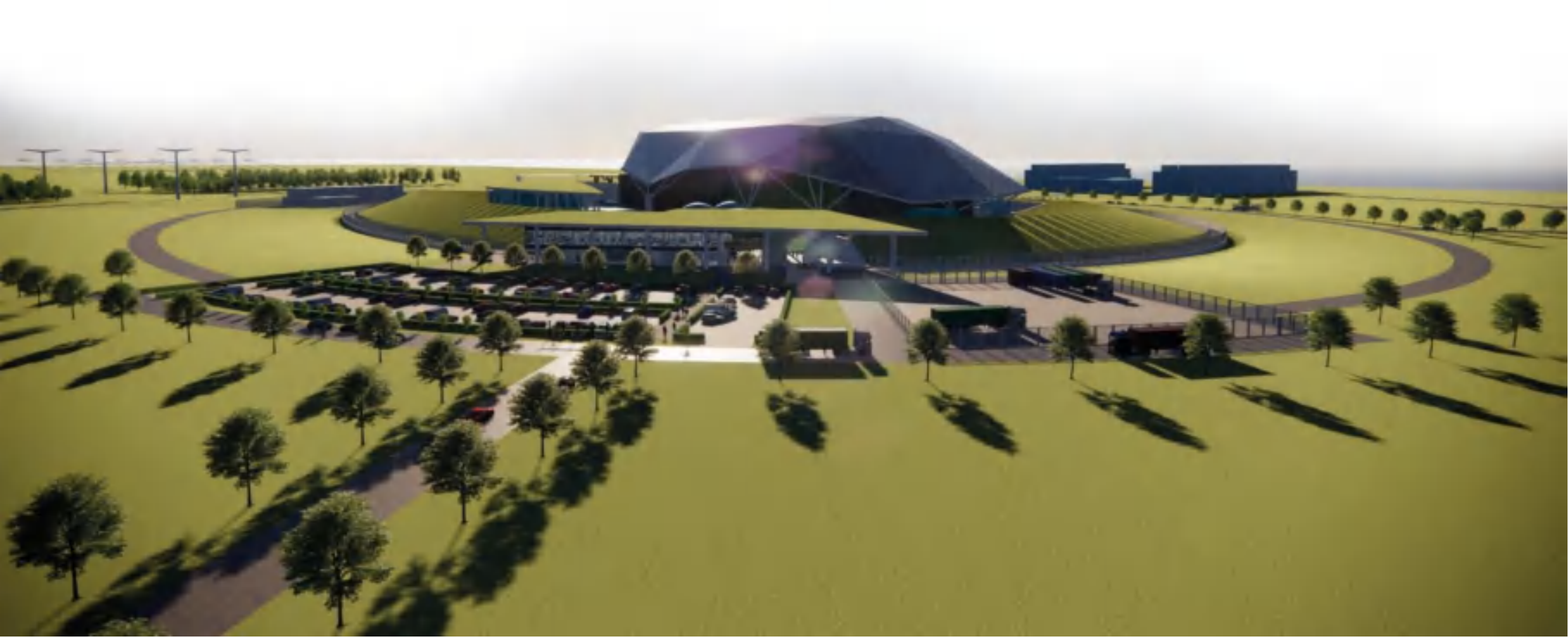
© Rolls-Royce SMR Ltd, 2024, all rights reserved – copying or distribution without permission is not permitted

Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 1: Introduction



Record of Change

Date	Revision Number	Status	Reason for Change
March 2023	1	Issue	First issue of E3S Case
January 2024	2	Issue	Incorporates revisions of site, plant, and environmental information at Reference Design 7, aligned to Design Reference Point 1 Also reflects updated content from the E3S Case Development and Management Arrangements (SMR0000627) and E3S Requirements and Analysis Arrangements (SMR0009132)
May 2024	3	Issue	Updated to correct revision history status at Issue 2. Chapter changes include: • Additional detail for how the E3S design principles are embedded into processes (section 1.1.2) • Clarifications on gate review processes for controlling maturing design (section 1.3.5) • Alignment of radioactive effluent discharge point description to E3S Case Version 2, Tier 1, Chapter 28 (section 1.7.5) • Alignment of liquid waste discharges description to E3S Case Tier 1, Version 2 Chapter 29 (section 1.7.6) Also minor template/editorial updates for overall E3S Case consistency.

Executive Summary

This chapter presents the introduction to the Rolls-Royce Small Modular Reactor (RR SMR) generic Environment, Safety, Security, and Safeguards (E3S) Case.

The E3S Case is being developed alongside the ongoing design programme and will provide the overall justification that the fundamental objective ‘to protect people and the environment from harm’ can be achieved at all lifecycle stages of the power station. It will demonstrate that risks can be reduced to as low as reasonably practicable (ALARP), applying best available techniques (BAT), and ensuring secure by design and safeguards by design. It will also demonstrate that the design is sustainable now and future generations.

During the current design lifecycle stage, a generic E3S Case is being developed. The objective of the generic E3S Case is to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it is developed from a concept design into a detailed design. Version 2 of the generic E3S Case is developed in support of the Reference Design 7 (RD7) design stage capturing the engineering design work and analysis undertaken, corresponding to design reference point 1 (DRP1) for the generic design assessment (GDA).

The E3S Case is developed in a hierarchical manner with three tiers of information. Tier 1 provides an overarching summary and entry point to the E3S Case and is comprised of 33 chapters (including this Introduction chapter). Tier 2 presents the first level of underpinning arguments and evidence, comprising a set of summary documents that present the detailed E3S requirements, arguments and/or evidence that underpin the lowest decomposed claims in the Tier 1 chapter, and also signpost out to the detailed evidence on Tier 3.

A claims, arguments, evidence (CAE) structure is used to provide a logical framework for presentation of the overall E3S Case. The generic E3S Case is being developed alongside the ongoing design programme, as such the full suite of documentation / data that will comprise the full generic E3S Case and underpin the claims made is still in development. The trajectory of arguments and evidence being generated, where known at this stage of the lifecycle, is documented in the E3S Case Route Map for each chapter. Commentary on the current gaps and maturity of arguments and evidence at Version 2 of the generic E3S Case, and the forward trajectory of information for the development the generic E3S Case and closure of gaps, is provided in the conclusions for each chapter.

The E3S design principles provide the framework against which the design is developed and evaluated, applicable to both the physical design itself and/or design processes. The principles are embedded into the E3S and engineering processes through design optioneering, derivation of E3S requirements, and iteratively E3S analyses. The application of these E3S and engineering processes result in outputs that comprise the arguments and evidence to underpin claims across the E3S Case.

An overview of the RR SMR engineering framework, plant layout, plant description, novel aspects of the design in comparison with other pressurised water reactor (PWR) designs, and summary of environmental aspects is presented within this chapter, with reference out to other chapters of the E3S Case for further detail.

Contents

Tables

Figures

1.1 Introduction

1.1.1 Objective of E3S Case

Rolls-Royce SMR Limited are progressing the design and development of the Rolls-Royce Small Modular Reactor (RR SMR) power station. The design programme of the RR SMR is a phased design cycle, which commenced in May 2016 and aims to deploy the first of a fleet (FOAF) RR SMR in the early 2030s.

The RR SMR has a fundamental objective 'to protect people and the environment from harm'. The Environment, Safety, Security and Safeguards (E3S) Case provides the overall justification that the fundamental objective can be achieved at all lifecycle stages of the power station.

The E3S Case is being developed and evolved through the Rolls-Royce SMR lifecycle. During the current design lifecycle stage, a generic E3S Case is in development. The objective of this generic E3S Case is to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design, including the demonstration that risks can be reduced to as low as reasonably practicable (ALARP), apply best available techniques (BAT), ensure secure by design and safeguards by design, and demonstrate sustainability for now and future generations.

1.1.2 Holistic E3S Approach

To achieve the E3S fundamental objective, a hierarchical decomposition of a complete set of E3S design principles [1] are established based on United Kingdom (UK) and international Relevant Good Practice (RGP), including the Office for Nuclear Regulation (ONR) Safety Assessment Principles (SAPs), Security Assessment Principles (SyAPs) and Technical Assessment Guides (TAGs), Environmental Agency (EA) Radioactive Substances Regulation (RSR) objectives and principles, International Atomic Energy Agency (IAEA) safety guides, European Utility Requirements (EURs) and Western European Nuclear Regulators Association (WENRA) Safety Reference Levels.

The E3S design principles provide the framework against which the design is evaluated and developed, applicable to both the physical design itself and/or design processes.

The E3S design principles are embedded into design through multiple E3S and engineering processes, including:

- Design optioneering and the design decision-making process [2]: design of structures, systems and components (SSCs) in accordance with E3S design and architectural considerations (for example, fail safe design, redundancy, separation and segregation etc.), with safety and regulatory team engaged in the process as stakeholders. The evaluation of options and rationale for selection of the design solution to support demonstration of ALARP, BAT, secure by design, and safeguards by design, as well as sustainability in the design, is recorded in design decision files

- A suite of iterative E3S analysis of the design as it matures, providing insights for ongoing development and improvements with respect to ALARP, BAT, secure by design and safeguards by design

- Derivation and application of E3S requirements from both the E3S design principles and the application of E3S analyses. Section 1.1.5.2 describes the RR SMR terminology for E3S requirements in relation to claims, and section 1.3.4 describes how the achievement of E3S requirements forms evidence for the case

Further information on the integration of these processes is provided in the E3S Requirements and Analysis Arrangements [3]. The application of all E3S and engineering processes result in outputs that comprise the arguments and evidence to underpin claims across the E3S Case.

The holistic approach to embedding E3S into engineering processes provides the benefit of optimised outputs with respect to ALARP, BAT, secure by design and safeguards by design, as well as sustainability in the design. This approach also reduces the need for repetition of information across the case as each discipline has visibility of information being produced for the case. It also enables the impact of design developments and changes to the E3S Case to be reviewed and assessed more holistically across the E3S disciplines.

The term as low as reasonably achievable (ALARA) is also a widely recognised acronym by worldwide organisations such as IAEA, United States Nuclear Regulatory Commission (U.S. NRC), World Nuclear Association (WNA) etc, used to define the principle of minimising radiation exposure. In GB, the terminology is broadly synonymous, with both ALARA and ALARP incorporating considerations on economic, environmental, and societal factors. Within the RR SMR E3S Case, the terminology ALARP is used when relating to minimisation of risk, noting ALARA is used within 'environment' chapters of the E3S Case when relating to impacts of waste and discharges.

1.1.3 E3S Case Maturity

The RR SMR is a developing design that is not based on an existing reference plant. As the design progresses through the concept design stage and into detail design, a generic E3S Case is being developed during the pre-construction and installation lifecycle stage based on a set of generic site characteristics and design parameters known as the generic site envelope (GSE).

The GSE is suitably bounding for a range of sites within Great Britain (GB) such that it facilitates a transition to a FOAF site-specific case that minimises the requirement for significant additional E3S justification. Further details on the GSE are provided in E3S Case Tier 1, Version 2 Chapter 2: Generic Site Characteristics [4].

The generic E3S Case is revised in alignment with engineering milestones, termed 'Reference Design (RD)', declared as the programme matures. There are a minimum of four planned versions of the generic E3S Case, corresponding to RDs declared throughout the concept design stage and into the detailed design stage, noting the RDs beyond RD8 are still to be defined.

The development of the generic E3S Case is illustrated in Figure 1.1-1, aligned to programme maturity stages and engineering RDs (known at this stage), with an indication of which revision is submitted at the end of each step of the regulatory generic design assessment (GDA) process.

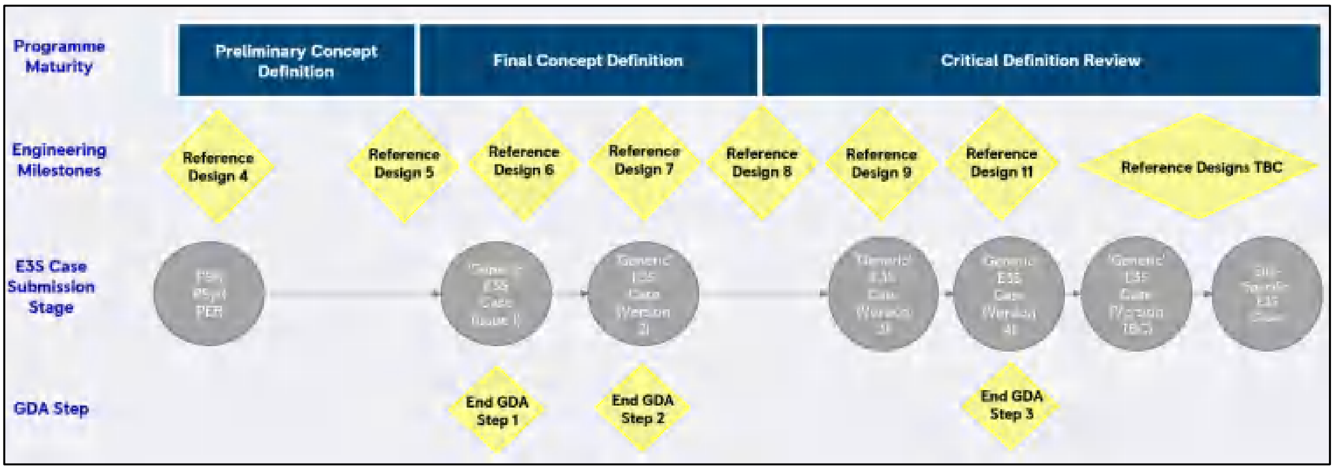


Figure 1.1-1: Generic E3S Case Evolution

In summary:

- Issue 1 of the generic E3S Case was issued upon completion of preliminary concept definition phase at RD5, capturing the engineering and analysis completed to underpin the preliminary concept

- Version 2 of the generic E3S Case (this revision) is issued based on RD7, capturing the engineering and analysis undertaken, as well as the output of regulatory assessment on Issue 1 of the generic E3S Case. Version 2 aligns to design reference point (DRP)1 for GDA, described in section 1.2

- Version 3 of the generic E3S Case will be issued based on RD9, capturing the engineering and analysis as the design matures through detailed design, as well as the output of regulatory assessment of Version 2 of the generic E3S Case (a corresponding DRP for GDA will be defined, described in section 1.2)

- Version 4 of the generic E3S Case will be issued based on an RD to be defined, to incorporate further detailed design development, analysis, and verification and validation (V&V) evidence where possible, as well as the output of regulatory assessment of Version 3 of the generic E3S Case (a corresponding DRP for GDA will be defined, described in section 1.2)

- Further issue(s) of the generic E3S Case during the critical definition (detailed design) phase at an RD(s) to be defined

Given the iterative nature of the E3S analyses informing the design development, the analysis outputs presented with each revision of the case may be based on an earlier design baseline. For example, the PSA outputs for RD7 are based upon modelling of the RD6 design – the analysis has informed the RD7 design and forms part of the suite of RD7 documentation that Version 2 of the E3S Case is based upon. The RD basis for the relevant E3S analyses at each revision of the case is clearly defined in each respective analysis chapter.

