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22.1 INTRODUCTION

The Fundamental Purpose of the Generic Design Assessment (GDA) Safety, Security and Environment Case (SSEC) is to demonstrate that the generic Small Modular Reactor (SMR)-300 can be constructed, commissioned, operated, and decommissioned on a generic site in the United Kingdom (UK) to fulfil the future licensee's legal duties to be safe, secure and protect people and the environment as defined in Part A Chapter 1 Introduction [1].

The Fundamental Purpose is achieved through the Fundamental Objective of the Preliminary Safety Report (PSR), which is to summarise the safety standards and criteria, safety management and organisation, claims, arguments and evidence to demonstrate that the generic SMR-300 design risks to people are likely to be tolerable and As Low As Reasonably Practicable (ALARP) [1].

Appendix A of this PSR chapter presents the Claims, Arguments and Evidence (CAE) for Internal Hazards.

22.1.1 Purpose and Scope

The Overarching SSEC claims are presented in Part A Chapter 3 Claims, Arguments and Evidence of the PSR [2].

This chapter (Part B Chapter 22) links to the overarching claims through Claim 2.1:

Claim 2.1: The nuclear safety assessment identifies plant initiating events, specifies the requirements for safety measures such that safety functions are fulfilled, informs operational and emergency arrangements and demonstrates that risk is tolerable and ALARP.

As set out in Part A Chapter 3, Claim 2.1 is further decomposed across several nuclear safety assessment disciplines which are responsible for development of the nuclear safety assessment. This chapter presents the Internal Hazards aspects for the generic SMR-300 and therefore directly supports Claim 2.1.6.

Claim 2.1.6: Risks from Internal Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

Further discussion on how the Level 3 claim is broken down into Level 4 claims and how the Level 4 claims are met is provided in sub-chapter 22.4.

Part B Chapter 22, Internal Hazards, presents a discussion of:

- The aspects of the SMR-300 design that protect against Internal Hazards (see sub-chapter 22.2).
- Overview of Internal Hazards (see sub-chapter 22.3).
- The CAE relevant to Internal Hazards (see sub-chapter 22.4).
- The codes and standards, Relevant Good Practice (RGP), and guidance applicable to the identification and assessment of Internal Hazards (see sub-chapter 22.5).
- The methodology for identification of Internal Hazards (see sub-chapter 22.6 and Appendix B).

  - The approach to combined hazards (external and internal) is outlined in full within Internal Hazards and External Hazards Combined Hazards Methodology [3].
- The identified Internal Hazards relevant to the generic SMR-300 and their characterisation and assessment methodologies (see sub-chapter 22.7).
- The resultant Structures, Systems and Components (SSC) that support the claims relating to Internal Hazards (see sub-chapter 22.8 and Appendix C).
- A technical summary of how the overarching claim for Internal Hazards is met and a summary of the contribution from this chapter to support the demonstration that risks are likely to be tolerable and ALARP for the generic SMR-300 design (see sub-chapter 22.9).

A master list of definitions and abbreviations relevant to all PSR chapters can be found in Part A Chapter 2 General Design Aspects and Site Characteristics [4].

All Internal Hazards identified within this PSR chapter could feasibly be initiated maliciously. These initiators are outside the scope of this PSR chapter and protection and mitigation from malicious persons are covered within the nuclear Generic Security Report (GSR) [5].

22.1.2 Assumptions

Assumptions which relate to this topic have been formally captured in the Commitments, Assumptions and Requirements (CAR) process [6]. Further details of this process are provided in Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [7].

The identified assumptions are:

- Although SSCs have been sentenced as ‘in scope’ and ‘out of scope’ within Part A Chapter 2 of the PSR [4], SSCs which present a risk to the design, significant sources of Internal Hazards have been included within this chapter, e.g. turbine disintegration. Internal Hazards from other SSCs that cannot be realistically captured at this generic stage will be addressed post Step 2 by further safety analysis.
- Beyond GDA timescales, the Internal Hazard analysis will continue to develop in line with the developing maturity of the generic SMR-300 design. Hazard verification studies will be planned for all relevant hazard types, in accordance with the identified hazard methodologies outlined throughout sub-chapter 22.7. An indicative list of future hazard verification studies is provided in Appendix A (shown in red) as part of the CAE table. Further details and development of the exact set of verification studies will be provided as part of the Pre-Construction Safety Report (PCSR) specification and development.

22.1.3 Interfaces with Other SSEC Chapters

The Internal Hazards chapter interfaces with the following PSR chapters.

The generic design aspects and site characteristics are described in Part A Chapter 2 [4].

Part B Chapter 1 Reactor Coolant Systems and Engineered Safety Features [8], Part B Chapter 2 Reactor [9], Part B Chapter 4 Control and Instrumentation Systems [10], Part B Chapter 5 Reactor Supporting Facilities [11], Part B Chapter 6 Electrical Engineering [12], Part B Chapter 18 Structural Integrity [13], Part B Chapter 19 Mechanical Engineering [14] and Part

B Chapter 20 Civil Engineering [15] present the SSCs relating to their topic area which will be substantiated / qualified / validated against relevant Internal Hazards.

Part B Chapter 12 Nuclear Site Health and Safety and Conventional Fire Safety [16] interfaces closely with Part B Chapter 22 in relation to the design of Internal fire protection, which covers the design and fire safety provisions for evacuation routes, control of external fire spread and fire-fighting access. Internal fire in this chapter focuses on the nuclear safety while Part B Chapter 12 is for life safety in the event of fire and fire prevention measures. In addition to fire, Chapter 12 also covers Nuclear Site Health and Safety and outlines the approach to meeting the needs of the Construction (Design and Management) (CDM) regulations [17] for the generic SMR-300.

All identified and screened Internal Hazards are to be treated as initiating events in the Design Basis Accident Analysis (DBAA) post Step 2. Part B Chapter 14 Design Basis Analysis (Fault Studies) [18] presents the assessment methodology that Internal Hazards will be subject to post Step 2.

Part B Chapter 15 Beyond Design Basis Accident (BDBA), Severe Accidents Analysis and Emergency Preparedness [19] presents an assessment of Beyond Design Basis (BDB) Internal Hazards and the generic site response to Severe Accidents that may lead to core damage. Part B Chapter 16 Probabilistic Safety Assessment [20] supports the DBAA and BDBA with an objective to demonstrate that the design of the generic SMR-300 is balanced such that risk is tolerable and ALARP.

Internal Hazards also interfaces with Part B Chapter 17 Human Factors [21]. The Human Factors discipline supports the identification, analysis and modelling of human failures related to Internal Hazards and is responsible for the substantiation of any developed human-based safety claims.

Internal Hazards interfaces closely with Part B Chapter 21 External Hazards [22] due to their common nature. Combinations of hazards is a key topic as an External Hazard could lead to one or more consequential Internal Hazards.

Internal Hazards also interfaces with the GSR [5] as there exists the potential for Internal Hazards to be initiated maliciously. These initiators are outside the scope of this PSR chapter and protection and mitigation from malicious persons are covered within the nuclear GSR [5].

22.2 ASPECTS OF DESIGN AGAINST INTERNAL HAZARDS

22.2.1 SMR-300 Passive Design Features Related to Internal Hazards

The Top-Level Plant Design requirements document [23] outlines the three design philosophies for SMR-300 (safety, performance, constructability) and then together with plant objectives and Electric Power Research Institute (EPRI) guidance provides the design requirements which drive the layout / configuration of the plant.

The key aspect of the passive philosophy and objective is 'The plant shall rely on passive means to mitigate Design Basis Accidents (DBA) (requirement 1001). This passive safety doctrine has a large influence on the layout of the SMR-300 [REDACTED]. The primary objective of the design process is improved overall plant safety (relative to conventional Gen-III Light Water Reactors (LWR)).

The adoption of passive engineered safety measures as a means to mitigate design basis accidents is considered to represent RGP. It is a logical response to global operational experience after examining causal and contributing factors to historical nuclear incidents, where failure of active systems and human error are a common factor. Adoption of these passive engineered safety measures will have a net-positive effect on overall risk. Any detrimental risks can be shown to be as low as reasonably practicable [4].

The SMR-300 design therefore incorporates a high degree of passive safety, as described in Part A Chapter 2 [4]. The design utilises passive operating and safety features to prevent and, if necessary, mitigate the consequences of design basis and beyond design basis accidents. Central to this, the SMR-300 design does not require operator action or reliance on off-site or on-site Alternating Current (AC) power for accident mitigation. This provides a robust design against Internal Hazards, as described below. The Fault Schedule for a wider set of DBAs appropriate to the UK environment is currently under development; there is no indication at this time that this wider set will undermine the claims being made here on passive safety.

All actions for mitigating the consequences of DBAs are automated, and the plant is designed to achieve and maintain a safe shutdown state without operator actions, without external water, without external power, and without active systems[1]. The plant is able to cope with an extended loss of all AC power for a minimum of 72 hours.

Should a DBA occur, the containment of the SMR-300 is designed to remain intact and sealed during all postulated events, and to reject its internal energy to the water in the AR, even if AC power is lost. The AR provides cooling for at least 30 days [24], and design measures are in place to allow the AR water to be replenished after this time.

The design of the plant reduces the burden on operators by providing substantial margins to safety limits, allowing increased time to evaluate plant conditions, and to decide what, if any, manual operator actions are appropriate [23].

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[1] The actuation by battery power is categorised as a Category D Passive Safety System in International Atomic Energy Agency (IAEA) TCS-69.

There are two redundant lines with Motor Operated Valves (MOV) available to initiate the Primary Decay Heat Removal System (PDH) and similarly two redundant MOVs available to initiate the Secondary Decay Heat Removal System (SDH).

[REDACTED]

The hydraulic parts of the PDH and SDH are each single trains, but both are passive designs and not subject to active failures (apart from the redundant MOVs described above).

The PDH is capable of cooling the Reactor Coolant System (RCS) from normal operating temperature to a safe shutdown condition by natural circulation, independent of the SDH. Over time, the PDH will heat the Passive Core Makeup Water Tank (PCMWT) to saturation conditions and boil the contents of the tank. This steam leaves the PCMWT through vents at the top of the tank, and condenses on the Containment Structure (CS) wall, passively conducting heat to the AR. The condensed water then returns to the PCMWT and Spent Fuel Pool Cooling System (SFP) [25].

The SDH also uses natural circulation to reject heat from the Steam Generator to the AR, through the SDH heat exchanger. The SDH is capable of cooling the RCS from normal operating temperature to a safe shutdown condition, independent of the PDH.

The passive Engineering Safety Features (ESF) are described in further detail in Part B Chapter 1 Reactor Coolant System and Engineered Safety Features [8].

In addition, the SMR-300 approach to Defence in Depth considers normal operating systems, active non-safety systems as well as passive safety systems for diversity.

[REDACTED]

22.2.2 Internal Hazards Considerations

The fundamental requirements for protection against Internal hazards are specified in the design standard for grouping and separation [26]. This standard requires suitable segregation for the two divisions of electrical equipment required to initiate the passive cooling systems. Divisional barriers are provided mainly in the Reactor Auxiliary Building (RAB). Within the containment the approach is to use suitable separation (although local protection is also an option).

[REDACTED]

The fire PSA takes into account the frequency of a fire in a given fire area, and also the potential for single failures (or maintenance) on another train. The frequency of a fire in a given area is determined as part of the fire PSA. The overall contribution of fire to the Core Damage Frequency is then determined by the fault and event tree analysis. A similar procedure is carried out for the internal Flood PSA.

In summary, the safety argument for internal hazards is that there is sufficient redundancy available to activate the passive safety systems, and once they have been initiated the design is robust against further hazards development and consequential hazards.

Preliminary fire and flood PSA studies were carried out for the SMR-160 and will be repeated for the SMR-300. They provide an indication that the SMR-300 risk will also be acceptable.

[REDACTED]

Further details on the PSA work undertaken for the SMR-160 and for the SMR-300 are outlined within Part B Chapter 16 [20].

22.2.3 Future Work

The current design has not been sufficiently developed to carry out detailed internal hazards assessments. These will be carried out after GDA Step 2 using the methodologies outlined in this PSR chapter when sufficient design information is available. These studies will ensure that:

- The effects of hazards that could affect key passive safety components and systems are minimised and reduced to ALARP levels.
- The cable routes and electrical supplies required for the 1E functions (i.e. initiation of the PDH, SDH and other passive systems) will not be disproportionately compromised by internal hazards.
- The non-safety systems are protected from internal hazards such that the demand frequency from internal hazards on the 1E and active equipment is proportionate and ALARP.

Where required, Design Challenge papers will be developed as the design and safety analysis becomes available. It is envisaged that any potential design changes will be informed by the SMR-300 Fire and Flood PSAs (see also [27]).

22.2.4 Conclusions

The SMR-300 passive safety systems together with the existing hazards protection features give a high degree of confidence that the internal hazards assessments to be carried out after Step 2 will demonstrate that the design is adequately safe.

Any differences between the United States (US) design and UK expectations will be addressed by Design Challenge papers and using PSA support, as noted above.

22.3 OVERVIEW OF INTERNAL HAZARDS

22.3.1 Internal Hazard Definition

Internal Hazards are defined within the Office of Nuclear Regulation (ONR) Safety Assessment Principles (SAP) [28] as:

'…hazards to the facility or its structures, systems and components that originate within the site boundary and over which the Dutyholder has control in some form.'

The term 'hazard' refers to any event which by damaging SSCs or civil structures has the potential to cause singly or in combination:

- One or more initiating faults which are within the Design Basis (DB).
- A significant reduction in the reliability and availability of plant safeguards.
- A more severe initiating fault than that assumed for DB calculations.
- An initiating fault which is not included within the DB.

Internal Hazards which are sufficiently frequent that they must be considered in the design are known as DB hazards. This is specified in the SAPs [28] by the engineering principle EHA.3:

'For each internal or external hazard, which cannot be excluded on the basis of either low frequency or insignificant consequence, a design basis event should be derived.'

