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PSR Part B Chapter 21 External Hazards

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21.1 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 Holtec SMR GDA Preliminary Safety Report (PSR) Part A Chapter 1 Introduction [1].

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

Part B Chapter 21 of the PSR presents the Claims, Arguments and intended Evidence (CAE) for the External Hazards topic that underpins the design of the generic SMR-300.

21.1.1 Purpose and Scope

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

This chapter (Part B Chapter 21) links to the overarching claim 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 As Low As Reasonably Practicable (ALARP).

As set out in Part A Chapter 3 [2], Claim 2.1 is further decomposed across several safety assessment disciplines which are responsible for the development of the overall nuclear safety assessment. This chapter (Part B Chapter 21) presents Claim 2.1.5 with the objective to demonstrate that risks from External Hazards, and their combinations, have been demonstrated to be tolerable and ALARP.

Claim 2.1.5: Risks from External Hazards and their combinations have been demonstrated to be tolerable and ALARP.

Further explanation of the decomposition of Level 3 claims into Level 4 claims and the substantiation of those Level 4 claims is provided in sub-chapter 21.3.

The chapter structure is set out to present the following:

- An overview of the approach to External Hazards undertaken within the development of the SMR-300 GDA Reference Design to demonstrate alignment with international regulatory guidance and Relevant Good Practice (RGP) – see sub-chapter 21.2.2.
- An overview of the approach undertaken for the fundamental GDA safety assessment of the generic SMR-300 against the External Hazards identified and characterised in the Generic Site Envelope Report (GSER) [3] to demonstrate that risks from those External Hazards, are tolerable and ALARP – see sub-chapter 21.2.3.

- The CAE architecture relevant to the External Hazards topic area – see sub-chapter 21.3.
- The applicable codes and standards, RGP and regulatory guidance used to identify and characterise External Hazards in both the GDA Reference Design and the development of the Great Britain (GB) Generic Site Envelope (GSE) – sub-chapter 21.4.
- The identification and screening methodology adopted to identify the External Hazards, and their combinations, which are relevant to the deployment of the generic SMR-300 in GB and can be considered on a generic basis. This sub-chapter also identifies the detailed hazard identification work to be undertaken beyond Step 2 – see sub-chapter 21.5.
- The generic SMR-300 Structures, Systems and Components (SSCs) with External Hazards related safety functions as identified within the Preliminary Fault Schedule (PFS) – see sub-chapter 21.6.
- An evaluation of each External Hazard including hazard characterisation, the derivation of the GB GSE Parameter(s) and a preliminary evaluation of the GDA Reference Design – see sub-chapter 21.7.
- A technical summary of how the overarching claim for External Hazards is substantiated including a summary of the contribution made by this chapter to support the demonstration that risks, specifically relating to External Hazards, are likely to be tolerable and ALARP for the generic SMR-300 design – see sub-chapter 21.8.

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].

21.1.2 Assumptions

Assumptions which relate to this topic have been formally captured in the Commitments, Assumptions and Requirements process [5]. Further details of this process are provided in Part A Chapter 4 Lifecycle Management of Safety and Quality Assurance [6].

The identified assumptions are:

- A_Exte_013: All External Hazards not screened as criteria 5a or 5b[1] within the GSER [3] are outside the scope of GDA (i.e. are excluded) and are to be assessed at the site-specific stage. The output of the hazard identification and screening process is provided in Appendix A of the GSER [3].
- A_Exte_014: A Site Justification Report or similar, will be produced at the site-specific stage to characterise the prospective site and confirm that the site is bounded by the GB GSE defined in the GSER [3]. This report will review the screening analysis presented in the GSER [3] and undertake a detailed hazard site specific analysis.
- A_Exte_015: For the purposes of this GDA, it has been assumed that the 'Generic Site' is 'dry' when subjected to flood levels up to the design basis, and as such the site

[1] Criteria 5a and 5b require External Hazards to be above the screening criteria for frequency (Criteria 1) and consequence (Criteria 2) as well as not bound by another External Hazard (Criteria 3). In addition External Hazards screened are not judged to be site specific (Criteria 4a) or sufficient information is available within GDA to make an assessment (Criteria 4b).

operator will develop the site accordingly. Further information on potential protection solutions and RGP is provided in sub-chapter 21.7.2.1.

21.1.3 Interfaces with Other SSEC Chapters

The External Hazards chapter interfaces with the following PSR chapters.

The SMR-300 High Level Functions, which are to be achieved for all plant states except where a postulated condition involves the loss of that function, are presented in Part A Chapter 2 [4]. The definition of the GB GSE, including the generic site characteristics to be used as the basis of the safety assessment, is also presented in Part A Chapter 2 [4].

A key interface for this PSR chapter is the Generic Site Envelope Report for SMR-300 UK GDA [3], which defines the generic SMR-300 GB GSE and the characteristics of the generic site to be used as the basis for the safety analysis. The GSER should be read in conjunction with this PSR chapter. The assumptions made in the development of the GB GSE are populated in Appendix B of the GSER [3].

All identified and screened External Hazards are to be treated as initiating events in the Design Basis Accident Analysis (DBAA). Part B Chapter 14 Fault Studies [7] presents a summary of safety assessment process and Revision 1 of the PFS Report provides a high-level overview of the External Hazards considered within the PFS. Beyond GDA Step 2 the PFS shall be further developed.

Part B Chapter 15 Severe Accidents Analysis and Emergency Preparedness [8] is considered as an extension of Part B Chapter 14 [7]. The aim of Part B Chapter 15 [8] is to address the evaluation of Design Extension Conditions (DECs)[2] for the generic SMR-300 and to demonstrate that accidents, including External Hazards, that have the potential to lead to severe consequences have been systematically identified and analysed with appropriate safety measures beyond those derived from the DBAA. Part B Chapter 16 Probabilistic Safety Assessment [9] supports the DBAA and Beyond Design Basis Analysis (BDBA) that consider External Hazards, with an objective to demonstrate that the design of the generic SMR-300 is balanced such that risk is tolerable and ALARP.

External Hazards and Part B Chapter 22 Internal Hazards [10] interface closely due to their nature. Combinations of hazards is a key consideration in the safety analysis as an Internal Hazard could occur as a consequence of an initiating External Hazard.

Part B Chapter 4 Control and Instrumentation Systems (I&C) [11], Part B Chapter 5 Reactor Supporting Facilities [12], Part B Chapter 6 Electrical Engineering [13] and Part B Chapter 19 Mechanical Engineering [14] identify and present the SSCs relevant to each discipline, which will be qualified against External Hazards. Due to the nature of External Hazards a key interface within Step 2 is Part B Chapter 20 Civil Engineering [15] which provides detailed

[2] DEC events are split into two categories, DEC-A and DEC-B events, further detail on DEC events is provided within Part B Chapter 15, BDBA, Severe Accident Analysis, and Emergency Preparedness [8].

descriptions of the civil structures that provide the substantiation of the load cases for External Hazards as well as the seismic classification approach for the SMR-300.

External Hazards also interfaces with Part B Chapter 17 Human Factors [16]. The Human Factors discipline supports the identification, analysis and modelling of human failures related to External Hazards and is responsible for the substantiation of any developed human-based safety claims.

21.2 OVERVIEW OF EXTERNAL HAZARDS

This sub-chapter presents the overview, definition and approach to External Hazards undertaken within the development of the SMR-300 GDA Reference Design with the objective to demonstrate alignment with international regulatory guidance and RGP.

The approach to External Hazards for the purposes of the generic SMR-300 GDA is then presented to outline the methodology undertaken to fundamentally assess the deployment of the generic SMR-300 on a generic site bounded by the GB GSE, when subjected to the generic and credible External Hazards identified in the GSER [3].

Sub-chapter 21.2.2 describes the approach taken for the United States (US) Reference design. Sub-chapter 21.2.3 describes the approach taken for the UK Generic design.

21.2.1 External Hazards Definition

External Hazards are defined by the Office for Nuclear Regulation (ONR), NS-TAST-GD-013, External Hazards [17] as:

'…natural or man-made hazards to a site and facilities that originate externally to both the site and its processes, i.e., the duty holder may have very little or no control over the initiating event'.

External Hazards have the potential to cause initiating events that progress to Design Basis (DB) and Beyond Design Basis (BDB) faults and cause common cause failures of SSCs which are required to deliver the High-Level Functions. These High-Level Functions are identified in Part A Chapter 2 [4] to ensure safety of the plant.

21.2.2 GDA Reference Design Approach

This sub-chapter presents the approach to External Hazards undertaken in the GDA Reference Design, and therefore inherent within the generic SMR-300, as detailed in the Holtec SMR-300 Specification – Human-Induced External Events [18] and the SMR-300 Specification - Environmental Conditions [19] reports. Further information on the GDA Reference Design is provided in Part A Chapter 2 [4] with the process for managing prospective design changes during GDA captured in Holtec SMR-300 GDA Reference Design Process and GDA Prospective Design Change Register [20].

The United States Nuclear Regulatory Commission (NRC) Title 10 Code of Federal Regulations, Appendix A to Part 50, General Design Criteria for Nuclear Power Plants [21], General Design Criterion 2, states that SSCs important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions.

The overall design objective for the SMR-300 relating to External Hazards states that:

- For Design-Basis Events (DBE), to demonstrate that failure of SSCs or a large release of radioactive material to the environment will not occur.
- For Beyond-Design-Basis Events (BDBE), to provide reasonable assurance that core-damage or a large release of radioactive materials to the environment will not or is unlikely to occur.

