneficial.
* The RP has documented an appropriate Integrated Waste Strategy (IWS), based on the extant design, with OPEX used to derive waste estimates. This includes due considerations of minimising the generation and accumulation of waste at a strategic level. Further work is necessary to fully substantiate that the approach in the IWS is achievable. The overall approach to waste management is consistent with regulatory expectations, and includes matters such as interim storage, waste processing, decay storage and management of damaged fuel and non-fuel core components.

1. Overall, we believe that the RP should be able to present an adequate case for minimisation and management of radioactivity for the generic Rolls-Royce SMR design.

**Decommissioning**

1. For Step 2 our focus has been on establishing whether the RP has given suitable consideration to decommissioning in the design, recognising that implementation will not be necessary for many decades.
2. The RP has started to develop a number of the key documents which would provide the basis for a decommissioning case. These include a strategy and optioneering reports which describe its intended approach, and a waste management plan. The overall approach is based upon “immediate” decommissioning and is therefore consistent with UK policy and regulatory expectations. Whilst it is clear that these documents give suitable emphasis to safety, they are immature and remain high-level, and do not yet have well developed links to other aspects of the E3S case, such as the IWS.
3. It is claimed that the Rolls-Royce SMR design is being developed with a “design for decommissioning” approach, to ensure that the eventual decommissioning needs and activities are considered during the design stage. This intent is positive. There is clear evidence of this as part of the RP’s design and engineering processes, however there is little evidence to date of this manifesting itself in the actual design. This includes within the modularisation of the design. We are expecting this will become clearer as the design matures.
4. Based on the information to date, our view is that the approach and intent adopted by the RP does appear to be consistent with UK and international guidance. Based on our own understanding of the design, the majority of the plant is comparable to existing PWRs and we are not expecting significant challenges for decommissioning, noting some areas of novelty where further consideration is needed by the RP. We expect a proportionate decommissioning case to be further developed in Step 3 as the design matures, which we have confidence the RP can achieve.

**Fuel Management**

1. The overall approach to fuel management for the generic Rolls-Royce SMR design is consistent with UK and international PWR designs. New fuel is imported into the facility before being transferred to the reactor. Used fuel removed from the reactor is subject to short-term pool cooling (up to 10 years) followed by long-term dry storage of spent fuel pending transport to a geological disposal facility.
2. Detailed design of the layout and design of the buildings and systems which support the management of fuel during its lifecycle is ongoing and has not been submitted in Step 2. While the RP has submitted some initial identification and assessment of hazards and faults, a full safety analysis of fuel handling and storage has not been produced. Our focus has therefore been to gain confidence in the design of the major SSCs related to fuel management, the sizing of the SFP and the arrangements for criticality control.
3. A number of SSCs are involved in fuel handling including the main overhead crane, a separate in-containment fuel handling machine, a transfer tunnel and a fuel handling machine for the SFP. The design and requirements for each of these are not yet fully defined. The RP’s aim is to design the fuel route to minimise the number of significant lifts of nuclear fuel, which we consider a desirable objective. This reduces the risk of dropped load faults but may introduce additional faults from the operation of the gates and other features which separate the various pools and pits. A comprehensive analysis of all potential faults will be needed to demonstrate that the fuel is adequately protected. We are content that the RP has plans to do so and to use this to inform the design.
4. During shutdown and refuelling modes, duty heat removal for the reactor is provided by the CSCS and duty heat removal to the SFP is provided by the FPCS. Both of these systems are class 2, and each comprise of two 100% cooling trains. The CSCS and FPCS can be cross-connected which provides redundancy to perform EIMT. Note however that this still needs to be demonstrated for supporting electrical equipment (as para. 179). The RP has indicated that the class 1 protection will be provided by evaporative cooling in both the SFP and reactor during shutdown modes. Limited information on this function has been provided in Step 2, and no supporting analysis. Nevertheless, we are content that, in principle, the fuel route provides sufficient DiD and redundancy in its heat removal systems.
5. There are 520 storage positions within the SFP which the RP considers offers the best combination of cooling time (10 years), footprint, contingency spaces, and compliance with expected safety criteria. Storage positions are provided for new, spent and partially-spent fuel, and other components. Sufficient spare capacity is provided to perform a full core off-load at any time. There is no specific allowance for CRs as these will be housed in their respective fuel assemblies. We agree that future capacity shortfalls are unlikely.
6. Criticality control within the SFP is provided by fixed neutron absorber panels attached to the storage racks (with no dissolved boron present in the pool water). No credit is taken for burn-up, neutron absorbers or CRs within the assembly. Although a limited amount of out of core criticality analysis has been carried out by the RP to date, the analyses show that the rack spacing meets the RP’s own criticality criteria and remains sub-critical when filled with fuel. Fault analysis has not yet been undertaken, but will need to consider the impact of dropping a fuel assembly or misloading. We are satisfied this can be undertaken as the design matures, and the RP has a comprehensive forward work plan to do so. Further substantiation is also required justify the use of fixed neutron absorber panels rather than geometrical constraints alone, to demonstrate that this reduces risks to ALARP.

