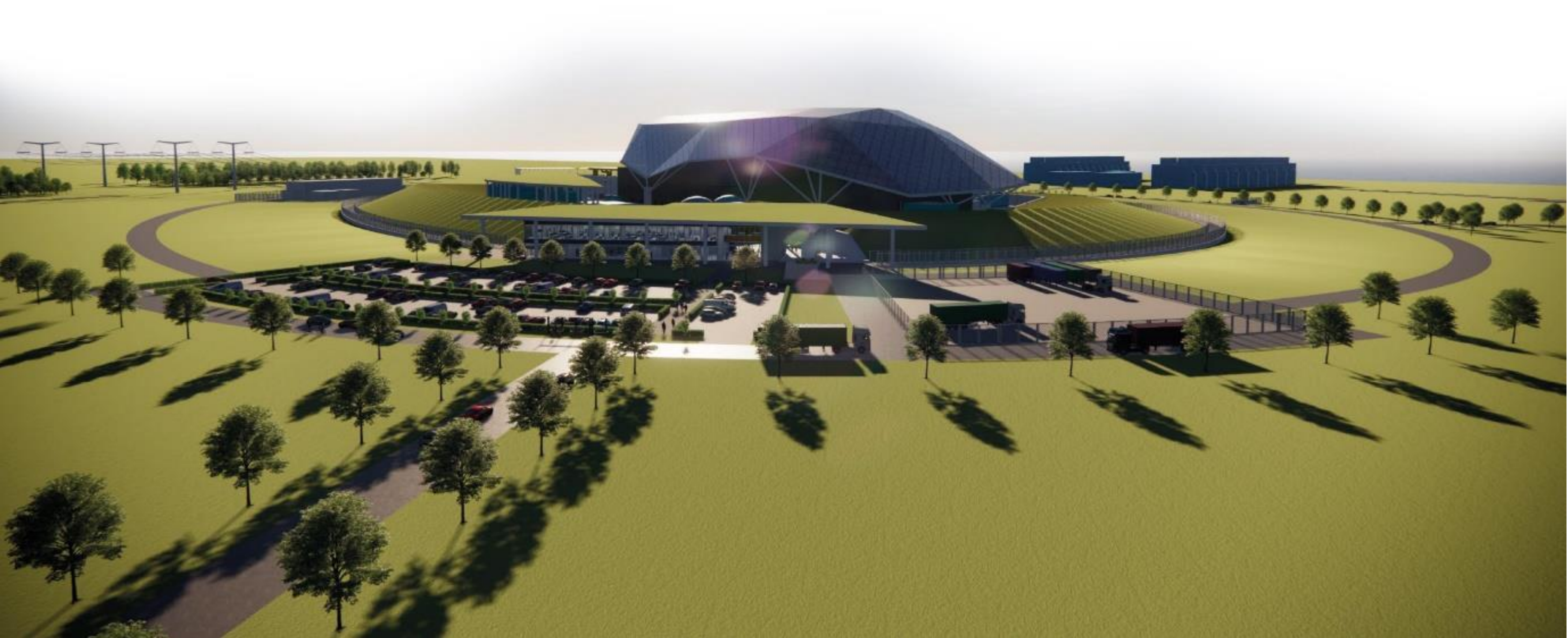
Environment, Safety, Security and Safeguards Case Version 2, Tier 1
Chapter 14: Plant Construction and Commissioning



Record of Change

Date	Revision Number	Status	Reason for Change
March 2023	1	Issue	First Issue
March 2024	2	Issue	This issue develops the key aspects associated with build certainty, and methods to be used for verification and validation of systems.
May 2024	3	Issue	Updated to correct revision history status at Issue 2. Changes include minor template/editorial updates for overall E3S Case consistency, particularly in terms of claims, arguments and evidence and overall chapter conclusions.

Executive Summary

This chapter of the Environment, Safety, Security, and Safeguards (E3S) Case presents the plant construction and commissioning aspects of the Rolls-Royce small modular reactor (RR SMR).

The chapter outlines the arguments and evidence available at design reference point (DRP) 1 to underpin the high-level claim that the structures, systems and components (SSCs) will be manufactured, assembled, installed, and commissioned to meet their design intent and reduce risks to as low as reasonably practicable (ALARP).

The plant construction and commissioning activities will continue to be developed in line with the strategies and philosophies outlined in this report, with continued focus on supporting the demonstration that inactive and radioactive risks introduced during construction and commissioning will be reduced to ALARP.

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14.0 Introduction to Chapter

14.0.1 Introduction

Chapter 14 of the Rolls-Royce Small Modular Reactor (RR SMR) environment, safety, security and safeguards (E3S) case (as defined in E3S Case Version 2, Tier 1 Chapter 1: Introduction [1]) 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, as defined at design reference point 1 (DRP1) level of design maturity.

14.0.2 Scope and design maturity

The scope of this chapter covers the overall construction and commissioning programme and philosophy, and activities being developed by RR SMR to deliver the programme and meet the requirements of the E3S Case.

Information on the organisational structure and detailed arrangements or procedures that need to be in place to safely deliver the construction and commissioning programmes are not covered at this stage.