21.2.2.1 Design Methodology

The general design methodology for the consideration of External Hazards in the GDA Reference Design is provided below. There are several different methods employed by the GDA Reference Design, which largely depend on the type of event and its frequency. However, the same general process is employed for all External Hazards.

- A set of External Hazard events has been developed for the GDA Reference Design through a comprehensive hazard identification process.
- External Hazards are classified based upon their frequency of occurrence, engineering judgement, prior industry experience, or a combination thereof.
    - Events are initially classified according to engineering judgement; however, events are later classified according to the calculated frequencies of occurrence by probabilistic analysis for a selected site.
- External Hazard events which are a consequence of the initiating hazard are defined and considered.
- Important to safety SSCs are either evaluated for or protected from the effects of the External Hazard event and any consequential hazards through one or more of these approaches (as appropriate for the event classification assigned in the second bullet point above. Further details on the event classification used by the SMR-300 and the generic SMR-300 are outlined within Part B Chapter 14 [7]):
    - For DBEs, the plant layout or design provisions may ensure the SSCs are protected, such as by barriers or physical separation.
    - For DBEs, the SSC may be designed to withstand the effects of the event(s).
    - For BDBEs, SSC designs may be demonstrated as sufficiently robust to remain intact and / or functional so as to still meet safety requirements.
- For BDBEs, important to safety SSCs which may not be demonstrated to remain intact and / or functional after the event are considered as such in the safety analysis.
- The safety goals of the deterministic or probabilistic safety analysis are demonstrated to be met, with due consideration of the state of important to safety SSCs.

21.2.2.2 Safety Requirements for Design Basis External Hazards

The following are the fundamental derived acceptance criteria which are inherent within the generic SMR-300 design for design basis External Hazards identified in the development of the GDA Reference Design, as detailed in the Holtec SMR-300 Specification – Human-Induced External Events [18] and the SMR-300 Specification – Environmental Conditions [19] reports.

a) The fundamental safety functions of the plant 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.

21.2.2.3 Safety Requirements for Beyond Design Basis External Hazards

The following are the fundamental derived acceptance criteria which are inherent within the SMR-300 design for beyond design basis External Hazards identified in the development of the GDA Reference Design, as detailed in the Holtec SMR-300 Specification – Human-Induced External Events [18] and the SMR-300 Specification – Environmental Conditions [19] reports:

a) The reactor shall remain capable of being shut down and maintained in a safe shutdown state.
b) To the greatest extent practical, the reactor shall remain coolable and confinable[3].
c) The containment function shall be maintained without significant degradation.
d) The ability to monitor the state of the plant shall be maintained.
e) Cliff-edge effects shall be eliminated such that a small change in accident parameters does not cause a disproportionately large change in accident progression or consequences.
f) On and off-site emergency measures shall be capable of responding to events in an appropriate timeframe.

21.2.2.4 Defence In Depth

The GDA Reference Design approach considers five levels of defence in depth, consistent with International Atomic Energy Authority (IAEA) No. SSG-30, Safety Classification of Structures, Systems and Components in Nuclear Power Plants [22] and IAEA INSAG-10, Defence in Depth in Nuclear Safety [23]. Further details on the DiD approach are outlined within Part A Chapter 2 [4]. These five levels of defence in depth are outlined below:

- Level 1: Prevention of abnormal operation and failures.
- Level 2: Control of abnormal operation and detection of failures.
- Level 3: Control of accidents within the design basis.
- Level 4: Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accident.
- Level 5: Mitigation of radiological consequences of significant releases and radioactive materials.

With respect to defence in depth, the following requirements are set in the assessment of External Hazards for the GDA Reference Design:

- For DB External Hazard events, the event shall not challenge the defence-in-depth beyond Level 3.

[3] The phrase 'greatest extent practical' is used throughout US NRC documentation with the implementation of it depending upon the context used. For BDB External Hazards NUREG-1555 Section 7.3 Severe Accident Mitigation Alternatives (SAMA) applies. The intent for SAMA is to evaluate the plant-design alternatives that could significantly reduce the radiological risk from a severe accident by preventing substantial core damage (i.e., preventing a severe accident) or by limiting releases from containment in the event that substantial core damage occurs (i.e., mitigating the impacts of a severe accident). This term is considered to be broadly equivalent to the 'practicable' aspect of ALARP.

- Level 4 and 5 defence-in-depth shall be defined to the extent practical with consideration of the identified beyond design basis External Hazard events.

21.2.2.5 GDA Reference Design Parameters

The design basis of the External Hazards identified in the GDA Reference Design has been established through the application of international regulatory design codes and standards, which are presented in sub-chapter 21.4.

The Holtec SMR-300 Specification – Human-Induced External Events [18] and the Holtec SMR-300 Specification – Environmental Conditions [19] specify the magnitude of the External Hazard DBEs applied in the GDA Reference Design. These design basis parameters are referred to as the 'GDA Reference Design parameters' throughout this chapter.

21.2.3 Generic SMR-300 GDA Approach

The following sub-chapters outline the approach to External Hazards in the context of carrying out a fundamental assessment on the deployment of the generic SMR-300 on a generic site in GB bounded by the GB GSE.

21.2.3.1 Hazard Identification

The definition of the GB GSE, including the generic site characteristics to be used as the basis for the safety analysis, is provided in Part A Chapter 2 [4] with further information provided in the GSER [3]. This definition includes credible External Hazards (screened as criteria 5a and 5b within the GSER [3]) which have been identified as affecting nuclear safety, can be considered on a generic basis and are relevant to the deployment of the generic SMR-300 on a generic site in GB.

A comprehensive hazard identification and screening methodology has been undertaken to identify these credible External Hazards with the methodology presented in sub-chapter 21.5. The codes and standards applied in this process are presented in sub-chapter 21.4.

21.2.3.2 Hazard Characterisation

A preliminary evaluation of each of the External Hazards identified and screened-in is provided in sub-chapter 21.7. The first step of this evaluation is to sufficiently characterise each of the hazards to understand the challenge made to the safety of the generic SMR-300. This challenge is often in the form of an external load applied to Civil SSCs.

External Hazards can be classified in terms of their severity and frequency of occurrence as either discrete or non-discrete hazards, as stated in ONR, Safety Assessment Principles (SAPs) for Nuclear Facilities [24]. Paragraph 232 and 233 of the ONR SAPs [24] states the following:

- Discrete External Hazards are those hazards that are realised at a single frequency (or set of discrete frequencies) with an associated hazard magnitude. Typically, these are hazards which do not occur with sufficient frequency to enable a relationship between magnitude and frequency to be established. Additionally, some External Hazards such as aircraft impact are discrete because there are a limited finite number of possible events that could occur.

- For some discrete External Hazards, a Maximum Credible Event (MCE) can be established to characterise a worst-case event for the hazard. This is typically employed when characterising discrete human-induced External Hazards.
- Non-discrete External Hazards are those hazards that can occur across a continuous range of frequencies and can be defined in terms of a hazard curve. The derivation and conservatisms applied to the GB GSE values are discussed in sub-chapter 21.2.3.3.

21.2.3.3 Derivation of GB GSE Parameters

DBEs have been derived for each of the credible External Hazards identified in the GSER [3], which are of a magnitude that is bounding of the sites considered within the development of the GB GSE to establish the GB GSE Parameters. A summary of this derivation is presented for each External Hazard in sub-chapter 21.7 with the codes and standards applied in this derivation presented in sub-chapter 21.4.

The derivation of DBEs in the development of the GB GSE has been undertaken in alignment with the ONR SAPs [24]. Typically, DBEs have been derived in accordance with the frequency of occurrence thresholds set in Principle FA.5 of [24], which is 1 in 10,000 years for natural External Hazards.

Conservatism has been included in the approach for the derivation of the DBEs caused by non-discrete hazards in accordance with ONR SAPs [24] paragraph 629 to reflect the uncertainties in the underlying data used for derivation of the GB GSE Parameters. The GB GSE Parameter has then been determined by adopting the DBE which bounds all the nine sites considered within the envelope, using a reasonable assessment of publicly available information. This approach is an implicitly conservative process, as it accounts for the worst-case site.

At this stage of the GDA, uncertainty analysis has not been conducted as part of the approach to derive GB GSE parameters, this will be possible at the site-specific stage with access to site-specific datasets, to allow conservative definition of hazard values with reasonable confidence intervals via the use of hazard curves. However, a BDB assessment has been carried out, as described within sub-chapter 21.2.3.4.2.

The DBEs derived for the GB GSE are referred to as the ‘GB GSE Parameters’ throughout this chapter. A summary of these GB GSE Parameters is provided in Part A Chapter 2 [4].

The UK Climate Projections 2018 (UKCP18) climate analysis tool [25] developed by the Met Office has been used in the derivation of the GB GSE Parameters to account for the effects of reasonably foreseeable climate change over the lifetime of the facility. Further explanation on the approach to the UK Climate Projections is provided in Part A Chapter 2 [4], which has been developed to align with the ONR’s position statement published in 2022, UKCP18 [26].

A detailed hazard analysis, including the production of hazard curves for the non-discrete External Hazards, has not been undertaken at this stage. This analysis will take place at the site-specific stage to establish a detailed characterisation of each External Hazard for the prospective site under consideration.