### Risk reduction

**Demonstration of ALARP**

1. The fundamental duty in GB health and safety legislation is for the dutyholder to demonstrate that risks have been reduced to ALARP. This is also part of the RP’s fundamental objective for its design. Our assessment focus for ALARP in Step 2 has been on the approach adopted, application in the design to date and the rationale for key design decisions that have already been made. This meets requirement [2.3] from Guidance to Requesting Parties (ref. [1]).
2. The ALARP Summary Report (ref. [59]) documents the RP’s approach, summarises optioneering decisions to date and how these are E3S informed. This report is thorough and addresses the main features we would expect for an ALARP demonstration. The described methodology is based on the RP’s optioneering and decision making processes, which form part of its IMS. We consider these processes to be suitable to guide the RP’s ALARP decision making. These cover both new and ongoing design work and include the requirement to consider options (or collection of options) to identify what is reasonably practicable, that give the best safety benefit, and make this consideration transparent. We are content that the RP’s methodology gives it the opportunity to demonstrate why its decisions represent the ALARP option.
3. Importantly the RP recognises that ALARP is not a discrete piece of work and it needs to be applied throughout the design and embedded throughout the E3S case. As a UK based organisation the RP is already familiar with the ALARP principle, and it is demonstrably a key factor in its design approach. Our assessment also showed that in the engineering disciplines, appropriate design codes and standards, which represent RGP, are being followed in the design. Similarly the RP is following established methods and techniques for analysis that represent RGP. These factors strengthen the RP’s ALARP arguments.
4. The RP had already taken key and fundamental design choices before entering GDA. The ALARP summary report provides a narrative and justification for how significant design choices were made, what factors were taken into consideration, and how the final position is consistent with the ALARP principle. We have not considered the outcome of these decisions yet, but they clearly demonstrate the successful application of the RP’s ALARP process to the design.
5. The report concludes that the generic design is capable of reducing risks to ALARP, but that the RP needs to complete further work to demonstrate this. Based on evidence to date, we agree with this conclusion. The RP commits to update it alongside the design and E3S case, with the intention that it will ultimately summarise the full demonstration that risks are indeed reduced to ALARP.
6. Collectively our assessments have given us confidence in the RP’s approach. We have not yet attempted to come to a view on whether the overall generic design reduces risks to ALARP. However, we are satisfied that the RP’s approach will allow it to present evidence in the E3S case that will allow us to make this judgement during GDA.