The submission of the E3S Case in the context of the GDA process is described further in Section 1.2.3. The overall evolution and maturity of the E3S Case through the facility lifecycle is described further in the E3S Case Development and Management Arrangements [5].

1.1.4 E3S Case Structure & Content

1.1.4.1 Overall Structure

The E3S Case will comprise many documents, therefore, to ensure its usability and accessibility for the different users and stakeholders, it is being developed in a hierarchical manner, comprising the following 'tiers' of information:

- Tier 1: an entry point to the E3S Case that presents the decomposition of claims with a proportionate, overarching summary of the arguments and evidence in lower tiers of the E3S Case
- Tier 2: the first level of underpinning information, comprising a set of summary documents that present the detailed E3S requirements, arguments and/or evidence that underpin the lowest decomposed claims in the Tier 1 chapter, and also signpost out to the detailed evidence on Tier 3
- Tier 3: the detailed evidence for different aspects of the E3S Case to underpin claims, supporting the arguments or evidence contained within Tier 2 documents

The hierarchy is illustrated in Figure 1.1-2.

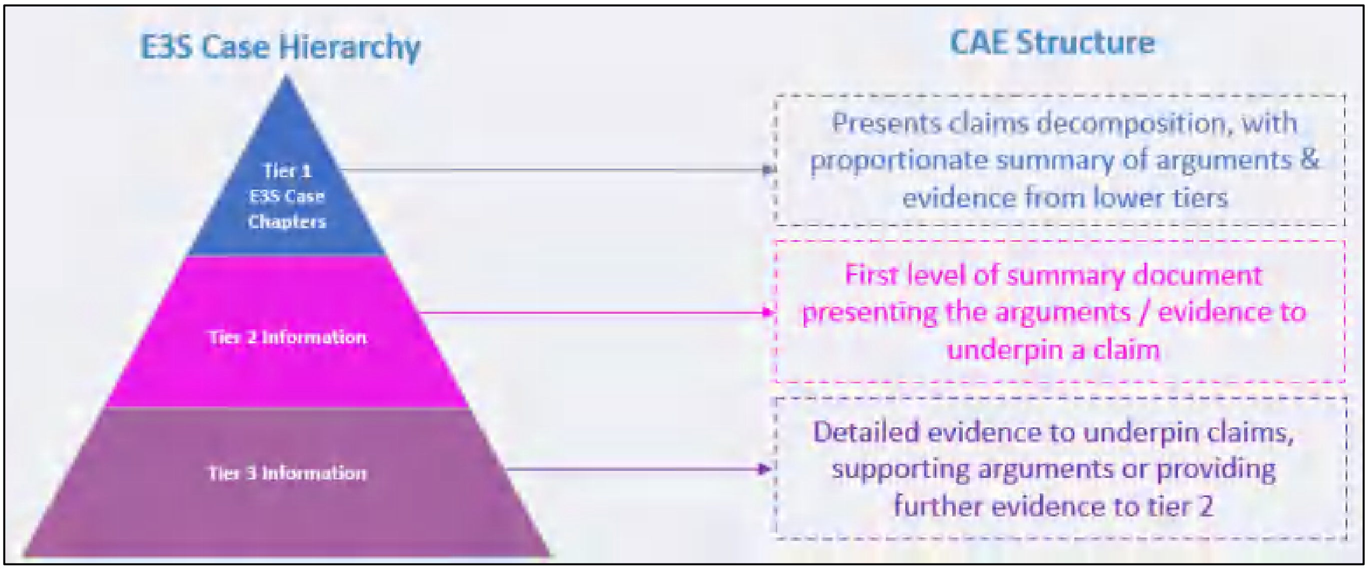


Figure 1.1-2: E3S Case Hierarchy

The term 'E3S Case' refers to all three tiers of information, not just the Tier 1 chapters. An example of the three tiers of information within the overall E3S Case is illustrated in Figure 1.1-3.

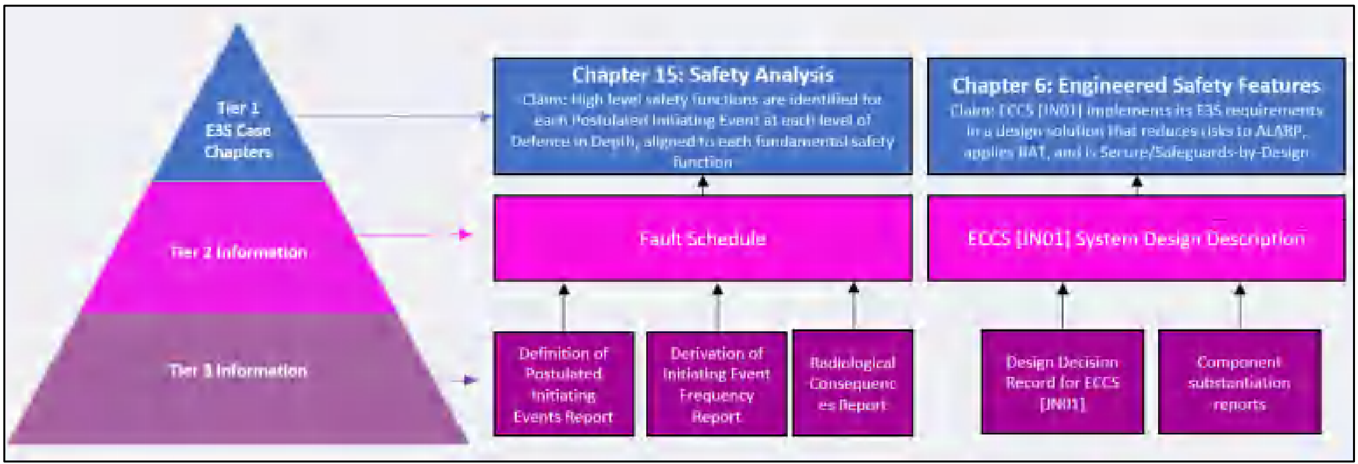


Figure 1.1-3: Example of Tiered Information in E3S Case Hierarchy

The contents of each tier of information are described further below, with information on the use of claims, arguments and evidence (CAE) described in Section 1.1.5.

1.1.4.2 Tier 1

Tier 1 of the E3S Case is split into 'chapters' covering different topic areas within each of the E3S disciplines.

The content of the 'safety' chapters is broadly aligned to the IAEA Safety Standard Guide (SSG)-61 [6] and taking cognisance of the structure set out in the U.S. NRC Regulatory Guides 1.70 [7] and 1.206 [8], providing a standardised format that is acknowledged as good practice by the UK regulators and is used by international nuclear power station operators, thus supporting achievement of the RR SMR key design objectives to be both 'licensable in the UK' and 'capable of global expansion'.

The IAEA approach is the starting point for structuring a safety case and can be adapted to reflect national regulatory expectations. For the generic E3S Case, the IAEA structure is adapted to ensure alignment with the UK context, with additional chapters added to facilitate presentation of topic-specific information to the UK regulators, including Chemistry, Conventional & Fire Safety, Structural Integrity, ALARP, and Sustainability.

The content of the 'environment' chapters is aligned to EA guidance [9], covering the stipulated information requirements with some adaptations to ensure an integrated case. For example, the environment-focussed chapter for 'Radioactive Waste Management Arrangements' is combined with the safety-focused chapter of 'Management of Radioactive Waste', given the similarity of their content.

The content of the 'security' chapter is informed by the ONR SyAPs [10] and associated international good practice set out in IAEA recommendations and guidance. The content of the 'safeguards' chapter is informed by the ONR Fundamental Safeguards Expectations (FSEs) [11] and IAEA guidance for safeguards by design [12].

Development of Tier 1 of the E3S Case as a series of integrated E3S chapters facilitates the holistic E3S approach described in Section 1.1.2, drawing upon a common base of information in the lower tiers, whilst minimising repetition of information across the chapters. The chapters provide an entry point to relevant stakeholders for different aspects of the overall case to provide confidence that the E3S fundamental objective can be met, whilst giving coherence to the overall suite of documentation.

The E3S Case chapters, summary of contents, and the primary E3S disciplines contributing to development of that chapter, is presented in Table 1.1-1. It is noted that the content within some chapters is more limited than others during the early design stage, such as the conduct of operations or the emergency preparedness arrangements, which will increase in level of detail as the E3S Case matures towards a pre-operations E3S Case.

Table 1.1-1: E3S Case Chapters

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
1	Introduction	✓	✓	✓	✓	Provides an overall introduction to the suite of 33 chapters that make up the E3S Case
2	Generic Site Characteristics	✓	✓	✓	✓	Presents the site bounding characteristics and parameters within which the RR SMR is designed, such that it is capable of being built and operated in accordance with the standards of safety, security, safeguards, and environmental protection required in GB sites throughout its entire lifecycle. Also presents a summary of the generic site description (GSD) which environmental assessments are based on
3	E3S Objectives and Design Rules for Structures, Systems and Components	✓	✓	✓	✓	Presents the key principles and associated methods, approaches, and requirements that provide the framework for the RR SMR to achieve its E3S objectives
4	Reactor (Fuel & Core)	✓	✓	✓	✓	Describes the fuel and core design, including its composition and configuration of fuel, control rods, etc., and associated operational parameters
5	Reactor Coolant System and Associated Systems	✓	✓	✓	✓	Describes the reactor coolant system (RCS) and associated systems, which include the reactor pressure vessel (RPV) and the primary coolant circuit components

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
6	Engineered Safety Features	✓	✓	✓	✓	Describes the systems which deliver the safety functions in response to fault and accident conditions in the reactor
7	Instrumentation and Control	✓	✓	✓	✓	Describes the control and instrumentation (C&I) systems of the RR SMR which support delivery of the E3S functions
8	Electrical Power	✓	✓	✓	✓	Describes the electrical power systems which supply power to systems during both normal and fault conditions
9A	Auxiliary Systems	✓	✓	✓	✓	Describes the auxiliary systems of the RR SMR, including the fuel handling and storage systems, water supply systems, and ventilation systems
9B	Civil Engineering Works and Structures	✓	✓	✓	✓	Describes the civil and structural design aspects of the RR SMR, including the hazard shield and the base isolation system for protection against external hazards
10	Steam and Power Conversion Systems	✓	✓	x	x	Describes the steam and power conversion systems of the RR SMR that are primarily located in Turbine Island (noting some aspects cross the boundary into Reactor Island)
11	Management of Radioactive Waste	✓	✓	✓	✓	Describes the radioactive waste treatment systems for RR SMR, and summarises the sources of solid, liquid, and gaseous waste streams. It also described the waste management arrangements, including solid waste quantities, and an overview of waste minimisation with focus on disposability and optimised disposal routes

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
12	Radiation Protection	✓	✓	✓	✓	Evaluates how radiation doses to onsite workers and members of the public will be controlled during normal operations, and describes the design features of the RR SMR that minimise exposures to ALARP
13	Conduct of Operations	✓	✓	✓	✓	Presents how the RR SMR design and operational documentation will facilitate a future Dutyholder/Licensee to fulfil its prime responsibility to implement E3S requirements in operation
14	Plant Construction and Commissioning	✓	✓	✓	✓	Presents a high-level overview of the proposed build and installation approach and programme for the RR SMR, and an overview of the proposed commissioning programme and associated strategies
15	Safety Analysis	✓	✓	x	x	Presents the methods and outputs of the safety analysis that evaluate the RR SMR against relevant criteria and inform the design development, including the deterministic analysis of faults and accidents, probabilistic analysis, and internal and external hazard assessment
16	Operational Limits and Conditions	✓	✓	✓	✓	Presents the processes to define the operational limits and conditions (OLCs) in the design and safety analysis, to ensure they are successfully transferred into operational documentation
17	Management for E3S and Quality Assurance	✓	✓	✓	✓	Presents the management and organisational arrangements to support the development of the RR SMR, including the processes and systems in place to ensure quality assurance and quality management of the design and E3S Case production