21.2.3.4 Preliminary Evaluation of GDA Reference Design

A preliminary External Hazards evaluation of the GDA Reference Design has been undertaken prior to the production of the PFS and a fully developed UK specific design basis analysis.

The objective of this preliminary evaluation is to demonstrate the fundamental adequacy of the approach to External Hazards inherent within the generic SMR-300 highlighting the robustness of the design to withstand the External Hazards relevant to the GB GSE. This evaluation also provides an early opportunity to identify whether there are any potential topics to be resolved to enable the development of a fully licensable detailed design suitable for deployment in GB.

At this stage, this preliminary evaluation consists of a high-level comparison study between the identified External Hazards in the GDA Reference Design and the GB GSE.

21.2.3.4.1 Preliminary External Hazards Design Basis Evaluation

The purpose of this exercise is to perform a high-level preliminary evaluation of deploying the GDA Reference Design on a generic site in GB. The acceptance criteria for design basis External Hazards for the generic SMR-300 shall align with those for the SMR-300 outlined within sub-chapter 21.2.2.2 with the following addition: No design basis External Hazard will lead to an event not bounded by a design basis fault.

In sub-chapter 21.7, for each External Hazard a comparison of hazard severity and magnitude is made between the GDA Reference Design parameters, which were introduced in sub-chapter 21.2.2.5, and the GB GSE Parameters presented in Part A Chapter 2 [4]. In many cases, significant margin is present, demonstrating the robustness of the design in the context of deploying the generic SMR-300 in GB.

It is important to note that the design of all SSCs will be fully examined following a fully developed UK specific design basis analysis. Further explanation is provided in Part B Chapter 14 [7] and the Safety Assessment Handbook (SAH) [27].

21.2.3.4.2 Preliminary External Hazards Beyond Design Basis Evaluation

The purpose of this evaluation is to meet the intent of ONR SAPs EHA.18 and EHA.7 [24], which identify the importance of considering ‘Beyond Design Basis Events’ and ‘Cliff-Edge Effects’ in the evaluation of External Hazards.

Further work has been undertaken to outline the methodology to evaluate External Hazard events beyond the design basis to demonstrate sufficient margins exist, and the absence of ‘Cliff-Edge Effects’. This work has been undertaken within the BDB Strategy for External Hazards report [28].

<u>Preliminary Cliff-Edge Evaluation</u>

At this stage of the GDA the Cliff-Edge analysis presents a sensitivity study on the design basis plant by demonstrating a margin between the design basis, defined in the GB GSE, and a reasonable increase in hazard level to reflect known uncertainties in both the hazard analysis and the plant response analysis.

The intent of Cliff-Edge analysis is to demonstrate that design basis safety functions are maintained despite the increased hazard severity, albeit with a lower confidence level than at design basis hazard levels. This is generally captured by success-based methods, such as a margins analysis.

The methodology adopted in the BDB Strategy for External Hazards report [28] broadly aligns with that presented in the Structural Mechanics in Reactor Technology (SMiRT) publication State-of-the-art review of Beyond Design Basis Evaluation Approach of a Generic Nuclear Power Plant in the UK [29], whereby hazards are categorised based upon a number of parameters. Figure 1 presents a modified version of the process flow for categorisation of BDB hazards for Cliff-Edge analysis, presented in [29]. This process flow has been modified to include an additional criterion to provide more granularity in the types of BDB approaches for External Hazards. An overview of each BDB category is presented in Table 1.

The key outputs of this work are captured within their respective External Hazard sub-chapters of this PSR chapter. Each External Hazard has been allocated a BDB category as summarised in Table 2 based upon the preliminary evaluations presented in the BDB Strategy for External Hazards report [28], the External Hazards US-UK Gap Analysis report [30], and the GSER [3].

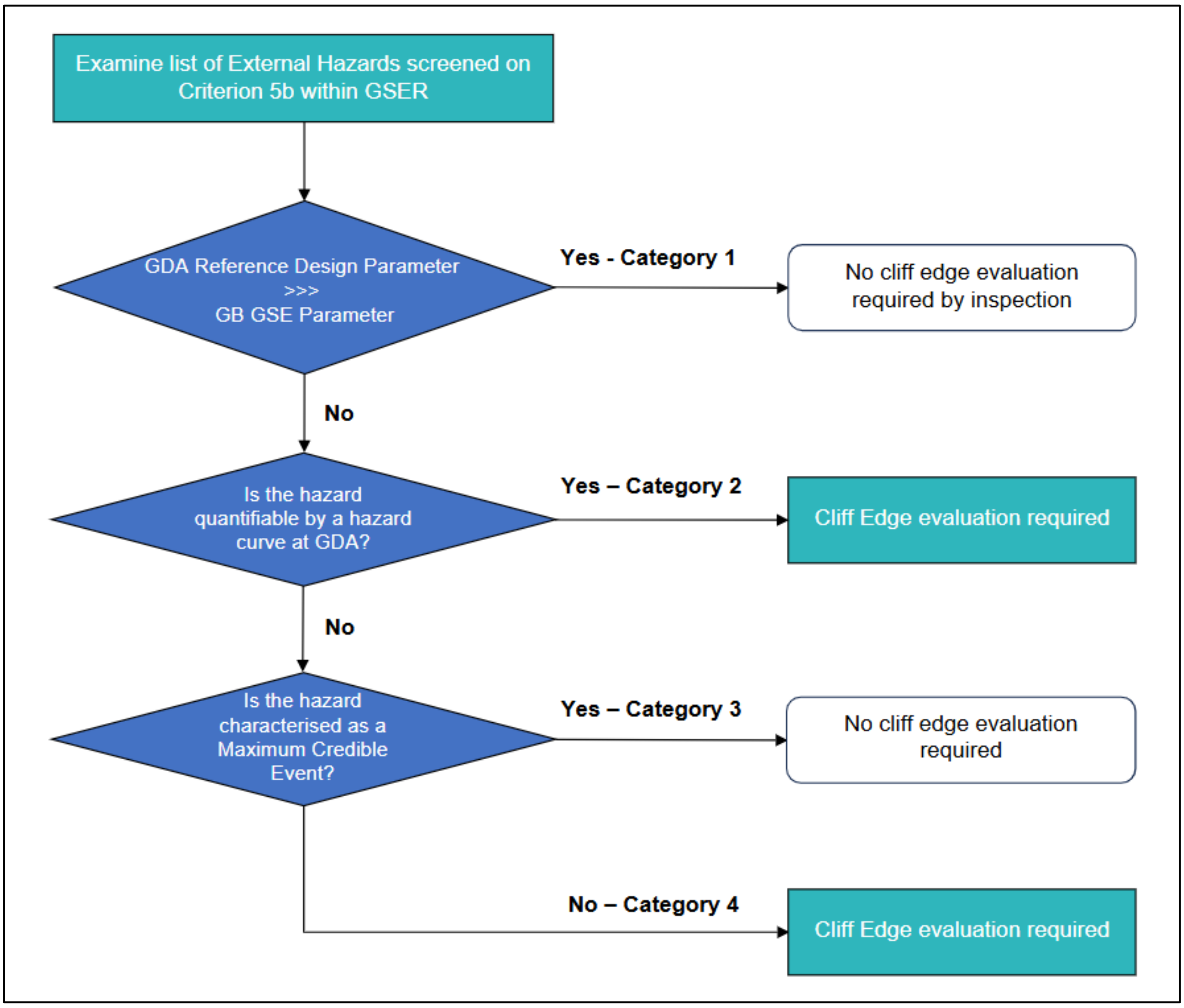

Figure 1: Modified Process Flow for the BDB Cliff-Edge Categorisation [29]

Table 1: Overview of External Hazards BDB Categories

Category	Description
1	External Hazards for which the design value is 'significantly' higher than the GB GSE Parameter. No value is provided for the term 'significantly' and this shall be based upon engineering judgement. Due to the 'significantly' bounding GDA Reference Design Parameter with respect to the GB GSE it is deemed that a BDB assessment is not required.
2	Hazards that can be quantified by a hazard curve within the GDA will be assessed at frequencies of occurrence of 10^{-5}/yr and below [29] on a best estimate basis. This assessment is beyond the scope of GDA, however, after GDA Step 2 SSCs shall be evaluated for these lower frequency External Hazards to evaluate their withstand capabilities. Within this evaluation the potential impacts upon the fulfilment of safety functions shall be assessed. Hazards that can be quantified by a hazard curve within the GDA are to be assessed at frequencies of occurrence of 10^{-5}/yr and below.
3	Hazards are classified as a MCE and therefore exceedance of this value is not deemed credible. Hazards categorised under Category 3 do not require further hazard assessment.
4	Hazards that cannot be quantified by a hazard curve, either within GDA or by the nature of the hazard, and are not considered a MCE, are classified as a Category 4 hazard. An example of this category includes accidental aircraft impact. Assessment of such a hazard will be undertaken at a single frequency and hazard level. For hazards that can only be defined by hazard curves during the site specific stage, a commitment is made by the Requesting Party (RP) that these hazards will be revisited during the site-specific stage and Cliff-Edges will be evaluated in a similar manner to the approach described for Category 2 hazards.