Internal Hazards that occur more frequently than 10^{-5} per year are considered to be DB hazards. Less frequent Internal Hazards still require assessment in order to ensure that there are no cliff-edge effects and that a balanced design has been achieved.

Generally, the overall aim of the Internal Hazards specification and analysis is to achieve a balance between the design requirements for Internal Hazards and those from other plant faults. The Internal Hazards requirements are not to be over-specified (or under-specified); the aim is to achieve an adequate degree of safety with respect to Internal Hazards.

Protection against Internal Hazards is achieved mainly by prevention, limitation of severity, and mitigation which is provided by segregation / separation or by qualification. In some cases, a combination of approaches is used.

22.3.2 Internal Hazard Locations

Internal hazards by definition occur internal to the site boundary; however, a further distinction can be made whereby these hazards occur 'internal' to buildings or 'external' to building. Typically, Internal Hazards that occur within the safety related buildings are the most significant due to their vicinity to SSCs important to nuclear safety. For Internal Hazards that occur external to the safety related buildings, the ability of the building structures to provide an additional safety measure helps reduce the risk of other SSCs important to nuclear safety being impacted. Within this report the distinction between these 'internal' and 'external' hazards is not covered, however, during Hazard Identification (HAZID) in sub-chapter 22.6.2, this will be explicitly captured to ensure differentiation.

22.3.3 Internal Faults

The Internal Hazards identified within sub-chapter 22.6 have the potential to result in Internal Faults[2] should the design / layout of the generic SMR-300 not preclude hazards or have insufficient / inadequate safety measures to prevent the hazard developing into a fault sequence.

The fault groups applicable to the generic SMR-300 that have been identified within Part B Chapter 14 [18], their identification and classifications are captured and explained further within Part B Chapter 14.

As part of ongoing work within Part B Chapter 14, a Preliminary Consolidated Fault List (CFL) has been produced based upon extant Pressurised Water Reactor (PWR) information, as well as undertaking a more detailed fault identification exercise on select topic areas, to identify Postulated Initiating Events (PIE) for the generic SMR-300 design. The PIEs considered for the generic SMR-300 design will need to include all foreseeable failures of duty systems[3] and SSCs of the plant, as well as human failures and possible failures arising from internal and external hazards, whether at full power, low power or shutdown states, in the reactor, the fuel pool, fuel handling system, waste operations or some other activity containing sources of radiation.

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[2] Internal Hazards are different to Internal Faults in their origin and impacts on the system. Internal Hazards are often caused by Internal Faults with the plant / process equipment, such as pump failure or instrumentation failure etc.

[3] Duty systems are defined within the PFS Report [93] as: The normal or continuously operating system that provides an operational safety function and therefore fulfils a fundamental safety function during normal operations and is designated as Level 1 of Defence in Depth (DiD) in the IAEA hierarchy [96]

22.4 INTERNAL HAZARDS CLAIMS, ARGUMENTS AND EVIDENCE

This chapter presents the Internal Hazards aspects for the generic SMR-300 and therefore directly supports Claim 2.1.6.

Claim 2.1.6: Risks from Internal Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

Claim 2.1.6 has been further decomposed within this PSR chapter to provide confidence that the relevant requirements on SSCs will be met during all lifecycle phases. The Internal Hazards analysis is predominantly focused around three main areas:

- Internal Hazards have been identified based upon a robust HAZID process including a review of RGP and Operating Experience (OPEX).
- Deriving safety features to be placed on SSCs to prevent, protect and mitigate against Internal Hazards.
- Analysis of Internal Hazards to demonstrate that the identified safety features ensure relevant safety objectives and targets are met.

This decomposition has been undertaken by breaking down Claim 2.1.6 into four further claims which support these three main areas.

Claim 2.1.6.1 is an enabling claim for the above areas to ensure that HAZID work has been undertaken to ensure all credible hazards have been identified.

Claim 2.1.6.2 ensures that the characterisation and methodologies that the Internal Hazards will be assessed against, are appropriate for the UK context.

Claim 2.1.6.3 supports the derivation of safety features and safety measures by identifying all relevant Internal Hazards and ensuring SSCs are correctly specified in terms of safety functions and classification, derived from the safety analysis.

Claim 2.1.6.4 presents the analysis to demonstrate that the plant can reach a safe state following an Internal Hazard Design Basis Event (DBE), noting that the maturity of evidence for this claim will be limited at the PSR stage.

Table 1 shows the breakdown of Claim 2.1.6 and identifies which chapter of this PSR these claims are demonstrated to be met.

Table 1: Claims Covered by Chapter B22

Claim No.	Claim	Chapter Section
2.1.6.1	A comprehensive set of Internal Hazards and their combinations are identified and screened for assessment.	22.5 Internal Hazards Codes and Standards
2.1.6.2	Internal Hazards are characterised and evaluated using appropriate methodologies taking due cognizance of RGP and OPEX.	22.6 Internal Hazard Identification
2.1.6.3	Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all Internal Hazards and provide sufficient lines of protection based on the fault frequency and consequence.	22.8 SSCs with Internal Hazard Safety Functions
2.1.6.4	Analysis demonstrates that the identified safety features (in conjunction with operator actions) enable the plant to reach a safe shutdown state for all Internal Hazard DBEs.	22.7 Internal Hazard Characterisation and Evaluation

Table 8 within Appendix A provides a full CAE mapping for Part B Chapter 22, which includes any lower-level claims, arguments and evidence needed to support the claims in the table above. This includes identification of evidence available at PSR v1 and aspects for future development of evidence to support these claims beyond PSR v1.

22.5 INTERNAL HAZARDS CODES AND STANDARDS

Claim 2.1.6.1: A comprehensive set of Internal Hazards and their combinations are identified and screened for assessment.

Claim 2.1.6.2: Internal Hazards are characterised and evaluated using appropriate methodologies taking due cognisance of RGP and OPEX.

Due to the nature of Internal Hazards, two claims have been identified as being applicable to codes and standards. Claims 2.1.6.1 has been identified and decomposed to ensure that the 'generic' Internal Hazards identified in sub-chapter 22.6.1 are suitable. The second claim, Claim 2.1.6.2, has been decomposed into a single argument to identify suitable codes and standards applicable to the assessment methodology for each of the identified Internal Hazards. These arguments and their available evidence are listed below:

Argument 2.1.6.1-A1: The SMR-300 identifies Internal Hazards based upon US NRC regulatory guidance. Within the UK context a comprehensive list of 'generic' Internal Hazards has been identified based upon OPEX and RGP.

- Sub-chapter 22.5 tables all the codes and standards referenced throughout this chapter for the identification of Internal Hazards for both the US and UK.
- Sub-chapter 22.6.1, supported by Appendix B, outlines the UK codes and standards and OPEX utilised to identify the 'generic' Internal Hazards.

Argument 2.1.6.2-A1: The overarching approach for Internal Hazards for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

- Sub-chapter 22.5 tables all the codes and standards referenced throughout this chapter for the assessment of Internal Hazards for both the US and UK.
- Sub-chapter 22.7 outlines the methodology for the assessment of Internal Hazards and their relevant codes and standards, this sub-chapter is supported by the following Step 2 documents:
    - Internal and External Hazards Combined Hazards Methodology [3].
    - Internal Hazards Impact Hazard Assessment [29].
    - Internal Hazards Impact Hazard Substantiation Methodology [30].
    - Internal Hazards Alignment Report [31].

This sub-chapter outlines the codes and standards used in both the identification and assessment of Internal Hazards. The Requesting Party has recognised that UK nuclear safety regulations are based on a non-prescriptive regime and consequently the technical codes and standards that must be used for nuclear power plants are not prescribed. However, the codes and standards must represent RGP.

22.5.1 Guidance Documents used to develop SMR-300 for Internal Hazards

Internal Faults for the SMR-300 are assessed based upon US Nuclear Regulatory Commission (NRC) regulations. Some Internal Hazards identified by the ONR, are not specifically assessed within US NRC guidance, however, this does not mean they are not covered in this GDA internal hazards assessment. This difference in regulatory approach to Internal Hazards has been identified within the UK GDA Gap Analysis Report [32] and is discussed further within this chapter. For each of the identified Internal Hazards within sub-chapter 22.6 the following US guidance documents, shown within Table 2, have been identified.

Table 2: Principal regulations, codes and standards

Label	Title	Revision / Date
American Concrete Institute (ACI) 349 Appendix F	Special Provisions for Impulsive and Impactive Effects [33]	2013
American National Standards Institute (ANSI) 56.11	Design Criteria for Protection Against the Effects of Compartment Flooding in Light Water Reactor Plants [34]	2013
American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Code, Section III	Rules for Construction of Nuclear Facility Components [35]	2017
National Fire Protection Association (NFPA) 804	Fire Protection for Advanced Light Water Reactors [36]	2020
US Nuclear Regulatory Guide Branch Technical Position (BTP) 3-4	Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment [37]	2
US Nuclear Regulatory Guide 10 Code of Federal Regulation (CFR) Part 50 Appendix A	General Design Criteria for Nuclear Power Plants [38]	-
US Nuclear Regulatory Guide NUREG-0800	Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants [39]	-
US Nuclear Regulatory Guide 1.115	Protection Against Turbine Missiles [40]	2
US Nuclear Regulatory Guide 1.180	Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems [41]	2
US Nuclear Regulatory Guide 1.189	Fire Protection for Nuclear Power Plants [42]	4
US Nuclear Regulatory Guide 1.102	Flood Protection for Nuclear Power Plants [43]	1
US Nuclear Regulatory Guide 1.244	Control of Heavy Loads at Nuclear Facilities [44]	0
US Nuclear Regulatory Guide 1.59	Design Basis Floods for Nuclear Power Plants [45]	2
US Nuclear Regulatory Guide 1.75	Criteria for Independence of Electrical Safety Systems [46]	5

An extensive list of Fire Protection Codes and Standards for the SMR-300 is presented within the GDA Step 1 Codes and Standards Report [47] and is not repeated here for brevity.

22.5.2 UK and International Guidance proposed for use by the generic SMR-300 Internal Hazards Approach

Due to the differences between the US and UK regulatory approaches a comprehensive review has been undertaken to identify Internal Hazards UK RGP and propose assessment methodologies / philosophies for all identified Internal Hazards. Within the UK's non-prescriptive regulatory regime, the expectation is that duty holders will develop facility designs consistent with ONR guidance. ONR guidance is generally consistent with guidance from International Atomic Energy Agency (IAEA) and Western European Nuclear Regulators' Association (WENRA). The key ONR SAPs identified in relation to Internal Hazards are listed below, this is a non-exhaustive list, other SAPs may also apply:

- EHA.1: Identification and Characterisations.
- EHA.3: Design Basis Events.
- EHA:4: Frequency of Initiating Event.

- EHA.6: Analysis.
- EHA.14: Fire, explosions, missiles, toxic gases etc – sources of harm.
- EHA.15: Hazards due to water.
- EHA.16: Fire detection and fighting.
- EHA.18: Beyond Design Basis Events.
- FA.2: Identification of Initiating Faults.
- FA.5: Initiating Faults.
- EKP.1: Inherent Safety.
- EKP.3: Defence In Depth.

ONR Guidance documents and other sources of RGP, such as the IAEA and WENRA have been reviewed and considered in line with ONR SAP and Technical Assessment Guide (TAG) guidance, these are shown within Table 3.

In addition to the ONR SAPs this chapter has been developed in accordance with the Environment Agency's (EA) Engineering Design Principles (ENDP) [48]. ENDP13 states that External and Internal Hazards that could affect the delivery of an environment protection function should be identified with the best available techniques used to avoid or reduce impact [48]. Environmental protection is one of the High-Level Functions identified for the generic SMR-300 in Part A Chapter 2 [4].

Table 3: UK RGP for Internal Hazards

Label	Title	Revision
ONR Documentation		
-	Safety Assessment Principles [28].	1
NS-TAST-GD-014	Technical Assessment Guide: Internal Hazards [49].	7.1
ONR-GDA-GD-007	Nuclear Power Plants Generic Design Assessment Technical Guidance [50].	0
ONR-GDA-GD-006	ONR GDA Guidance to RPs [51].	0
NS-TAST-GD-036	Redundancy, Diversity, Segregation and Layout of Structures, Systems and Components [52].	3
NS-TAST-GD-051	The Purpose, Scope, and Content of Safety Cases [53].	4
NS-TAST-GD-094	Categorisation of Safety Functions and Classification of Structures, Systems and Components [54].	2
NS-TAST-GD-005	Guidance on the Demonstration of ALARP [55].	11.2
IAEA Documentation		
SSG-64	Protection Against Internal Hazards in the Design of Nuclear Power Plants [56].	1
IAEA-TECDOC-1944	Fire Protection in Nuclear Power Plants [57].	1
SSR-2/1	Safety of Nuclear Power Plants: Design [58].	1
NS-G-2.1	Fire Safety in the Operation of Nuclear Power Plants [59].	1
SSG-2	Deterministic Safety Analysis for Nuclear Power Plants [60].	
SSR-2/2	Safety of Nuclear Power Plants: Commissioning and Operation [61].	1
WENRA Guidance		
-	Safety Reference Levels for Existing Reactors [62].	2021
-	Report on Safety of new Nuclear Power Plant (NPP) [63].	2013
-	WENRA Statement on Safety Objectives for New Nuclear Power Plants [64].	2010
'Other' Guidance		
Health and Safety Executive (HSE) L138	Dangerous Substances and Explosive Atmospheres, Approved Code of Practice and Guidance [65].	2

Label	Title	Revision
HSE L122	Safety of Pressure Systems, Pressure Systems Safety Regulations 2000 Approved Code of Practice [66].	2
HSE L113	Safe Use of Lifting Equipment, Lifting Operations and Lifting Equipment Regulations 1998 [67].	2
Structural Mechanics in Reactor Technology (SMiRT)	UK's Regulatory Safety Assessment of Nuclear Plants Pressure Part Failure – A Multi-Disciplinary View [68].	1
SMiRT	UK's Regulatory Consideration of Partial Failures in High Energy Components – A Multi-Discipline View [69].	1

In line with ONR TAG guidance for Internal Hazards [49], the following extant GDA submissions have also been reviewed:

- UKEPR-0002-132, PCSR Sub-Chapter 13.2: Internal Hazards Protection [70].
- SMR0003977, E3S Case Chapter 15: Safety Analysis [71].
- UKP-GW-GL-793NP, AP1000 Pre-Construction Safety Report [72].
- GA91-9101-0101-07000, Generic PCSR Chapter 7 Internal Hazards [73].
- UK HPR1000 Preliminary Safety Report Chapter 19 Internal Hazards [74].