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
18	Human Factors Engineering	✓	✓	✓	✓	Provides the demonstration that human factors (HF) are fully integrated into the RR SMR design and substantiation processes
19	Emergency Preparedness and Response	✓	x	✓	x	Presents the UK and international relevant good practice relating to emergency preparedness and response, and the design features and arrangements of the RR SMR that facilitate compliance
20	Chemistry	✓	✓	x	x	Presents the definition and justification of the RR SMR chemistry regime, chemistry specification for systems, and the design substantiation to meet chemistry specifications
21	Decommissioning and End of Life Aspects	✓	✓	✓	✓	Presents the RR SMR decommissioning and waste strategies for the RR SMR, and the provisions within the design to facilitate safe decommissioning
22	Conventional and Fire Safety	✓	✓	✓	x	Presents the strategies for implementation of conventional and fire safety into design of the RR SMR, including compliance with Construction (Design and Management) Regulations 2015 (CDM 2015)
23	Structural Integrity	✓	x	x	x	Presents the RR SMR demonstration of structural integrity for safety-classified metallic pressure boundary components and their supports
24	ALARP Summary	✓	x	x	x	Presents the overarching summary of how the RR SMR reduces nuclear and conventional safety risks to ALARP through the lifecycle

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
25	Detailed Information about the Design	x	✓	x	x	Presents a technical description of the facility's main plants, systems, and processes, which have a bearing on radioactive waste (solid, liquid and gaseous) generation, treatment, measurement, assessment and disposal, drawing upon information from other E3S Case chapters
26	Sustainability	x	✓	x	x	Presents the sustainability aspects of the RR SMR
27	Demonstration of BAT	x	✓	x	x	Presents a summary of how BAT methodology has been applied in the design of the RR SMR
28	Sampling and Monitoring Arrangements	x	✓	x	x	Presents the RR SMR sampling & monitoring arrangements for in-process and final discharge monitoring
29	Quantification of Radioactive Effluent Discharges and Proposed Limits	x	✓	x	x	Presents an assessment of potential discharges of aqueous and gaseous radioactive effluent from the RR SMR plant to the environment under normal operating conditions
30	Prospective Radiological Assessment	x	✓	x	x	Presents the radiological assessment of doses to members of the public and non-human species. It describes the method used to calculate doses and justifies why the model's data and assumptions used are appropriate
31	Conventional Environmental Impact and Other Environmental Regulations	x	✓	x	x	Presents conventional environmental aspects associated with RR SMR and how impacts are being managed to minimise taking into consideration legal requirements and RGP

No.	Title	Safety	Environment	Security	Safeguards	Summary of Contents
32	Generic Security Report	x	x	✓	✓	Presents the demonstration of security in the design of the RR SMR, covering measures to ensure protection from sabotage, protection from theft, cyber security and information assurance, and to ensure security by design
33	Safeguards	x	x	✓	✓	Presents the demonstration that the design of RR SMR facilitates safeguarding through material accountability, and containment and surveillance

It is noted that the term 'systems engineering chapters' may be used within the E3S Case to describe the design description focused chapters 4 to 11. The SSCs within scope of the generic E3S Case and their associated chapter are listed in Appendix A (section 1.10).

1.1.4.3 Tier 2 and Tier 3

Much of the Tier 2 and Tier 3 information is developed through the application of the integrated engineering and E3S processes, described in the E3S Requirements and Analysis Arrangements [3].

In general, Tier 2 documents are summaries that provide the first level of information to underpin a claim (or multiple claims) in the Tier 1 chapters. This could be arguments that provide the link to detailed evidence on Tier 3, or a summary of detailed evidence. An example of a Tier 2 document could include a probabilistic safety assessment (PSA) summary report that documents the outputs of detailed PSA modelling, which underpins claims that the design achieves its numerical safety objectives and corroborates the overall plant architecture reduces risks to ALARP. Alternatively, it could be a system design description (SDD) that documents the design of an SSC, which provide the arguments that underpin claims that the SSC is designed to achieve its E3S requirements towards a solution that reduces risks to ALARP.

Tier 3 provides the detailed underpinning evidence to underpin a claim (or multiple claims) in the Tier 1 chapters. It may provide the evidence to support arguments that are presented in Tier 2 documents, or it may provide detailed evidence underpinning evidence summarised in a Tier 2 document. Examples of Tier 3 documents could include a design decision record for an SSC, which provides underpinning evidence to support the arguments presented in the Tier 2 SDDs that the SSC is designed to achieve its E3S requirements towards a solution that reduces risks to ALARP and demonstrates BAT. Alternatively, it could include the individual hazard identification studies to support the consolidated evidence summarised in a Tier 2 hazard log, or it could be a detailed verification report to substantiate a specific set of E3S requirements.

The content and format for Tier 2 and Tier 3 information is presented according to its defined scope and the claims it is intending to underpin. Given the broad range of information in these tiers, it could be presented in a combination of many formats, such as reports of prose text (such as topic reports), data spreadsheets (such as hazard identification outputs), or bespoke software outputs (such as PSA modelling outputs).

There is no requirement to use a defined ‘CAE’ structure to present Tier 2 or Tier 3 information, and often a simple narrative to present an argument or evidence to underpin a higher-level claim is sufficient. However, it may be used if deemed beneficial for the purposes of presenting content in a clear and logical manner.

1.1.5 Claims, Arguments, Evidence Approach

1.1.5.1 High-level Claims, Arguments, Evidence

The E3S fundamental objective, 'to protect people and the environment from harm', is achieved through the application of E3S design principles [1]. The E3S Case provides the demonstration of compliance against the E3S design principles through the development and decomposition of claims aligned to the principles, which are underpinned by arguments and evidence that is developed from the application of E3S and engineering processes.

A small set of fundamental E3S claims are derived that broadly cover the E3S design principles, which are in turn decomposed into a set of top-level claims aligned to each Tier 1 chapter of the E3S Case; this is illustrated in Figure 1.11-1 in Appendix B (section 1.11).

Each top-level chapter claim is then decomposed into sub-claims, with decomposition to a level such that the lowest level of sub-claim is of sufficient detail to point to arguments and/or evidence within Tier 2. Where necessary, the decomposition logic can be described using ‘reasoning rules’, which provide context on how the sub-claims satisfy its parent claim / sub-claim.

The claims decomposition and mapping to Tier 2 and Tier 3 information is presented for all E3S Case chapters in an E3S Case Route Map [13]. The E3S Case Route Map is a ‘live’ tool used by the E3S Case Manager and E3S Case Authors to manage the E3S Case as it develops alongside the maturing design, as such it aims to illustrate the trajectory of arguments and evidence for each issue of the generic E3S Case. The route map is referred to within each chapter of the E3S Case to provide the context for how underpinning arguments and evidence are being developed for that chapter.

1.1.5.2 E3S Requirements

The terminology of ‘E3S requirements’ is also used for specific assertions that an SSC (or human) will achieve an E3S function or exhibit a property to meet an E3S objective. E3S requirements are a sub-set of the wider requirements set generated through the integrated systems engineering and E3S processes, described in the E3S Requirements and Analysis Arrangements [3].

The term ‘E3S requirements’ covers the following:

- E3S categorised functional requirements: functional requirements on an SSC to deliver an E3S function, derived from the E3S analyses, which are categorised as part of the E3S processes
    - Non-functional performance requirements are linked to E3S categorised functional requirements, for example, availability and response times determined through performance (transient) analysis

- Non-functional system requirements: 'transverse' requirements derived from the E3S design principles, which specify the architecture or property of an SSC, such as redundancy of trains or minimising reliance on operator action. Transverse requirements are not only linked to SSCs, where applicable, they can be specified holistically across the plant, such as independence and diversity between safety measures or facilitation of examination, maintenance, inspection and testing (EMIT) in the layout

E3S requirements derivation for SSCs is iterative in its nature as the analysis progresses to inform the maturing design; this is controlled through the definition review (DR) process for SSCs, described in Section 1.3.5.2.

1.2 Project Implementation

1.2.1 GDA Background

The GDA is a voluntary process whereby requesting parties (RPs) submit their designs for new nuclear power plant to the Regulators: the ONR, EA, and Natural Resources Wales (NRW). The regulators jointly review the designs to assess their acceptability for use in GB for safety, security, safeguards, environmental protection and waste management.

The objective of the process is to provide confidence that a design is capable of being constructed, operated, and decommissioned in GB in accordance with the required standards for safety, security, and environmental protection. Further details of the GDA process are provided in [14].

Rolls-Royce SMR Limited entered the three-step GDA process in April 2022. Following a period of familiarisation and detailed planning during GDA Step 1, the information presented in the E3S Case at Version 2 has formed the basis for the fundamental assessment of the design during Step 2.

1.2.2 Vendor Information

Rolls-Royce SMR Limited is the vendor of the integrated nuclear power station. Rolls-Royce SMR Limited is also the RP for the technology that is submitted into the GDA process. The company comprises shareholders who have significant experience and pedigree in design, manufacture, and operation of nuclear reactors. Collectively this includes design, manufacture, and delivery of over one hundred reactor cores across six different plant generations for use in the UK's Royal Navy Submarine programme, design and manufacture of safety critical control and instrumentation systems and emergency diesel generators for civil nuclear plants globally, and operator for the United States (US) largest fleet of nuclear plants.

Within the Rolls-Royce SMR organisation, the Safety & Regulatory Affairs Directorate is responsible for the provision of all safety, security, safeguards, and environmental input into the design development undertaken by the Engineering Directorate in an integrated manner. With respect to GDA, the Safety & Regulatory Affairs Directorate is also responsible for the delivery of the GDA programme.

The Engineering Directorate is responsible for the design and integration of the whole power station solution, configuration control of the design, the design analysis and engineering justification. Furthermore, the Engineering Directorate is responsible for ensuring product safety.

The Safety & Regulatory Affairs and Engineering Directorates are supported in the execution of their programmes by enabling functions within the organisation, including the Talent and Human Resources Directorate that is responsible for setting up frameworks to demonstrate Rolls-Royce SMR have suitably qualified and experienced personnel (SQEP) appropriately deployed in roles that have key responsibilities in delivering nuclear safety, conventional health and safety, security, and environmental protection in the design.

The structure of the Regulatory Affairs organisation and the associated interfaces are outlined in the Regulatory Affairs Group Functional Manual [15].

1.2.3 E3S Case Submissions during GDA

Unlike previous designs that have been submitted through the GDA process, the design of the RR SMR is not based on an existing reference plant, and the generic E3S Case is developing alongside the evolving design as described in Section 1.1.3.

Rolls-Royce SMR Limited is required to define and establish a DRP for GDA. The DRP constitutes the suite of documents that represents a snapshot of the reference design that forms the basis of regulatory assessment.

The first DRP, DRP1 [16], has been established during GDA Step 2 and comprises documentation used to develop Version 2 of the generic E3S Case (this revision), which forms the basis for the fundamental regulatory assessment of the design. This regulatory submission includes a Tier 1 report to consolidate the Tier 2 and Tier 3 information that has been submitted throughout GDA Step 2, and to provide the starting point for regulatory assessment at the start of Step 3.

Tier 2 and Tier 3 information will continue to be submitted throughout GDA Step 3 reflecting the RD8 and RD9 baselines; the DRP will be updated as necessary to align with future design baselines in agreement with the regulators. The purpose of these Tier 2 and Tier 3 submissions is to provide the basis for more detailed regulatory assessment of the design during GDA Step 3. This set of submissions will be consolidated into an ‘Version 3’ of the Tier 1 chapters of the generic E3S Case during Step 3 that will be used as the basis for the EA public consultation.

Any agreed changes and outcomes resulting from regulatory assessment during GDA Step 3, and any outcomes from the EA public consultation, will be consolidated into a final ‘Version 4’ of the Tier 1 chapters of the E3S Case at the end of GDA Step 3, again with a DRP to be agreed.

The full scope of GDA is presented in the Rolls-Royce SMR GDA Scope Document [17]. This is supported by individual scope and submission plans for each GDA topic area, which list the relevant Tier 2 and Tier 3 information and any exclusions.

1.2.4 Management Arrangements

The Rolls-Royce SMR management and organisational arrangements for production of the E3S Case are summarised in E3S Case Tier 1, Version 2 Chapter 17: Management for E3S and Quality Assurance [18], including details of the governance and assurance arrangements for the E3S Case. Arrangements for response to regulatory queries (RQs), regulatory observations (ROs), and regulatory issues (RIs) during GDA are outlined in project operating instructions.

1.2.5 Assumptions and Commitments for the Future Dutyholder / Licensee / Permit Holder

An essential element of the E3S Case development process is the capture and tracking of assumptions and commitments that are generated from the E3S Case, which need to be passed on to a future Dutyholder / Licensee / Permit Holder. These include matters such as operating rules, maintenance requirements, training programmes, or emergency preparedness. They are defined as:

- Assumption: statements that enable work to continue but need validation before they can be confirmed as true

- Commitment: an assumed obligation on a future Dutyholder / Licensee / Permit Holder to conduct a specified activity

Assumptions and commitments will be captured and logged in an 'Assumptions and Commitments for future Dutyholders / Licensee / Permit Holders Register' in accordance with the relevant Project Operating Instruction [19].

1.3 Engineering Framework

1.3.1 Systems Engineering Approach

The RR SMR programme utilises, where appropriate, a set of systems engineering and design techniques to develop an integrated design solution that is optimised to meet all key requirements. This includes E3S requirements that support the demonstration that risks are acceptable and reduced to ALARP, BAT is applied, and ensuring secure by design and safeguards by design.

Systems design is, by nature, continuous and iterative. The Safety & Regulatory Affairs team are key stakeholders throughout the design process, involved in key activities described in Section 1.1.2, including derivation of requirements, optioneering and alignment to RGP, operating experience (OPEX), and analysis of options.

This section summarises the engineering arrangements of the RR SMR programme, with focus on the aspects that are relevant to development of the E3S Case. Further detail of the processes and controls summarised in this section is provided in the RR SMR engineering management plan (EMP) [20].