The constructability and commissioning risks and regulations, including Construction (Design and Management) Regulations 2015 (CDM 2015), associated with conventional health and safety are covered in E3S Case Version 2, Tier 1 Chapter 22: Conventional and Fire safety, [2].

This revision of the plant construction and commissioning chapter of the E3S Case is based on design maturity at DRP1, and the focus is on the development of strategies and activities required to meet the requirements of the E3S Case, the development of construction and commissioning requirements to embed into the design and developing methodologies for strategy implementation.

14.0.3 Claims, arguments and evidence route map

The generic E3S Case objective at Version 2 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' [1]. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence.

The Chapter level Claim for E3S Case Version 2, Tier 1 Chapter 14: Plant Construction and Commissioning is:

Claim 14: Structures, Systems and Components will be manufactured, assembled, installed, and commissioned to meet their design intent and reduce risks to As Low As Reasonably Practicable.

A decomposition of this claim into level 1 sub-claims, arguments, and link to the relevant section of this report is provided in (Appendix A), section 14.5.1 below, and these claims will be further broken down and more detailed evidence presented in future revisions of this chapter. The complete suite of evidence to underpin the claims in the E3S case will be generated through the E3S case programme and documented in the claims, arguments, evidence (CAE) route map [3] described further in [1]. It is also noted that the intention is to review and re-structure these claims in future editions of the case, where appropriate.

14.0.4 Applicable regulations, codes and standards

The plant construction and commissioning activities described in this report follow international and United Kingdom (UK) relevant good practice (RGP) described in the E3S design principles [4].

International Atomic Energy Agency (IAEA) safety standards and specific safety guides (SSGs) relevant to construction include:

- IAEA SSG-38: Construction for Nuclear Installations [5]
- IAEA Safety Standards, Safety of Nuclear Power Plants: Design, Series Specific Safety Guide No. SSR-2/1, 2012 [6].

In addition, non-nuclear regulations also apply, for example, Construction (Design and Management) Regulations 2015 (CDM 2015), as mentioned above.

International Atomic Energy Agency (IAEA) safety standards and specific safety guides (SSGs) relevant to commissioning include:

- IAEA SSG-28: Commissioning for Nuclear Power Plants [7]
- IAEA NP-T-2.10: Nuclear Energy Series: Commissioning Guidelines for Nuclear Power Plants [8]
- IAEA Safety Standards, Safety of Nuclear Power Plants: Commissioning and Operation, Series Specific Safety Guide No. SSR-2/2 (Rev. 1), 2016 Reference [9].

In the UK, construction and commissioning are a key part of the thirty-six Nuclear Site Licence Conditions (LC) [10], including LC1, LC6, LC19, LC20, LC21, LC24, LC28, which a permit/dutyholder/licensee must demonstrate compliance with:

- Commissioning definition LC1
- Documents, records, authorities and certificates LC6
- Construction or installation of new plant LC19
- Modification to design of plant under construction LC20
- Commissioning LC21
- Operating instructions LC24
- Examination, inspection, maintenance and testing LC28.

14.1 Build and Installation

14.1.1 Introduction

The RR SMR design is being developed based on key design objectives and requirements [11], one of the key objectives being to maximise the build certainty.

These requirements are informing design development and will continue to be developed beyond DRP1. One of the primary methods adopted by RR SMR to achieve build certainty is modularisation. It is intended that the bulk of the RR SMR will be manufactured and assembled in offsite factories and will be transported to site and installed as a series of modules within a site factory.

Modules are designed to allow as many complex processes as possible to be completed in the factory and for the installation to be as simple as practicable with as few interfaces as possible, whilst ensuring the E3S requirements from the E3S Case are incorporated into the as-built plant.

The study of relevant good practice (RGP) and operating experience (OPEX) is also a key part of the design process as this provides insights into established practices and identifies possible issues and solutions based on lessons from other projects. Project decision records and proposed construction strategies include reference to RGP when assessing the suitability of proposed civil solutions, [12], [13].

14.1.2 Build programme

A RR SMR first of a fleet (FOAF) build programme [14] has been developed collating inputs from various stakeholders for each phase of the build programme, and includes:

- Manufacture, assembly and initial testing of separate modules in off-site factories.
- Site enabling works, including site establishment and the set-up, testing and validation of the batching plant and on-site laboratory.
- Site factory and groundwork development, including craneage and the controlled environment to enable construction activities over reactor island [R01], turbine island [T01], as well as site enabling works for balance of plant [BOP] and cooling water island [C01].
- Civil and structural build, based on the modular civil concept design.
- Turbine island [T01], cooling water island [C01] and balance of plant [B01] process and mechanical equipment module installation.
- Reactor island [R01] process and mechanical equipment installation.
- Electrical, control and Instrumentation [E01] equipment installation.

Verification and validation of engineering solutions cuts across all phases of the build programme, and Rolls-Royce SMR's (RR SMR) approach to verification and validation (V&V) [15] includes a structured approach and provides a range of processes and guidance for V&V delivery.