In addition to the above, a review of applicable Regulatory Observations (RO) and Regulatory Issues (RI) from previous GDAs has been undertaken.

22.5.3 CAE Summary

The generic SMR-300 Internal Hazards Identification, characterisation and analyses has been undertaken using best practice nuclear industry codes and standards and RGP identified from recent UK GDA submissions. These codes and standards include guidance and expectations from both the US NRC and ONR. In relation to codes and standards aspects of Claims 2.1.6.1 and 2.1.6.2, these claims have been fulfilled to the extent consistent with the maturity of this project at this time. Further details on the fulfilment of the remainder of Claims 2.1.6.1 and 2.1.6.2, to identify Internal Hazards and their characterisation and evaluation methodologies are outlined within sub-chapters 22.6 and 22.7 respectively.

22.6 INTERNAL HAZARD IDENTIFICATION

Claim 2.1.6.1: A comprehensive set of Internal Hazards and their combinations are identified and screened for assessment.

Claim 2.1.6.1 has been decomposed into three arguments to capture the multiple sources of Internal Hazards, covering the 'generic' Internal hazards identified based upon OPEX and RGP, hazards identified from formal HAZID activities and finally hazard combinations. Each of these three arguments and the available evidence are covered within their own respective sub-chapters:

- Argument 2.1.6.1-A1: Sub-chapter 22.6.1 outlines the methodology for the identification of 'generic' Internal Hazards based upon RGP and OPEX.
- Argument 2.1.6.1-A2: Sub-chapter 22.6.2 presents the approach to be followed for HAZID works to be undertaken to identify Internal Hazards for the generic SMR-300.
- Argument 2.1.6.1-A3: Sub-chapter 22.6.3 summarizes the methodology followed to identify credible Internal Hazard combinations within the scope of GDA, as well as the methodology to be followed post GDA.

The identification of Internal Hazards is required in line with ONR SAP EHA.1 with notable Internal Hazards being identified within their own specific ONR EHA SAPs, e.g., EHA.14 identifies the need to cover fire, explosion, missiles, toxic gases etc.

22.6.1 Generic Internal Hazards

Argument 2.1.6.1-A1: The SMR-300 identifies Internal Hazards based upon US NRC regulatory guidance. Within the UK context a comprehensive list of 'generic' Internal Hazards has been identified based upon OPEX and RGP.

Internal Hazards have been identified from the codes, standards and RGP listed within sub-chapter 22.5. A comparison of the Internal Hazards from relevant guidance documents and extant GDA documentation has been undertaken within Table 9 of Appendix B, with the identified Internal Hazards listed below:

- Internal Fire.
- Internal Explosions (including internal blasts).
- Internal Flooding.
- Pipe Whip and Jet Impact.
- Internal Missiles (including turbine disintegration).
- Dropped Loads.
- Toxic and / or Corrosive Solid, Liquid or Gaseous Release.
- Vehicle Impact.
- Electromagnetic Interference.
- Combined Hazards.

22.6.2 Hazard Identification

Argument 2.1.6.1-A2: A comprehensive hazard identification exercise has been undertaken to identify sources of Internal Hazards that could challenge the critical safety functions for the generic SMR-300.

Formal HAZID of Internal Hazards is required in line with ONR SAP EHA.1 for the generic SMR-300 design. Supplemental HAZID, building on existing US safety assessment, is required to ensure all credible sources of Internal Hazards are identified such that they can be characterised, and, where required, further assessment undertaken to ensure that suitable and sufficient safety measures are available to meet UK expectations. Identified Internal Hazards are to be recorded with sufficient detail and context to enable ease of review / audits at a later date. Within the scope of Step 2 limited HAZID work has been undertaken due to the availability of design information, consequently, this sub-chapter focuses on the methodology to be applied post Step 2.

As noted within sub-chapter 22.3.2, HAZID work shall identify the location of the Internal Hazards with respect to the safety classified buildings. The differentiation is made between safety and non-safety classified buildings as a fire within one of the safety classified buildings is likely to have more severe consequences than a fire outside a safety classified building. Internal hazards outside safety classified buildings also include hazards within the 'yard'. Generic examples for each Internal Hazard identified within sub-chapter 22.6.1, for varying locations, are presented in Table 4.

Table 4: Example Internal Hazards from Differing Sources

Internal Hazard	'Outside Safety Classified Building' Examples	'Within Safety Classified Building' Examples
Internal Fire	External combustible material ignites	Electrical equipment shorts within building
Internal Explosions	Failure of hydrogen storage tanks	Hydrogen build-up from failed Uninterruptible Power Supply (UPS) ventilation
Internal Flooding	External water storage tank fails	Pipe failure
Pipe Whip and Jet Impact	Pipework external to the buildings fails	Failure of Reactor coolant system
Internal Missiles (including turbine disintegration)	External gas cylinder regulator fails	Failure of coolant pump
Dropped Loads	Temporary external crane fails	Failure of Polar Crane
Toxic and / or Corrosive Solid, Liquid or Gaseous Release	External chemical storage tanks	Local gas bottle storage fails leading to release of asphyxiant
Vehicle Impact	Heavy Goods Vehicle (HGV) delivering fuel to storage tanks crashes	Internal forklift truck impacts SSC
Electromagnetic Interference	TETRA (Terrestrial Trunked Radio) emergency transmitters, ground penetrating radar	Cellular phones, wireless networking and Bluetooth devices

Interaction of Internal Hazards between buildings are to be considered. Although a generic list of Internal Hazards has been identified within sub-chapter 22.6.1 consideration is required for how individual buildings, including those outside the scope of the GDA, could impact upon buildings within the scope of the GDA. An example of this is how Internal Hazards from the turbine building, outside the scope of the GDA, could impact upon the buildings within the Nuclear Island as a result of Internal Hazards such as Internal Fires, Internal Floods etc.

22.6.2.1 Hazard Identification Methodology

The methodology to identify each Internal Hazard and the information to be captured during HAZID work will differ from hazard to hazard, e.g. for Dropped Loads the load details are required whereas for Pipe Whip the pipework specification will be required. The below generic methodology shall be applied to Internal Hazard HAZID work:

1. Systematic review of room / locations / buildings for credible sources of Internal Hazards for all plant states. This review shall utilise design information such as Piping and Instrumentation Diagrams (P&ID), layout drawings, system descriptions, as well as additional tools such as the 3D model.
    a. Identification of potential hazardous events that could occur from SSCs within the room, e.g. dropped load, source of internal fire etc.
        i. Consideration shall be given to if a hazardous event has the potential to initiate another hazard event (consequential hazards).
        ii. Onus shall be given to ‘novel’ aspects of the generic SMR-300 that differ in comparison to ‘traditional’ PWRs, e.g. the AR.
        iii. Where possible, if multiple sources of hazards are identified, preliminary bounding shall be undertaken, ensuring it is captured in support of the ‘golden thread’.
2. Identification of the SSCs within the room / location / building that could be impacted by the hazardous event, in their unmitigated form.
    a. This assessment shall also capture the impacts upon the wider system, e.g. should a pump be damaged, the system this pump supports shall also be noted.
    b. Within the scope of Step 2, a high-level desktop exercise was undertaken based upon the Design Reference Point (DRP) to identify Internal Hazards from layout drawings. This desktop exercise resulted in a draft ‘Hazard Schedule’. The outputs of this exercise are heavily caveated due to the omission of key design information such a pipe and cable routings.
3. Identification of safety measures available to protect against such hazardous events, including any relevant design standards for hazard sources, e.g. pressure vessels designed in line with ASME BPVC.

Within the scope of GDA Step 2, two Hazard and Operability (HAZOP) ‘I’ studies have been undertaken on the below topic areas with the findings of these HAZOPs captured within their respective HAZOP reports:

- Fuel Storage and Transport Route [75].
- Radioactive Waste Management [76].

A number of the Internal Hazards keywords were used within these HAZOPs, these are listed below, this is a non-exhaustive list. The outputs of these HAZOPs have been included within the CFL.

- Dropped Load.
- Hazardous Material.
- Fire / Smoke / Ventilation.
- Loss of Containment.
- Collision / Impact.

Beyond GDA Step 2, the methodologies utilised within the above HAZOPs shall form the basis for additional studies, and where appropriate, alternative HAZID techniques shall be used. The Safety Assessment Handbook (SAH) [77] outlines the below as alternative HAZID techniques, the selection of these shall be undertaken by a Suitably Qualified and Experienced Personnel (SQEP) chair based upon the system / room / building being assessed and the available information:

- Failure Modes and Effects Analysis (FMEA).
- Master Logic Diagrams (MLD).
- Review of System Design Documents, P&IDs etc.
- Systems Theoretic Process Analysis (STPA).

22.6.2.2 Layout Optimisation

During the HAZID process, focus shall be given to the layout of the generic SMR-300 regarding fault locations and the location of redundant safety systems to ensure a single Internal Hazard is not able to challenge multiple safety 'trains'. The principles employed by the SMR-300 in relation to grouping and separation are outlined within Part A Chapter 2 [4]. Should multiple systems be identified as being vulnerable as a result of a single Internal Hazard / or are within the same zone or area, a review of their locations shall be undertaken, and relocation / additional segregation considered. Any design alteration required by the SMR-300 will be subject to the design change process outlined within Part A Chapter 4 [7].

The following design challenge and commitment have been raised for the SMR-300 in relation to layout optimisation:

C_Inte_117: The Design Challenge Paper 'Design Challenge – Internal Hazards' (HI-2250235-R0.0) is with the Design Authority for Design Decision. [REDACTED]. A Commitment is raised to progress this Design Challenge through the Design Management process (HPP-3295-0017-R1.0) to completion. Target for Resolution - Issue of Pre-Construction SSEC.

This design challenge paper and its associated commitment are discussed further within sub-chapter 22.10.2.3 and 22.10.2.4.

22.6.3 Combined Hazard Identification

Argument 2.1.6.1-A3: Credible combinations involving Internal Hazards have been identified that could challenge the critical safety functions for the generic SMR-300.

In addition to standalone Internal Hazards, the identification of credible Internal Hazard combinations is required. The Internal and External Hazards Combined Hazards Methodology [3] report outlines the methodology to be followed for the identification of combined hazards. This report also undertakes the initial identification of combinations based upon available Step 2 information.

The identification of combined hazards is undertaken based upon the Advanced Safety Assessment Methodologies: Extended PSA (ASAMPSA) methodology [78], this is comprised of the following key steps, and are outlined in full within [3]:

1. Identification of External and Internal Hazards.
2. Identification and Categorisation of Hazard Combinations:

    a. Identification of Hazard Combinations.
    b. Categorisation of Hazard Combinations.
        i. Correlated Hazards.
        ii. Consequential Hazards / Effects.
        iii. Coincidental (Independent Hazards).
3. Screening of Hazard Combinations based upon:
    a. Frequency.
    b. Consequences of combination.
    c. Bounding of combination.
    d. Site-Specific Combination.

The following quantities of hazard combinations were identified within [3] for each Internal Hazard - hazard combination group, as summarised in Table 5.

Table 5: Quantity of Hazard Combinations Identified

Hazard Combination Group	Category	Quantity
External-Internal	Consequential	8
Internal-Internal	Consequential	49

Beyond GDA when site-specific information and more complete design information is known, combinations of hazards screened as site-specific shall be reassessed, notably the External Hazards that can lead to Internal Hazards. The credible combinations will then be subject to hazard assessment to identify if there are suitable and sufficient safety measures, and that the risks are ALARP.

22.6.4 CAE Summary

An extensive review of available Codes and Standards and extant GDAs has been undertaken to identify 'generic' Internal Hazards. This work, in combination with the proposed HAZID methodologies, to be applied post GDA Step 2, and the assessment of combined hazards, provides a comprehensive set of Internal Hazards for assessment. The undertaking of the two HAZOP I studies provides further confidence that the application of the HAZID methodologies results will provide meaningful outputs.

Layout to support this primary objective may be geometrically constraining in some specific areas and may need detailed investigation for some specific hazards [REDACTED] after Step 2. Currently the general layout can be considered to be "as well optimised as can be" at this stage of the design and analysis. Therefore, Claim 2.1.6.1 has been met to the extent consistent with the maturity of this project at this time.

22.7 INTERNAL HAZARD CHARACTERISATION AND EVALUATION

Claim 2.1.6.2: Internal Hazards are characterised and evaluated using appropriate methodologies taking due cognizance of RGP and OPEX.

Claim 2.1.6.2 has been decomposed into five arguments to cover the overarching Internal Hazard methodologies and each of the Internal Hazard groups. These arguments identify the US methodology applied to Internal Hazards and capture any deviations, and therefore additional assessment, required to align with UK regulatory expectations.

- Sub-chapter 22.7.1 outlines the overarching approach for the assessment of Internal Hazards in line with UK expectation.
- Sub-chapter 22.7.2 covers each of the Internal Hazard groups outlined in 22.7.2. This identifies the individual Internal Hazard assessment methodologies and compares the US and UK approaches. This sub-chapter is supported by the following Step 2 Internal Hazard deliverables:
  - Internal and External Hazards Combined Hazards Methodology [3].
  - Internal Hazards Impact Hazard Assessment [29].
  - Internal Hazards Impact Hazard Substantiation Methodology [30].
  - Internal Hazards Alignment Report [31].