1.3.2 Key Design Objectives and Assessment Criteria

A consistent set of design objectives and assessment criteria have been defined for the RR SMR project to direct the progression of the design architecture/solutions based on market and functional needs. The objectives form part of the design decision-making process, used as the comparison criteria in the decision Pugh matrices to evaluate design options, providing a consistent framework to ensure progression of the design basis in line with the principle of ALARP, BAT, secure by design, and safeguards by design, as well as sustainability in the design.

These key design objectives and criteria for the programme are summarised in Table 1.3-1, which also includes a mapping of the criteria to the United Nations (UN) Sustainable Development Goals (SDG) and to the seven well-being goals defined in the Well-being of Future Generations (Wales) Act 2015 (WoFG). This alignment ensures the design objectives and assessment criteria incorporates international sustainability goals to ensure the RR SMR is sustainable by design, both now and for future generations. Evidence is recorded through the design decision-making process, and will be presented in E3S Case Tier 1, Version 2 Chapter 26: Sustainability, as it is developed.

A three-tier weighting score is shown in the table for each criterion which provide a simplified numerical basis for quantification of judgments as to the relative priorities:

- Weighting of 3 – Critical
- Weighting of 2 – Major
- Weighting of 1 – Significant

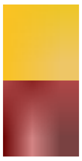
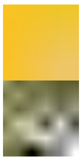
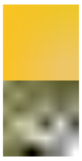
Full justification of the criteria and their weightings is provided in key assessment objectives and criteria report [21].

Table 1.3-1: RR SMR Key Design Objectives

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
1	Safety	Must meet UK legislative requirements (licensable and permittable)	Risk of compatibility with UK regulatory and legislative requirements and the meeting of key principles and goals. Includes nuclear and conventional health and safety and environmental requirements.	3	E3S		Prosperous
2	Safety	Minimise need for operator reliability / maximise passivity	Measure of degree of operator intervention required (total claims on operator). How well does the option support this principle?	2	E3S		Healthier
3	Safety	Support continuous safety improvement, below the Basic Safety Objective (BSO) 1E-6 / yr but targeting below 1E-7 Core Damage Frequency (CDF)/yr	CDF/yr. Safety comparison, looking at impact on fault schedule / PSA and compatibility with safety targets.	3	E3S		Healthier
4	Safety	Minimise normal operation and maintenance dose to ALARP levels	A measure of impact on potential worker and public dose, taking account of time, distance and shielding.	3	E3S		Healthier

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
5	Environm -ent	Minimise environmental impact: showing compliance with BAT principles for minimisation of conventional and radioactive waste and ensuring sustainable development	Estimates of the volume and activity of waste generated and effluent discharged via different routes over plant lifecycle including decommissioning. Clear adherence to BAT principles.	3	E3S		Prosperous Resilient Healthier
6	Security	Security compliance and continuous improvement	Qualitative judgement based on the impact of the option on meeting the security requirements. See secure by design principles.	3	E3S		-
7	Cost	Minimise Overnight Capital Cost (capital cost comparison)	£/MW (compare capital cost impact difference between the options, considering broader plant impacts, factoring in any differential on potential power output as a result of the option)	3	Socio - Economic		Prosperous
8	Cost	Minimise Cost of Energy and associated impact(s) (through life cost factors)	Cost/MWhr Balance of maximising power output and minimising cost through life.	3	Economic, Environment, Social		Prosperous Globally Responsible
9	Cost	Minimise cost of decommissioning and associated impact(s)	£ (compare the impact on decommissioning complexity and costs)	1	Economic, Environment		Prosperous Globally responsible

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
10	Cost	Highly reliable and available (No unplanned maintenance and utilisation)	Availability (% of time averaged over lifetime), taking account of planned maintenance needs and failure reliability	3	Socio-Economic, Environment		Prosperous
11	Program-me and Cost	Minimise build schedule duration	Compare manufacturing and build duration (build target <3yrs)	3	Socio-Economic		Prosperous Cohesive communities
12	Program-me and Cost	Maximise modular build, standardisation and commoditisation	Contribution to achieving >60 % power station modularisation. Consider comparison of weight and size, connectivity and standardisation potential of the option	3	Socio-Economic		Prosperous Cohesive communities
13	Program-me and Cost	Maximise use of proven technology (minimise development cost/risk)	Technology/ manufacturing capability/material readiness level assessment and development risk measured as a development cost comparison, taking account of technology development and substantiation	1	E3S, Economic		-
14	Program-me and Cost	Compatible with existing UK / global infrastructure and capability	Novelty of capability and infrastructure required to support this option at all stages of development and through life. Qualitative comparison of risk	2	Socio-Economic		Prosperous

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
15	Program-me	Development Programme Timescale	Risk of not achieving deployment date - a measure of development programme timescale	2	Socio-Economic		Prosperous Resilient
16	Program-me	Enhanced UK public perception	Attractiveness to public - qualitative judgement regarding how appealing a feature would make the overall SMR. Covers aspects of aesthetics, siting and UK localisation intent (impact on jobs, security, environment etc.)	1	Socio-Economic		Prosperous Cohesive communities
17	Market	Maximise site availability and flexibility	Availability of sites (number of sites). How well the option maximises the potential sites compatible with the SMR deployment	2	Socio-Economic		Prosperous
18	Market	Capable of global expansion	Compatibility with global regulatory bodies and specific targeted regional requirements	2	Socio-Economic		Prosperous Globally responsible
19	Market	Optimised for baseload power generation	Ability to support base load power unit performance as the primary mode. Compare maximum reliable top end power output level, within other constraints of size	1	Socio-Economic		Prosperous

ID	Category	Key Objective	Metric	Weight	Sustainability Categories	UN SDG	WoFG
20	Market	Compatible with alternative usage/ application to base load power as a secondary demand	Compatibility with alternative usage for example, heat, flex (how well the option enables this). Compare ability to support flexible load following	1	Socio-Economic		Prosperous

1.3.3 Reference Designation System

Reference designation for SSCs within the RR SMR power station scope is implemented in accordance with the Standard Reference Designation System for Power Plants (RDS-PP®). RDS-PP® is internationally recognised and is referenced within the International Electrotechnical Commission (IEC)/International Organization for Standardization (ISO) 81346 series of standards. RDS-PP® provides a unique designation for each plant object throughout planning, licensing, construction, operation, maintenance, and decommissioning.

A functional product breakdown structure has been developed for the RR SMR architecture, which assigns unique RDS-PP® codes to SSCs using a hierarchical approach, from the power station (Level 0) to island (Level 1), to plant (Level 2), to system (Level 3), through to sub-system (Level 4) and component (Level 5).

The functional product breakdown structure enables consistent naming and designation of SSCs across the design of the RR SMR. The E3S Case is aligned to the functional product breakdown structure throughout each chapter of the E3S Case, with SSCs referred to by their RDS-PP® 'system' code using one or more capital letters enclosed within a square bracket '[XX]'. The SSCs within scope of the generic E3S Case, including their RDS-PP® code, are listed in Appendix A (section 1.10).

1.3.4 E3S Requirements Management

Requirements management underpins a systematic approach to engineering design of systems and components. As part of the systems engineering approach, requirements are flowed from the power station to structures or systems, and down to sub-system / component level in a clear, consistent, integrated, and traceable approach. The resultant hierarchical design then undergoes progressive V&V to demonstrate evidence-based compliance with the requirements set, and to give confidence that the solution meets the operational needs of the programme/customer.

Requirements are captured in RR SMR's requirements management database, in a structure that aligns to the functional product breakdown structure. Requirements management is a continuous process, applicable throughout the project delivery lifecycle. Requirements are managed such that at each stage of definition or phase of project, there is a defined and agreed set of approved and baselined requirements. Any change to these requirements shall be managed and communicated, with clear traceability of the reason for change and the impact of that change on the activity/design definition.

Requirements for a particular system are developed by stakeholders and documented within a requirements module in the requirements management database. E3S Requirements are part of the overall requirements set that feed into the requirements management process and information set. E3S requirements include both functional and non-functional requirements, described in Section 1.1.5.2.

E3S Requirements are derived through E3S analyses and from the E3S design principles and are captured within the requirements management database to enable full traceability from the derivation source, for example from the fault schedule to the SSC they are placed on, through to their V&V. Further details of E3S requirements generation and integration with engineering processes is described in the E3S Requirements and Analysis Arrangements [3].

SSCs are designed to achieve E3S requirements by engineering teams in conjunction with the E3S team, with the design solution documented in a design description report, and the application of the design optioneering process and conclusions with respect to ALARP, BAT, secure by design and safeguards by design documented in a design decision record template [22]. These outputs provide the arguments and evidence to underpin relevant claims in the E3S Case.

Verification and validation of E3S requirements provides the substantiation evidence to underpin relevant claims in the E3S Case, starting with development of a verification strategy to define the tasks that will incrementally generate the substantiation evidence in line with the V&V lifecycle. Verification strategies could include physical test rigs, simulations, or performance analysis, with the information stored in a verification module in the requirements management database that is linked to the requirements module. Further information on the V&V process is described in E3S Case Tier 1, Version 2 Chapter 3: E3S Objectives and Design Rules for SSCs [23].

The outputs of design and E3S analyses will include requirements for EMIT and OLCs, which inform the specification of the safe operating envelope (SOE) for operation of the plant. Further information on the process to ensure requirements are appropriately captured for plant operation is described in E3S Case Tier 1, Version 2 Chapter 16: Operational Limits and Conditions [24].

1.3.5 Control of Maturing Design

1.3.5.1 Reference Design

The maturity of the RR SMR as it evolves through the design lifecycle is controlled at a top-level through a series of programme maturity review gates, whereby an independent panel evaluates and confirms the maturity status of the power station design. The review gates progress as the product matures, from early readiness review, through concept and detailed design definition, to final installation and product readiness programme stages.

The programme maturity review process [25] defines a sequential gated review framework that evaluates the status of the RR SMR programme against maturity expectations, including the design definition and E3S Case, with the aim of identifying and managing programme risks.

Typically, at each programme maturity gate review an overall baseline for the RR SMR power station will be declared, at which point associated design certification and configuration records will be issued, and a master records index (MRI) that lists all the underpinning documentation. This baseline is referred to as the ‘Reference Design’ point.

The programme maturity review gates and associated RD will typically coincide with the design lifecycle stage. Each revision of the E3S Case is aligned to an RD maturity point, as described in Section 1.1.3.

1.3.5.2 Definition Review for SSCs

The maturity and definition of SSCs is controlled through the more detailed DR process [26]. It is structured around nine review gates as the SSC design matures, from DR0 (Launch) through to DR8 (Production Readiness). Multi-disciplinary reviews are staged at each gate, covering a broad range of topics such as scope and requirements definition, technical maturity of the design definition, E3S assessment, and verification strategies. A checklist of expected contents is defined for each gate to support the multi-disciplinary reviews.

E3S Subject matter experts are key stakeholders in the DR process to ensure development of each SSC is appropriately evaluated against E3S criteria and the E3S design principles, and that E3S requirements placed on the SSC are suitable and informed by analysis.

The design of individual SSCs may mature at different rates, and the design programme for concept definition has prioritised development of SSCs with higher E3S significance, including safety class 1 and 2 SSCs and radioactive waste systems. Therefore, at a given declared RD baseline for the overall design, some SSCs maybe at higher levels of maturity than others.

For each DR gate, a list of engineering outputs (i.e. the design definition) are developed, for example, an SDD, piping and instrumentation diagram (P&ID), design decision records, and verification strategies. Many of these outputs provide the arguments and evidence to underpin high-level claims in the E3S Case, that a system is designed and verified to deliver its E3S functions through-life, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with secure by design and safeguards by design.

During the current design lifecycle stage, the generic E3S Case is developed for the concept design as it is developed into a detailed design. For completion of the concept design of an SSC, the DR3 maturity gate is a key milestone, with the general expectation of stable E3S requirements and a suitable level of underpinning E3S and performance analysis. Typical maturity expectations of the DR3 gate with respect to the E3S Case, outlined in the DR process [26] and associated DR checklist, include (but are not limited to):

- Relevant non-functional system requirements from the E3S design principles are applied to the SSC for compliance, with any known gaps noted
- Codes and standards that each SSC is being designed to are identified and captured in requirements
- Identification of where SSC functions contribute to a safety measure with traceability to the fault schedule via the Safety Measures module (or timebound action to implement traceability)
- Categorisation of safety functions and classification of the SSC

Beyond DR3, SSCs are subject to a change control process [27], which controls design changes that may occur outside the detailed design development, for example, in response to analysis that highlights a shortfall against E3S numerical targets, regulatory assessment, or international requirements. The design change process and how changes to the design are addressed in the E3S

Case are described further in E3S Case Tier 1, Version 2 Chapter 17: Management of E3S and Quality Assurance [18].

1.4 Site Layout

The RR SMR general site layout at RD7 design stage (corresponding to GDA DRP1) is illustrated in Figure 1.4-1, with further detail of each area and their interfaces described in the RD7 design report [28] and associated general arrangement site plans [29] and [30].