### **ONR numerical targets**

1. The RP has established, as part of the design principles (ref. [31]), a number of numerical targets which are used within the E3S case to evaluate the tolerability of risks and inform design decisions. Dose or risk is evaluated against numerical targets which are based on the BSLs and BSOs in ONR SAPs Targets 1 to 9 (ref. [35]), and consistent with similar international targets. Our assessment considered whether these Targets are likely to be met for the generic Rolls-Royce SMR design.
2. ONR’s Targets 1 to 3 set limits for radiation doses to people on or off the site. The RP provided initial dose estimates and targets for comparison against its own numerical targets (which are identical to the SAPs). The underpinning for these estimates are based on an earlier design and layout than DRP1, and are informed by OPEX from operating facilities given detailed EIMT activities and occupancy models have not yet been defined. Whilst incomplete, these estimates give us confidence that the Rolls-Royce SMR design will meet the Target 1 to 3 BSLs and we are content that the RP intends to implement further design measures to reduce these doses towards the BSOs to demonstrate ALARP. Our assessment of the RP’s methodologies and approach to radiation protection and shielding give us confidence this can be achieved in the design.
3. ONR’s Target 4 is a numerical target for Design Basis Analysis (DBA) which represents criteria for assessing the safety of the facility’s design and operations for faults that could have significant consequences. We are content that the RP has integrated the expectations of this target into its design basis methods and will submit a comparison of radiological consequences from design basis faults against this target in Step 3. Based on our assessment of submissions to date and noting that the analysis submitted in Step 2 shows that there is no fuel damage for the reactor faults analysed, we are content that the RP should be able to demonstrate that this target is met for relevant reactor faults.
4. ONR’s Targets 5, 6, 7, 8 and 9 provide a framework to assess the risk from accidents, with the numerical estimation of risk generated through a PSA.
5. The RP has provided a level 1 PSA that considers initiating events at power for reactor based faults. The PSA reports a core damage frequency of slightly above 10-7 per year. However, this PSA does not include any faults for shutdown modes, the fuel route or SFP. There is no hazards modelling for internal or external hazards. There is no level 2 or level 3 PSA modelling. The PSA that was submitted was based on an earlier version of the design. Without these aspects the PSA is incomplete and both the RP’s ability to risk-inform the design and our ability to assess the design would be limited.
6. The RP always indicated its intention to develop, within GDA timescales, a full-scope modern-standards PSA that includes the missing aspects described above. This would meet our expectation that the PSA should cover all significant sources of radioactivity, all permitted operating states and all relevant initiating faults. However, our assessment considered that its strategy was inadequate to deliver this and Regulatory Observation RO-RRSMR-002 was raised (ref. [60]).
7. This RO detailed four Actions which required the RP to provide a revised strategy, relevant plan and procedures that will be used to develop the PSA, demonstrate the integration of this plan into the E3S case and show how the PSA is informing the design. The RP’s resolution plan (ref. [61]) commits to produce submissions to respond to these Actions. Most of these will be submitted to ONR after Step 2. However, an update to the PSA Development Strategy has been submitted in which the RP has clarified:

* The scope of the PSA and the work expected to be produced during Step 3;
* That they will consider fuel in the reactor and fuel route during GDA, with other radioactive sources considered post-GDA;
* The intention to eventually use the PSA as a risk monitor and to risk inform operations;
* The intention to use the PSA to support worker risk assessments, noting that additional methods still need to be produced; and
* The hazards PSA methodology, but more information is required to understand what will be produced during GDA which should be submitted early in Step 3.

1. We are confident through the updated development strategy that an adequate PSA can be produced during GDA. The initial calculation of CDF gives us confidence that ONR’s numerical targets 5 to 9 can be met by the Rolls-Royce SMR design but significant development of the PSA is required to confirm this.

### **Conventional health and safety risks**

1. Our focus during Step 2 has largely been on the RP’s approach to meeting the duties under the Construction (Design and Management) Regulations 2015 (CDM) (ref. [62]). The RP has an important role to ensure the design complies with GB legislative requirements, and can ultimately demonstrate conventional health and safety risks are reduced to ALARP.
2. During Step 2 the RP has worked to improve its arrangements to comply with the requirements of CDM, including processes and resources. The RP’s stated intention is to focus on hazard identification and elimination, before reducing and controlling risks ALARP in the detailed design. The intent underpinning this is reasonable and should allow the RP to much more holistically consider conventional risks as part of its design work going forwards. As these arrangements have been implemented later in Step 2, there remains work for the RP to do to demonstrate how the principles of prevention have been applied to foreseeable risks throughout the design to date. In addition to addressing these aspects, we expect to receive further evidence of the adequacy and implementation of these arrangements in the next step of GDA.