Within the scope of GDA Step 2, only methodologies have been defined, the future assessments to be undertaken beyond GDA Step 2 are outlined within sub-chapter 22.9.

The assessment of Internal Hazards typically depends upon the hazardous components and materials. Internal Hazards SSCs can typically be split into two classifications, in line with ONR TAG 003 Safety Systems [79], depending upon where the SSC intersects the fault progression. Depending upon their classification, these faults are typically assessed by different topic areas, either within the Fault Studies topic area, or by Internal Hazards, these classifications are defined below. Within the scope of Step 2 this distinction of Safety-System and SSCs that could place a demand on a safety system is not made.

- Safety-System:
  - These are SSCs which are required to act in response to an initiating event and are a safety measure. These fault progressions are typically captured under DB faults, which are outlined further within Part B Chapter 14. For Internal Hazards not bounded by DB Faults, further assessments shall be undertaken, as outlined within this sub-chapter.
- An SSC that could place a demand on a safety system (i.e. Safety Related according to [79]):
  - These are SSCs which should they fail, act as an initiator for a fault, e.g. failure of a lifting device. For these SSCs, it is typical for the Internal Hazards topic area to lead on defining the requirements for these devices to ensure adequate safety.

22.7.1 Internal Hazards Overarching Approach

Argument 2.1.6.2-A1: The overarching approach for Internal Hazards for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

The following sub-chapters outline the overarching approach to assess Internal Hazards for the generic SMR-300. Hazard specific discussions are captured in the sub-chapter 22.7.2.

The fundamental derived acceptance criteria which must be met by the SMR-300 for all DB Internal Hazards is that all such events are bounded by a DB fault. These acceptance criteria are as follows:

a. The fundamental safety functions of the plant (control, cool, contain, monitor, and control releases) shall remain available.
b. There shall be no failure of fuel or the reactor coolant pressure boundary.
c. The containment function shall be maintained.
d. The ability to monitor the state of the plant shall be maintained.
e. Dose acceptance criteria for DB Accidents from Internal Hazards shall be met.

22.7.1.1 Characterisation of Internal Hazards

ONR SAP EHA.1 requires the characterisation of both Internal and External Hazards to be defined. The characterisation of each Internal Hazard will differ between the hazards, e.g. blast overpressure, or a time and temperature profile for a fire. The characteristics of the Internal Hazards will be determined, and where uncertainty is present, conservative assumptions will be used. Characterisation of Internal Hazards is required to enable a suitable analysis to be undertaken. Further details on the characterisation of 'generic' Internal Hazards are given within their corresponding sub-chapter throughout sub-chapter 22.7.2.

As a part of the characterisation of Internal Hazards, there is also a requirement to identify and demonstrate the integrity of the hazard volume e.g. divisional boundaries, room boundaries, dampers, seals, tank requirements and local protection etc. In characterising these hazard volumes close interfaces with some engineering disciplines will be required, e.g. Civil Engineering for building structures and seals, and Mechanical Engineering for dampers and tanks.

Internal Hazard Initiating Event Frequencies (IEF) will be identified, and where values from suitable experience are not available, estimates will be used and justified, as outlined within the SAH [77].

The need to quantify the frequency of an initiating event aligns with ONR SAPs [28] EHA.4. The fault screening then identifies the design basis internal hazards, in line with ONR SAPs [28] EHA.19. This screening process is a pragmatic approach to the Internal Hazards assessment, and ensures that full assessments are undertaken for those hazards that present the greatest overall risk to the plant / system / SSCs.

22.7.1.2 Unmitigated Consequences

Unmitigated consequences for Internal Hazards will be identified, i.e., the dose to each of the exposure groups should all safety measures that can credibly be affected by the hazard fail. Where possible, plant faults caused by Internal Hazards shall be identified and the unmitigated consequences derived for the plant fault utilised, by assuming that SSCs affected by the fault provide no mitigation.

Part A Chapter 2 of the PSR [4] General Design Aspects and Site Characteristics introduces the UK numerical targets that will be applied to the generic SMR-300 (which are equivalent to ONR SAPs [28] NT.1 to NT.9). In line with ONR SAP EHA.19, Internal Hazards with a low consequence, that 'have no significant identified consequential effect on the safety of the facility' can be screened out from further assessment, [28] para. 235(a).

22.7.1.3 Safety Measures

The methodology for the categorisation and performance requirements of safety measures is outlined in full within the SAH [77]. A high-level overview is provided within this sub-chapter for context.

For each fault progression, using both the IEF and unmitigated consequence, a UK aligned Safety Functional Category will be assigned. The Safety Functional Category categorisation informs the number and classification of safety measures required. Substantiation of this Safety Function is then achieved through the provision of safety measures to the required classification by the engineering disciplines.

For each Internal Hazard it will be shown that the available safety measures ensure that the risks are tolerable and ALARP and the cost of implementing further safety measures would be deemed grossly disproportionate to the risk reduction gained. The ALARP methodology to be applied to the generic SMR-300 is outlined within Part A Chapter 5 Summary of ALARP and SSEC [80].

22.7.2 Individual Internal Hazard Methodologies

The following sub-chapters outline the assessment methodologies for individual Internal Hazards. Where US and UK regulatory expectations are relatively aligned, the methodology shall outline the US approach and note the differences required to align with UK expectations. Where the expectations are not aligned, or there is no assessment approach within the US, the UK approach shall be outlined.

22.7.2.1 Internal Fires and Explosions

Argument 2.1.6.2-A2: The approach for Internal Fires and Explosions for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

22.7.2.1.1 Internal Fire

Conventional Fire Safety for the generic SMR-300 is covered within Part B Chapter 12 Nuclear Site Health and Safety and Conventional Fire Safety [16]. Internal Fire and Conventional Fire have a key interface for defining the holistic design protection against fires, and aligning the design of fire compartments, evacuation routes, fire alarm warning, control of external fire spread and fire-fighting systems. Conventional Fire covers the risk to life of personnel, whereas Internal Fire within this chapter focuses on the fires which have the potential challenge to nuclear safety. Assessment and sentencing of identified fire scenarios will depend upon the potential consequences.

The assessment of Internal Fire is required in line with the following ONR SAPs:

- EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm.
- EHA.16 Fire Detection and Fighting.
- EHA.17 Appropriate Materials in Case of Fire.

The SMR-300 has been designed in line with fire compartmentalisation guidance defined by General Design Criteria (GDC) 3 Fire Protection in Appendix A of 10 CFR Part 50 [38] and complies with NRC Regulatory Guide 1.189 Fire Protection for Nuclear Power Plants [42]. NRC Regulatory Guide (RG) 1.189 is a compendium of multiple guidance documents provided by the NRC. The key protection measures against Internal Fire are outlined below, these align with the hierarchy of control expected within UK regulatory guidance:

- Prevents fires from starting:
  - SSCs important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Non-combustible and heat-resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room.
- Rapidly detects, controls, and extinguishes a fire that may occur:
  - Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on SSCs important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these SSCs.
- Provides protection for SSCs important to safety so that a plant can continue to safely shutdown if a fire is not promptly extinguished by the fire suppression activities:
  - The SMR-300 will comply with the applicable provisions specified in NFPA 804, Fire Protection for Advanced Light Water Reactors, [36] related to the protection of post-fire safe-shutdown capability and the mitigation of a radiological release resulting from a fire.
  - In line with NRC RG 1.189 fire compartments shall have a three-hour minimum fire resistance rating and where this cannot be achieved, either due to penetrations or material selection, further assessment shall be undertaken.

A Fire PSA [81] was undertaken for the SMR-160 in line with the Fire PSA methodology defined within [82], work is ongoing to reassess the SMR-300 for Internal Fire. Consequently, within the scope of this PSR the findings of the SMR-160 Fire PSA are not addressed here as there are significant differences between the two designs. As noted within sub-chapter 22.7.2.1.1.1, the findings of the Fire PSA and analysis for the SMR-300 shall provide key inputs to the deterministic Internal Fire assessment for the generic SMR-300.

22.7.2.1.1.1 Internal Fire Assessment Methodology

As outlined in sub-chapter 22.7.2.1, and assessed in detail within the Internal Hazards Alignment report [31], the fire assessment undertaken for the SMR-300 in line with the US NRC is partially aligned with the UK regulatory expectations. However, a number of differences exist between the two regulatory regimes, consequently for the generic SMR-300 the following shall be implemented for the assessment of internal fires in line with UK regulatory expectations:

- Provide justification when the fire influence approach is used.
    - The fire influence approach is used within the US Internal Fire assessment where full segregation is not practical. While justification, such as low combustibles present in the area, can be extracted from the findings of the US fire hazard analysis, further specific physical effects modelling (or testing) to substantiate the adequacy of separation of redundant trains or safety measures or local fire barriers may be required for the generic SMR-300. ALARP review of available options may also be needed to demonstrate that the associated risk is ALARP.
- Suitable modelling of combustible inventories to ascertain the temperature time profile of a compartment burn in line with ONR SAPs EHA.1, EHA.5 and EHA.6. Using the output of this fire modelling, the fire analysis shall define the fire-resistance requirements for fire barriers as well as the requirements for other firefighting responses.
- Identify DB internal fire hazards to be assessed against the acceptance criteria listed in sub-chapter 22.7.1.
    - Using the existing US fire hazard analysis and fire PSA, the frequency, consequences, and safety measures for fire scenarios shall be identified and a DB fire defined for assessment.
- Identify additional fire safety measures which are not claimed (deterministically) in ensuring safe shutdown capability to help demonstrate that risks are ALARP. Where necessary, undertake ALARP assessment of further options if suggested by RGP or findings of DBA or PSA. The fire PSA and fire analysis being developed for the SMR-300 shall act as a significant source of fundamental information relating to fire safety measures.

22.7.2.1.2 Internal Explosions

Internal explosions cover any explosions that occur within the site boundary. Off-site explosions, outside the control of the licensee, will be covered by the External Hazards assessment Part B Chapter 21 [22]. Assessment of Internal Explosions is required in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm.

As noted within the ONR SAPs [28], ignition of flammable gases or vapours in confined or congested conditions can result in acceleration of the flame front to produce significant overpressure and thermal effects. Depending on the subsonic or supersonic characteristics of the flame progression, explosions can involve deflagration and / or detonation phenomena, respectively, with the latter having more destructive effects. Deflagrations can progress to detonation (commonly known as Deflagration to Detonation Transition (DDT)) depending on plant geometry and building / compartment atmosphere.

In addition to the above 'ignition' explosions, the failure of high-pressure systems can result in a 'blast' wave. Blast waves from deflagration, detonation or high-pressure system failure events can interact with surrounding SSCs, including nuclear safety barriers, and can lead to failure due to blast waves directly, or by impact by entrained debris / missiles.

Within the US, the assessment of explosions is covered under the assessment of fire, consequently, the SMR-300 has been designed in line with GDC 3 Fire Protection in Appendix A of 10 CFR Part 50 [38] and complies with NRC Regulatory Guide 1.189 Fire Protection for Nuclear Power Plants [42]. NRC RG 1.189 is a compendium of multiple guidance documents provided by the NRC.

The internal explosions assessment will identify sources of internal explosions and, in line with the hierarchy of control and ONR guidance [49], the following approach shall be applied, from most preferential to least. This approach broadly aligns with NRC RG 1.189, however, RG 1.189 focuses on the elimination of sources of explosions, not their characterisation and assessment.

- Elimination of Explosive Sources:
    - In line with ONR SAP EKP.1 the design shall seek to minimise the presence of explosive sources, both chemical and other sources of overpressure. The exact approach to eliminating explosive sources will depend upon the type of explosive sources identified. An example of potential elimination is where an explosive material is present, e.g., hydrogen could be substituted for another material.
- Prevention of Explosion:
    - In line with UK Regulations, locations / areas where potential explosive / flammable material is present shall be subject to Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) assessments.
    - Where systems containing high energy, pressure, or explosive materials are present there is the potential for an internal explosion or blast to occur. Systems are to be designed to appropriate codes and standards. Suitable Examination, Inspection, Maintenance and Testing (EIMT) schedules are to be in place to monitor these systems for degradation and defects.
    - Design measures in locations where explosive gases are present, stored or generated shall ensure they remain below their Lower Explosive Limits (LEL) for their respective atmospheres. This includes areas were batteries / UPS are present, as charging of these items is a credible source of hydrogen generation. It is anticipated that the SMR-300 will employ the use of ventilation within battery rooms to prevent the LELs being reached.
        - The use of batteries within the SMR-300 design philosophy has been identified and therefore the requirement for adequate hydrogen removal from the relevant battery rooms to prevent LELs being reached is a requirement.

22.7.2.1.2.1 Internal Explosions Assessment Methodology

As outlined within the Internal Hazards Alignment report [31], there is general alignment between the US and UK assessment methodologies in the prevention of Internal Explosions, however, the US approach does not outline a methodology for the assessment of explosions and blasts should they occur. The following high-level methodology, separated for explosion and blasts shall be followed for Internal Explosions in line with UK regulatory expectations.

Internal Explosions:

1. Identification of safety-classified SSCs and claimed operator actions to deliver safety functions.
2. Identification of Internal Explosion hazard sources including the following sources:
    a. Oil Mists from systems containing oil.
    b. High Energy Arcing Fault (HEAF) from Electrical panels and switchgear above 440V.
    c. Sources of Hydrogen from stored hydrogen, use of hydrogen within the plant and the potential radiolysis of water.
3. Depending upon the Internal Explosion sources as identified in Step 2 above, different characterisation shall be undertaken. The methodologies for each are outside the scope of this report and are outlined within the Internal Hazards Alignment Report [31].
4. Identification and Assessment of Safety Measures:
    a. For all bounding credible Internal Explosions suitable and sufficient safety measures shall be identified, to the required classification. Safety measures to protect against Internal Explosions may take other forms of withstands and may be higher up the hierarchy of safety, e.g. Heating, Ventilation and Air Conditioning (HVAC) could be used to prevent the formation of an explosive atmosphere being formed.