Table 2: BDB Categorisation of External Hazards

External Hazard		Hazard Category
Extreme Ambient Air Temperature		2
Humidity		3
Extreme Cooling Water Temperature	High	1
	Low	3
Extreme Wind		2
Tornadic Wind		1
Tornado-Generated Missiles		1
Icing		3
Snow		1
Lightning		3
External Flooding		4
Extreme Rainfall		2
Seismic[4]		4
Electromagnetic Interference (EMI)[5]		N/A
Space Weather[5]		N/A
Aircraft Impact[6]		N/A
Malicious Activity[6]		N/A

[4] Although seismic is categorised as Category 4 i.e. there is no hazard curve available at GDA, at the site-specific stage this will be assessed as a Category 2 hazard. Further discussion of the BDB seismic hazard assessment is provided in the Beyond Design Basis Strategy for External Hazards report [28].

[5] These hazards have been screened as criterion 5a (screened in for GDA with no DBE derived) in the GSER. These hazards are therefore outside the scope of the BDB assessment. It is anticipated that at the site-specific stage a maximum credible event will be established for each hazard to characterise a worst-case event.

[6] Accidental and malicious aircraft impact addressed in separate reports; Aircraft Impact Safety Case Strategy report [32] and Aircraft Impact Evaluation Methodology report [33].

More Severe BDB Analysis

As noted within the SMiRT paper [29], 'more severe' BDB events are broadly equivalent to DEC-B events as defined by Western European Nuclear Regulators' Association (WENRA) and are related to postulated or unforeseen severe plant faults or fuel damage, where significant nuclear safety functions could be severely challenged. This is closely linked with the Severe Accident Analysis (SAA).

Unlike Cliff-Edge analysis, the 'more severe' BDB events will have different acceptance criteria, further discussion on acceptance criteria for DEC-A and DEC-B events are provided within the SMR-300 Safety Concept for Severe Accidents report [31].

Further details on the identification and analysis of DEC-A and DEC-B events are provided in Part B Chapter 15, BDBA, Severe Accident Analysis, and Emergency Preparedness [8]. The aim of Part B Chapter 15 [8] is to demonstrate that the plant is capable of preventing, controlling, and mitigating sequences which are beyond the design basis.

Furthermore, the BDB Strategy for External Hazards report [28] identifies the following 'more severe' BDB External Hazards for the generic SMR-300 based upon their potential for 'extreme consequences'.

- Accidental and Malicious Aircraft Impact – Covered within Aircraft Impact Safety Case Strategy Report [32] and Aircraft Impact Evaluation Methodology Report [33].
- External Flooding – To be assessed at site-specific stage, refer to Beyond Design Basis Strategy for External Hazards [28] for preliminary hazard assessment.
- Seismic – To be assessed at site-specific stage, refer to Beyond Design Basis Strategy for External Hazards [28] for preliminary hazard assessment.
- Combined Hazards – Credible hazard combinations covered within the Internal and External Hazards Combined Hazards Methodology report [34], site-specific hazard combinations shall be assessed at the site-specific stage.

External Hazards listed in Table 2 but not covered within the above bullet points are not assessed further as 'more severe' BDB External Hazards due to insufficient maturity of the information available during the GDA. These External hazards will be assessed post GDA Step 2.

21.2.3.5 Hazard Protection

As the fault studies topic area progresses, protection measures are to be identified for each External Hazard. Within the scope of GDA Step 2, a provisional high-level External Hazards PFS has been produced as outlined within sub-chapter 21.6. The External Hazards PFS identified preliminary External Hazards requirements for SSCs. Within the scope of GDA Step 2, these are predominantly the civil structures which protect the SSCs important to safety from External Hazards. Beyond the scope of GDA Step 2, formal hazard identification shall be undertaken to identify further fault progressions and additional External Hazard requirements.

21.3 EXTERNAL HAZARDS CLAIMS, ARGUMENTS, AND EVIDENCE

This chapter presents the External Hazards aspects for the generic SMR-300 and therefore directly supports Claim 2.1.5.

Claim 2.1.5 Risks from External Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

Claim 2.1.5 has been further decomposed within this chapter (Part B Chapter 21) to provide confidence that the relevant requirements on SSCs will be met during all lifecycle phases. Table 3 presents a summary of the Level 4 claims highlighting in which sub-chapter these claims are addressed. Further rationale on the decomposition of claim 2.1.5 into level four claims is also provided below.

Table 3: CAE Chapters

Claim No.	Claim	PSR Chapter
2.1.5.1	External Hazards are identified and characterised using appropriate Codes and Standards, taking cognisance of RGP and Operating Experience (OPEX).	Sub-Chapter 21.4
2.1.5.2	A comprehensive set of External Hazards and their combinations are identified and screened for assessment.	Sub-Chapter 21.5
2.1.5.3	Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all External Hazards and provide sufficient lines of protection based on the fault frequency and consequence.	Sub-Chapter 21.6
2.1.5.4	Analysis demonstrates that for all External Hazards, the identified safety features, in conjunction with operator actions, enable the plant to reach a safe state.	Sub-Chapter 21.7

Claim 2.1.5.1 contributes to the hazard identification and characterisation step of the *Safety Analysis* phase by defining the codes and standards used to identify the External Hazards to be considered within the safety analysis. Additionally, the claim contributes to the *Design Phase* by defining the codes and standards used to derive the design basis of each of the identified External Hazards to be used within the design basis engineering analysis.

Claim 2.1.5.2 contributes to the hazard identification step of the *Safety Analysis* phase and provides confidence that all External Hazards relevant to the deployment of the generic SMR-300 on a generic site in GB have been identified and appropriately screened through a comprehensive process aligned with RGP.

Claim 2.1.5.3 contributes to the *Safety Analysis* phase and the *Design* phase, to ensure SSCs are correctly specified in terms of safety functions and classification, derived from the safety analysis (e.g., to withstand impacts), noting that the maturity of evidence for this claim will be limited at a PSR stage.

Claim 2.1.5.4 then ensures that the *Safety Analysis* phase demonstrates that the plant can reach a safe state following an External Hazard, noting that the maturity of evidence for this claim will be limited at a PSR stage as the PFS is developed.

Table 20 outlines the CAE breakdown for External Hazards and the identified evidence. Evidence included within Table 20 outlines information available within GDA Step 2 at a sufficient maturity for Step 2 and also evidence identified within GDA Step 2 that is expected to be available at the site-specific stage (PCSR). This is not an exhaustive list and should it be required beyond GDA Step 2 further evidence may be produced.

21.4 CODES AND STANDARDS

Claim 2.1.5.1: External Hazards are identified and characterised using appropriate Codes and Standards, taking cognisance of RGP and OPEX.

Claim 2.1.5.1 has been decomposed into a single argument to capture the codes and standards used in the identification and preliminary assessment of External Hazards.

Argument 2.1.5.1 – A1: The SMR-300 assesses External Hazards as required by the US NRC regulatory environment. This is enhanced by comprehensive topic reports for each external hazard to identify any additional analyses required to underpin the demonstration of ALARP within the UK regulatory context.

This sub-chapter identifies the codes and standards used in developing the SMR-300 for External Hazards, the relevant good practice considered, and the operational experience taken into account. Codes and standards that have been applied in the design of the SMR-300 against External Hazards are listed throughout sub-chapter 21.4.1, the codes and standards used for External Hazards within the UK context are listed throughout sub-chapter 0.

21.4.1 GDA Reference Design

The GDA Reference Design is based upon the US Palisades design, with the Holtec SMR-300 Specification – Human-Induced External Events [18] and the Holtec SMR-300 Specification – Environmental Conditions [19] specifying the guidance, codes, and standards applied in the identification and characterisation of External Hazards in the GDA Reference Design.

21.4.1.1 Hazard Identification

A comprehensive hazard identification has been conducted for the GDA Reference Design, within Holtec 'SMR-300 Specification – Human-Induced External Events [18] and the Holtec SMR-300 Specification – Environmental Conditions [19] documents. The External Hazards have been considered and defined to envelope anticipated site-specific hazards. Table 4 presents the list of guidance documents examined to develop the External Hazards considered in the GDA Reference Design.

Table 4: Codes and Standards used in the Hazard Identification for the GDA Reference Design

Author	Title
Canadian Nuclear Safety Commission	REGDOC-2.5.2 Design of Reactor Facilities: Nuclear Power Plants, May 2014 [35].
Canadian Nuclear Safety Commission	REGDOC-2.4.1 Deterministic Safety Analysis, May 2014 [36].
Canadian Nuclear Safety Commission	REGDOC-2.4.2 Probabilistic Safety Assessment for Nuclear Power Plants, May 2014 [37].
International Atomic Energy Agency	Safety Guide No. NS-G-1.5 External Events Excluding Earthquakes in the Design of Nuclear Power Plants, 2003 [38].
International Atomic Energy Agency	Safety Guide No. NS-G-3.1 External Human Induced Events in Site Evaluation for Nuclear Power Plants, 2002 [39].
US Nuclear Regulatory Commission	NUREG-0800 Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Plants [40].

Author	Title
US Nuclear Regulatory Commission	10 CFR Part 50 App. A General Design Criteria for Nuclear Power Plants, Domestic Licensing of Production and Utilization Facilities [21].
US Nuclear Regulatory Commission	Regulatory Guide 1.221 Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants, Revision 0 [41].
US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [42].
US Nuclear Regulatory Commission	Regulatory Guide 1.102 Flood Protection for Nuclear Power Plants, Revision 1 [43].
US Nuclear Regulatory Commission	Regulatory Guide 1.59 Design Basis Floods for Nuclear Power Plants, Revision 2 [44].
US Nuclear Regulatory Commission	Regulatory Guide 1.78 Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release, Revision 1 [45].
US Nuclear Regulatory Commission	Regulatory Guide 1.91 Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants, Revision 2 [46].
US Nuclear Regulatory Commission	Regulatory Guide 1.217 Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts, Revision 0 [47].
US Nuclear Regulatory Commission	Regulatory Guide 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants [48].