V&V across the system lifecycle includes:

- Design requirements V&V: verification is conducted when system design requirements are confirmed to follow engineering rules, that they are correctly defined [16]; and validation ensures they fulfil stakeholder needs.

- Design definition V&V: verification is the process of demonstrating the design definition complies with the requirements [17] including that systems important to safety can perform the safety functions under the relevant conditions; and validation ensures this aligns with stakeholders needs.

- Implemented solution V&V: verification assesses whether the implemented form of the engineered system complies with its design definition, via manufacturing quality assurance (QA) or construction verification and takes place both in off-site factories and on-site during installation. Validation ensures the system meets its design intent and does what the stakeholders require and includes factory acceptance testing (FAT). This will be delivered in several steps building up from components to systems and plant level [18].

The commissioning phase (on or off-site) is when much of the implemented solution validation takes place, noting that the commissioning phase goes beyond system validation as it is also when systems are made operational, and when some final design definition verification may be conducted.

14.1.3 Build certainty in design

As indicated above, the RR SMR design uses a ‘requirements led’ approach, as described in [1] which includes a consistent set of design objectives and requirements that have been defined for the RR SMR to direct the progression of the design architecture/solutions based on market and functional needs. This includes the build certainty requirements and drivers for modularisation which are followed by all design teams.

The build certainty objectives [19] are included below and form a key input into the development of architecture, system concept, and component design.

- Maximise off-site build and assembly

- Simplify logistics flow for on-site build

- Minimise variation across all areas

- Reduce and simplify interfaces (plug and play)

- Increase robustness to variation

- Reduce human interaction.

Examples of the application of build certainty objectives include [20]:

- The layout prioritises the grouping of equipment into modules which are manufactured, built, tested and commissioned off-site. Modular structures are employed for standard areas such as access, shielding and hazard protection. Individual area layout reports include a requirement to detail the relevant modularization solutions.

- The layout facilitates a multi-crane aerial distribution system which provides lifting capabilities to and from every specified point on the R01 and T01 construction site, adding to the safety and simplicity of construction operations.
- The R01 layout makes provision for parallel construction workflows on-site. For example, R01 layout includes space to allow for the parallel build of the containment vessel and the hazard shield, which is an area which, historically, has suffered from scheduling issues.
- Optimisation of system module design to reduce the number of connections to be made on-site, and inclusion of space envelopes around connection points to allow for joining and inspection.
- Layouts make provision for internal space envelopes to ensure space is allocated to allow modules to be installed and connected.
- As design concepts for structures, systems and components (SSCs) are developed, they are down selected through the Conduct Design Optioneering process (C3.2.2-2) [21], including evaluation against the design objectives [22], and other engineering and E3S processes [1] [23] which ensure the design meets the requirements. As such, SSCs are designed to achieve their safety requirements in a manner that supports build certainty and modularisation.

Some of these elements now form part of a set of transverse engineering construction requirements which guide the design. The requirements focus on a range of areas including the use of a grid layout to provide structure for equipment locations, and the use of standard sizes for equipment modules (including larger primary grid dimensions and smaller secondary grid dimensions). Additional requirements are still in development and relate to aspects such as the need for working room and access around modules. These elements each contribute to reducing risks associated with large construction projects.

Design and requirements V&V ensures the design meets its requirements and performs to customer satisfaction. This can either use codified methods of analysis, analogy to existing precedents on similar construction projects, or using physical demonstration and test rigs at a dedicated facility established for initial power station proving.

14.1.4 Build standardisation and modularisation

The most significant of the build certainty principles are judged to be “maximise off-site build and assembly” and “reduce and simplify interfaces”. The aim is therefore that the bulk of the SMR plant be assembled in factories and delivered and installed as a series of modules. The modules are to be designed to include as many complex processes as possible to be completed in the factory in order that the on-site installation phase be simple with as few interfaces as possible. These requirements could drive an approach which increases module size and weight to maximise the utility of off-site processes. However, this creates a logistical challenge and reduced flexibility which has resulted in development of a sizing strategy (as mentioned above), modularisation philosophy [19] and standardisation philosophy [24] to determine the best approaches for RR SMR.

Build certainty can be achieved with significant benefits throughout the plant life cycle by standardising components, processes, tooling and aspects of plant construction. The process of standardisation provides a method for analysing commodities and components which comprise a sub-system and grouping these components to reduce the number of different part types used throughout the facility. Some examples of the benefits of standardisation include:

- Reduction in the number of different parts required, reducing logistics requirements and spare parts inventory

- Increased robustness to unexpected changes in schedule as standard parts can be re-routed if construction sequences change

- Reduced build complexity so processes are standardized and repeated regularly resulting in more 'right first time' operations

- Reduced potential for delays due to re-design during on-site installation

- Improved product quality through off-site manufacturing and production techniques.

The standardisation philosophy generates a master parts catalogue which is to be used as the single configured list of products from which components or commodities are selected, allowing the components to be assembled, into standard modules, and tested inside a pre-built modular factory.

RR SMR has developed methods for modularisation [19], including:

- A standardised mechanical, electrical and plumbing (MEP) module kit of parts (MKoP) has been developed to facilitate modularisation of SSCs, providing the primary method for their installation into the plant. The MkoP is a bespoke system of module frames and accessories that form both a seismically qualified building structure and a module system for the installation of SSCs and equipment.