**Security risks**

1. The overall focus of our security assessment during Step 2 was on the RP’s concept for security and its overall approach to risk management together with methodologies for establishing the magnitude of risk within the design. This included SbD, Vital Area Identification and Categorisation (VAI&C), and cyber security (as described previously in Section 4.4.4). For each of these the RP provided its methodology, worked examples and a summary report.
2. SbD is a key expectation within the SyAPs (ref. [36]). The application of which ensures the integration and influence of security alongside safety as the design matures. In addition to enabling deconfliction, this approach provides a means by which security risks might be designed-out or mitigated early in the design so to meet security outcomes, achieve efficiency and cost effectiveness. Rolls-Royce SMR Limited has adopted a SbD “philosophy” within its core processes and has aligned this with the other engineering activities. Through its methodology and examples of its implementation during Step 2 the RP demonstrated a commitment to taking practical steps to include this thinking about security risk, and ultimately to influence the design. This approach represents good practice in a number of areas and we have confidence that, should this be implemented to the extent the RP expects, will have positive benefits on the security of the generic design.
3. We are satisfied that each of the key components of a VAI&C methodology are present, albeit the demonstration of this has been limited by design and E3S case maturity during Step 2. Similarly, the RP has used an alternative Design Basis Threat (DBT) definition. These aspects will need to be addressed as the VAI&C analysis is updated and completed. While the VAIs identified at this stage for the generic design will likely change given the above, we are confident that the use of the RP’s methodology should produce adequate outcomes.
4. These meet requirement [2.10] from Guidance to Requesting Parties (ref. [1]).
5. Late in Step 2 the RP also provided the first iteration of the Integrated Security Solution (ISS), which details the security outcomes expected for GDA and to evidence how the RP has used adequate risk assessments and SbD to influence the design. Importantly the ISS will form the basis for a future site-specific security plan, as required under the Nuclear Industries Security (Amendment) Regulations 2017 (NISR) (ref. [63]). Whilst the ISS will be an important element of future regulatory scrutiny, our assessment during Step 2 has provided confidence that this aspect is progressing as expected. This meets requirement [2.5] from Guidance to Requesting Parties (ref. [1]).

**Safeguarding of nuclear material**

1. The focus of our safeguards assessment was towards the RP demonstrating a sufficient understanding of UK and international safeguarding requirements, and confidence that the generic design facilitates meeting these.
2. From our assessment, we are content that the RP has demonstrated sufficient understanding of safeguarding of nuclear material commensurate with the current status of its design. It is also implementing a safeguards by design approach, consistent with our expectations. The RP has also engaged with the IAEA. This further demonstrates that it recognises the importance of safeguards by design and supports the development of safeguards measures as the design matures.
3. As the Rolls Royce SMR design is similar to other PWRs, we do not expect that there will be any significant challenges with the design from a safeguards perspective. The RP recognises that, the key aspects that make this design different are the size of the facility and the impact this may have on the size of the fuel and the fuel route. The RP has considered these factors as part of the design and this is evidenced in the documentation submitted. Further details will be required on the intended control system for nuclear materials and relevant design information as the design matures.