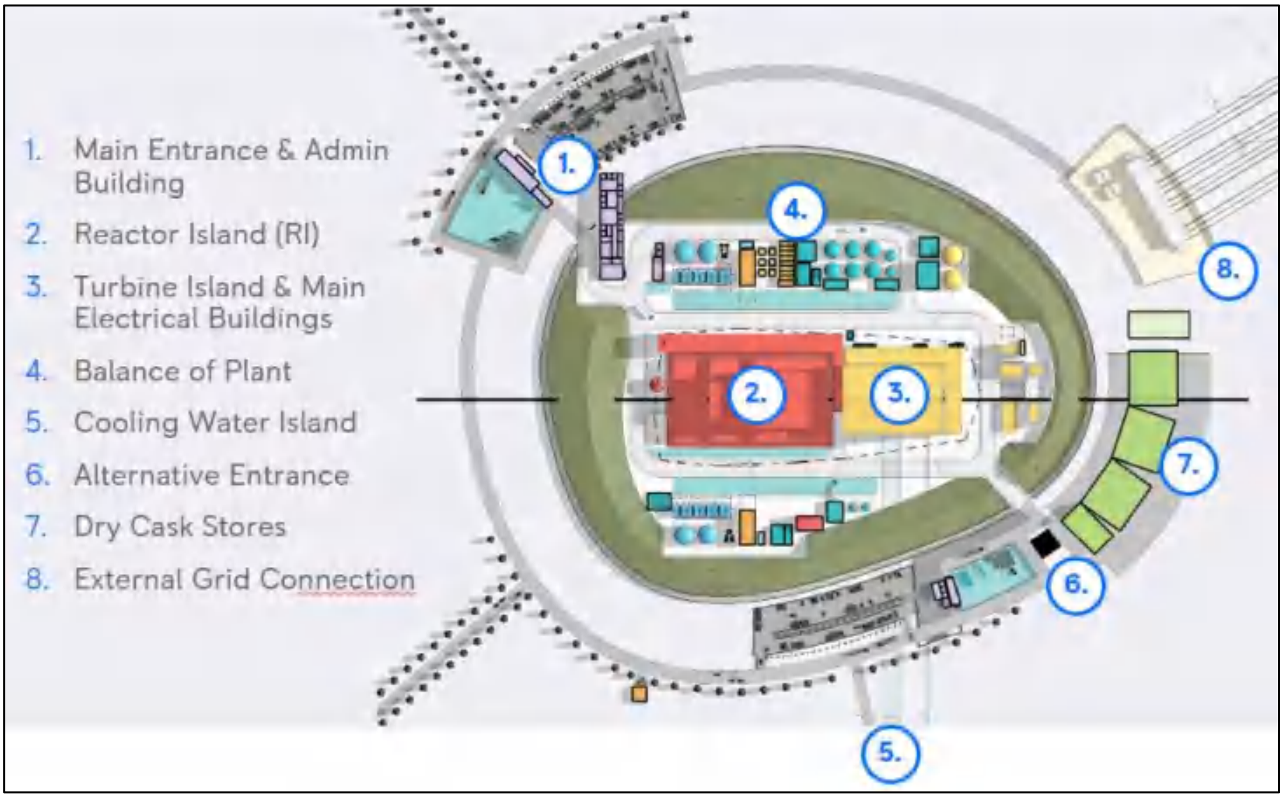


Figure 1.4-1 RR SMR Site Layout

Turbine Island [T01] has been located adjacent to Reactor Island [R01], to enable ease of connection and routeing, particularly of the steam and the feedwater pipes running between containment within Reactor Island [R01] and the Turbine/Condenser within Turbine Island [T01], to minimise steam pressure losses which maximises electrical output.

An axial route between Reactor Island [R01] and Turbine Island [T01] has been utilised to inform the main routeing of the major elements required to enable a nuclear power plant to function. New fuel import, fuel handling, fuel transfer channel, containment, outage, steam and feedwater pipes, turbine hall and main generator, transmission area and main feed to National Grid are all located along the central axis from West to East of the site. The main transmission area [A], which contains the grid connection, has been positioned directly adjacent to Turbine Island [T01] to minimise routeing and power loss. The axial arrangement also minimises exposure of Reactor Island [R01] structures to hazards related to turbine disintegration debris.

The primary access point to RR SMR has been positioned to the north-west of Reactor Island [R01] so as to have a close relationship with the Reactor Island [R01] support building, which contains the access functions.

The location of Reactor Island [R01], Turbine Island [T01], and the main transmission area [A] along the central axis also enables efficient enclosure within the site factory during construction. The generic RR SMR layout has been set out specifically to separate routeing for pedestrian and vehicular access (to the ‘northwest’), water connections (to the ‘south’) and electrical connections (to the ’east’). The generic design can be rotated to suit sites while ensuring pedestrians, water and electrical routes are separated.

The main bulk of the Reactor Island [R01] building has been utilised as the separating factor between the two trains of, respectively, essential services water system (ESWS) [PB] and backup generation [BD01] and [BD02]. The two ESWS [PB] and backup generation [BD01] [BD02] trains have been specifically located as far north and south of RI as practicable to maximise separation. Each backup generation [BD01] [BD02] train sits adjacent to the respective train of ESWS [PB] and has been located to provide the minimum free airspace that avoids air recirculation and enables functional efficiency. The siting of the ESWS [PB] and backup generation [BD01] [BD02] has been located to coordinate with the spatial requirements for the construction and demolition sequence of the site factory and to enable early construction whilst the site factory is in place.

Further details of the layout of buildings and site levels are described in the layout summary report [31].

1.5 General Plant Description

1.5.1 RR SMR Overview

The RR SMR design is based on an optimised and enhanced use of proven technology, with a single unit, three-loop PWR providing a target power output of 470 MW_e.

The following sub-sections provide a summary of the RR SMR technical parameters, and a summary of each of the 'islands' that comprise the power station.

1.5.1.1 Fundamental Characteristics

The major technical parameters of the RR SMR [32] are summarised in Table 1.5-1, with site footprint parameters are listed in Table 1.5-2.

Table 1.5-1: RR SMR Major Technical Parameters

Parameter	**Value**
Thermal Capacity	1358 MW_{th}
Net Electrical Power (dependent on configuration and site)	450 – 470 MW_e
Design Life	60 years
Expected Capacity Factor	>90 %
Coolant / Moderator	Light Water
Primary Circulation	Pumped at power Natural Circulation for backup decay heat removal
Primary System Operating Pressure	15.5 MPa
Primary System Design Pressure	17.6 MPa
Fuel Cycle	18 months
Fuel Type / Assembly Array	Industry standard Uranium Oxide fuel in 17x17 array
Fuel Active Length	2.8 m
Number of Fuel Assemblies	121
Fuel Enrichment (Maximum)	4.95 %
Reactivity Control Mechanism	89 Control rods for primary control and alternative boron shutdown system as backup
Outage Duration	18 days (target)
Containment Type	Steel Containment
RPV Height	7.82 m

Parameter	Value
RPV Diameter	Overall Diameter (outer flange): Approximately 4 m Maximum Diameter (safe end nozzles): Approximately 5 m
Number of Steam Generators	3

Table 1.5-2: RR SMR Site Footprint Parameters

Parameter	Value
Site footprint area – under the shell	18,550 m^2
Site footprint area – inside berm	54,500 m^2
Site footprint area – inclusive of berm	100,000 m^2

1.5.1.2 Reactor Island [R01]

The Reactor Island [R01] includes the systems that form the reactor, transfer, and storage of new and used fuel, and any associated nuclear auxiliary systems. The purpose of Reactor Island [R01] is to use the heat from a controlled nuclear fission reaction to generate steam, which is then passed to the Turbine Island [T01]. Reactor Island [R01] includes the Reactor Plant [J], Handling of Nuclear Equipment [F] and Nuclear Auxiliary Systems [K].

The Reactor Plant [J] comprises:

- Reactor System [JA], containing the systems and components that generate and transfer nuclear heat in a safe, controlled manner. It comprises a RPV [JAA] of very high reliability, an Integrated Head Package (IHP) [JAB] to facilitate core loading and core unloading, and RPV Internals [JAC10] to hold the fuel assemblies in place. Descriptions of the associated systems and components are summarised in E3S Case Tier 1, Version 2 Chapter 4: Reactor (Fuel & Core) [33].

- Reactor Reactivity Control Systems [JD], which provide the control of reactivity (CoR) fundamental safety function (FSF). This includes the Scram Function [JD01], which uses control rods to provide solid neutron absorption during normal operating modes and rapid shutdown in the event of a fault, and the independent and diverse Alternative Shutdown Function (ASF) [JD02], which injects potassium tetraborate into the Reactor System [JA] at high pressure during relevant fault conditions. Descriptions of the associated systems are summarised in E3S Case Tier 1, Version 2 Chapter 6: Engineered Safety Features [34].

- RCS [JE], comprising a three-loop system each with a steam generator (SG), associated pipework and a single pump. The configuration of the SG pipework and pump layout in each loop ensures a robust thermal driving head for natural circulation flow in fault conditions. The system also contains a pressurising system with a heater and pump induced spray configuration and associated pressure relief system. Descriptions of the associated systems and components are summarised in E3S Case Tier 1, Version 2 Chapter 5: Reactor Coolant System & Associated Systems [35].

- Reactor Plant Containment Systems [JM], providing the systems that ensure the confinement of radioactive material (CoRM) FSF in normal and fault conditions. Descriptions of the associated systems are summarised in E3S Case Tier 1, Version 2 Chapter 6: Engineered Safety Features [34].

- Reactor Heat Removal Systems [JN], containing the systems that provide decay heat removal to provide the control of fuel temperature (CoFT) FSF in response to fault conditions. This includes the Emergency Core Cooling (ECC) [JN01], which is the principal means of providing passive decay heat removal in the event of an intermediate or large loss of coolant accident (LOCA), and the Passive Decay Heat Removal (PDHR) [JN02], which provides decay heat removal in the event of an intact circuit fault. Descriptions of the associated systems are summarised in E3S Case Tier 1, Version 2 Chapter 6: Engineered Safety Features [34].

- Reactor Island C&I [JQ][JR][JS][JT][JY], containing the nuclear C&I systems for control, monitoring and protection of SSCs delivering a nuclear safety function. Descriptions of the C&I systems are summarised in E3S Case Tier 1, Version 2 Chapter 7: Instrumentation & Control [36].

The Handling of Nuclear Equipment [F] includes those systems that cover the fuel route from initial receipt of new fuel to final disposal, summarised in E3S Case Tier 1, Version 2 Chapter 9A: Auxiliary Systems [37].

The Nuclear Auxiliary Systems [K] comprises of auxiliary systems supporting Reactor Plant [J] operations, including:

- Component Cooling Systems [KA] and associated coolant treatment and sampling, to transfer heat from reactor components to the ultimate heat sink in a safe manner. Descriptions of the associated systems are summarised in E3S Case Tier 1, Version 2 Chapter 9A: Auxiliary Systems [37].

- Heating, Ventilation and Air Conditioning (HVAC) systems [KL], summarised in E3S Case Tier 1, Version 2 Chapter 9A: Auxiliary Systems [37].

- Solid Waste Treatment [KM], Liquid Waste Treatment [KN], Gaseous Waste Treatment [KP] and Collection & Drainage Systems [KT] summarised in E3S Case Tier 1, Version 2 Chapter 11: Management of Radioactive Waste [38].

The Electrical Power System [B] is also located within Reactor Island [R01], described in section 1.5.1.6.

A composite P&ID of Reactor Island [R01] is presented in [39].

1.5.1.3 Turbine Island [T01]

The Turbine Island [T01] provides the link between the Reactor Island [R01] where steam is generated, and the electrical connections where generated electricity is provided to the power grid. The primary equipment in Turbine Island [T01] is the steam turbine and generator arrangement, where the mechanical energy of steam is converted into electrical energy. The Turbine Island [T01] includes the Steam, Water, Condensate System [L] and Main Turbine Generator System [M].

The main systems within the Steam, Water, Condensate Systems [L] include:

- Feedwater System [LA], Steam System [LB], Condensate System [LC], and Condensate Polishing System [LD], summarised in E3S Case Tier 1, Version 2 Chapter 10: Steam & Power Conversion Systems [40].

- Emergency Feedwater System [LJ], which provides an independent feedwater provision following loss of main feedwater due to a fault, summarised in E3S Case Tier 1, Version 2 Chapter 6: Engineered Safety Features [34].

The Main Turbine Generator System [M] will be housed within a dedicated turbine hall along with other turbine equipment. Its purpose is to convert steam into mechanical energy through centrifugal action. The key systems include the Steam Turbine System [MA], the Generator System [MK], and Auxiliary Systems [MU], summarised in E3S Case Tier 1, Version 2 Chapter 10: Steam & Power Conversion Systems [40].

1.5.1.4 Cooling Water Island [C01]

Cooling Water Island [C01] provides the primary means of removing heat from the power station, passing it to the ultimate heat sink, relying on the external environment to provide a means of cooling. Rolls-Royce SMR's aim is to provide a standardised product that can operate on a wide range of sites through minimal adaption and optimisation of a single design, where such sites potentially including inland, lake, river, estuarine and coastal locations. An indirect system at a coastal site has been selected as the baseline design, noting the final solution will be site-specific.

Cooling Water Systems [P] are summarised in E3S Case Tier 1, Version 2 Chapter 9A: Auxiliary Systems [37], comprising:

- Main Cooling Water System (MCWS) [PA]

- Auxiliary Cooling & Make-up System (ACMS) [PE]

- Essential Service Water System [PB]

- Turbine Island Closed Cooling Water System [PG]

- Common Systems for the Cooling Water Systems [PU]

1.5.1.5 Balance of Plant [B01]

The Balance of Plant [B01] systems support the availability of the power station by providing a range of support functions to the rest of the plant, which are of low safety significance but important to maximising output and plant efficiency and minimising environmental impacts. This includes the provision of chemicals, utilities, water and sampling services, and general storage areas. The facilities include the Water Supply, Disposal, Treatment System [G], Auxiliary Systems [Q], Storage Systems [V] and Ancillary Systems [X]. The Balance of Plant [B01] systems in scope of GDA are summarised in E3S Case Tier 1, Version 2 Chapter 9A: Auxiliary Systems [37].