21.4.1.2 Derivation of GDA Reference Design Parameters

A comprehensive set of codes and standards have been referenced in the derivation of the GDA Reference Design parameters. Table 5 presents the list of the codes and standards used to derive hazard parameters. These items have been reproduced from reference [18] and [19].

Table 5: Codes and Standards used in the Derivation of GDA Reference Design Parameters

External Hazard	Author	Title
Ambient Conditions (Wet and Dry Bulb Temperatures, Precipitation)	Electric Power Research Institute	Technical Report Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13 [49].
	Dominion Virginia Power (Dominion)	North Anna, Unit 3, Combined License Application, Part 2: Final Safety Analysis Report, Revision 9 [50].
	American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)	ASHRAE Handbook Climactic Design Conditions, 2021 edition, Weather Monitor Station No. 722343 (South Haven Area Regional Airport), South Haven, MI, USA [51].
Wind Conditions, and Seismic Conditions	American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI)	ASCE/SEI 7/16 Minimum Design Loads for Buildings and Other Structures, 2016 [52].
Hurricane Wind and Hurricane Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.221 Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants, Revision 0 [41].
Tornado Wind and Tornado Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [42].
Lightning	US Nuclear Regulatory Commission	Regulatory Guide 1.204 Guidelines for Lightning Protection of Nuclear Power Plants, Revision 0 [53].
EMI	US Nuclear Regulatory Commission	Regulatory Guide 1.180 Guidelines for Evaluating Electromagnetic and Radio Frequency Interference in Safety-Related Instrumentation and Control Systems, Revision 1 [54].
Precipitation Conditions	Entergy Nuclear Operations, Inc.	Palisades Nuclear Plant, Updated Final Safety Analysis Report, Revision 35 [55].
	National Oceanic and Atmospheric Administration	Hydrometeorological Report No.51, Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, 1978 [56].

External Hazard	Author	Title
Michigan Lake Water Conditions	National Oceanic and Atmospheric Administration	Lake Michigan Average Great Lake Surface Environmental Analysis(GLSEA), Average Surface Water Temperature [57].
Seismic	US Nuclear Regulatory Commission	Regulatory Guide 1.60 Design Response Spectra for Seismic Design of Nuclear Power Plants [48].
Aircraft impact	US Nuclear Regulatory Commission	10 CFR 50.150(a) Aircraft impact assessment [58].
	US Nuclear Regulatory Commission	Regulatory Guide 1.217 Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts, Revision 0 [47].
	Nuclear Energy Institute (NEI)	NEI 07-13, Methodology for Performing Aircraft Impact Assessments for New Plant Designs, Revision 8 [59].

21.4.2 Great Britain Generic Site Envelope

The GB GSE has been established in accordance with RGP and international regulatory guidance. The hazard identification process undertaken in the GSER [3] consisted of a comprehensive literature review of UK and International Regulatory Guidance documents, RGP, previous GDA submissions and previous work undertaken by Holtec International to define a “Universe of External Hazards”, which consisted of an extensive unscreened list of External Hazards. This included guidance from the ONR [17], [24], IAEA [60], WENRA [61], [62], SKI [63], ASAMPSA [64], the Organisation for Economic Co-operation and Development (OECD) [65], [66] and the US NRC [67]. This extensive list of External Hazards has then been screened applying a criteria developed in accordance with RGP from the ONR [17], [24] and the IAEA [68].

21.4.2.1 Hazard Identification

A comprehensive hazard identification process has been conducted in the development of the GB GSE. Table 6 presents the list of guidance documents examined to identify credible External Hazards which can affect nuclear safety, can be considered on a generic basis and are relevant to the deployment of the generic SMR-300 on a generic site in GB.

Table 6: Codes and Standards used in the Hazard Identification of the GB GSE

Author	Title
ONR Safety Assessment Principles	Safety Assessment Principles for Nuclear Facilities, Revision 1 [24].
ONR Technical Assessment Guide (TAG) 13	ONR Technical Assessment Guide: External Hazards, Issue 9, October 2023 [17].
International Atomic Energy Agency	Specific Safety Guide No. SSG-68 Design of Nuclear Installations Against External Events Excluding Earthquakes [60].
Western European Nuclear Regulators' Association	Safety of new Nuclear Power Plants (NPPs) [61].
Western European Nuclear Regulators' Association	Guidance Document Issue TU: External Hazards Head Document [62].
Swedish Nuclear Inspectorate (SKI)	SKI Report 02:27: Guidance for External Events Analysis [63].
Advanced Safety Assessment Methodologies: Extended PSA (ASAMPSA_E)	List of External Hazards to be considered in ASAMPSA [64].
Organisation for Economic Co-operation and Development, Nuclear Energy Agency	PSA of Other External Events than Earthquake [65].
Organisation for Economic Co-operation and Development, Nuclear Energy Agency	PSA of Natural External Hazards Including Earthquakes [66].
European Utility Requirements	EUR Vol. 2 Chapter. 2.4 Generic and Nuclear Island Requirements, Revision E [69].

Author	Title
US Nuclear Regulatory Commission	NUREG-1407 Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities [67].
Holtec International	HI-2200558 PSA Screening of Other External Events [70].
Holtec International	HI-2240977 SMR-300 Specification – Human-Induced External Events [18].
Holtec International	HI-2240117 SMR-300 Specification – Environmental Conditions [19].
UK European Pressurised Reactor (EPR)	UKEPR-0002-022: UK EPR PCSR – sub-chapter 2.2 – Site Environmental Characteristics, Issue 4 [71]. UKEPR-0002-131: UK EPR PCSR – sub-chapter 13.1 – External Hazards Protection [72].
UK Advanced Passive -1000 (AP1000)	UKP-GW-GL-025: UK AP1000 Generic Site Report [73]. UKP-GW-GL-793NP: AP1000 Pre-Construction Safety Report, Chapter 12 [74].
UK Advanced Boiling Water Reactor (ABWR)	XE-GD-0213:UK ABWR Generic PCSR Chapter 2: Generic Site Envelope [75]. AE-GD-0168: UK ABWR Generic PCSR Chapter 6: External Hazards [76].
UK Hua-long Pressurised Reactor 1000 (HPR1000)	HPR/GDA/REPO/0015: UK HPR1000 Generic Site Report [77]. HPR/GDA/PCSR/0018: UK HPR1000 Pre-Construction Safety Report Chapter 18 - External Hazards [78].

21.4.2.2 Derivation of GB GSE Parameters

Table 7 presents the list of the codes and standards used to derive the GB GSE Parameters which are also presented in Part A Chapter 2 [4] and the GSER [3].

Table 7: Codes and Standards used in Derivation of GB GSE Parameters

External Hazard	Author	Title
UK Climate Projections	Met Office	UK Climate Projections (UKCP) [79].
	Met Office	UKCP18 Derived Projections of Future Climate over the UK, 2018 [80].
	Met Office	UKCP18 Guidance: Representative Concentration Pathways [81].
	Environment Agency (EA)	Flood Risk Assessments: Climate Change Allowances, May 2022 [82].
Extreme Ambient Air Temperature	British Standards Institution	BS EN 1991-1-5:2003 Eurocode 1: Actions on Structures - Part 1-5: General Actions - Thermal Actions, 2010 [83].
	British Standards Institution	NA to BS EN 1991-1-5:2003 UK National Annex to Eurocode 1: Actions on Structures - Part 1-5: General Actions - Thermal Actions, 2007 [84].
Humidity	Met Office	UK Climate Averages [Online] [85].
Extreme Cooling Water Temperature	Met Office	UKCP18 Marine Report, 2018 [86].
Extreme Wind	British Standards Institution	BS EN 1991-1-4:2005 + A1:2010 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, 2011 [87].
	British Standards Institution	NA to BS EN 1991-1-4:2005 + A1:2010 UK National Annex to Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, 2011 [88].
Tornadic Wind and Tornado Generated Missiles	US Nuclear Regulatory Commission	Regulatory Guide 1.76 Design Basis Tornado and Tornado Missiles for Nuclear Power Plants, Revision 1 [42].
Icing	British Standards Institution	BS EN 1993-3-1:2006 Eurocode 3 - Design of steel structures - Part 3-1: Towers, masts and chimneys - Tower and masts, 2010 [89].