## Summary

1. The summary findings from our assessment of the generic design and E3S case are:

* The foundation of the Rolls-Royce SMR design is established PWR technology in which we have extensive regulatory experience. This underpinning technology has been supplemented with passive safety features, which simplify the design and minimise the claims on support systems. The RP is also designing to achieve UK (and international) expectations and is using tools, standards and approaches we have seen applied in similar circumstances. We consider this to be a sound basis on which to substantiate the design, which gives us confidence that an adequate justification can be produced by the RP.
* To date, the RP has focused its analysis work on those aspects it considers most significant or where greater confidence was needed to inform the design. This is a sensible approach given the maturing and iterative nature of the RP’s work to date, and was sufficient for us to form a view on the adequacy of the main claims and whether the design is likely to fulfil these. Based on the representative or bounding analyses presented to us in Step 2, which are typically conservative and show suitable margins, and the approach, methodologies, codes and standards used, we have confidence that the building blocks to further develop the case are suitable.
* Key SSC architecture, functions and requirements have been presented during Step 2. Detailed SSC design and requirements information continues to mature. We are satisfied that the design demonstrates application of important considerations to enable a safe and secure design, including matters such as inherent safety, fault tolerance, defence in depth and the hierarchy of controls, including consideration of matters such as common cause failure, segregation, redundancy and diversity. Future versions of the E3S case will need to provide the complete set of relevant design requirements and detailed supporting evidence to demonstrate that the design can deliver the credible claims made during Step 2.
* The approach to and examples of operational matters (such as operating rules and examination, inspection, maintenance and testing activities) were presented. We take confidence that the RP understands the importance and need to develop and justify these, and is actively considering these with plans to present those necessary to underpin the design during GDA.
* The preliminary radiological analysis for normal operations and faults gives confidence that ONR’s numerical targets are likely to be met. The RP has committed to document a comprehensive suite of analyses, based on the matured design, in a future version of the E3S case.
* We are satisfied that the RP’s approach to demonstrating safety risks are reduced to ALARP is adequate, and this is inherent in its thinking. Whether the generic design achieves this requirement can only be judged once a matured design and E3S case are available. We are satisfied the RP is working towards this.

1. We have not identified any RIs, which would represent a fundamental shortfall with the design, or any potential conflicts with relevant government policy. During our assessment we raised two ROs, where we identified potential shortfalls that required further work from the RP to resolve. These relate to development of the E3S case and the Probabilistic Safety Analysis. We are content that both of these ROs will be resolvable by the RP, and good progress has been made.
2. Overall, based on our assessment to date, and subject to the provision and assessment of suitable and sufficient supporting evidence, we have not identified any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the generic Rolls-Royce SMR design.
3. There remains a significant amount of work ahead for the RP to submit quality and timely documentation to achieve its stated objective of a DAC at the end of Step 3 of GDA. For our own assessment we have identified a number of areas of further regulatory scrutiny moving forwards. We have sufficient confidence that the RP has plans to address these.

# Readiness for Step 3

## Readiness reviews

### Rolls-Royce SMR Limited

1. In accordance with requirement [2.25] of Guidance to Requesting Parties (ref. [1]), Rolls-Royce SMR Limited undertook a self-assessment and review of its readiness to proceed to Step 3 of the GDA. The evidence presented to ONR to support the outcomes of this review is documented in the RP’s readiness review report (ref. [64]).
2. The readiness review report documents the outcomes from application of the RP’s hold point release process. This is the same process that was used for the readiness review for Step 2. The process involved documenting a series of criteria against which evidence was produced and judged by a panel comprising of key stakeholders within the RP’s organisation. Where gaps in readiness were identified, the significance of these was considered and mitigating actions developed. This process involved the head of regulatory affairs (responsible for delivery of GDA), engineering director (responsible for the design), head of quality, health and safety and environment (responsible for quality assurance) and the head of nuclear assurance, as an independent view. Evidence was produced by staff across all of the E3S purposes. We are content that this is an adequate process, which is proportionate and suitably robust for this review.
3. The four high level expectations defined by the RP were against the arrangements needed to support GDA, status of the design and E3S case, organisational capacity and capability and project maturity. 22 more detailed expectations sit below these. These met our expectations in terms of breadth of matters considered.
4. The RP reviewed its readiness against each of the 22 expectations. No matters were identified which preclude progression to Step 3 and the majority were considered covered by normal business activities. Four of the expectations were rated as “amber” by the RP, which indicates that a gap was identified in meeting the expectation for which additional oversight is necessary. For the latter:

* Two relate to aspects of design and E3S maturity. We are content that these are aspects which are within the scope of RO-RRSMR-001, as described in Section 4.3.1. We are confident these will be progressed under that RO, and therefore do not preclude progression to Step 3.
* The other two relate to the capacity and capability of Rolls-Royce SMR Limited to deliver Step 3, and the project plan. However, we view these as related and both concern the risk of changes to the scope and programme for Step 3 (with corresponding impacts on the RP’s resources). Whilst the RP has made efforts to ensure its plans for Step 3 are fully resourced and aligned, there is an inevitable risk that assumptions and plans change. A significant mitigation to this is the planning undertaken as part of developing our Step 3 assessment plans. Our view is that, whilst this does remain a risk, there are arrangements and process currently in place to manage this as part of normal business should it occur. The RP has demonstrated its extant plan for Step 3 is resourced, has integrated its design and E3S case activities, and allowance has been made for aspects which are uncertain, such as responding to regulatory questions. We are content that the RP has made reasonable efforts to mitigate this risk and this does not preclude progression to Step 3.

1. A number of more detailed actions were identified by the RP. We are content that these are normal business for the RP to manage during Step 3. We also note that the 49 improvement actions identified by the RP as part of its readiness review for entry to Step 2 have been completed (refer to ONR’s Step 1 Summary report for details (ref. [65])). A number of these actions relate to the RP’s gap analysis undertaken in Step 1, hence this satisfies requirements [2.12] and [2.22] from Guidance to Requesting Parties (ref. [1]).
2. In our assessment of the RP’s readiness review we also sought further information relating to capability, design and E3S maturity, information management, access to third-party information and responses to public comments. These areas were based on our learning from Step 2, and the RP’s own readiness review outcomes. The RP’s responses were satisfactory, and provided reassurance that these matters had been considered appropriately as part of its readiness review, and suitable mitigations were in place where necessary. No matters which would preclude progression to Step 3 were identified, but we will continue to maintain oversight of these as part of our normal interactions with the RP during Step 3.
3. The overall conclusion of the RP’s readiness review is that it considers itself ready to begin Step 3. The review also confirmed that the RP considered it had met all of the relevant requirements in Appendix 3 of Guidance to Requesting Parties (ref. [1]), as Table 3.
4. Overall, we are content that the information provided is sufficient to satisfy requirement [2.25] from Guidance to Requesting Parties.

### ONR

1. In line with the requirements of Guidance to Requesting Parties (ref. [1]), ONR undertook a review of our own readiness to progress to Step 3 (ref. [66]). In addition to considering the outcomes from the RP’s readiness review, we also confirmed that we:

* Agree that the RP has met requirements [2.1] to [2.25] of Guidance to Requesting Parties, as Table 3, as described throughout this report;
* Have completed all of the requirements against us as defined in Appendix 3 of Guidance to Requesting Parties, namely [2.26] to [2.32];
* Have implemented suitable project management and arrangements to undertake the GDA;
* Have secured sufficient internal resources and have allocated budget for external contractor support to undertake the activities identified in our assessment plans for Step 3;
* Have taken account of the outcome of the Environment Agency’s own readiness review; and
* Consider that, based on the agreed GDA scope (ref. [50]) and submission schedule (ref. [42]), the assessment:
  + Will remain meaningful during Step 3;
  + Is aligned to that necessary to make a decision on the award of a DAC, as per the RP’s objective for the GDA; and
  + Warrants the continued deployment of regulatory resource.

1. The outcome from our readiness review was that we consider we are ready to proceed to Step 3 of GDA for the Rolls-Royce SMR.