Internal Blasts:

1. Identification of safety-classified SSCs and claimed operator actions to deliver safety functions.
2. Identification of Internal Blast hazard sources:
    a. Typical sources of Internal Blast sources shall include high pressure systems, including tanks, pipework and other components. Within a given room / area / building, numerous hazard sources may be present. To ensure a pragmatic assessment, bounding blasts shall be identified.
3. Characterisation of identified Internal Blasts:
    a. The full methodology for the characterisation of Internal Blasts is provided within the Internal Hazards Alignment Report [31].
4. Identification and Assessment of Safety Measures:
    a. For all bounding credible Internal Blasts suitable and sufficient safety measures shall be identified, to the required classification.

22.7.2.2 Internal Flooding

Argument 2.1.6.2-A3: The approach for Internal Flooding for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

Internal flooding requires consideration in line with ONR SAP EHA.12 Flooding and EHA.15 Hazards due to water. External flooding is covered within Part B Chapter 21 [22]. Internal flooding has the potential to damage / compromise SSCs related to safety, either through spray or submersion. Sources of internal flooding are typically the release of water from pipes / tanks / vessels; however, consideration is also given to other fluids. Toxic and corrosive liquid leaks from systems / vessels are covered within sub-chapter 22.7.2.3.5.

Internal flooding covers any source of flooding within the site boundary, this includes flooding sources such as large water tanks outside the safety classified buildings (but excluding external hazards such as rainfall).

The SMR-300 will be designed to comply with the following for Internal Floods:

- NRC GDC 2 Design Bases for Protection against Natural Phenomena [38].
- NRC GDC 4 Environmental and Dynamic Effect Design Basis [38].
- US NRC 1.59: Design Basis Floods for Nuclear Power Plants [45].
- US NRC 1.102: Flood Protection for Nuclear Power Plants [43].
- ANSI/ANS-56.11: Design Criteria for Protection Against the Effects of Compartment Flooding in Light Water Reactor Plants [34].

In addition to submersion and spray, an Internal Flood event may also impact upon SSCs through the following mechanisms. This is a non-exhaustive list which will be developed further during formal HAZID activities:

- Compression wave forces.
- Differential Pressures.
- Waves.
- Humidity changes.
- Thermal effects from hot or cold fluids.

The following approach for the SMR-300 Internal Flooding risk evaluation is performed in line with ASME RA-Sa-2009, Standard for Level 1 / Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications [83]. The methodology for the flooding PSA is outlined in full within [84].

- Plant Partitioning:
    - A plant partitioning activity is performed to evaluate the design and establish physical boundaries in which the effects of flooding can be contained. These boundaries define flood areas, which can consist of a building, a room within a building or other defined areas.
- Identification of Internal Flooding Source and Characterisation:
    - Potential sources of internal flooding are identified by review of SSC lists and system descriptions. Flooding from fluid-containing components may be initiated by both SSC failure and operational / human errors. Sources of flooding include the following:
        - High and moderate energy line breaks.
        - Firefighting activities.
        - Failure of non-seismic and non-extreme weather protected piping, tanks and vessels.
        - Internal Flooding from External Sources.

- Internal Flood Scenarios:
  - Internal flooding scenarios are developed to assess the effect of potential flooding in an area on the SSCs in the affected area. The potential scenarios consider propagation pathways, mitigation factors, and the affected SSCs. Protection measures considered include: flood doors, height of SSCs above the flood level, sumps / drains, and SSC qualification.
  - The following assumptions are used to determine flood water volumes in rooms and areas:
    - Floor drains and sump pumps are not credited for reducing flood water volume during the event.
    - Rooms or areas with a floor grating are credited.
    - Backflow through floor drains is not considered. Flood water volumes are assumed to be bounded by the direct flooding pathways.
    - Interior doors, unless specified as a watertight door, are assumed to fail open or provide a high leak flow rate between rooms.
    - In areas with multiple sources, each source is considered separately.
    - All components located within a flood zone are assumed to fail if flood height reaches 30cm (one foot) unless the components are located above the assessed flood level.

Within the UK the assessment of moderate energy pipe failures is to be carried out for full bore pipe failures, i.e. the Standard Review Plan Branch Technical Position 3-4 Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment [37] will not apply. Reference [37] states that 'Fluid flow from a leakage crack should be based on a circular opening of area equal to that of a rectangle one-half pipe diameter in length and one-half pipe wall thickness in width'. It is recognised that the US approach does not reflect the current ONR position.

22.7.2.2.1 Internal Flooding Assessment Methodology

As outlined in sub-chapter 22.7.2.2, and assessed further within the Internal Hazards Alignment report [31], the flooding assessment undertaken for the SMR-300 in line with the US NRC regulatory expectations, is partially aligned with the UK regulatory expectations. A number of differences exist between the two regulatory regimes, consequently for the generic SMR-300 the following shall be implemented for the assessment of Internal Flooding:

- Provide justification for the approach regarding pipe break exclusion and isolation actions or adopt the UK approach where the excluded breaks are considered in the flooding analysis, and no credit is initially taken for operator action.
- Perform internal flooding analysis, with assumptions in-line with UK expectation, on all locations where flooding could potentially cause an initiating event, including within containment.
- Identify DB internal flooding hazards to be assessed against the acceptance criteria listed in sub-chapter 22.7.1.
- In collaboration with the flood PSA, identify the frequency, consequences, and safety measures for DB flooding hazards.
  - An Internal Flooding PSA was undertaken for the SMR-160 [85], this PSA assessed the occurrence of a flood at full power. The methodology for the undertaking of the Internal Flooding PSA is defined within [84], this methodology shall also be applied to the SMR-300. In the absence of defined

pipe routing and equipment locations these were assumed based upon reviews of system descriptions and plant layouts. Following the upgrade from the SMR-160 to the SMR-300, the flooding PSA shall be re-evaluated based upon the new plant layout and equipment locations, this shall be undertaken beyond the scope of Step 2.

- Identify additional flooding safety measures which are not claimed in ensuring safe shutdown capability to demonstrate internal flooding risk is ALARP and, where necessary, undertake ALARP assessment of further options if suggested by RGP or findings of the flood DBA or PSA.

To capture this difference in assessment approach between the US and UK regulatory regimes, the following design challenge and commitment has been raised for the generic SMR-300 in relation to internal flooding:

C_Inte_095: Regulatory expectations related to the consideration of internal flooding differ between the US and the UK, notably in the areas of moderate energy and non-seismically-qualified pipes. A Commitment is raised to assess if the SMR-300 design is sufficiently robust against the more conservative UK internal flooding expectations through the Design Management process (HPP-3295-0017-R1.0). Target for Resolution - Issue of Pre-Construction SSEC.

22.7.2.2.2 [REDACTED]

[REDACTED]

22.7.2.3 Impact Hazards

Argument 2.1.6.2-A4: The approach for Impact Hazards for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

22.7.2.3.1 Pipe Whip and Jet Impact

Assessment of Pipe failure is required in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm [28]. Pipe whip and jet impacts are associated with high energy pipe systems and a guillotine failure that results from deformation of the pipe, typically around a fixed point, causing it to bend and whip. Jet impacts occur when the high energy fluid from the system impacts an SSC. The impact of such events upon nearby SSCs can result in their failure, and inability to fulfil their required safety functions. The SMR-300 design protects against pipe whip in line with the NRC GDC 4 Environmental and Dynamic Effects – Design Bases and NUREG-1061 Volume 3 requirements.

Analysis will be undertaken on high-energy[4], and where applicable, moderate energy systems, based upon the potential consequences following a pipe whip / jet impact. In addition to

[4] High-energy systems are defined differently by the ONR [49] and the US NRC [90]. For alignment reasons, the definition of high-energy used by the US NRC shall be used by the generic SMR-300. The US NRC definition of high-energy also aligns with the IAEA definition [56] and uses slightly lower temperature and pressure values than that defined by the ONR.

pipework that poses a pipe whip / jet impact risk, consideration will be given to other pipework systems where the fluid pressure / volume of fluid could lead to significant consequences.

Where high / medium energy pipe systems are identified, localised SSCs that could be impacted by pipework failures will be identified and evaluated. Should SSCs be identified as vulnerable to potential pipe whip / jet impact additional safety measures may be required.

Within the SMR-300 design, the routing of pipework is such that, where possible, pipework, is routed away from SSCs related to safety in line with [26]. Defence in depth for pipe whip and jet impacts will be employed whereby the pipework is substantiated to suitable codes and standards for the fluid being transported to minimise the likelihood of a failure. The SMR-300 pipework is designed in line with classification within the following:

- ASME BPVC, Section III Rules for Construction of Nuclear Facility Components [86].
- NRC BTP 3-4 Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment [37].

For Civil and Steel Structures the following design standards are being used:

- ACI 318-19, Building Code Requirements for Structural Concrete and Commentary [87].
- ANSI/AISC 360-16, Specification for Structural Steel Buildings [88].

Specific codes and standards for SSCs relating to interfacing disciplines e.g., Part B Chapter 18 Structural Integrity [13] and Part B Chapter 19 Mechanical Engineering [14] are covered within their respective PSR Chapters.

Within the US, Leak Before Break (LBB) exemptions may be applied to pipework in line with 10 CFR 50.12 [89] to demonstrate extremely low probability of pipe rupture to reduce the volume of protective hardware required. Within NRC guidelines, the use of LBB is not a required design condition, it is a form of analysis to justify the removal of protective hardware. The LWR Standard Review Plan (SRP) for LBB (SRP 3.6.3) on Class 1 piping has the following ‘screening criteria’ for application of LBB:

- Assessment to be applied to entire system / line.
- Cannot be used for piping susceptible to erosion-corrosion, creep, etc. (i.e., no degradation mechanisms that can cause long surface cracks).
- Systems with a history of fatigue cracking cannot be considered.
- Pipes with likely water hammer are not considered.
- Piping systems with possible brittle fracture are not considered – indirect failure must be shown not to cause rupture.

The provision of redundant safety systems in the SMR-300 in segregated locations minimises the risk of a single failure impacting multiple safety trains. Where pipework cannot be routed away from SSCs important to safety, physical barriers / brackets / restraints can be implemented to separate safety systems from the potential pipework impact. Where qualification is used to reduce or eliminate the source of the hazard, the methodology for identifying High Reliability (HR) and Very High Reliability (VHR) components and their definitions is outlined within Part B Chapter 18 Structural Integrity [13].

In addition to ONR SAP and TAG guidance, the following multi-discipline review documents have been produced by the ONR:

- UK's Regulatory Safety Assessment of Nuclear Plants Pressure Part Failure – A Multi-Disciplinary View [68].
- UK's Regulatory Consideration of Partial Failures in High Energy Components – A Multi-Discipline View [69].

The UK SMR-300 approach will be consistent with the UK RGP, i.e. partial pipework failure (LBB) will not be used as the primary safety case argument.

22.7.2.3.1.1 Pipe Whip / Jet Impact Assessment Methodology

The following high-level methodology shall be applied to the assessment of Pipe Whip / Jet Impact. Full details of the methodology to be applied are outlined within the SSC Impact Assessment Step 2 document [29].

1. Identification of Pipework:
    a. Pipework shall be identified and classified in line with US NRC moderate and high energy systems to ensure alignment.
2. Identification of Break Locations:
    a. For identified pipework, possible break locations shall be identified in line with the following US NRC documents, noting that the use of LBB shall be excluded:
        i. BTP 3-3: Protection against Postulated Piping Failure in Fluid Systems Outside Containment [90].
        ii. BTP 3-4: Postulated Rupture Locations in Fluid System Piping Inside and Outside Containment [37].
3. Consequences of Pipe Whip / Jet Impact:
    a. For identified breaks / leaks, pipework shall be assessed for the following and their relation to an unmitigated consequences dose:
        i. Physical impact.
        ii. Jet impact.
        iii. Flooding / spray.
        iv. Environmental impacts such as pressurisation and thermal loading.
    b. Consequences shall be based upon the most onerous pipework state / fault condition (e.g. highest temperature and pressure), irrespective of the time at that condition (i.e. exclude the 2% criteria). This assessment shall identify their impact energy following a Pipe Whip / Jet Impact.
4. Frequencies of Pipework Failure:
    a. Frequencies of pipework failure shall be based upon OPEX and PSA.
5. Safety Measures to Protect against Pipework Failure:
    a. Safety measures shall be identified for the required Safety Functional Category derived from the consequences and frequencies. Safety measures shall be derived based upon the hierarchy of safety.
    b. The substantiation of safety measures against such impacts shall be undertaken in line with the methodology outlined within the Impact Hazard Substantiation Methodology report [30].

22.7.2.3.1.2 [REDACTED]

[REDACTED]

22.7.2.3.2 Internal Missiles

Assessments of Internal Missiles is required in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm. Internal issiles cover a variety of origins, including failure of rotational equipment, over pressurisation of equipment including pipes / tanks / vessels, fragmentation following an explosion, or from a gravitational force i.e., dropped loads (covered within sub-chapter 22.7.2.3.4). Internal Missiles have the potential to physically impact SSCs leading to damage, such that they may cause an initiating fault or are unable to fulfil their safety function.

Missiles from external sources, such as wind and tornados are outside the scope of this sub-chapter and are covered within Part B Chapter 21 External Hazards [22].