External Hazard	Author	Title
	British Standards Institution	NA to BS EN 1993-3-1:2006 UK National Annex to Eurocode 3: Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts, 2010 [90]
Snow	British Standards Institution	BS EN 1991-1-3:2003 +A1:2015 Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow Loads, 2015 [91].
	British Standards Institution	NA+A2:2018 to BS EN 1991-1-3:2003+A1:2015 UK National Annex to Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads, 2018 [92].
Lightning	British Standards Institution	BS EN 62305-1:2011 Protection against lightning - Part 1: General Principles," February 2017 [93].
	International Council on Large Electric Systems (CIGRE)	Lightning Parameters for Engineering Applications, August 2013 [94].
	Energy Technologies Institute (ETI)	Enabling Resilient UK Energy Infrastructure: Natural Hazard Characterisation Technical Volumes and Case Studies, Volume 9: Lightning, February 2018 [95].
	British Standards Institution	BS EN 62305-2:2012 Protection against lightning - Part 2: Risk management, May 2012 [96].
	British Standards Institution	PD 62305-2:2014 Flash density map 2014 - Supplement to BS EN 62305-2:2012 - Protection against lightning - Part 2: Risk management, 2014 [97].
Extreme Rainfall	UK Centre for Ecology & Hydrology	Flood Estimation Handbook (FEH) Web Service [98] [99].
	Met Office	UKCP18 Factsheet: Precipitation [100].
	Office for Nuclear Regulation	European Council "Stress Tests" for UK nuclear power plants, National Final Report [101].
Seismic	European Utility Requirements	EUR Vol. 2 Chapter. 2.4 Generic and Nuclear Island Requirements, Revision E [69].
	ONR	"Stress Tests" for UK non-Power Generating Nuclear Facilities Final Report [102].
	British Geological Survey	National seismic hazard maps for the UK: 2020 update [103].
	British Standards Institution	BS EN 1998-1:2004+A1:2013 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings [104].

21.4.3 CAE Summary

The External Hazard identification and characterisation undertaken in the development of both the GDA Reference Design, and the GB GSE has been conducted in accordance with codes and standards, RGP, and international regulatory guidance. This guidance includes learning from previous UK GDA submissions and expectations outlined by both the US NRC and ONR. Claim 2.1.5.1 has therefore been met to the extent consistent with the maturity of this project at this time.

21.5 EXTERNAL HAZARD IDENTIFICATION

Claim 2.1.5.2: A comprehensive set of External Hazards and their combinations are identified and screened for assessment.

Claim 2.1.5.2 has been further decomposed into three arguments to capture the sources of External Hazards, covering the 'generic' Internal hazards identified based upon the review of OPEX and RGP, to formal Hazard Identification activities and hazard combinations. Each of these three arguments and the available evidence are covered within their own respective sub-chapters:

- Argument 2.1.5.2-A1: Sub-chapter 21.5.1 outlines the methodology for the identification of External Hazards based upon RGP and OPEX and lists those External Hazards which are screened-in.
- Argument 2.1.5.2-A2: Sub-chapter 21.5.2 outlines the methodology to be applied to carry out any required Hazard Identification (HAZID) activities.
- Argument 2.1.5.2-A3: Sub-chapter 21.5.3 summarises the methodology followed to identify credible External Hazard combinations within the scope of GDA, as well as the methodology to be followed post GDA.

21.5.1 Hazard Identification

Argument 2.1.5.2-A1: A comprehensive list of External Hazards has been identified based upon OPEX and RGP. This builds on the External Hazards identified by compliance with the US NRC regulatory environment.

Part A Chapter 2 [4] defines the GB GSE and the generic site characteristics to be used as the basis for the safety analysis. A comprehensive identification and screening process has been undertaken to identify the External Hazards relevant to the deployment of the generic SMR-300 on a generic site in GB. This process has been developed in accordance with ONR SAPs EHA.1 and EHA.2 [24], and ENDP13 of the EA's Engineering: generic developed principles guidance [105].

Figure 2 presents the methodology applied in the GSER [3] to identify credible External Hazards that are relevant to the GB context, can affect nuclear safety, and can be considered on a generic basis. The first step of this methodology involved a comprehensive literature review of UK and International Regulatory Guidance documents, RGP, previous GDA submissions and previous work undertaken by Holtec to define a "Universe of External Hazards". The codes and standards, and regulatory guidance examined in this process is provided in sub-chapter 21.4.2.1.

21.5.1.1 Screening of External Hazards

The result of the first step of Figure 2 is an extensive list of External Hazards which have been screened into the scope of the GB GSE. The following criteria have been developed in accordance with RGP to screen the extensive list of External Hazards, such that those remaining represent generic hazards relevant to the GB GSE:

1. The hazard has a frequency of < 10^{-7}/year for a site in GB – events occurring at less than this return frequency are unlikely to occur in the lifetime of the plant and can be screened out (ONR SAPs FA.5 and EHA.19) [24], [17].

2. The hazard does not affect nuclear safety, i.e., low consequence[7] – events that have no significant contribution to overall risks from the facility can be screened out (ONR SAPs EHA.19) [24], [17].
3. The hazard effect is bounded by / included within the definition of another External Hazard, such that it doesn't need to be specifically assessed. This bounding approach limits the number of assessments that need to be undertaken [68].
4. The hazard is intrinsically site-specific and can only be assessed in detail at the site-specific stage.[8]
5. The hazard is screened-in to the scope of the GDA.
    a. No DBE is derived for the definition of the GB GSE at this stage, but a commentary and a confidence statement is provided. The hazard is within scope of GDA but can only be assessed in detail at the site-specific stage.[9]
    b. A DBE can be derived for the definition of the GB GSE.

This screening methodology is illustrated in Step 2 of Figure 2.

21.5.1.2 GSER External Hazard Identification Summary

The full output from the External Hazards identification and screening process is presented in Appendix A of the GSER [3]. The following External Hazards have been screened-in with DBEs derived to define the GB GSE Parameters, which establish the bounding characteristics of the GB GSE.

- Extreme Ambient Air Temperature.
- Humidity.
- Extreme Cooling Water Temperature.
- Extreme Wind.
- Tornadic Wind.
- Tornado-Generated Missiles[10].
- Icing.
- Snow.
- Lightning.
- Extreme Rainfall.
- Seismic.
- Loss of Off-Site Power (LOOP) and Extended LOOP (ELOOP)[11].

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[7] Where a hazard has been screened out on screening criterion 2, this judgement has been made based on common practice in the nuclear industry and is in keeping with other new build nuclear projects in the UK.
[8] Where a hazard has been screened out on screening criterion 4, an assumption has been made in Appendix A of the GSER with regards to the protection concept to be implemented at the site-specific stage.
[9] Where a hazard has been screened-in on screening criterion 5a, no UK DBE has been derived for the GB GSE either due to the maturity of the hazard characterisation at this stage of GDA, the sensitive malicious nature of the hazard or due to unknown site-specific variables required for the derivation of a UK DBE.
[10] Within the GSER Tornado-Generated Missiles also includes Hurricane-Generated missiles. Within HI-2240117 Hurricane-Generated missiles are bounding of Tornado-Generated Missiles. Further details are captured within Table 14.

[11] The External Hazards of LOOP and ELOOP are to be treated as a design basis fault in the safety analysis as defined in Part A Chapter 2 [4].

Additionally, the following External Hazards have also been screened-in, but no DBE has been derived to establish a GB GSE Parameter either due to the maturity of the hazard at this stage of the GDA, the sensitive nature of the hazard, or due to unknown site-specific variables:

- Aircraft Impact.
- Malicious Activity.
- EMI.
- Space Weather.

Malicious aircraft impact parameters are defined by the ONR through the threat definition provided in the regulatory expectation letter. However, these parameters will be excluded from this chapter because of the sensitive nature of the hazard.

An evaluation of each identified and screened-in External Hazard is provided in sub-chapter 21.7.