# Conclusions

1. This is ONR’s second report summarising our assessment of the generic Rolls-Royce SMR design, produced at the end of Step 2 of the GDA.
2. This is the first time ONR has undertaken assessment using the revised three-step GDA guidance. This means that it is not possible to compare our outcomes reported here with other completed GDAs at this point in the process, as the scope and objective of the assessments differ.
3. In this step we have undertaken an assessment of the fundamental adequacy of the design and E3S case. The objective was to identify shortfalls which could preclude future deployment of that design in GB. This has been undertaken by 21 assessment topics covering the full range of ONR’s statutory purposes. In this step we have also maintained oversight of the RP’s arrangements, organisation and capacity to undertake the GDA and agreed a submission schedule for Step 3, which has allowed us to develop detailed assessment plans for each of our technical topics.
4. Based on the work carried out by ONR, we are satisfied that:

* The RP has completed all of the requirements for Step 2 from our guidance;
* Interactions with the RP throughout Step 2 have continued to be professional and constructive, and we have confidence that this will continue;
* The RP has matured significantly during the step, in developing its organisation and arrangements to support GDA, and has embraced continual learning and improvement;
* Those agreements that are necessary to undertake the GDA remain in place, and have been amended as necessary to reflect the project needs;
* The RP submitted a large body of quality information which demonstrated a good understanding of our regulatory expectations and has started to document the basis for how the generic design can be shown to fulfil the claims made in the E3S case;
* The RP has taken account of UK specific expectations and its methodologies and approaches align to our expectations and provide a sound basis for further development;
* Based on our assessment to date, and subject to the provision and assessment of suitable and sufficient supporting evidence, we have not identified any fundamental safety, security or safeguards shortfalls that could prevent ONR permissioning the construction of a power station based on the generic Rolls-Royce SMR design;
* The RP is aware of the significant efforts needed to mature the design and E3S case on timescales compatible with its stated objective of achieving a DAC at the end of Step 3, and has put in place credible plans to that end;
* We have continued to build our knowledge, and have used this to inform our planning for further assessment activities; and
* We, and the RP, are ready to proceed to Step 3 of the GDA.

1. During Step 3 we will continue to rigorously assess the RP’s submissions in line with our assessment plans, raising any matters of concern as they arise with the RP via interactions and using the established tools available to us, including ROs or RIs, as necessary.
2. Informed by our Step 2 activities, we have planned our assessment activities for the detailed assessment of the generic Rolls-Royce SMR design during Step 3. These will allow us to efficiently and appropriately decide whether to grant a DAC, iDAC or no DAC in line with our GDA guidance.

# Recommendations

1. Based upon the work described in this report, we recommend that:

* Recommendation 1: ONR should publish a Step 2 GDA Statement for the generic Rolls-Royce SMR design which indicates that, based upon our assessment to date, we have not identified any fundamental shortfalls with the design.
* Recommendation 2: ONR should proceed to Step 3 of the GDA for the generic Rolls-Royce SMR design.

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# Appendix 1

Table 3: Step 2 requirements from Guidance to Requesting Parties (ref. [1])