- Civil kit of parts (CKoP), [25], provides modular solutions for civil structures utilising pre-engineered elements to solve challenges such as retaining walls, tunnels, concrete walls, aseismic bearings, hazard shield, and other large scale civil assemblies.

- Original equipment manufacturer (OEM) supplied modules or skids, for systems small enough to be fully self-contained or where a system does not need to be integrated into a cluster of RR SMR modules.

- Custom modularised structures or assemblies, where other modularisation approaches are not possible a bespoke modularized solution may still benefit build certainty. Thess will be built in sections and assembled on-site.

There is an iterative design relationship between plant layout, the CKoP and MKoP, and the relevant requirement sets. Specific claims may be made by the MKoP on the plant layout and these will be satisfied with evidence substantiated by the MKoP. This approach aims to simplify the E3S case and evidence may be re-used across successive applications. The final cluster layout will undergo a systems performance verification related to the specific deployment scenario which is covered separately from the MKoP verification.

To further aid layout design a 3-D grid system is used to aid the definition of the interface points between systems, modules, civil structures and large components. The grid is based on factors of the major and minor grid dimensions which are used as a standardised units of length across all engineering design disciplines.

Elements of the 'kit of parts' concept are observed across a range of related industries and applications. However, the specific characteristics of the RR SMR MKoP and the associated processes are considered novel for the construction for a nuclear power station. Relevant good practice from both nuclear and non-nuclear applications is therefore relevant for the different aspects of the design and, thus, both sources are consulted.

14.1.5 Off-site factory testing

Off-site testing of build modules is used to reduce the testing which would traditionally be completed on-site during power station construction and is undertaken in off-site factories. These module factories are assembly and test facilities manufacturing a selection of modules, including modules such as heating, ventilation and air-conditioning (HVAC) skids, and other modules in designed frames. In addition, separate factories will also be used for standard civil module construction, including prefabricated concrete forms, not within the scope of on-site construction.

The V&V testing activities that can be undertaken in an offsite factory are described in [26], including:

- Manufacturing quality assurance (MQA) tests and inspections intended to verify the as-built component or assembly meets its design definition. These fall into the following categories; incoming quality inspection, in-process inspection, special inspections or tests of finished products, and include visual inspections, dimensional inspection or non-destructive testing (NDT).

- Factory acceptance testing (FAT), which intends to validate the quality of the assembly process and the functional performance of an assembly or module. Inspections may include visual inspections, vibration tests, thermography tests, pressure testing and electrical, control and instrumentation (EC&I) checks.

Inspection and test plans will be used with suppliers to ensure inspection and testing activities are undertaken to confirm that delivered products and services fully conform to technical, safety, and quality requirements.

Once FAT testing has been completed for individual modules they may be required to spend a significant time in storage or transport before it reaches the nuclear site, and thus preventative actions are in development to preserve the integrity of the FAT.

The FAT forms part of pre-commissioning and commissioning activities, and these are documented using ‘commissioning storyboards’ which map out the activities that must take place during the lifecycle of a module, from the supplier all the way to installation at the power station. Commissioning activities are detailed further in section 14.2 below.

14.1.6 Transportation

The transport philosophy directly impacts the build certainty, as the RR SMR prioritise off-site construction with the aim of transporting completed sections of plant to site in as few deliveries as possible. It is recognised that potential sites may be difficult to access and, thus, it is intended that the parts will be designed to be road transportable without the need for specialised or extreme transport solutions. Other transport solutions will be considered where appropriate, depending on the specifics of the construction site and local transport networks.

To inform the design of modules and equipment a range of transport limits have been set in tiers (Tier 1 being least restrictive to tier 3 which is most restrictive), which provide limits of item size and weight and any associated transport restrictions. The aim being that, where possible, equipment falls within the limits of tier 1 to reduce the complexity and restrictions placed on the transport.

Further work is also underway to ascertain the transport profile and peak volumes generated during the construction phase to develop aspects which form part of the overall site factory layout:

- Internal roadways and access infrastructure requirements
- Designated parking and off-load areas
- Crane installation requirements.

14.1.7 Site as a factory

The outline construction method statement [27] provides a summary of the overall construction methodology and build sequence, and the construction health and safety strategy, as understood at DRP1, and will evolve as the design matures. This demonstrates alignment of the construction methodology with the principle to achieve build certainty, which is described above.

The RR SMR employs modern methods of construction (MMC) which use modular design and manufacturing methods which provide opportunities to gain greater control of the work programme and isolate hazards in off-site facilities. This aids in reducing conventional safety hazards, (in line with CDM requirements) which can be significant during the construction phase of a project lifecycle.

RR SMR is adopting a 'Site as a Factory' approach to onsite construction and assembly to achieve build certainty. This approach assumes modularisation has been maximised to reduce on site complexity, such that on-site activities are limited largely to lifting and placement, jointing and final commissioning.