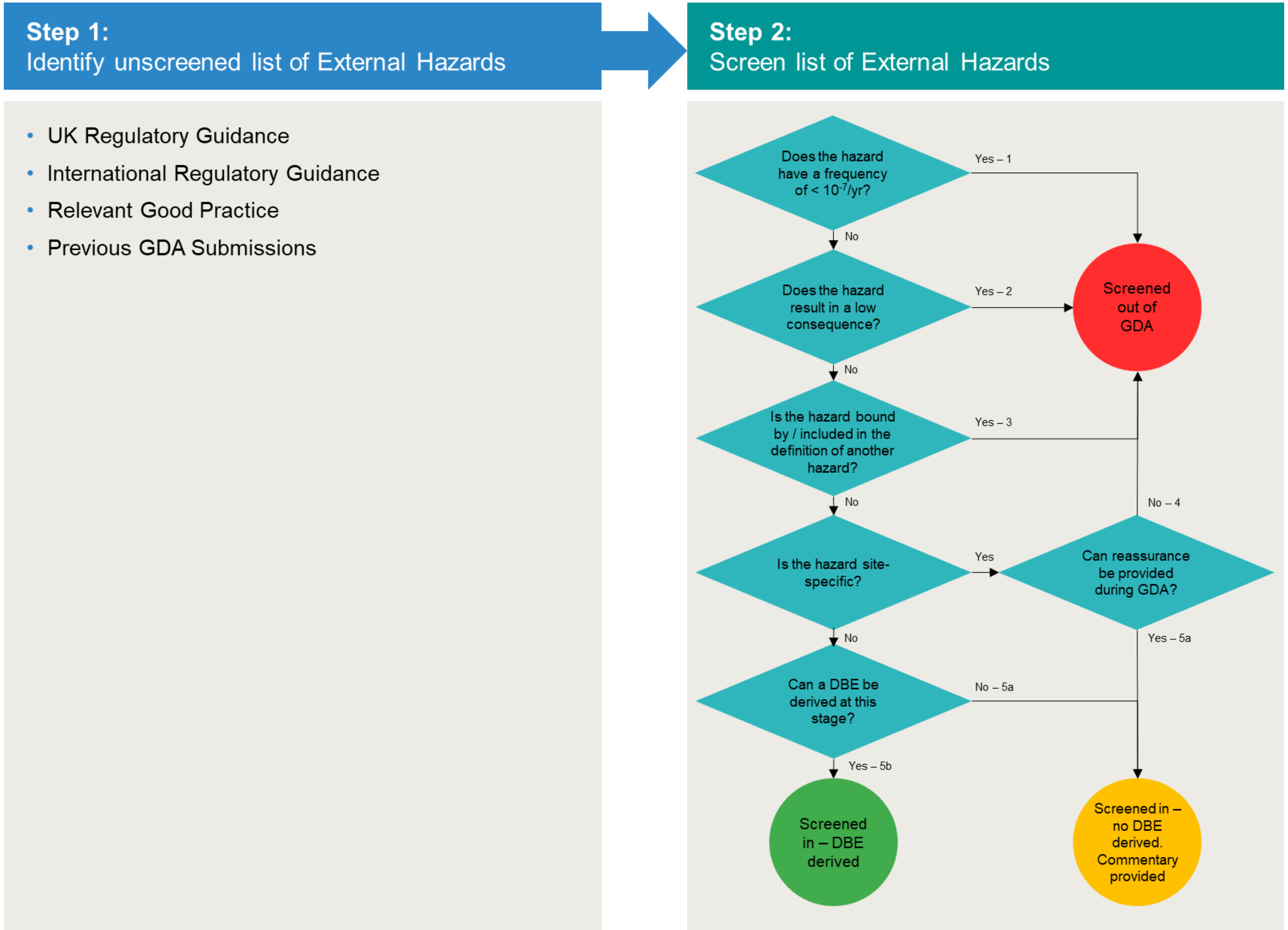

Figure 2: External Hazards Identification and Screening Methodology

21.5.2 Detailed Hazard Identification

Argument 2.1.5.2-A2: A comprehensive list of External Hazards has been identified based upon OPEX and RGP. This builds on the External Hazards identified by compliance with the US NRC regulatory environment.

Within the scope of GDA Step 2, formal HAZIDs for External Hazards have not been widely undertaken for External Hazards, however, two Hazard and Operability (HAZOP) 'I' studies were undertaken on the below topic areas which considered External Hazards as a keyword:

- Fuel Storage and Transport Route [106].
- Radioactive Waste Management [107].

Beyond GDA Step 2, the methodologies utilised within the above HAZOPs shall be utilised for additional studies, and, where appropriate, alternative hazard identification techniques shall be used. The Safety Assessment Handbook [27] outlines the techniques listed below as potential HAZID techniques, the selection of these shall be undertaken by Suitably Qualified and Experienced Personnel (SQEP) assessment based upon the system / room / building being assessed and the available information:

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

21.5.3 Hazard Combinations

Argument 2.1.5.2-A3: Credible combinations of External Hazards have been identified that could challenge the fundamental safety functions for the generic SMR-300.

In line with ONR SAP [24] EHA.6, hazard combinations should be considered in the analysis of External and Internal Hazards. Hazard combinations are where the two or more hazards occur at the same time. The concern is that with a compounding effect safety measures for individual hazards could be challenged or defeated. As hazard combinations are not explicitly considered in the US regulatory approach to External Hazards analysis, further work has been conducted to address this and presented in the Internal and External Hazards Combined Hazards Methodology report [34].

This sub-chapter presents a high-level summary of the hazard combination methodology adopted in [34] for the identification and screening of hazard combinations for the generic SMR-300 and presents a summary of the identified combinations.

Figure 3 presents the process flow of the high-level overall approach adopted, consisting of the following key steps:

- Step 1 – Identification of External Hazards and Internal Hazards.
- Step 2 – Identification and Categorisation of Hazard Combinations.
- Step 3 – Screening of Hazard Combinations.

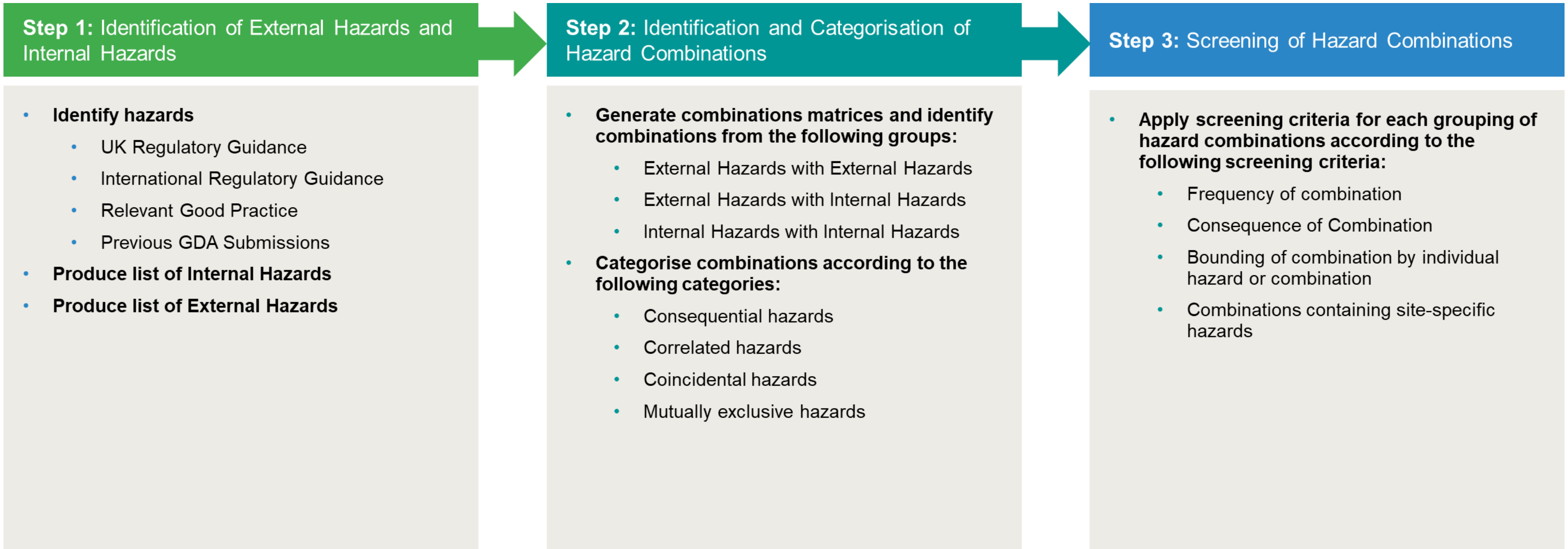

Figure 3: High-Level Overall Approach for Hazard Combinations

21.5.3.1 Identification and Categorisation of Hazard Combinations

Step 1 of the methodology identified the unscreened list of individual External and Internal Hazards. It is recognised that External Hazards previously screened out on low consequence required reassessment in the context of combinations on the basis that the hazard combination may exacerbate the consequences. Further explanation of the individual hazard identification is discussed in the Internal and External Hazards Combined Hazards Methodology Report [34].

Based on the ASAMPSA_E methodology [64], the identification of potential hazard combinations was achieved by utilising two-dimensional (2-D) matrices which enabled the comparison between two lists of hazards in order to identify credible combinations. The 2-D matrix approach makes use of an unscreened list of External Hazards to identify all potential combinations, this approach is considered good practice and consistent with EHA.1 [24]. Further explanation of the 2-D matrices hazard combination identification approach and the full outputs of the 2-D matrices identification is presented in the Internal and External Hazards Combined Hazards Methodology Report [34].

Step 2 of the methodology categorised the identified hazard combinations into the following four categories, in alignment with ONR's guidance in TAG 13 [17]:

- **Correlated hazards** – a combination of hazards that can occur simultaneously between the primary and secondary hazard, as both hazards depend on a common physical process (e.g., a storm may give rise to both rain and lightning hazards at the same time).
- **Consequential hazards / effects** – a combination of hazards that are the derived effects of primary, correlated, and secondary hazards and / or their typical effects, leading to a direct challenge to site safety and / or site operations (e.g., a lightning strike may cause fire).
- **Coincidental (independent)** – realistic combinations of randomly occurring independent External Hazards affecting the site simultaneously with no causative link. These hazards are not correlated through a physical process (e.g., earthquake and extreme ambient air temperature).
- **Mutually exclusive** – a combination of hazards that cannot occur as their causes / effects are mutually exclusive, i.e., the hazard combination is not credible. These hazards are a result of the remaining hazards that do not satisfy the other three categories (e.g., a high extreme ambient air temperature event resulting in icing hazards).

An unscreened list of credible correlated and consequential combinations were identified and extracted from the 2-D matrices to form an unscreened list of hazard combinations. Coincidental hazards and hazard combinations of three or more were then determined through a review of RGP and engineering judgement. Further explanation of the hazard combination categorisation process, and explanation of the approach to identification of coincidental hazards and hazard combinations of three or more, is discussed in the Internal and External Hazards Combined Hazards Methodology Report [34].

21.5.3.2 Screening of Hazard Combinations

The hazard combinations screening process was used to refine the candidate list of identified and categorised hazard combinations. The screening criteria were used to screen hazard combinations such that those remaining represent a list of reasonably foreseeable hazard combinations for consideration in the GDA.