|  | Requirement on the RP during Step 2 | Section |
| --- | --- | --- |
| [2.1] | **Agree with ONR** any changes necessary to the GDA scope, to ensure that the assessment remains meaningful | 4.2.1 |
| [2.2] | **Agree with ONR** any changes to the overall GDA timescales and associated schedule, including subsequent Steps | 4.2.1 |
| [2.3] | **Submit to ONR** any additional relevant information which arises due to on-going assessments performed by other regulators on the proposed design, including any significant findings and any changes made or proposed as a result | 2.4.1 |
| [2.4] | **Submit to ONR** a demonstration that the proposed design is likely to reduce risks to human health to ALARP | 4.4.7 |
| [2.5] | **Submit to ONR** a demonstration that the proposed design is likely to be compliant with the Nuclear Industries Security Regulations (NISR) | 4.4.7 |
| [2.6] | **Submit to ONR** a demonstration of the application of the RP’s categorisation of safety functions and classification of structures, systems and components within the proposed design | 4 |
| [2.7] | **Submit to ONR** a schedule of faults (including internal events, internal and external hazards), including protection and mitigation measures and the links this has to the associated engineering | 4 |
| [2.8] | **Submit to ONR** a demonstration of the application of the RP’s approach adopted to defence in depth and the hierarchy of controls, including consideration of matters such as common cause failure, segregation, redundancy and diversity within the proposed design | 4.4.3 |
| [2.9] | **Submit to ONR** a demonstration of how the RP’s own design, security and safety principles have been adopted in the proposed design | 4 |
| [2.10] | **Submit to ONR** information on the methodologies to be adopted for the identification of Vital Areas, the analysis of cyber security risks and the approach to security related defence in depth | 4.4.4 and 4.4.7 |
| [2.11] | **Submit to ONR** the agreed submissions, which align with the expectations given in the discipline technical guidance (Ref. 5), in accordance with the GDA scope. This should include:  Sufficient detail for ONR to satisfy itself that relevant Assessment Principles (SAP and SyAPs) are likely to be satisfied  A safety and security case ‘head document’, or equivalent, which provides the overall safety and security narrative and structure; including a demonstration that the design will meet the safety and security objectives before construction or installation commences, and that sufficient analysis and engineering substantiation has been performed to prove that the operational plant will be adequately safe and secure  Details on the methodologies, approaches, codes, standards and philosophies used and a justification that these are consistent with what would be considered as Relevant Good Practice (RGP). Identification and explanation of any deviations, including how these have been resolved or demonstrated to reduce risks to ALARP  Supporting safety analysis, including deterministic and probabilistic safety analyses to cover the GDA scope  Details of the verification and validation of any software or computer codes used within the supporting analysis  Detailed descriptions of system architectures and key structures, systems and components, their safety or security functions, and reliability and availability requirements   1. Identification of the safe operating envelope and the operating regime that maintains the integrity of that envelope | 4 |
| [2.12] | **Submit to ONR** the documentation identified within the resolution plans produced in response to the gap analysis against regulatory expectations | 5.1.1 |
| [2.13] | **Submit to ONR** information regarding any outstanding information in the generic safety and security cases that remains to be developed and its significance | 3.3 |
| [2.14] | **Agree with ONR** a schedule of generic safety and security case information which will be submitted to ONR prior to the start of Step 3 | 3.3 |
| [2.15] | **Continue** to maintain and update the Master Document Submission List (MDSL) in accordance with the RP’s arrangements produced during Step 1, at regular intervals throughout the Step | 4.1.2 |
| [2.16] | **Submit to ONR** the first Design Reference Point (DRP) in accordance with the RP’s arrangements produced during Step 1. Continue to update this as necessary throughout the Step. | 4.1.3 |
| [2.17] | **Submit to ONR** a demonstration that the arrangements for capturing assumptions, commitments and requirements from the safety and security cases have been applied. Continue to apply these arrangements throughout the Step | 4.1.4 |
| [2.18] | **Continue** to apply the DR change control arrangements throughout the Step. **Submit to ONR** any design change information specified under these arrangements | 4.1.3 |
| [2.19] | **Put arrangements in place** for developing the safety case into a site-specific Pre-Construction Safety Report which clearly demonstrates that this can be achieved by a future licensee. **Submit to ONR** a description of those arrangements and a demonstration of their adequacy for GDA | 4.3.1 |
| [2.20] | **Put arrangements in place** for developing the security case into a Nuclear Site Security Plan for the operating site, which clearly demonstrates that this can be achieved by a future licensee. **Submit to ONR** a description of those arrangements and a demonstration of their adequacy for GDA | 4.3.1 |
| [2.21] | **Submit to ONR** responses to any questions raised by ONR during its assessment (RQs, ROs and RIs) | 4.1.2 |
| [2.22] | **Submit to ONR** information regarding its intentions for evolution of its GDA resources and a demonstration of the on-going sufficiency of resources to be applied through the Step | 5.1.1 |
| [2.23] | **Continue** to facilitate meetings between ONR and relevant RP’s personnel to share information and discuss technical matters | 3.2 |
| [2.24] | **Continue** to facilitate the public comment process including hosting a public website, containing relevant and updated generic safety and security cases, and responding to comments made by the public. | 5.1.1 |
| [2.25] | **Undertake** a review of its readiness to begin Step 3 and **submit to ONR** evidence to support the outcomes | ‎5.1.1 |