The site factory provides an environmental shelter to the RI / RI assembly areas, providing a significant change in the construction methodology from traditional nuclear construction, enabling installation of mechanical, electrical, control and instrumentation, and process equipment in a controlled environment for up to 24 hours a day, 365 days a year. In addition, the modular approach will provide greater control of hazards thus reducing conventional safety risks as compared to more standard construction approaches.

The site factory provides a number of benefits, including:

- Reduction in the environmental impact of construction activities by reducing and providing an enclosure for on-site construction, dust and air pollution, light pollution and visual disruption, and water pollution
- Reduction in on-site construction times and potential impact of adverse weather leading to lost time and programme extensions
- Increasing construction safety and productivity as the site factory layout provides protection for the movement of plant, labour and materials.

Ten key principles [28] have been identified and are included in the 'site as a factory' approach.

- Establishing designated island workstreams to allow access from different sides to create multiple work faces
- Just-in-time deliveries and material management
- Direct off-load from transport to final location, to reduce handling
- Optimisation of shift working for delivery certainty and resilience
- Takt time commonality around kit of parts and by areas
- Trade continuity to enable rolling factory process
- High productivity joint and fixing process (plug and play)
- Reduction of temporary works
- Optimisation of crane utilization
- Digitally enabled in-process verification.

It is recognised that this approach will require a complex supply chain, logistics and site operation network which highlights the need to be able to control and clearly visualise the interactions and interdependencies. The strategy for planning, controlling, and operation of a generic site factory is presented in [28] and requires a fully digital integrated model to enable delivery.

Further assessment of the construction requirements to support development of the site factory [29] is on-going to consider the number of lifts, number of deliveries, raw materials (concrete) demand, as well as consideration of personnel numbers and positioning of welfare facilities. This provides information to feed into general aspects such as construction schedule and logistics, resource planning, and the requirements for crane layout and design.

Further V&V inspections / testing is undertaken during module installation to confirm the systems are in line with the design requirements and continue into the plant commissioning phase.

14.2 Commissioning

14.2.1 Introduction

Commissioning is one of the key steps towards putting into service a new nuclear facility, or a new system, structure or component within an existing facility. The IAEA defines it as: "The process by means of which systems and components of facilities and activities, having been constructed, are made operational and verified to be in accordance with the design and to have met the required performance criteria." Commissioning activities need to be planned for early in the design and procurement process, with careful consideration given to acceptance criteria and test methods, including those for tests performed in vendor factories.

As commissioning will ultimately be the responsibility of the site permit/dutyholder/licensee, the design of the RR SMR has been optimised to assist future licensees in complying with relevant site licence conditions, particularly license condition 21 relating to commissioning aspects. RR SMR's overall commissioning strategy intends to ensure that the plant design, along with the approach to manufacture, construction and installation, delivers a safe, predictable, and resilient commissioning programme.

Key to delivering this strategy is utilising the modular design and manufacture intent of RR SMR, which provides opportunities to gain greater control of work and isolate hazards in off-site facilities, enabling either early de-risk testing or specific factory acceptance testing (FAT) that could contribute to the overall commissioning programme where preservation can be assured. Work is underway to determine exactly what contribution to commissioning can be delivered through FAT, or associated activities in the supply chain, together with structured risk assessments on preservation.

In addition, the commissioning strategy clearly highlights the need for embedding a commissioning mindset early in the overall programme, with dedicated work packages on 'Design for Commissioning' planned throughout the facility design phase. This intent relates to another strategic enabler to develop a robust lessons learnt process across the RR SMR fleet.

'Design for Commissioning' will be driven through various means, including by specifying explicit commissioning requirements that are assigned to all relevant SSCs. The latest iteration of this requirement set is approved for DRP1 and will continue development as part of the systems engineering design philosophy. Another area of focus is to conduct commissioning focused reviews of key SSCs to identify the specific commissioning activities required early and capture rationale for potential off-site test opportunities. The output of these reviews is being captured directly in their associated design documentation.

Furthermore, RR SMR is developing a programme for commissioning that is robust, based on RGP and integrated planning, the latter of which will ultimately derive input from and be recorded in a structured form based on the plant requirements and design definition.