The design philosophy for protecting against such missiles is to prevent the generation of a missile in preference to substantiating the SSC to withstand an impact. Where missile sources cannot be eliminated, the SMR-300 has been designed in line with NRC GDC 4 Environmental and Dynamic Effects Design Bases [38] and in line with US NRC RG 1.115 Protection Against Turbine Missiles [40], using the following design philosophy:

- Locating the system or component in a missile-proof structure.
- Separating redundant systems or components from the missile path or range.
- Providing local shields and barriers for systems and components.
- Designing the SSC to withstand the impact of the most damaging missile:
  - The SMR-300 design philosophy for SSC withstands for internal missiles in line with Appendix F Special Provisions for Impulsive and Impactive Effects of ACI 349.
- Providing design features to prevent the generation of missiles.
- Orienting missile sources to prevent missiles from striking safety-related SSC.

The implementation of redundant and segregated safety trains with suitable safety barriers in place to withstand credible internal missiles within the SMR-300 design aims to limit the impact of an Internal Missile to a single safety division.

22.7.2.3.2.1 Internal Missile Assessment Methodology

As outlined in sub-chapter 22.7.2.3.2 and in detail within the Internal Hazards Alignment report [31], there is reasonable alignment between the US and UK assessment methodologies for Internal Missiles. The following high-level methodology shall be followed for internal missiles to ensure alignment with UK regulatory expectations:

1. Identification of safety-classified SSCs and claimed operator actions to deliver safety functions.
2. Identification of internal missiles sources:
   a. Missile sources are identified which includes pressurised vessels, pipework and components, rotating machinery, and systems which can contain explosive mixtures under normal or fault operating conditions. The frequency and

trajectory of the generated missiles, as well as consequences of impact on targets important to safety shall then be identified.

   b. The Internal Hazards Alignment report [31] outlines in full internal missile exclusions that can be undertaken along with exclusions that have been rejected in previous GDAs. This includes differences between the US and UK such as the exclusion of moderate energy systems from the US assessment.

3. Characterisation of identified internal missiles:
   a. Internal missile sources should be characterised based upon their mass, impact trajectory and interactions with SSCs, suitable conservatism will be built into these assessments such as:
      i. No loss of energy during rupture of the vessel / failure of SSC.
      ii. No loss of energy during impact with the SSC.
      iii. The ‘type’ of missile, unless otherwise substantiated, should be assumed to be a ‘hard’ missile.
4. Identification and Assessment of Safety Measures:
   a. In line with the hierarchy of safety, the preference for the protection against Internal Missiles shall be via prevention, spatial segregation, protective barriers and through redundancy of safety-related SSCs.

22.7.2.3.3 Turbine Disintegration

Although turbine disintegration can be considered as an ‘Internal Missiles’, due to the potentially high energy of the missiles and the associated consequences, assessment of this hazard is considered separately, as noted within TAG-014 [49]. The requirement to assess this hazard is in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm [28].

The failure of the main turbine leading to the generation of missiles is a major hazard, however the plot plan for proposed sites has the turbine axis in line with the reactor, so that any missile from the turbine will be directed away from the reactor building and the safety-related SSCs.

The frequency of turbine disintegration is low, and the probability of impact on SSCs following turbine disintegration is significantly lower due to the distribution of the blade and rotor fragments. As noted within ONR TAG [49] guidance, the US NRC Regulatory Guidance 1.115 [40] provides the general expectation for turbine disintegration analysis that expects missile protection for relevant SSCs to ensure the integrity of the reactor coolant pressure boundary. However, as the SMR-300 operates at 3600 rpm [4], the following statement from RG 1.115 is applicable: ‘The NRC will review turbine designs that are significantly different from the current 1800 rpm machines on a case-by-case basis to determine the applicability of the strike zones’. It also expects that the plant can be shut down (and maintained in a safe shutdown condition) or that the plant is capable of preventing accidents resulting in potential offsite exposures, as applicable. This will be achieved primarily by judicious site layout.

It can be expected that the UK turbines will also be ‘full speed’, i.e. will operate at 3000 rpm.

22.7.2.3.3.1 Turbine Disintegration Methodology

The focus of the assessment of turbine disintegration shall be on the orientation of the turbine with respect to safety classified buildings and SSCs fulfilling safety functions.

As noted in sub-chapter 22.7.2.3.3 and within the Internal Hazards Alignment report [31] the assessment of turbine disintegration in line with US NRC RG 1.115 [40] broadly aligns with UK RGP. However, the list of SSCs required for turbine missile consideration, listed within Appendix A of RG 1.115, is not consistent with the UK approach. Consequently, consideration shall be given to all SSCs fulfilling safety functions for the generic SMR-300 to ensure the risks from turbine disintegration, including consideration of site layout, are ALARP.

22.7.2.3.4 Dropped Loads

Assessment of dropped loads is required in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm. A dropped load has the potential to result in damage to SSCs important to nuclear safety, leading to loss of containment, redistribution of nuclear material, and loss of bulk shielding etc. Within the UK the term ‘dropped load’ does not solely refer to the vertical dropping of a load, it also covers the following:

- Impacting Loads (swinging leading to horizontal impact etc).
- Overlifting.
- Snagged Loads.
- Hangman’s drops.

Within the US, if a ‘lifting device’ or ‘special lifting device’ is deemed to be ‘single failure proof’ as defined within NUREG-0612, no assessment of the dropped loads is required to be undertaken. Stress compliance criteria for ‘lifting devices’ are taken from the applicable code and standard for the type of lifting equipment being used. For a ‘lifting device’ to be considered single failure proof, the design safety factors established based on the requirements of the aforementioned codes should be doubled, or a redundant ‘lifting device’ should be provided e.g., an additional sling or lift. Stress criteria for ‘special lifting devices’ are defined within ANSI N14.6.

Within US guidance if a lifting device does not fulfil the ‘single failure proof’ criteria then a dropped load analysis is required, dependent upon the type of lifting device that fails, assessments are undertaken either in line with NUREG-0612 or ANSI N14.6.

Within the UK the term ‘single failure proof’ does not apply and the assessment of dropped loads requires the assessment of the consequences following a dropped load [49] to be assessed via suitable modelling or analysis. Following assessment of the consequences of a dropped load, where necessary, suitable and sufficient safety measures are required to be identified.

The analysis of lifting equipment will confirm that either a dropped load will not occur, due to use of high integrity equipment[5], and / or a dropped load will not result in damage to SSCs related to safety such that they are unable to fulfil their nuclear safety functions. Lifts are currently expected for the below activities:

- Movement of fuel and associated systems.
- Movement of Casks and other transportation issues.

[5] Within this context, ‘high integrity’ refers to the lifting device, below hook adapter / sling and the load itself.

- Preparation of RPV for refuelling activities.
- Movement of SSCs during EIMT activities:
    - [REDACTED].

In addition, there will be additional lifting activities not yet formally identified such as maintenance operations on pumps, heat exchangers and other equipment.

Within the UK all lifts required within the generic SMR-300 facility and site will comply with the Approved Codes of Practice (ACoP) for Lifting Operations and Lifting Equipment Regulations (LOLER) [91] and Provision and Use of Work Equipment Regulations (PUWER) [92] guidance.

22.7.2.3.4.1 Dropped Load Assessment Methodology

The following high-level methodology shall be applied to the assessment of representative dropped loads, full details on the methodology to be applied to dropped loads are outlined within the SSC Impact Assessment Step 2 document [29].

1. Identification of Dropped Loads:
    a. A rationalised list of all cranes and lifting devices shall be produced along with their credible loads, lift pathways, plant state[6], load dimension and frequency of lifts.
    b. A consolidated set of cranes and lifting devices with a bounding load shall be identified. This will contain the information from the previous bullet point.
2. Consequences of Dropped Loads:
    a. Each dropped load shall have a set of unmitigated consequences associated with the dropped load being assessed.
3. Frequency of Dropped Loads:
    a. For all dropped loads a conservative frequency of drops with suitable sensitivity / uncertainties built into it shall be identified. Consideration of OPEX and Human Factors shall be given in identifying potential frequencies.
4. Safety Measures to Protect Against Dropped Loads:
    a. For all bounding credible dropped loads suitable and sufficient safety measures to the required classification shall be identified to the required substantiation.
    b. The substantiation of safety measures against such impacts shall be undertaken in line with the methodology outlined within the Impact Hazard Substantiation Methodology report [30].

To capture this difference in assessment approach between the US and UK regulatory regimes, the following design challenge and commitment have been raised for the generic SMR-300 in relation to dropped loads:

C_Inte_096: Regulatory expectations related to dropped loads differ between the US and the UK, notably that in the US if a lifting device is ‘single failure proof’ a dropped load need not be

[6] Heavy loads are not typically lifted within the CS of the SMR-300 during normal at-power operations (reactor state PS-1 defined within the PFS Report [93]) since most heavy loads are associated with refuelling operations. The exact philosophy for lifts is being developed within the SMR-300 outage strategy [95], which shall be finalised beyond Step 2. Consequently, a heavy load drop would not result in a plant trip during normal power operations. There is the potential for lifts to be undertaken within the RAB during power operations which, should equipment failure occur, could result in a reactor trip.

further assessed, whereas in the UK an assessment of a dropped load is still expected by the Regulator. A Commitment is raised to assess if the SMR-300 design is sufficiently robust against the more conservative UK expectations through the Design Management process (HPP-3295-0017-R1.0). Target for Resolution - Issue of Pre-Construction SSEC.

This design challenge paper and its associated commitment are discussed further within sub-chapter 22.10.2.3 and 22.10.2.4.

22.7.2.3.5 Vehicle Impact

Dependent upon the size and velocity of a vehicle, a vehicle impact has the potential to cause significant damage to SSCs important to safety, either structurally or through secondary hazards such as fire or loss of transport containment. Assessment of vehicle impacts within the US is not directly undertaken, other than for aircraft impact which is discussed in Part B Chapter 21 [22].

For vehicle impact the following high level design philosophy, based on the principle of hierarchy of control, will be followed for the SMR-300. The presence of vehicles within vulnerable parts of the site will be removed / prevented or minimised; where this is not possible physical barriers will be put in place to prevent impacts of buildings and SSCs. Should barriers not be suitable, SSCs will be substantiated to withstand credible impacts from vehicles. The installation of vehicle impact barriers external to the generic SMR-300 safety classified buildings is likely to have no impact upon the building structural performance. Areas of potential structural weakness or vulnerability to vehicle impacts will be assessed and safety measures provided accordingly, e.g., kerbs, impact barriers, bollards etc. Finally, administrative controls will be in place, for example to limit the speed of vehicles on site.

The use of redundant segregated safety trains for the generic SMR-300 design minimises the risk of a single vehicle impact leading to loss of safety function.

22.7.2.3.5.1 Vehicle Impact Assessment Methodology

As outlined within sub-chapter 22.7.2.3.5 and within the Internal Hazards Alignment report [31], the assessment of vehicle impacts is not directly undertaken within US NRC assessments. Consequently, the assessment of vehicle impacts shall be carried out in line with the UK regulatory expectations outlined below:

1. Identify Safety Classified SSCs.
    a. SSCs that fulfil safety functions shall be identified and recorded.
2. Identify of Vehicle Impact Hazard Sources:
    a. Types, locations and routes of vehicles shall be identified. The routing of some vehicles may not be defined until later in the design development. Consideration should also be given to vehicles such as the [REDACTED] as well as other ‘traditional’ vehicles like forklift trucks and HGVs.
3. Characterisation of vehicle Impact Hazard Sources:
    a. The dynamic load of vehicles upon SSCs should be assessed based upon their worst-case impact speeds and angles.
4. Identification and Assessment of Safety Measures:
    a. The available safety measures shall be identified and validated that will prevent the impacts upon SSC fulfilling safety functions identified in Step 1, e.g. the substantiation of building structures or crash barriers against vehicle impacts.

22.7.2.4 Miscellaneous Internal Hazards

Argument 2.1.6.2-A5: The approach to Miscellaneous Internal Hazards for the SMR-300 utilises methodologies required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each hazard type, to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context

22.7.2.4.1 Toxic and / or Corrosive Solid, Liquid or Gaseous Release

Assessment of Toxic and / or Corrosive Solid, Liquid or Gaseous Release is required in line with ONR SAP EHA.14 Fire, Explosion, Missiles, Toxic Gases etc – Sources of Harm. The release of toxic and corrosive substances has the potential to result in a wide variety of consequences (radiological and non-radiological) depending upon the substance and location e.g., a corrosive substance in a high energy pipeline could result in a pipe whip / jet impact or toxic vapour release into a confined area that could result in an asphyxiation risk to personnel. Combustible and explosive materials are covered within their respective Internal Hazard sub-chapters above.

Toxic and / or corrosive substances produced as a result of a fire are to be covered under Internal Fires, in line with NRC guidance, the release of such materials from other sources is covered within this sub-chapter.

In line with the hierarchy of control principle the emphasis initially will be on removing these potential sources of Internal Hazards. Should this not be possible their quantities will be minimised to only what is required for normal operations. Following this, hazardous materials that are identified as having potential adverse impacts will have engineered safety measures applied. Depending upon their type of storage, volume and location these safety measures will differ, however, examples could include the provision of bunds, double walled piping, etc. In addition to these physical engineering safety measures, suitable EIMT schedules will be in place to monitor SSCs important to nuclear safety.

22.7.2.4.1.1 Toxic and / or Corrosive Solid, Liquid or Gaseous Release Assessment Methodology

As outlined within the Internal Hazards Alignment report [31], the following methodology for the characterisation and evaluation of Toxic and / or Corrosive material release shall be implemented for the generic SMR-300, in line with UK regulatory expectations:

1. Identification of safety-classified SSCs and claimed operator actions to deliver safety functions.
2. Identification of toxic and / or corrosive release hazards.
3. Characterisation of identified toxic and / or corrosive hazard sources:
    a. Due to the variation in potential sources of such hazards, the characterisation of such hazards shall be dependent upon the source of the toxic and / corrosive hazard. For sources such as asphyxiants, this would include information as to the type, volume, release pathways and locations of the material.
4. Identification and Assessment of Safety Measures:
    a. The available safety measures shall be identified and validated that will prevent the impacts upon SSC fulfilling safety functions identified in Step 1, e.g. that there is suitable ventilation to prevent the accumulation of asphyxiants within areas which may prevent operators from fulfilling operator actions.