1.5.1.6 Electrical, Control and Instrumentation Systems [E01]

Electrical, Control and Instrumentation Systems [E01] includes systems relating to grid connection and intra-site electrical distribution, including the Grid Transmission System [A], Electrical Power System [B], Generator Transmission Main Connection [MS] and Earthing and Lightning Protection System [XF].

The Electrical Power System [B] includes the provision of emergency power supplies, which incorporates significant defence in depth to provide backup power in the event of Loss of Off-site Power (LOOP) and Station Blackout (SBO) faults.

Descriptions of electrical power systems are summarised in E3S Case Version 2, Tier 1, Chapter 8: Electrical Power [41] and C&I systems are summarised in E3S Case Version 2,Tier 1, Chapter 7: Instrumentation & Control [36].

1.5.1.7 Civil, Structural & Architectural Systems [CIV]

Civil, Structural & Architectural Systems [CIV] provide the physical structures which house, support and protect all other systems across the power station. This includes the base isolation system delivered by the aseismic bearings, and the hazard shield providing protection from external hazards.

Descriptions of the associated structures for the power station are summarised in E3S Case Version 2, Tier 1, Chapter 9B: Civil Structures [42].

1.5.2 Construction & Build Certainty

The RR SMR is designed as a modular and standardised power station product. This means that each RR SMR is substantively the same as the others; so far as is possible within the constraints of site-specific geography. To achieve this design outcome, the RR SMR civil design is split into two: groundworks/foundations, and power station modules and buildings.

The groundworks and foundations supporting the RR SMR are necessarily bespoke and matched to local site conditions. They support an aseismic bearing, upon which the critical modules and buildings reside.

The modules and buildings are identical from site to site and consist of factory produced modules and components that are assembled into a functioning RR SMR on-site.

During construction, most RR SMR structures and equipment will be enclosed within a ‘site factory’, which minimises the impact of factors such as adverse weather conditions on programme schedules, whilst enabling 24/7 working. The site factory provides both isolation of the site from the environment, and isolation of the environment from the site.

1.5.3 Operating Philosophy

1.5.3.1 RR SMR Applications

The baseline application for RR SMR, and scope of the generic E3S Case (and GDA), is electricity production. The RR SMR also has other potential applications such as:

- Combined Heat and Power (CHP) – grid electricity plus steam off-take, for example, district heating
- E-fuels:
    - Hydrogen only via ‘high’ temperature solid oxide electrolysis with steam off-take

  - As above but with electricity to off-grid synthetic fuel plant, for example, Fischer-Tropsch process
  - 'Pure' electricity for Hydrogen production
  - Carbon capture for E-fuels
- Desalination – electricity and/or steam off-take to desalination plant

Each application requires the RR SMR to operate in different ways:

- Base load – consistent output of steam and/or electricity
- Load following – responding to changes in demand from the application. These changes in demand could be regular and significant and require turbine and reactor systems to respond to provide the required increase or decrease in demand
- Frequency response – responding to small changes in frequency, these changes are largely accommodated within the turbine systems. Frequency response is required for any application which provides electricity, and could have changes in load, which subsequently results in a change in frequency

The RR SMR is designed for full compliance with the UK Grid Code [43]. The Connection Conditions in the Code specify the "minimum technical, design and operational criteria" for connection to the grid. The Conditions include some minimum requirements for the 'flexibility' of the power station, which include:

- Limits on the minimum and maximum power output
- Withstanding grid frequency and voltage variations
- Grid fault ride-through capability
- The capability to operate in a frequency-sensitive mode in which power output is automatically adjusted in response to the grid frequency

Similar capabilities will be required for connection to the grid in other countries, which will be assessed as the locations for the RR SMR deployment are confirmed. A summary of the applications and capabilities for the RR SMR is provided in the power station operating philosophy [44].

1.5.3.2 Modes of Operation

Fundamentally, the power station operates in distinct modes of Power Operations or Shutdown Operations. The modes are developed further and characterised by RCS [JE] temperature, pressure, and refuelling status:

- Mode 1 – Power Operation
- Mode 2 – Low Power
- Mode 3 – Hot Standby
- Mode 4A – Hot Shutdown – Steaming

- Mode 4B – Hot Shutdown – Non-Steaming
- Mode 5A – Cold Shutdown (Pressurised)
- Mode 5B – Cold Shutdown (Depressurised)
- Mode 6A – Refuelling with Reduced Water Level above Fuel
- Mode 6B – Refuelling with Water Level above Fuel at Nominal Full

The power station is safely shutdown when the control rods are fully inserted on the transition from Power Operations (Modes 1 and 2) to Shutdown Operations (Modes 3-6). The power station remains shutdown in Modes 3-6, and on the return to Power Operations the control rods are first withdrawn in Mode 2.

The RCS temperature and pressure for each operating mode is presented in Figure 1.5-1.

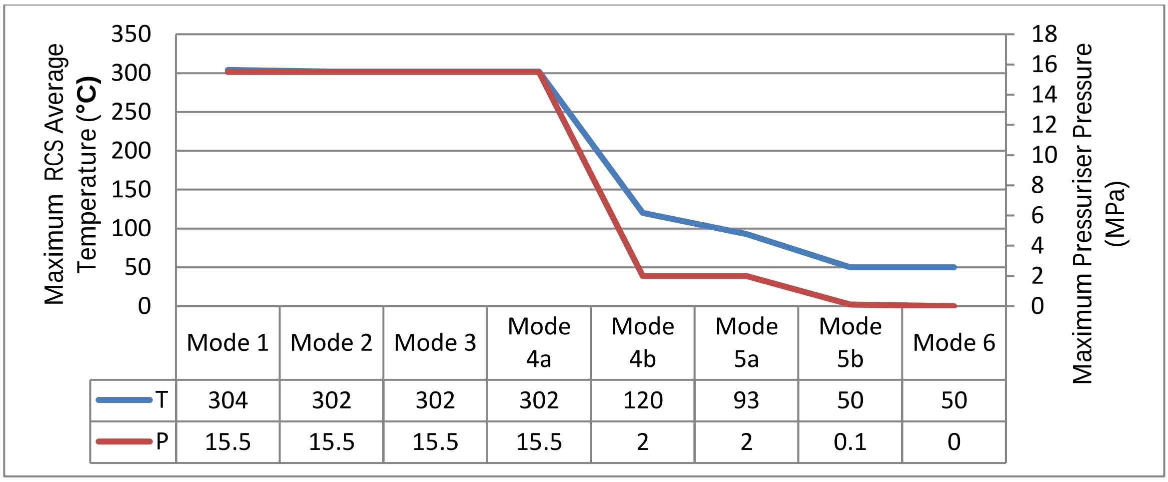


Figure 1.5-1: Operating Mode Parameters

There will be a clear distinction between each of these modes for Reactor Island [R01], with changes in RCS temperature, pressure and alignment or release of systems. Other areas may be required to provide different functions to Reactor Island [R01] across each of the modes.

The means by which the plant and operator maintain control of key functions across the operating modes are outlined in further detail in E3S Case Version 2, Tier 1, Chapter 13: Conduct of Operations [45].

1.5.3.3 RR SMR Lifecycle

The RR SMR has a planned lifetime of approximately 60 years, with refuelling and maintenance required periodically. Refuelling is carried when the reactor is offline and not producing power. The frequency and duration of these 'outages' will be minimised as far as is safe and practicable to optimise the availability of the RR SMR.

Maintenance is completed throughout the lifetime of the power station; depending on the activities required these can be completed whilst the reactor is on-line or off-line. In targeting at least 90 % availability over the 60-year life of the RR SMR, on-line maintenance (where safe to do so) and short outage durations (18-day target) will be key enablers.

1.5.3.4 RR SMR Control

Monitoring and control of the RR SMR will be centralised within the main control room (MCR), located within Reactor Island [R01]. From here, the operators monitor the reactor response to changes in turbine load, driven by demand from the facility which the RR SMR is supporting (for example, the electricity grid).

From the MCR, the operators can take action to correct identified deviations, however the design of the plant means that no remote operator actions are required within the first 30 minutes of a fault being identified. In addition, no local operator actions will be required within the first hour of a fault being identified. Whilst actions are not required to support the E3S Case, the operators will be able to act if they are able to correctly diagnose the fault, and procedures are available to support them.

If the MCR is uninhabitable (e.g., due to fire), then the operators can transfer to the supplementary control room (SCR). The SCR is also located within Reactor Island [R01], such that a single incident should not threaten both control rooms (for example, with appropriate separation and segregation) but also to allow safe transfer of personnel. The SCR will include monitoring and control of safety related systems, to ensure a safe shutdown state is achieved and maintained. The SCR is not intended for continuing normal power operations.

The RR SMR will also include an emergency control centre (and associated facilities) on-site for managing events. An off-site emergency control centre will also exist; this may be shared between power stations dependent on location. A security control centre (and additional access control points) will provide the ability to monitor the site and control access.

1.5.3.5 Fleet Approach

The RR SMR is a single design, deployable across regions and customers without significant design modifications. One of the benefits which this approach delivers is the potential to share data and knowledge across the RR SMR operators, supporting optimisation of various aspects such as operations, maintenance, or staffing.

The various options for a fleet support approach will be implemented in conjunction with licensees, which could range from individual RR SMR stations that are co-ordinated by the licensee through to options for centralised hubs and data centres which can share data, equipment, and resource across multiple SMRs and licensees. In all operating models the licensee retains their Duty Holder / Design Authority responsibilities.

1.6 Comparison with other Plant Designs

The RR SMR programme commenced in 2016, with key design principles established early that were driven by market requirements and lessons learnt from previous nuclear power plant programmes. This led to the 20 key design objectives being established for RR SMR, which have been consistently applied as the basis for design optioneering (see Table 1.3-1).

The RR SMR is a FOAF design and not based on a currently operating reference plant. The design is however fundamentally based on proven PWR technology, using industry standard uranium fuel. The initial reference design baseline, RD1, was established in 2015 with limited maturity, reflecting fundamental decisions such as the selection of PWR technology and a boron-free chemistry regime. The RGP and decision rationale is described in E3S Case Version 2, Tier 1, Chapter 24: ALARP Summary [46].

The design definition for the RR SMR has significantly increased in maturity since RD1 through extensive optioneering and design decisions undertaken in line with ALARP, BAT, secure by design and safeguards by design, with progressive design baselines established. RD7 was established in November 2023, which forms the basis for Version 2 of the E3S Case (see Section 1.1.3).

The main innovations for RR SMR are in the fabrication and construction of the modular nuclear plant, incorporating use of proven techniques and RGP from other industries. In comparison to existing PWR power stations, the RR SMR at RD7 (aligned to GDA DRP1) does incorporate notable innovations that provide benefits with respect to E3S, including:

- Passive and diverse heat removal systems (the ECC [JN01] and PDHR [JN02]) to provide decay heat removal in response to fault conditions, each with significant internal redundancy, and with no reliance on essential services supplied from on-site mobile equipment for 72 hours or from off-site for 7 days.

- Boron-free chemistry, with full shutdown margin provided by the control rods alone, which allows 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 use of potassium hydroxide (KOH) as the pH raiser, rather than lithium hydroxide (LiOH) that is used in conjunction with boric acid in traditional PWRs, also offers benefits such as reduction in the tritium source term and potential mitigation of fuel cladding corrosion.

- A base isolation system, which reduces the seismic hazard for the Reactor Island [R01] and adjacent safety significant structures. 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.

- A forced draught cooling system, which is adaptable to different cooling water constraints such that the RR SMR is deployable across a wide range of sites.

- Emergency blowdown relies on a mechanical valve design that provides reactor coolant relief in conditions where ECC [JN01] is demanded. The design of this valve practically eliminates a spurious opening of the blowdown line fault and minimises the safety requirements placed onto the C&I systems.

The innovations for the RR SMR with respect to reducing risks to ALARP are described further in E3S Case Version 2, Tier 1, Chapter 24: ALARP Summary [46].

1.7 Summary of Environmental Aspects

1.7.1 GDA Information Requirements

This section provides a summary of key information contained in the primary environmental chapters of the E3S Case (Version 2, Tier 1, chapters 2, 11 and 26 to 31). Table 1.7-1 maps the 'General information about the RP and the design' requested in the GDA guidance to RPs to the relevant chapters where such information is presented. More detailed requirements are mapped in subsequent sections.

Table 1.7-1: Map of Information Requirements to E3S Case

GDA Information Requirements	Chapter of E3S Case
Details about the RP, including its company structure and its experience of reactor design and plants in service are provided	E3S Case Version 2, Tier 1, Chapter 1 [Section 1.2.2]
A simple, outline description of the design including schematic diagrams is provided	E3S Case Version 2, Tier 1, Chapter 1 [Sections 1.4 and 1.5] E3S Case Version 2, Tier 1, Chapter 25
A brief history of the design of traditional PWR and the main design changes from this plant	E3S Case Version 2, Tier 1, Chapter 1 [Section 1.6]
Identification of discharge points to the environment for gaseous and aqueous radioactive wastes	E3S Case Version 2, Tier 1, Chapter 1 [Section 1.7.5] E3S Case Version 2, Tier 1, Chapter 25 E3S Case Version 2, Tier 1, Chapter 29 E3S Case Version 2, Tier 1, Chapter 11
A summary of the proposed disposals of radioactive waste and their potential impact on members of the public and non-human species at the generic site	E3S Case Version 2 Tier 1, Chapter 1 [Section 1.7.7] E3S Case Version 2, Tier 1, Chapter 11 E3S Case Version 2, Tier 1, Chapter 29 E3S Case Version 2, Tier 1, Chapter 30
A summary of the proposed conventional environmental impacts	E3S Case Version 2, Tier 1, Chapter 1 [Section 1.7.8] E3S Case Version 2, Tier 1, Chapter 31
A description, and the characteristics, of the generic site (or sites) that the RP will use for its assessment of radiological and conventional impacts on people and the environment	E3S Case Version 2, Tier 1, Chapter 1 [Section 1.7.2] E3S Case Version 2, Tier 1, Chapter 2

1.7.2 Generic Site Description

The GSD describes the characteristics of a generic site for purposes of the GDA. This includes associated location parameters, that will form the basis for assessing radiological and conventional impacts on people and the environment, predicted to arise from operating the RR SMR. The generic site is assumed to be a rural coastal site, set on a flat plain with no freshwater bodies within or close to the site, and no freshwater courses traversing the site. The GSD also assumes that there are no designated sites or species of conservation importance within or close to the site, nor is there contamination of the ground or groundwater.