14.2.2 Commissioning programme

Non-nuclear and nuclear commissioning activities

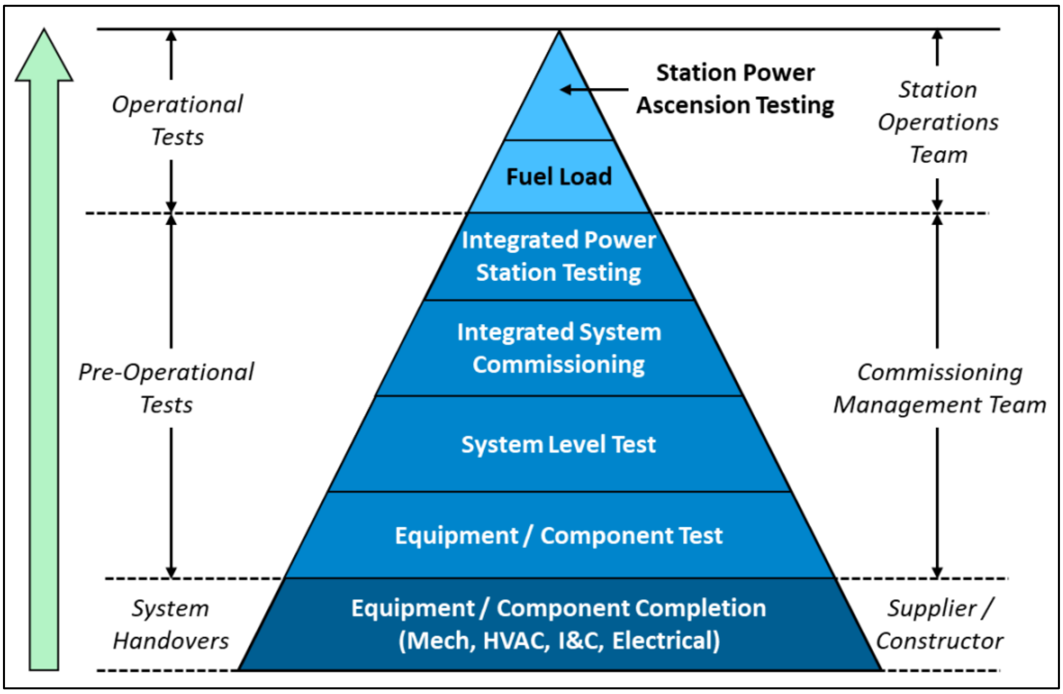
Commissioning will be performed in a systematic sequence, with tests arranged to be progressive so that the plant is exposed to less onerous conditions first before the plant moves through commissioning to the start of normal operation.

The different aspects and stages of on-site commissioning are illustrated in Figure 14.2-1. The premise is that before moving on to the next level of the pyramid it is important to ensure the previous level is secured, robust and traceable.

System handover activities are performed by the Installer/Constructor, after which the equipment passes to the commissioning organisation through a formal and traceable handover. This handover is to include a description of all commissioning tests required (including test prerequisites, test sequencing, evaluation of results, acceptance criteria, and management of deviations) and work may be performed in collaboration between installer and commissioning organisations and witnessed to de-risk or contribute to upstream activities. Pre-operational tests follow with dedicated component inspections and tests by the commissioning organisation, steadily progressing to testing at the single system level. Testing then follows a staged approach, starting from testing interfacing systems all the way up to integrated testing of systems at the power plant level.

After successful commissioning tests the systems may be handed over to the licensee such that operational tests can be undertaken including the station operations team. These start at the point of fuel load, leading onto initial criticality, low power physics tests and power ascension testing. Additional design verification, performance and warranty testing may be incorporated prior to commercial operation/final completion.

Figure 14.2-1: Overview of Commissioning Phases



The full RR SMR commissioning programme is in development and will be refined in an iterative manner through the design programme and beyond. It being structured as shown in Figure 14.2-1, and in line with the sequencing outlined in the IAEA Commissioning Guidelines, Reference [8].

Hold points

RR SMR recognises the need for clear hold points through the commissioning programme, which can be used as part of permissioning. These are being defined as part of the work to develop the commissioning programme. An initial programme was created early in the overall design programme [30], which remains valid and will be re-assessed as the design moves forward from DRP1 as the schedule matures.

Design Verification Tests

The initial commissioning programme does not directly incorporate any additional design verification tests, such as First-Plant-Only-Tests (FPOT) or First-Three Plant-Only-Tests (F3POT). The criteria for identifying these tests are being developed as the design progresses as part of the V&V approach, in parallel to the development of the commissioning programme. It is recognised that this will require early engagement with both the permit/dutyholder/licensee and regulators to determine the acceptability for allowing FPOT or F3POT to be credited, where demonstrated to be valid, for subsequent RR SMR units of similar design. This approach remains valid and will be re-assessed as both the commissioning programme and V&V plans mature, beyond DRP1.

Relevant international and UK guidance will be followed in the identification of these tests (FPOT, F3POTs), such as the Multinational Design Evaluation Programme (MDEP) common position paper addressing FPOT, [31] and MDEP Working Group Design-Specific Technical Report on Lessons Learnt from Implementation of the Common Position on FPOT for AP1000, [32].

Nuclear site permit/dutyholder/licensee

RR SMR will ensure that the overall objectives of commissioning are aligned with those of the permit/dutyholder/licensee, who is responsible for making and implementing adequate arrangements for the commissioning of any plant or process which may affect safety. It is anticipated that the licensee's commissioning arrangements will include activities to:

- Validate, where reasonably practicable, through commissioning that the as-built installed SSCs operate in accordance with the design intent stated in the E3S case, through all relevant operating modes and operating range.
- Demonstrate, where reasonably practicable, for which the commissioning tests provide representative activities and/or conditions, that emergency operating procedures, operating rules, operating instructions, and examination, inspection, maintenance, and testing requirements are validated as claimed in the E3S case.
- Ensure suitably qualified and experienced station and operations staff are directly involved at all levels and in all areas in the commissioning activities to allow them to gain physical plant experience ahead of SMR operation.
- Facilitate the collection of baseline data for SSCs for retention by RR SMR and the dutyholder/licensee for future reference.