22.7.2.4.2 Electromagnetic Interference

Electromagnetic Interference (EMI) has the potential to impact the functionality of electrical SSCs. Should EMI impact upon SSCs important to safety then the nuclear safety of the NPP could be compromised and is required to be assessed in line with ONR SAP EHA.10. EMI can arise from varying sources, including lightning strikes (covered under Part B Chapter 21), electrical SSCs such as generators, UPS's, switch stations, HVAC systems, Bluetooth wireless links, wireless Local Area Networks (LAN) and communication facilities on vehicles (including shipping) etc. HAZID will be undertaken to ensure all credible sources of EMI from normal and potential maintenance operations, applicable to the generic SMR-300, are identified.

For the SMR-300, the EMI hazard is addressed by equipment qualification. Protection is provided in line with NRC RG 1.180 Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems [41]. Where appropriate equipment will be qualified to International Electrotechnical Commission (IEC) Electromagnetic Compatibility (EMC) 61000 family of standards.

Redundancy and independence of Electrical, Instrumentation and Control (I&C) equipment to protect against impacts of EMI are protected against via the implementation of NRC RG 1.75 Criteria for Independence of Electrical Safety Systems [46].

Protection against EMI and other grid resilience safety measures used within the SMR-300 design are outlined in detail Part B Chapter 6 [12] of the PSR, a high-level summary of some of these safety measures are outlined below:

- Isolation of 1E Class and non-Class systems.
- Multiple earthing systems, separate earthing for instrumentation and computer systems.
- Grounding and Lightning Protection (GLP) Systems.

22.7.2.4.2.1 EMI Assessment Methodology

As outlined above in sub-chapter 22.7.2.4.2, and assessed further within the Internal Hazards Alignment report [31], the assessment of EMI for the SMR-300 is in line with the US NRC approach, and is partially aligned with the UK regulatory expectations. However, no overarching approach exists within HI documentation, consequently for the generic SMR-300 the following shall be implemented for the assessment of EMI in line with UK regulatory expectations:

- Ensure all safety-related systems under the UK categorisation and classification system comply with RG 1.180.
- Ensure all Electrical, Electronic and Programmable Electronic (E/E/PE) systems are identified and subjected to EMI consideration including electrical systems which contains EMI sources such as battery chargers, switchgear, variable speed motor drives etc, and may also contain susceptible electronic devices.
- Document the ALARP position, including how sources and their influence have been minimised so far as is reasonably practicable.

22.7.2.4.3 Combined Hazards

In line with ONR SAPs EHA.4 and EHA.5, the consideration of combined hazards is required. Combined hazards are where the occurrence of multiple hazards occur either simultaneously or are causally linked with a compounding effect such that safety measures could be challenged / defeated. Combinations of External and Internal Hazards can occur, typically whereby the external hazard leads to a consequential Internal Hazards, e.g., Earthquake leads to an Internal Fire.

The methodology for the identification of Internal Hazard combinations and the number of credible combinations identified are presented in sub-chapter 22.6.3 and are not repeated here for brevity.

22.7.2.5 CAE Summary

The key requirement of the SMR-300 is to protect the reactor and its support systems from all credible identified Internal Hazards, including their combinations, and to provide containment and shielding to protect people and the environment.

The methodologies outlined within sub-chapter 22.7 identify a number of differences between the US and UK regulatory expectations. These differences have been captured in the form of design challenges, which shall be progressed beyond Step 2. Consequently, within the scope of Step 2, for the proposed methodologies and the design challenges identified, the assessment of Internal Hazards is deemed compliant and in line with UK regulatory expectations for the given design maturity.

22.8 SSCs WITH INTERNAL HAZARD SAFETY FUNCTIONS

Claim 2.1.6.3: Safety functions and safety measures are identified, categorised and classified based on their importance to nuclear safety for all Internal Hazards and provide sufficient lines of protection based on the fault frequency and consequence.

Claim 2.1.6.3 has been decomposed into a single argument covering the identification of safety measures and safety functions for Internal Hazard fault progressions. The argument also covers the suitable categorization and classification of these items to ensure their importance to nuclear safety is apparent.

Argument 2.1.6.3-A1: For all identified Internal Hazards, the required safety functions and safety measures have been identified and suitably classified to enable the plant to reach a safe state and the risks are ALARP.

This sub-chapter outlines the current list of identified in-scope SSCs with Internal Hazards related Safety Functional Requirements (SFR) and Non-Safety Functional Requirements (N-SFR), noting that this will be further refined following application of a UK aligned safety assessment process beyond GDA Step 2, as set out in GDA Commitment C_Faul_103.

In addition, this sub-chapter summarises the methodology for the integration of Internal Hazards events into the fault schedule beyond GDA Step 2.

[REDACTED]

The methodology for safety categorisation and classification is also outside the scope of this chapter and is contained within the SAH [77].

22.8.1 Identified Internal Hazard SSCs

The methodology for the identification of Internal Hazards SSCs is outlined in full within Appendix C. Table 6 presents the SSCs identified following the application of this methodology.

Table 6: High-Level Plant Functions for SSCs relating to Internal Hazards

Title	System	High-Level Safety Function	US SMR Class
Containment Enclosure Structure	CES	Containment Integrity	C
Containment Structure	CS	Containment Integrity	B
Reactor Auxiliary Building	RAB	Containment Integrity	C
Intermediate Building	IB	Containment Integrity	D
Chemical and Volume Control System	CVC	Control Reactivity	B
Residual Heat Removal System	RHR	Post-Accident Heat Removal	A-D
Containment Ventilation System	-	Containment Integrity	B
Passive Core Cooling System	PCC	Post-Accident Heat Removal	A

Title	System	High-Level Safety Function	US SMR Class
Main Control Room Habitability System	MCH	Post-Accident Heat Removal	C
Passive Containment Heat Removal System	PCH	Post-Accident Heat Removal	B
Reactor Coolant System	RCS	Control of Reactivity	A-B
Control Rod Drive System (inc. Control Rod Control and Rod Position Indication Systems)	CDS, CRC, RPI	Control of Reactivity	A / B
Gaseous Radwaste System	GRW	Containment Integrity	D
Liquid Radwaste System	LRW	Containment Integrity	D
Solid Radwaste System	SRW	Containment Integrity	D
Main Feedwater System	MFS	Containment Integrity	B
Main Steam System	MSS	Containment Integrity	B
Plant Control System	PCS	Control of Reactivity	D/F
Plant Safety System	PSS	Control of Reactivity	C
Post Accident Monitoring System	PAM	Control of Reactivity	C/D
Low Voltage AC Distribution System	LVE	Control of Reactivity	C
Medium Voltage AC Distribution System	MVE	Control of Reactivity	TBC
Non-Class 1E DC Power Distribution System	DCE	Control of Reactivity	C
Non-Class 1E I&C Power Distribution System	ICE	Control of Reactivity	C
Class 1E DC Power Distribution System	DCE	Control of Reactivity	C
Class 1E I&C Power Distribution System	ICE	Control of Reactivity	C

Beyond Step 2, the methodology outlined within sub-chapter 22.8.2 will be applied to produce an Internal Hazards Fault Schedule from which a rationalised list of SSCs can be identified.

22.8.2 Internal Hazard Fault Schedule Methodology

As discussed in sub-chapter 22.6, the HAZID work associated with Internal Hazards is limited at this stage due to the lack of maturity of the design. Therefore, a full understanding of all Internal Hazard sources, the resultant hazard magnitudes and the fault sequence progressions to plant faults cannot be fully determined in Step 2 timescales. A PFS has been developed for the generic SMR-300 [93], however, at this time it does not consider Internal Hazards fault sequences. Beyond Step 2, as the design matures and sufficient information is available to assess Internal Hazards, an Internal Hazards fault schedule will be completed. The following steps provide a high-level summary of the methodology that will be used to populate the Internal Hazards schedule:

1. Formal HAZID work shall be undertaken as outlined within sub-chapter 22.6.2.1.
2. The outputs of the HAZID work shall be incorporated into the CFL. As noted in the SAH, the CFL is a living document that shall be updated as and when additional hazard sources are identified.
    a. The CFL shall form a part of the 'golden thread' ensuring identified hazards can be traced both forwards and backwards within the safety case.
3. Internal Hazard fault progressions that are not bounded by existing entries or plant faults within the CFL shall have additional entries populated for further assessment. This is in line with the methodologies outlined within sub-chapter 22.7.
4. Following the completion of the safety assessment work to identify the required number, categorisation and classification of safety measures, the outputs of the safety assessment shall be entered into the Fault Schedule.

Beyond Step 2 the methodology outlined above will be applied for all Internal Hazards.

22.8.3 CAE Summary

The key requirement of the SMR-300 Internal Hazards assessment is to protect the reactor and its support systems from all credible identified Internal Hazards, including their combinations, and to ensure containment integrity to protect people and the environment.

A provisional list of SSCs has been identified based upon SMR-300 System Design Descriptions (SDD) and Design Specification (DS) to identify SSCs with Internal Hazard requirements. In addition to this work, a comprehensive methodology is outlined within this sub-chapter to provide suitable confidence, that, when undertaken formally beyond Step 2, the PFS shall capture Internal Hazards, and their available safety measures, in sufficient detail.

22.9 FUTURE INTERNAL HAZARD ASSESSMENTS

Claim 2.1.6.4: Analysis demonstrates that the identified safety features (in conjunction with operator actions) enable the plant to reach a safe shutdown state for all Internal Hazard DBEs.

As shown within

Table 8 within Appendix A, Claim 2.1.6.4 has been decomposed into six arguments, four of these arguments have been developed based upon 'groups' of Internal Hazards. These 'groups' of Internal Hazards and the individual Internal Hazards that comprise them are listed below:

1. Fire and Explosions:
    - Internal Fires.
    - Internal Explosions and Blasts.
2. Internal Flooding.
3. Impact Hazards:
    - Pipe Whip and Jet Impacts.
    - Dropped Loads (including Load Topples).
    - Internal Missiles (including Turbine Disintegration).
    - Vehicle Impacts.
4. Miscellaneous Internal Hazards:
    - EMI Impacts.
    - Toxic and Corrosive Material Release.

In addition to these groups of Internal Hazards, two additional arguments have been developed to assess individual buildings / areas / zones as well as exceptions to segregation. Two additional arguments have been derived to ensure a complete analysis is undertaken.

The following sub-chapters provide a high-level overview of the above groups and provide an overview of the evidence, or expected evidence for each.

22.9.1 Fire and Explosions

Argument 2.1.6.4-A1: For all identified sources of Fire and Explosions capable of challenging critical safety functions there are suitable safety measures to ensure the plant reaches a safe state for all Internal Hazard DBEs.

The safety measures and the preliminary assessment described in Section 2 will be developed beyond Step 2. Detailed hazard assessments for both Internal Fires and Internal Explosions will be developed. These reports will assess the credible hazards captured within the CFL and undertake further hazard assessments. The Internal Fire assessment shall utilise work undertaken by the Internal Fire PSA being produced for the SMR-300.

22.9.2 Internal Flooding

Argument 2.1.6.4-A2: For all identified sources of Internal Flooding capable of challenging critical safety functions there are suitably qualified safety measures to ensure the plant reaches a safe state for all Internal Hazard DBEs.

The safety measures and the preliminary assessment described in Section 2 will be developed beyond Step 2. Detailed hazard assessments for internal flooding will be developed. These reports will assess the credible internal flooding events captured within the CFL and undertake further hazard assessments. Internal Flooding shall utilise work undertaken by the Internal Flooding PSA being produced for the SMR-300.

22.9.3 Impact Hazards

Argument 2.1.6.4-A3: For all identified sources of Impact Hazards capable of challenging critical safety functions there are suitably qualified safety measures to ensure the plant reaches a safe state for all Internal Hazard DBEs.

The safety measures and the preliminary assessment described in Section 2 will be developed beyond Step 2. Detailed hazard assessments will be developed for the following Internal Hazards under the impact hazards group:

- Pipe Whip and Jet Impacts.
- Internal Missiles.
- Turbine Disintegration.
- Dropped and Collapsed Loads.
- Vehicle Impacts.

These reports will assess and characterise credible hazards captured within the CFL and undertake further hazard assessments.

22.9.4 Miscellaneous Internal Hazards

Argument 2.1.6.4-A4: For all identified sources of miscellaneous Internal Hazards (Toxic and/or corrosive material release and EMI) capable of challenging critical safety functions, there are suitably qualified safety measures to ensure the plant reaches a safe state for all Internal Hazard DBEs.

Beyond Step 2 individual hazard assessments will be developed for the following Internal Hazards under the miscellaneous hazards group:

- Toxic and / or Corrosive Solid, Liquid or Gaseous Release.
  - Where required, DSEAR assessments / reports shall be produced to support the above assessment.
- EMI.
- Combined Hazards.

These reports will assess and characterise credible hazards captured within the CFL and undertake further hazard assessments. In addition to the above Internal Hazard reports, inputs will be taken from the site Control of Major Accident Hazards (COMAH) Regulations report to be produced.

22.9.5 Individual Building Assessments

Argument 2.1.6.4-A5: The individual Building / Area / Room Assessments for Internal Hazards support the L4 Claim that the plant can reach a safe shutdown state for all Internal Hazard DBEs.

The safety measures and the preliminary assessment described in Section 2 will be developed beyond Step 2. Detailed hazard assessments of each of the individual buildings will be carried out to ensure that all credible Internal Hazards have been identified for each building, and ensure suitable and sufficient safety measures have been identified. By assessing each building individually, this helps to mitigate the possibility of building specific internal hazards and combined hazards not being identified.

22.9.6 Segregation Requirements

Argument 2.1.6.4-A6: Where segregation is required, safety measures are identified to ensure that the consequences of any Internal Hazard are limited to a single train such that critical safety function can be fulfilled and that the plant can reach a safe shutdown state for all Internal Hazard DBEs.