Geographical parameters and site characteristics defined in the GSD are typical of GB coastal locations, where the RR SMR plant is assumed to be situated for purposes of the GDA, and include information such as:

- Meteorological and other parameters which affect the dispersion and depositions of gaseous discharges from the RR SMR
- Hydrographic and other parameters which affect the dispersion of aqueous discharges from the RR SMR
- The habitation of local exposure groups and their food source locations, relative to the RR SMR plant
- Food consumption rates and other human habits data
- A list of reference organisms assumed to be present in the vicinity of the site (for the assessment of radiological impacts on non-human biota)

Details of the GSD are presented in E3S Case Version 2, Tier 1, Chapter 2: Generic Site Characteristics [4].

1.7.3 Radioactive Waste Management Arrangements

An integrated waste strategy (IWS) outlining the proposed approach for managing conventional and radioactive wastes arising from RR SMR has been prepared. The IWS presents a summary of predicted RR SMR waste inventory, and strategies for managing the different waste streams making up this inventory (including radioactive and conventional wastes in solid, liquid, and gaseous form, and materials that could become waste), and covers all phases of the plant lifecycle.

The IWS also describes how the strategy has been developed and applied in the context of the political, regulatory, and business requirements associated with the operation of new nuclear power plants (NPPs) in the UK.

Further, Rolls-Royce SMR Limited have initiated engagements with the Nuclear Waste Services (NWS) to support the development and assessment of disposability case; to support the demonstration that predicted arisings of higher activity waste and spent fuel can be disposed of in a future geological disposal facility (GDF).

The IWS and disposability assessment form the key inputs into the radioactive waste management arrangements, along with the radioactive waste systems, details of which are presented in E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [38].

1.7.4 Demonstration of BAT

The application of BAT in the context of the RR SMR design development is framed around four fundamental radiological claims (following the CAE approach described in Section 1.1.5), which seek to demonstrate that the RR SMR design:

- Eliminates or reduces the generation of radioactive waste
- Minimises the amount of radioactivity discharged or disposed of to the environment
- Minimises the volume of radioactive waste disposed to other premises
- Minimises the impacts on the environment and members of the public from radioactive waste discharged or disposed of to the environment

The approach to BAT is fully integrated into the engineering design process. Details of the approach for, and demonstration of, the use of BAT in the RR SMR design are presented in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of BAT [47].

1.7.5 Radioactive Effluent Discharges Points

Aqueous radioactive effluent will be discharged via a single discharge line to the cooling water outfall prior to release into the receiving environment. The accountancy points for final discharge of all aqueous radioactive effluent are currently going through engineering design process (optioneering). Flow proportional sampling equipment to enable samples to be taken to comply and flow measurement will be located to achieve compliance with future permits.

At RD7/DRP1, gaseous radioactive effluent will be discharged to the environment through a main exhaust emission stack at the top of the Reactor Island building, see E3S Case Version 2, Tier 1, Chapter 28: Sampling and Monitoring Arrangements [48]. As the design matures, it is likely that other radioactive gaseous outlets will be identified (such as from waste stores or from other islands) and will be captured as part of the E3S Case development.

The design of the main exhaust stack is currently in development, but it is expected to receive gaseous effluents from the Gaseous Radioactive Effluent Treatment System [KPL] and the nuclear HVAC system [KL]. As the design develops it will be supported by appropriate atmospheric dispersion modelling to ensure that the stack is optimised to minimise the impact of discharges on people and the environment, consistent with the use of BAT.

Details of the RR SMR radioactive waste treatment systems and associated structures will be presented E3S Case Version 2, Tier 1, Chapter 25: Detailed Information about the Design [49] and E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [50], with the demonstration of BAT for these systems and structures presented in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of BAT [47].

1.7.6 Discharges of Liquid and Gaseous Radioactive Effluent to the Environment

An assessment of potential discharges of liquid and gaseous radioactive effluent from the RR SMR to the environment, under normal operating conditions, has been performed. Annual discharge limits are also proposed for significant radionuclides present in the predicted discharges to the environment. The assessment was performed using available design information and published OPEX data from PWR plants and reflects the current level of maturity of the RR SMR.

Normalised discharges of liquid waste to the environment are well below the maximum values reported at a range of operational light water reactors, and within the range of predicted discharges from other GDA candidate reactors. The normalised annual discharge of gaseous radioactive effluent from the RR SMR is broadly consistent with the average of forecast or reported discharges from other PWR plants. Higher values reported for some selected radionuclides are considered to be a consequence of conservative assumptions made in relation to primary source term radionuclide concentration, abatement technology or radionuclide speciation, and are expected to be reduced as further information on the primary source term and reactor design develops.

Details of the quantification of radioactive effluent discharges to the environment, including an overview of the approach, underlying assumptions, parameter values and design information are presented E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [50].

1.7.7 Prospective Impacts of Radioactive Discharges on Members of the Public and Non-Human Species

A detailed assessment of prospective radiological impacts associated with discharges of aqueous and gaseous radioactive effluent from the RR SMR (at proposed annual limits) has been carried out. The assessment was performed using the EA's initial radiological assessment tool, utilising RR SMR RD6 (and RD7 information where available) design information and primary source term and the characteristics of a generic site. Conservative assumptions have been made to account for data such as the contribution from direct radiation pathways, which are currently unavailable.

The prospective annual dose to a representative member of the public (based on continuous discharge of radioactive effluents) is estimated to be around 7 μSv/yr, which is well below the source dose constraint of 300 μSv/yr. The dose rate to the worst affected non-human organism is estimated at around 0.02 μGy/h, which is significantly less than the screening dose rate of 10 μGy/hr and the guideline dose rate of 40 μGy/hr.

Details of the radiological assessment are presented in E3S Case Version 2 Tier 1, Chapter 30: Prospective Radiological Assessment at the Proposed Limits for Discharges and for any On-Site Incineration [51].

1.7.8 Conventional Environmental Impacts

An appraisal of other environmental regulations and associated environmental impacts has been undertaken, based on the RR SMR design maturity at RD7 (aligned to GDA DRP 1). The appraisal considered the GDA information requirements for other environmental regulations and included a preliminary review of conventional (i.e., non-radioactive) environmental aspects of the RR SMR in the following topic areas:

- Water use and abstraction
- Discharges to surface water
- Discharges to groundwater

- Operation of installations (combustion plant and incinerators)
- Fluorinated greenhouse gases and ozone-depleting substances

Each of these topics, and details of the other environmental regulations and conventional environmental aspects, are presented in E3S Case Version 2, Tier 1, Chapter 31: Conventional Impact Assessment [52].

1.8 Conclusions

This chapter presents the introduction to the suite of 33 chapters that comprise Version 2 of the generic E3S Case. It outlines the holistic approach to E3S that is adopted for the RR SMR, and the overall structure of the E3S Case that facilitates the demonstration that the fundamental objective 'to protect people and environment from harm' can be achieved at all lifecycle stages of the power station, and demonstrate that risks can be reduced to ALARP, using BAT, and ensuring secure by design and safeguards by design, as well as sustainability in the design.

Version 2 is developed as a generic E3S Case and provides the basis for submissions as part of the GDA regulatory assessment process, aligned to DRP 1, that was declared during GDA Step 2.

The generic E3S Case is being developed alongside the ongoing design programme, as such the full suite of documentation / data that will comprise the full generic E3S Case and underpin the claims made is still in development. The trajectory of arguments and evidence being generated, where known at this stage of the lifecycle, is documented in the E3S Case Route Map for each chapter. Commentary on the maturity of arguments and evidence at Version 2 of the generic E3S Case, and the forward trajectory of information for the development the generic E3S Case, is provided in the conclusions for each chapter.

1.9 References

[1] Rolls-Royce SMR Limited, SMR0001603/001, “Rolls-Royce SMR Environment, Safety, Security and Safeguards Design Principles,” August 2022.

[2] Rolls-Royce SMR Limited, C3.2.2-2, Conduct Design Optioneering.

[3] Rolls-Royce SMR Limited, SMR0009132 Issue 1, Environment, Safety, Security and Safeguards (E3S) Requirements and Analysis Arrangements, 2023.

[4] Rolls-Royce SMR Limited, SMR0004542 Issue 3, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 2: Generic Site Characteristics,” May 2024.

[5] Rolls-Royce SMR Limited, SMR0000627 Issue 2, E3S Case Development and Management Arrangements, 2023.

[6] IAEA, “SSG-61: Format and Content of Safety Analysis Report for Nuclear Power Plants,” 2021.

[7] U.S. Nuclear Regulatory Commission, Regulatory Guide 1.70, Revision 3, Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition.

[8] U.S Nuclear Regulatory Commission, Regulatory Guide 1.206, Revision 1 - Applications for Nuclear Power Plants, October 2018.

[9] Gov.UK, New nuclear power plants: Generic Design Assessment guidance for Requesting Parties. Available from: https://www.gov.uk/government/publications/new-nuclear-power-plants-generic-design-assessment-guidance-for-requesting-parties/new-nuclear-power-plants-gen, October 2023.

[10] Office for Nuclear Regulation, Revision 1, “Security Assessment Principles for the Civil Nuclear Industry,” March 2022.

[11] ONR-CNSS-MAN-001 Rev5, “ONR Nuclear Material Accountancy, Control, and Safeguards,” 2022.

[12] IAEA, NP-T-2.9, International Safeguards in the Design of Nuclear Reactors.

[13] Rolls-Royce SMR Limited, SMR0002155 Issue 3, E3S Case Route Map, November 2023.

[14] ONR, ONR-GDA-GD-006 Revision 0, “New Nuclear Power Plants: Generic Design Assessment Guidance to Requesting Parties,” October 2019.

[15] Rolls-Royce SMR Limited, SMR0001328 Issue 2, Regulatory Affairs Group Functional Manual, 2023.

[16] Rolls-Royce SMR Limited, SMR0009043 Issue 2, Rolls-Royce SMR – GDA Design Reference Report, April 2024.

[17] Rolls-Royce SMR Limited, SMR0002183/002, “Rolls-Royce SMR Generic Design Assessment Scope,” January 2023.

[18] Rolls-Royce SMR Limited, SMR0004334 Issue 3, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 17: Management for E3S and Quality Assurance,” May 2024.

[19] Rolls-Royce SMR, SMR0002119 Issue 1, Identifying, recording, and tracking GDA and Licensing Assumptions and Commitments, 2023.

[20] Rolls-Royce SMR Limited, SMR0000520/003, “Engineering Management Plan for Rolls-Royce SMR,” October 2022.

[21] Rolls-Royce SMR Limited, SMR0003036/001, “Rolls-Royce SMR Programme Key Objectives and Assessment Criteria,” 2022.

[22] Rolls-Royce SMR Limited, TS-DD-02, SMR Decision Record Template.

[23] Rolls-Royce SMR Limited, SMR0004589 Issue 3, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs,” May 2024.

[24] Rolls-Royce SMR Limited, SMR0004555 Issue 3, “Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 16: Operational Limits and Conditions,” May 2024.

[25] Rolls-Royce SMR Limited, SMR0001035, SMR Programme Maturity and Gates Review Definition.

[26] Rolls-Royce SMR Limited, C3.2.1-2, Definition Review (DR) Process.

[27] Rolls-Royce SMR Limited, C3.2.1-9, Manage Change Process.

[28] Rolls-Royce SMR Limited, SMR0009029 Issue 2, RD7 Design Report, April 2024.

[29] Rolls-Royce SMR Limited, SMR0001286, General Arrangement Site Plan Whole Site.

[30] Rolls-Royce SMR Limited, SMR0001287, General Arrangement Site Plan - Berm Site.

[31] Rolls-Royce SMR Limited, SMR0007298 Issue 1, Architectural and layout summary report.

[32] Rolls-Royce SMR Limited, SMR0006243 Issue 1, Rolls Royce Small Modular Reactor Power Station Data Sheets.

[33] Rolls-Royce SMR Limited, SMR0004210 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 4: Reactor (Core & Fuel)," May 2024.

[34] Rolls-Royce SMR Limited, SMR0003771 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 6: Engineered Safety Features," May 2024.

[35] Rolls-Royce SMR Limited, SMR0003984 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 5: Reactor Coolant System & Associated Systems," May 2024.

[36] Rolls-Royce SMR Limited, SMR0003929 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 7: Instrumentation and Control," May 2024.

[37] Rolls-Royce SMR Limited, SMR0003863 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 9A: Auxiliary Systems," May 2024.

[38] Rolls-Royce SMR Limited, SMR0004502 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste," May 2024.

[39] Rolls-Royce SMR Limited, SMR0003005 Issue 2, Reactor Island Composite P&ID, 2023.

[40] Rolls-Royce SMR Limited, SMR0003880 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 10: Steam and Power Conversion Systems," May 2023.

[41] Rolls-Royce SMR Limited, SMR0004010 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 8: Electrical Power," May 2024.

[42] Rolls-Royce SMR Limited, SMR0003778 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 9B: Civil Systems," May 2024.