- Implement programme hold points, which will be required to ensure ordered and sequential progress between defined steps within the commissioning programme.
- Validate main design parameters, including compliance with applicable codes, standards, and the quality assurance requirements.

14.2.3 Commissioning strategy

The initial RR SMR Commissioning Strategy [33] captured areas of RGP and innovation from across industry that RR SMR is assessing and down-selecting, where they deliver a benefit in terms of the safety, environmental impact or schedule of the commissioning programme. As such, the RR SMR commissioning strategy will be refined over time and re-issued at suitable milestones in the overall programme, to communicate intent. The next issue will be delivered as part of reference design RD8.

One of the key topics identified in this report is the opportunity to utilise enhanced FAT on SSCs constructed within RR SMR modules in the offsite factory, in order to reduce the activities (for example, completions, handovers) that need to be carried out on-site. This builds on, and is enabled by, the project's modularisation philosophy (see section 14.1.4). Dedicated working groups are developing options for FAT opportunities, as well as opportunities more generally in the supply chain, that will be reported in future report editions.

Testing in a clean factory environment, where specialist equipment and capabilities are close at hand and systems are more easily accessible, can provide safety benefits and reduce onsite risks, as well as reducing the schedule of on-site activity. Similarly, utilising the expertise and equipment of dedicated suppliers will be considered, as part of utilising the supply chain opportunities that arise from the RR SMR modularised design philosophy.

RR SMR is further developing the strategy for these opportunities, whilst conducting studies on the necessary investment, facility design impact and associated preservation/risk studies that are critical to deployment. This activity involves considering the scope of inspection and test activities that can be more safely and efficiently conducted within off-site facilities and those specific measures necessary for preservation, the latter of which will run iteratively alongside the maturing design.

RR SMR will continue to review and develop the overall commissioning strategy as the plant design is matured, and as the integrated manufacturing, construction and installation plans develop, and as further industry operating experience (OPEX)/RGP is assimilated. This will ultimately be reported in further issues of the commissioning strategy, as mentioned above.

14.3 Conclusions

14.3.1 ALARP, BAT, Secure by Design, Safeguards by Design

The principles and approaches described in this chapter are being applied to the ongoing development of the design, analysis, and verification of SSCs, to ensure the E3S fundamental objective can be met by the RR SMR at all lifecycle stages. Their application enables the design and analysis outputs presented throughout the E3S Case to provide a suitable demonstration that risks are and/or will be reduced to ALARP, apply BAT and ensure secure by design and safeguards by design.

14.3.2 Assumptions and commitments on future dutyholder

Table 14.3-1: Assumptions and commitments on future permit/dutyholder/licensee

Reference	Assumption/Commitment	Description
FA14.1	Owner responsible for facility commissioning	Owner to make adequate arrangements for the commissioning of the facility.

14.3.3 Conclusions and forward look

The generic E3S Case objective at Version 2 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' [1]. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence. The top-level claim for chapter 14 is that 'the RR SMR civil structures are conservatively designed and verified to deliver 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'. This contributes to the overall E3S objective to protect people and the environment from harm, and the demonstration that risks are reduced ALARP.

The preliminary evidence provided includes summaries of programmes, strategies, methodologies used across the construction and commissioning aspects of the facility and these will continue to be expanded in line with development of further design detail.

As the generic E3S case is developed to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective further arguments and evidence to underpin the claim will be developed in line with the E3S case route map [3] and reported in future revisions of the generic E3S case. This broadly includes refinement of construction and commissioning requirements from iterative internal and external hazards analysis, as well as environment, security, and safeguards requirements. It will also include further development of both construction and commissioning strategies, programmes and schedules which will be included in future editions of this chapter, which will also include greater detail in terms of arrangements for system verification and validation and consider RGP from recent projects.

14.4 References

[1] Rolls Royce SMR SMR0004294 Issue 3, E3S Case Version 2, Tier 1 Chapter 1: Introduction, May 2024.

[2] Rolls Royce SMR, SMR0004367 Issue 3, "E3S Case Version 2, Tier 1 Chapter 22: Conventional and Fire Safety," May 2024.

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

[4] Rolls Royce SMR, SMR0001603 Issue 1, "Environment, Safety, Security and Safeguards Design Principles," August 2022.

[5] IAEA Safety Standards Series SSG-38, "Construction for Nuclear Installations," 2015.

[6] IAEA Safety Standards, "Safety of Nuclear Power Plants: Design, Series Specific Safety Guide No. SSR-2/1,," 2012.

[7] IAEA Safety Standards Series No. SSG-28, "Commissioning for Nuclear Power Plants," May 2014.

[8] IAEA No. NP-T-2.10, "Commissioning Guidelines for Nuclear Power Plants," May 2018.

[9] IAEA SSR-2/2 (Rev. 1), Safety of Nuclear Power Plants: Commissioning and Operation, February 2016.

[10] Office of Nuclear Regulation, "The Licence Condition Handbook," February 2017.

[11] Rolls Royce SMR EDNS10000895298 Issue 1, "SMR Programme Key Objectives and Assessment Criteria," 2022.