The safety measures and the preliminary assessment described in Section 2 will be developed beyond Step 2. Detailed hazard claims on segregation will be made for the generic SMR-300. Individual safety reports will be produced to ensure that the loss of a single train or division does not impact the generic SMR-300's ability to fulfil the required safety functions.

[REDACTED]

22.9.7 CAE Summary

Within GDA Step 2, due to the maturity and availability of design information, the focus for Internal Hazards has been to outline the assessment methodologies to be applied for the identified Internal Hazards. Signposting to future Internal Hazard assessments for post GDA aims to provide confidence that at the next design phase there is a clear roadmap of the work to be undertaken and to ensure a handshake with the work undertaken during the GDA phase.

22.10 CHAPTER SUMMARY AND CONTRIBUTION TO ALARP

This sub-chapter provides an overall summary and conclusion of the Internal Hazards chapter and how this Chapter contributes to the overall demonstration of ALARP for the generic SMR-300. Part A Chapter 5 [80] sets out the overall approach for demonstration of ALARP and how contributions from individual Chapters are consolidated.

This sub-chapter therefore consists of the following elements:

- Technical Summary.
- ALARP Summary:
    - Review against Relevant RGP.
    - Demonstration Against Risk Targets.
    - Risk Reduction Options.
    - GDA Commitments.
- Conclusion.

A review against these elements is presented below under the corresponding headings.

22.10.1 Technical Summary

This Part B Chapter 22, Revision 1 describes the methodology for the identification and assessment of Internal Hazard SSCs after GDA Step 2. It will allow the requirements for the Internal Hazards substantiation to be met and will enable the demonstration that the high-level claims of the SSEC can be substantiated. This will be demonstrated through the following Level 3 claim:

Claim 2.1.6: Risks from Internal Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

The key requirement of the SMR-300 is to protect the reactor and its support systems from all credible identified Internal Hazards, including their combinations, and to provide containment and shielding to protect people and the environment. The identification of specific Internal Hazards based upon room layouts, item locations, pipe routing etc shall be undertaken in future design stages with the PFS acting as the vehicle to capture Internal Hazards along with their fault progressions, consequences and safety measures. Substantiation and validation of these safety measures will be provided by their corresponding disciplines, i.e. civil engineering, mechanical engineering etc.

Internal Hazards protection will employ the following hierarchy of safety principles. These are listed below in order of most to least preferable:

- Eliminate:
    - The hazard is eliminated completely, e.g., the design of the plant precludes the need for an item of equipment etc., so that that for example a dropped load is no longer credible.
- Reduce:
    - The source term of the hazard is reduced, e.g., radiological / explosive inventory is reduced.

- Isolate:
  - The hazard has been isolated e.g., explosive sources are isolated, either through location away from vulnerable areas or through the installation of adequate protective barriers such as a blast wall.
- Control:
  - Using administrative controls, e.g., there are time limitations for operators / staff working in high radiation areas.
- Protect:
  - Operators are provided with Personal Protective Equipment (PPE), e.g., respirators etc.
- Discipline:
  - Enforcement of safe systems of work, e.g., site speed limits for vehicles, training of staff for emergency situations etc.

For each of the identified Internal Hazards the SMR-300 design will either eliminate / prevent the hazards or provide suitable and sufficient safety measures, to prevent the release of radioactivity to the environment. The assessment methodology and design philosophies for each of the identified Internal Hazards are outlined within sub-chapter 22.7.

For Revision 1 it is judged that the maturity of the safety methodology presented in Part B Chapter 22 is appropriate for a PSR and the proposed methodologies for the identification and assessment of Internal Hazards will allow adequate support of Claim 2.1.6.

Beyond Step 2, there is sufficient confidence from the hazards PSA assessments described in Section 22.2.2 that once the methodologies are applied, Claim 2.1.6 will be met in future safety submissions and risks evaluated as tolerable and ALARP.

22.10.2 ALARP Summary

22.10.2.1 Demonstration of RGP

Due to the differing regulatory approaches between the UK and US, Internal Hazards are assessed in differing ways. Within the UK a formal deterministic hazards assessment is required to enable the 'golden thread' to be followed from hazard identification to development of available safety measures. In the US the more prescriptive licensing regime does not require this approach. Instead, design rules are prescribed by the NRC and where detailed analysis is required, this is primarily assessed using a hazards PSA.

[REDACTED] Sub-chapter 22.7 outlines the assessment methodologies to be adopted for each Internal Hazard which will ensure that the assessments are in line with UK RGP.

It will be ensured that the alignment reduces risk in line with the ALARP principle.

These assessments are included in the commitment C_Faul_103, as described in Part B Chapter 14 Design Basis Analysis [18].

Future, post-GDA Internal Hazards work, is recorded in the CAR Register, and is managed as described in Part A Chapter 4 [7]. Post-GDA, the CAR Register will be utilised as an essential input to the scope and specification of the developing future Internal Hazards safety case.

The CAR Register will ensure that commitments remain clear, visible and their resolution managed with progress / close-out recorded. A complete copy of the CAR Register will be retained as part of the design technical file. Further details of commitments raised in PSR v1 are provided in Part A Chapter 5, as described in Part A Chapter 4 [7].

22.10.2.2 Evaluation of Risk and Demonstration Against Risk Targets

The numerical targets against which the demonstration ALARP is considered can be found in Part A Chapter 2 [4]. Internal Hazards SSCs, through their defined safety functions, will contribute to the demonstration of ALARP by comparison against the risk targets in the following ways:

- By ensuring the cumulative risk from identified Internal Hazard fault progressions are below the required targets 4-9, along with the identification of a list of contributors (basic events, system failures, human errors, etc.) ranked according to risk importance measures.
- Where possible, Internal Hazard fault progressions shall be bounded by plant faults and utilise the associated risk values from these progressions.
- The Internal Hazards PSAs will demonstrate that the risks from the principal Internal Hazards are below the required targets 4-9 and are ALARP.
- Duty and protection systems will have been shown to meet their reliability targets and this will confirm the allocated safety classification.

Risks below the Basic Safety Objectives (BSO) are considered broadly acceptable; however, the Requesting Party is still required to identify further risk reduction measures in line with the ALARP approach. Risks between the BSOs and Basic Safety Levels (BSL) require a consideration of risk reduction options.

This work will be carried out after Step 2.

22.10.2.3 Options Considered to Reduce Risk

Three design challenges have been raised in relation to the Internal Hazards topic area. In line with the Design Adaptation Committee (DAC) process, once raised, these are required to progress through a number of ‘gates’ prior to acceptance. Within the scope of GDA a number of these design challenges are still due to enter the DAC process, or progressing through the DAC process, and are therefore subject to change. The process for the assessment of risk reduction options is presented in Holtec SMR-300 GDA Reference Design Process and GDA Prospective Design Change Register [94]. Part A Chapter 5 ALARP Summary [80] considers the holistic risk-reduction process for the generic SMR-300.

The following design challenges have entered the DAC process for Internal Hazards, however, have not completed this process and are therefore still in draft form:

- C_Inte_095 – Flooding from Moderate Energy Pipes and Seismic Events.
- C_Inte_096 – Dropped Load Integrity.
- C_Inte_117– Level of Segregation.

The process for the assessment of risk reduction options is presented in the Generic Design Assessment Reference Design Process and GDA Prospective Design Change Register [94].

22.10.2.4 GDA Commitments

At Revision 1 there are three GDA commitments identified for Part B Chapter 22, Internal Hazards, these are summarized in Table 7:

Table 7: Internal Hazard GDA Commitments

Commitment ID	Commitment
C_Inte_095	Regulatory expectations related to the consideration of internal flooding differ between the US and the UK, notably in the areas of moderate energy and non-seismically-qualified pipes. A Commitment is raised to assess if the SMR-300 design is sufficiently robust against the more conservative UK internal flooding expectations through the Design Management process (HPP-3295-0017-R1.0). Target for Resolution - Issue of Pre-Construction SSEC.
C_Inte_096	Regulatory expectations related to dropped loads differ between the US and the UK, notably that in the US if a lifting device is 'single failure proof' a dropped load need not be further assessed, whereas in the UK an assessment of a dropped load is still expected by the Regulator. A Commitment is raised to assess if the SMR-300 design is sufficiently robust against the more conservative UK expectations through the Design Management process (HPP-3295-0017-R1.0). Target for Resolution - Issue of Pre-Construction SSEC.
C_Inte_117	The Design Challenge Paper 'Design Challenge – Internal Hazards' (HI-2250235-R0.0) is with the Design Authority for Design Decision. This Design Challenge presents risks to the SMR-300 design against UK expectations on the level of segregation for a new reactor design. A Commitment is raised to progress this Design Challenge through the Design Management process (HPP-3295-0017-R1.0) to completion. Target for Resolution - Issue of Pre-Construction SSEC.

22.10.3 Conclusion

The conclusion of Part B Chapter 22 of the PSR is that:

- All generic Internal Hazards have been identified to a level suitable for a PSR.
- Suitable hazard methodologies have been outlined to undertake future hazard assessment activities beyond Step 2 of the GDA. It is judged that application of these methodologies will allow the Claims, Arguments and Evidence 'Golden Thread' to be satisfactorily developed and completed.
- A comprehensive methodology is provided for the input of Internal Hazards into the CFL and the Fault Schedule for post Step 2 assessments.
- By outlining future documentation to be produced beyond Step 2, further confidence is provided to ensure adequate assessments will be undertaken for Internal Hazards.

Part A Chapter 5 of this PSR [80] concludes that it can be demonstrated that the generic SMR-300 reduces risks to ALARP and provides confidence that the Fundamental Purpose of the SSEC can be fulfilled at PCSR stage. This PSR chapter provides assurance that the Internal Hazards assessment will support the overall SSEC conclusions.

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[94] Holtec Britain, “HPP-3295-0017, Design Management Process,” Revision 1, 2024.

[95] Holtec Britain, “HI-2250400, Outage Strategy for SMR-300,” Revision 0, 2025.

[96] International Atomic Energy Agency, “Defence in Depth in Nuclear Safety, INSAG-10, A Report By The International Nuclear Safety Advisory Group,” 1996.

22.12 LIST OF APPENDICES

Appendix A PSR Part B Chapter 22 CAE Route Map

Table 8: PSR Part B Chapter 22 CAE Route Map

REDACTED

Appendix B RGP and Extant Internal Hazards Review

Table 9: RGP and Extant Internal Hazards Sources

Primary Hazard (Name as given in source document)	Preferred Terminology for Project	Source Document(s)								
		ONR SAPs [28] / TAG14 [49]	ONR-GDA-GD-007 May 2019 - Section 3.11 [50]	IAEA Safety Standards Series No. SSG-64 [56]	IAEA Safety Standards SSR-2/1 (Rev.1) [58]	UK EPR [70]	RR SMR [71]	UK AP1000 [72]	UK ABWR [73]	UK HPR1000 [74]
Fire	Internal Fire	x	x		x	x	x			x
Internal Fire				x				x	x	
Explosions	Internal Explosions	x	x		x		x			
Internal Explosions				x		x			x	x
Blast (pressurised equipment)							x		x	
Explosive Materials						x				
Flooding / Spray	Internal Flooding	x			x		x		x	x
Internal Flooding			x	x		x		x	x	x
Immersion									x	
Release of fluid					x					x
Pipe Whip and Jet Impact	Pipe Whip and Jet Impact	x	x		x		x		x	x
Pressure Part Failure								x		
Pipework System Failures			x							x
Pipe breaks				x		x				
Internal Missiles	Internal Missiles	x	x	x		x			x	x
Turbine Missiles		x							x	

Primary Hazard (Name as given in source document)	Preferred Terminology for Project	Source Document(s)								
		ONR SAPs [28] / TAG14 [49]	ONR-GDA-GD-007 May 2019 - Section 3.11 [50]	IAEA Safety Standards Series No. SSG-64 [56]	IAEA Safety Standards SSR-2/1 (Rev.1) [58]	UK EPR [70]	RR SMR [71]	UK AP1000 [72]	UK ABWR [73]	UK HPR1000 [74]
Missiles					x		x			
Rotating Machinery			x							
Tanks, pumps, and valve failures						x				
Dropped Loads	Dropped Loads	x				x	x	x	x	x
Heavy Load Drops				x						
Collapsed Loads										
Collapse of structures and falling objects[7]					x					x
Toxic and / or Corrosive Solid, Liquid or Gaseous Releases	Toxic and / or Corrosive Solid, Liquid or Gaseous Releases	x	x					x		
Release of hazardous substances inside the plant				x			x			
Noxious release following a fire						x				
Hot Gas and Steam Release	Hot Gas and Steam Release	x	x				x		x	

[7] Collapse of structure to be covered under specific Internal Hazard withstands e.g. protection from a blast overpressure. Collapse of a structure from External Hazards is covered within Part B Chapter 21 External Hazards.

Primary Hazard (Name as given in source document)	Preferred Terminology for Project	Source Document(s)								
		ONR SAPs [28] / TAG14 [49]	ONR-GDA-GD-007 May 2019 - Section 3.11 [50]	IAEA Safety Standards Series No. SSG-64 [56]	IAEA Safety Standards SSR-2/1 (Rev.1) [58]	UK EPR [70]	RR SMR [71]	UK AP1000 [72]	UK ABWR [73]	UK HPR1000 [74]
Vehicular Transport Impacts	Vehicle Impact	x					x			
Vehicle impact			x							
Onsite Transport Accidents								x		
Electromagnetic Interference	Electromagnetic Interference	x	x	x		x	x	x	x	
Radio Frequency Interference									x	
Combinations of Hazards	Combinations of Hazards	x					x			x

Appendix C SSCs with High-Level, Safety and Non-Safety Functions for Internal Hazards

[REDACTED]

Table 10: SSCs with Internal Hazard SFRs

[REDACTED]