[43] National Grid ESO Limited, "The Grid Code, Issue 6, Revision 16," January 2023.

[44] Rolls-Royce SMR Limited, SMR0005213 Issue 1, Power Station Operating Philosophy, 2023.

[45] Rolls-Royce SMR Limited, SMR0004247 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 13: Conduct of Operations," May 2024.

[46] Rolls-Royce SMR Limited, SMR0004487 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 24: ALARP Summary," May 2024.

[47] Rolls-Royce SMR Limited, SMR0008113 Issue 2, Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 27: Demonstration of BAT, May 2024.

[48] Rolls-Royce SMR Limited, SMR0010323 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 28: Sampling and Monitoring Arrangements," May 2024.

[49] Rolls-Royce SMR Limited, SMR0010327 Issue 1, Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 25: Detailed Information about the Design, May 2024.

[50] Rolls-Royce SMR Limited, SMR0004486 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits," May 2024.

[51] Rolls-Royce SMR Limited, SMR0004490 Issue 4, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Case Chapter 30: Prospective Radiological Assessment," May 2024.

[52] Rolls-Royce SMR Limited, SMR0004514 Issue 3, "Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 31: Conventional Impact Assessment," May 2024.

1.10 Appendix A: E3S Case Chapter and Associated SSCs

Table 1.10-1: E3S Case Chapter and Associated SSCs

Primary Chapter	RDS-PP®	SSC
4	JAC10	Reactor vessel internals
	JAC20	Fuel assemblies
	JAC30	Neutron sources
	JDE	Control rods
5	JAA	Reactor vessel
	JAB	Reactor vessel closure head
	JAB10	Reactor pressure vessel closure assembly
	JAB20	Control rod drive mechanism cooling system
	JAB30	Integrated head package lifting assembly
	JAB40	Integrated head package structure
	JAH	Reactor pressure vessel insulation
	JE	Reactor coolant system
	JEA	Steam generation system
	JEB	Reactor coolant pump system
	JEC	Reactor coolant pipework system
	JEF	Reactor coolant pressurising system
	JEG	Reactor coolant pressure relief system
	JNA	Cold shutdown cooling system
	KB	Chemical and volume control system
	KBA	Level and volume control system
	KBD	Chemistry control system
	KBE	Coolant purification system
6	JD01	Scram
	JD02	Alternative shutdown function
	JDK	Emergency boron injection system
	JM	Reactor plant containment systems
	JMA	Containment vessel structure
	JM01	In-vessel retention
	JMB	Core melt stabilisation system

Primary Chapter	RDS-PP®	SSC
	JMD	Containment penetration for fuel transfer
	JME	Equipment transfer airlock
	JMF	Personnel airlock
	JMK	Containment mechanical penetrations
	JML	Containment cable penetrations
	JMM	Containment leak monitoring and collection
	JMN	Containment spray
	JMR	Containment venting and filtering
	JMS	Hydrogen mixing
	JMT	Hydrogen reduction
	JMU	Hydrogen monitoring
	JN	Reactor heat removal systems
	JNM	Reactor vessel cavity injection system
	JN01	Emergency core cooling system
	JNF	Automatic depressurisation system
	JNG	Low pressure injection system
	JN02	Passive decay heat removal system
	JNB	Passive steam condensing system
	JND	High pressure injection system
	JNK	Local ultimate heat sink system
	JN03	Shut down decay heat removal system
	FAN	Emergency heat removal system for coolant used for storage of spent fuel assemblies
	FCF	Airlock system for fuel assemblies /reactor internals between rooms
	KAX	Safety measure coolant supply subsystem
	KH	Nuclear heat tracing systems
	LJ	Emergency feedwater supply system
7	JRA	Reactor protection system
	JQA	Diverse protection system
	JRQ	Accident management system
	JSA	Reactor plant control system
	JSS	Reactor monitoring system
	MY	Turbine island control and protection system

Primary Chapter	RDS-PP®	SSC
	LY	Feedwater, steam and condensate control and protection system
	PY	Cooling water island control and protection system
	KY	Radioactive waste management system C&I
	FY	Fuel route C&I
8	A	Grid transmission system
	AC	Interface to grid transmission system
	B	Electrical power system
	BB	High Voltage (HV) Main Alternating Current (AC) supply system
	BC	HV Main AC standby supply system
	BD	HV Essential AC standby supply system
	BF	Low Voltage (LV) Main AC supply system for process equipment
	BG	LV Main AC supply system for non-process equipment
	BK	LV Essential AC standby supply system
	BL	LV Essential AC alternate supply system
	BM	LV Uninterruptible AC supply system
	BP	LV Uninterruptible Direct Current (DC) supply system
	BQ	LV Uninterruptible DC supply system safety services
	MS	Generator transmission main connection
	XF	Earthing and lightning protection system
	XQ	Lighting systems
9A	F	Handling of nuclear equipment
	FA	Internal fuel storage
	FAA	New fuel receipt and inspection area
	FAB	Storage of spent/irradiated fuel assemblies and other radioactive parts system [FAB]
	FAE	Refuelling cavity
	FAF	Refuelling pool
	FAK	Spent fuel cooling system
	FAL	Spent fuel coolant purification system
	FAM	System for removal of surface contaminants on components in fuel assembly storage
	FAT	Coolant supply system
	FB	Handling of fuel assemblies and other reactor core internals

Primary Chapter	**RDS-PP®**	**SSC**
	FBC	Cleaning system for fuel assemblies (also includes reflector assemblies)
	FCJ	System for conveyance of fuel assemblies/internals within reactor area
	FCK	System for conveyance of fuel assemblies/internals between reactor and storage areas
	FCL	System for conveyance of fuel assemblies/internals within storage area
	FD	External storage of spent fuel
	KA	Nuclear auxiliary systems
	KJ	Nuclear chilled water systems
	KL	HVAC systems in controlled areas and exclusion areas
	KU	Reactor coolant sampling system
	PA	Main cooling water system
	PB	Essential service water system
	PE	Auxiliary cooling and make-up system
	PG	Turbine island closed cooling water system
	PU	Common systems for the cooling water systems
	G	Water supply disposal and treatment system
	GA	Water supply System
	XBF	Space heating system in structures for handling of nuclear equipment
	XBJ	Space heating system in structures for nuclear heat generation
	XBK	Space heating system in structures for nuclear auxiliary systems
	XG	Fire extinguishing system
	XK	Chilled water system
	XM	Mechanical Handling System
	XV	Rainwater systems
9B	U	Structures and areas for systems inside of the power plant process
	U01	Reactor island structures and areas
	UW	Structures for common systems
	UWA	Seismic isolation system
	UWB	Foundation and basemat
	UWC	Retaining wall

Primary Chapter	RDS-PP®	SSC
	UWD	Hazard shield
	UF	Structures for the handling of nuclear equipment
	UFA	Structure for internal storage of fuel assemblies (if separate from reactor building [UJA]
	UJ	Structures for reactor plant
	UJA	Reactor building interior
	UK	Structures for reactor auxiliary systems
	UKA	Reactor auxiliary building
	UKB	Reactor ancillary building
	UPJ	Structures for cooling towers (auxiliary and secondary processes)
	UPJ10	ESWS cooling tower 1
	UPJ20	ESWS cooling tower 2
	UBM	Structures for power generation for safety services
	UBM01	Backup generation 1 and fuel store
	UBM02	Backup generation 2 and fuel store
10	L	Steam water condensate system
	LA	Feedwater system
	LB	Steam system
	LC	Condensate system
	LD	Condensate polishing system
	LX	Fluid supply systems for control and protection systems
	M	Main turbine generator system
	MA	Steam turbine system
	MK	Generator system
	MU	Common systems of the main turbine generator system
11	KM	Solid radioactive waste processing systems
	KN	Liquid radioactive effluent processing system
	KNF	Processing and treatment system for liquid radioactive effluent
	KP	Gaseous radioactive effluent processing systems
	KT	Reactor island collection and drainage system

1.11 Appendix B: Claims Mapping

Figure 1.11-1 presents a mapping of the E3S fundamental claims derived from the E3S fundamental objective, mapped to the associated E3S design principles and top-level claims for each chapter of the E3S Case. The top-level claims are described with the first section of each chapter.

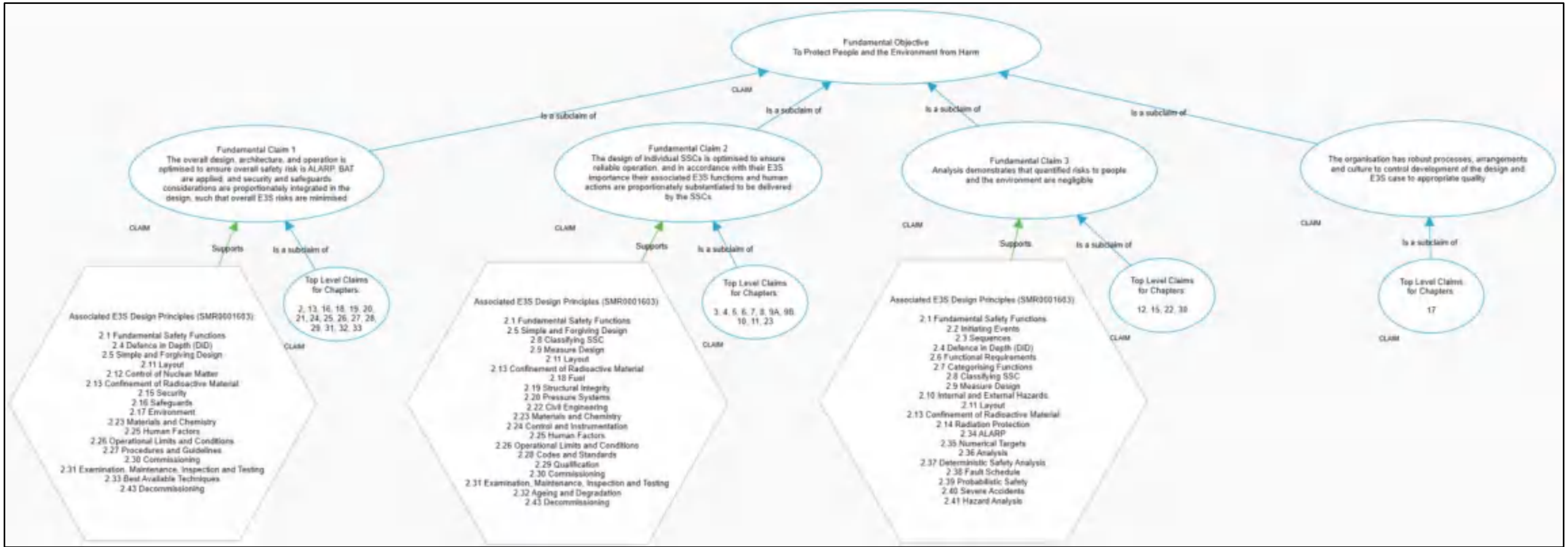


Figure 1.11-1: E3S Claims Mapping

1.12 Abbreviations

AC	Alternating Current
ACMS	Auxiliary Cooling and Make-up System
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
ASF	Alternative Shutdown Function
BAT	Best Available Techniques
BSO	Basic Safety Objective
C&I	Control and Instrumentation
CAE	Claims, Arguments, Evidence
CDF	Core Damage Frequency
CDM 2015	Construction (Design and Management) Regulations 2015
CHP	Combined Heat and Power
CoFT	Control of Fuel Temperature
COMAH	Control of Major Accident Hazard Regulations 2015
CoR	Control of Reactivity
CoRM	Confinement of Radioactive Material
DC	Direct Current
DR	Definition Review
DRP	Design Reference Point
E3S	Environment, Safety, Security and Safeguards
EA	Environment Agency
ECCS	Emergency Core Cooling System
EMIT	Examination, Maintenance, Inspection and Testing
EMP	Engineering Management Plan
ESWS	Essential Service Water System
EUR	European Utility Requirements
FOAF	First of a Fleet
FSE	Fundamental Safeguards Expectations

FSF	Fundamental Safety Function
GB	Great Britain
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GSD	Generic Site Description
GSE	Generic Site Envelope
HF	Human Factors
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IHP	Integrated Head Package
ISO	International Organization for Standardization
IWS	Integrated Waste System
LOCA	Loss of Coolant Accident
LOOP	Loss of Off-site Power
LV	Low Voltage
MCR	Main Control Room
MCWS	Main Cooling Water System
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRW	Natural Resources Wales
NWS	Nuclear Waste Services
OLCs	Operating Limits and Conditions
ONR	Office for Nuclear Regulation
OPEX	Operating Experience
P&ID	Piping & Instrumentation Diagram

PDHR	Passive Decay Heat Removal System
PSA	Probabilistic Safety Assessment
PWR	Pressurised Water Reactor
RCS	Reactor Coolant System
RD	Reference Design
RDS-PP®	Reference Design System – Power Plants
RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
Rolls-Royce SMR Limited	Rolls-Royce Small Modular Reactor Limited (Organisation)
RR SMR	Rolls-Royce Small Modular Reactor (Design)
RSR	Radioactive Substances Regulation
SAPs	Safety Assessment Principles
SBO	Station Blackout
SCR	Supplementary Control Room
SDD	System Design Description
SDG	Sustainable Development Goals
SG	Steam Generator
SOE	Safe Operating Envelope
SQEP	Suitably Qualified and Experienced Personnel
SSC	System, Structure, Component
SSG	Safety Standard Guide
SyAPs	Security Assessment Principles
UN	United Nations
US	United States
V&V	Verification and Validation

WENRA	Western European Nuclear Regulators' Association
WoFG	Well-being of Future Generations (Wales) Act 2015
WNA	World Nuclear Association