[12] Rolls-Royce SMR SMR0006814 Issue 1 , "Civil Solution: Deep Slabs with multiple layers of reinforcement," 2023.

[13] Laing O'Rourke SMR0006834 Issue 2, "Outline Lifting Strategy (including heavy vessels lifting)," 2024.

[14] Rolls Royce SMR, EDNS01000959021 Issue 1, "FOAK SMR Build Schedule (D46/RD4) Narrative," April 2021.

[15] Rolls Royce SMR SMR0008444 Issue 1, "Approach to Verification and Validation," 2023.

[16] Rolls Royce SMR IMS C3.1.1, "Design and Manage Requirements," 2023.

[17] Rolls Royce SMR IMS C3.2.3, "Verify Design Definition," 2023.

[18] Rolls Royce SMR IMS C3.2.6, "Validate Solution," 2023.

[19] Rolls Royce SMR, SMR0001579 Issue 1, "Build Certainty Philosophy," August 2022.

[20] Rolls Royce SMR SMR0007298 Issue 1, "Reactor Island Architectural and Layout Summary Report," 2024.

[21] Rolls Royce SMR IMS Process C3.2.2-2, "Conduct Design Optioneering," 2023.

[22] Rolls Royce SMR SMR0003036 Issue 1, "Key Objectives and Design Criteria," 2022.

[23] Rolls Royce SMR SMR0004589 Issue 3, "E3S Case Version 2, Tier 1 Chapter 3: E3S Objectives and Design Rules for Structures, Systems and Components," 2024.

[24] Rolls Royce SMR SMR0001634 Issue 1, "Standardisation Philosopy and Guidance," 2023.

[25] Laing O'Rourke SMR0009009 Issue 1, "Civil Kit of Parts Definition Report," 2023.

[26] Rolls Royce SMR SMR0005992 Issue 1, "MEP Modules Factory Acceptance Test Methods Development," 2023.

[27] Laing O'Rourke SMR0006837 Issue 2, "Outline Construction Method Statement," 2024.

[28] Rolls Royce SMR, SMR0001359 Issue 1, “Site as a Factory Definition,” 2024.

[29] Laing O'Rourke SMR0006836 Issue 2, “Construction Requirements to Support SIte Factory Development,” 2024.

[30] Rolls Royce SMR, SMR0001021 Issue 1, “PCD Commissioning Primary and Secondary Commissioning Hold Points,” June 2022.

[31] Multinational Design Evaluation Programme, CP-STC-01, “Common Position addressing First-Plant-Only-Test (FPOT),” April 2018.

[32] Multinational Design Evaluation Programme Working Group Design-Specific Technical Report on Lessons Learnt from Implementation of the Common Position on FPOT for AP1000, TR-AP1000WG-05.

[33] Rolls Royce SMR, EDNS01000919142 Issue 1, “Commissioning Strategy in the Concept Phase,” December 2020.

14.5 Appendix A

14.5.1 Claims, arguments and evidence

Table 14.5-1 provides a mapping of the claims to the corresponding sections of the chapter that summarise the arguments and/or evidence. The full decomposition of the claims and the link to underpinning Tier 2 and Tier 3 information containing the detailed arguments and evidence is presented in the E3S case route map [3].

Table 14.5-1: Mapping of claims to evidence

Claim	Reference for Arguments / Evidence
SSC design minimises risks during manufacture, assembly, installation and commissioning	Section 14.1.3
Layout design minimises risks during manufacture, assembly, installation and commissioning	Section 14.1.4, [20]
Modularisation approach minimises risks during manufacture, assembly, installation and commissioning	Section 14.1.3 and 14.1.4 Design for construction and commissioning requirements on requirements database (DOORS)
The commissioning programme verifies as-built SSCs will achieve their E3S requirements	Section 14.1.5, 14.2.2

14.6 Glossary of Terms and Abbreviations

ALARP	As Low As Reasonably Practicable
BAT	Best Available Technique
CAE	Claims, Arguments, Evidence
CDM	Construction (Design and Management) Regulations 2015
CKoP	Civil Kit of Parts
DRP	Design Reference Point
E3S	Environment, Safety, Security and Safeguards
EC&I	Electrical, Control and Instrumentation
FAT	Factory Acceptance Testing
FCD	Final Concept Definition
FOAF	First of a Fleet
FPOT	First-Plant-Only-Tests
F3POT	First-three Plant-Only-Tests
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
LC	Licence Condition
MDEP	Multinational Design Evaluation Programme
MEP	Mechanical, Electrical and Plumbing
MKoP	Module Kit of Parts
MQA	Manufacturing Quality Assurance

NDT	Non-Destructive Testing
OEM	Original Equipment Manufacturer
OPEX	Operating Experience
PAT	Power Ascension Testing
PCD	Preliminary Concept Definition
PCSR	Pre-Construction Safety Report
RD	Reference Design
RGP	Relevant Good Practice
RR SMR	Rolls-Royce Small Modular Reactor
SSC	Structures, Systems and Components
SSG	Specific Safety Guide
UK	United Kingdom