Further discussion of the specific screening criteria applied to each hazard combination group (External ↔ External, External ↔ Internal) and explanations for each screening criterion is presented in the Internal Hazards and External Hazards Combined Hazards Methodology report [34]. The key screening principles are outlined below:

- **Frequency of combinations** – Combinations were screened based on the frequency of the combination; this principle aims to screen out combinations with low probability of occurrence. This is typically set at a frequency of < 10^{-7}/year for a GB site. Hazard combinations screened out under this criterion shall be reassessed at the site-specific stage when site-specific information is available as frequencies of individual hazards and combinations may differ depending on the site.
- **Consequence of combination** – Combinations were screened out based on the consequence of the combination with respect to nuclear safety. This principle aims to screen out combinations with low consequence, i.e., combinations that are judged to have no consequential effect to the safety of the plant or leading to the loss of fundamental safety functions. Hazard combinations screened out under this criterion shall be reassessed at the site-specific stage when site-specific information is available as consequences of individual hazards and combinations on the plant may differ depending on the site.
- **Bounding of combination** – Combinations were screened out if the effect of the combinations is bounded by / included within the definition of another External Hazard, event, or hazard combination. Hazard combinations screened out under this criterion shall be reassessed at the site-specific stage when site-specific information is available as the bounding hazard / combination may change at the site-specific stage.
- **Site-specific combinations** – Combinations were screened out if one or more of the hazards are site-specific. This applies to hazards that require site-specific information to further assess the credibility of the combination and where such information is unavailable during the GDA. Hazard combinations screened out under this criterion shall be reassessed at the site-specific stage when site-specific information is available.

21.5.3.3 Outputs of Hazard Combinations

The full list of credible hazard combinations identified within the scope of the GDA are presented in full within the Internal and External Hazards Combined Hazards Methodology report [34], including the rationale and outputs of the 'External Hazards combinations of three or more' evaluation. It is also noted within the hazard combinations report that a subset of the identified hazard combinations shall be reassessed when site-specific information is known, these are discussed in further detail in the Internal and External Hazards Combined Hazards Methodology Report [34].

The following quantities of hazard combinations were identified for each hazard combination group, as summarised in Table 8.

Table 8: Quantity of Hazard Combinations Identified

Hazard Combination Group	Category	Quantity
External-External	Correlated	7
	Consequential	4
	Coincidental	6
External-Internal	Consequential	8

21.5.4 CAE Summary

A comprehensive hazard identification and screening methodology has been undertaken in accordance with RGP to identify credible External Hazards which are relevant to the deployment of the generic SMR-300 on a generic site in GB, that could affect nuclear safety and can be considered on a generic basis. This work, including the methodology for the consideration of hazard combinations, provides a comprehensive set of External Hazards for assessment. In addition, a methodology for the formal HAZID work is outlined to be undertaken at the next design phase. This methodology has been applied for two HAZOP I's undertaken and provides confidence that External Hazards will be suitably included in HAZID activities moving forward.

21.6 SSCS WITH EXTERNAL HAZARD SAFETY FUNCTIONS

Claim 2.1.5.3: Safety functions and safety measures are identified, categorised, and classified based on their importance to nuclear safety for all External Hazards and provide sufficient lines of protection based on the fault frequency and consequence.

Claim 2.1.5.3 has been decomposed into a single argument covering the identification of safety measures and safety functions for External Hazard fault progressions. The argument also covers the suitable categorisation and classification of these items to ensure their importance to nuclear safety is apparent.

Argument 2.1.5.3-A1: For all identified External 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 presents a high-level overview of the External Hazards included in the PFS and assesses the suitability of these findings within the context of the Step 2 fundamental assessment.

The methodology for production of the PFS is outside the scope of this chapter and is outlined within Part B Chapter 14 [7] and the Preliminary Fault Schedule Report [108]. The methodology for the safety categorisation and classification is also outside the scope of this chapter and is contained within the SAH [27]. There is a high level of confidence that the SSC identification and safety classification methodology defined in the SAH will provide a suitable basis for the assessment of External Hazards.

21.6.1 External Hazard PFS

Within the scope of GDA Step 2 a high-level set of External Hazards has been included in the PFS. These have been produced to identify preliminary SSCs and preliminary requirements. Beyond GDA Step 2, following the undertaking of formal HAZID work and hazard assessments for the identified External Hazards, e.g. a seismic assessment, the Fault Schedule will identify all credible fault progressions and the SSCs and Safety Functions claimed to prevent, minimise and mitigate these fault sequences.

The SSCs identified within the PFS with External Hazard claims are outlined within the PFS Report [108], they are not repeated in full within this PSR Chapter for brevity, however the key SSCs are listed below:

- Safety Classified Buildings (Containment Enclosure Structure (CES), Reactor Auxiliary Building (RAB) etc).
- Ground Lightning Protection System.
- Heating, Ventilation and Air Conditioning (HVAC) systems.
- Seismic monitors.
- Passive Core Cooling (PCC).

The key SSCs with External Hazard claims are predominantly related to the civils structural withstand of the buildings which contain other SSCs that fulfil safety functions. This is because they protect these SSCs from the effects of External Hazards.

The key exception to this is for seismic events as all SSCs within the safety classified buildings are affected. As a result of this the SSCs required for safe shutdown following a seismic event have been identified within the External Hazards PFS and these will require seismic qualification.

Within the scope of GDA Step 2, only a high-level assessment of External Hazards has been undertaken to ensure the SMR-300 has no fundamental shortfalls against these hazards. The SSCs identified within the PFS Report [108], and those summarised above, identify suitable and sufficient safety measures commensurate with the level of design detail available within Step 2.

Beyond GDA Step 2, at the site-specific stage, further assessment shall be undertaken in line with the methodology outlined within the Safety Assessment Handbook [27] and Part B Chapter 14 [7]. This work shall include work such as fault progression development and DBAA.

21.6.2 CAE Summary

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

A provisional strategy for categorisation and classification is provided within Part B Chapter 14 [7] and its supporting deliverables. At this stage, the application of the US NRC guidance and US-based RGP and the PFS provides confidence that key safety functions and safety measures, within the scope of GDA, have been identified, categorised, and classified based on their importance to nuclear safety for all External Hazards. Beyond the scope of Step 2, at the site-specific stage, further assessment shall be undertaken to develop External Hazard fault progressions with the outputs of these detailed assessments being captured within the PFS.

21.7 EXTERNAL HAZARD EVALUATION

Claim 2.1.5.4: Analysis demonstrates that the identified safety features (in conjunction with operator actions) enable the plant to reach a safe shutdown state for all Design Basis External Hazards and for the selected Beyond Design Basis External Hazards.

As shown within Table 20 of Appendix A, Claim 2.1.5.4 has been decomposed into six arguments, five of these arguments have been developed based upon 'groups' of External Hazards. These 'groups' of External Hazards and the individual External Hazards that comprise them are listed below:

- Meteorological External Hazards:
    - Extreme Ambient Air Temperature.
    - Humidity.
    - Extreme Cooling Water Temperature.
    - Extreme Wind.
    - Tornadic Wind.
    - Tornado Generated Missiles.
    - Icing.
    - Snow.
    - Lightning.
- External Flooding and Hydrological Events:
    - Extreme Flooding.
    - Extreme Rainfall.
- Seismic Events.
- Human Induced External Hazards:
    - Aircraft Impact.
    - Malicious Activity.
- External EMI[12] and Space Weather.

This sub-chapter presents a preliminary evaluation of the External Hazards identified in sub-chapter 21.5, for both DB and BDB events, taking inputs from additional documentation produced (Beyond Design Basis Strategy for External Hazards [28], and External Hazards US-UK Gap Analysis report [30]) within GDA Step 2, following the approach outlined in sub-chapter 21.2.3.

The sixth argument (2.1.5.4-A6) is not repeated within each of the below subchapters for brevity, however, it supports all External Hazards:

Argument 2.1.5.4-A6: Suitable Cliff-edge and More Severe Beyond Design Basis analysis has been under to ensure risks from External Hazards to the generic SMR-300 are ALARP

[12] Although External EMI will have sources from Human Induced activities, it has been grouped alongside Space Weather to capture all potential sources, e.g. lightning, storms etc.

21.7.1 Meteorological External Hazards

Argument 2.1.5.4-A1: For all identified sources of Meteorological Hazards capable of challenging fundamental safety functions there are suitably qualified safety measures to ensure the plant reaches a safe state for all External Hazards.

21.7.1.1 Extreme Ambient Air Temperature

21.7.1.1.1 Hazard Characterisation

Extreme ambient air temperatures can be a hazard to safety related SSCs via the increase/ decrease in internal temperatures resulting in the loss of their respective safety functions if the SSCs cannot be insulated and adequately protected.

Extreme high and low ambient air temperatures can affect safety related SSCs as these need to be maintained within design temperature limits. Extreme ambient air temperature is also a key design parameter in the design of HVAC systems and cooling towers which may be providing cooling to safety related SSCs or maintaining a habitable environment for plant operators.

21.7.1.1.2 Derivation of GB GSE Parameter

Present-day peak hourly maximum and minimum dry bulb temperatures have been calculated to Eurocode BS EN 1991-1-5 [83] and the associated UK National Annex [84].

Maximum ambient air temperatures are projected to increase with climate change through the lifecycle of the generic SMR-300. The UKCP18 25 km probabilistic land projection models have been used to determine this projected increase in temperature to ensure the derived GB GSE Parameters account for reasonably foreseeable climate change.

The GB GSE Parameters for maximum and minimum dry bulb temperatures, and maximum wet bulb temperatures are presented in Table 9 below. Further explanation on the derivation of the maximum, minimum and wet bulb temperatures is provided in the GSER [3].

Table 9: GB GSE Parameters for Extreme Ambient Air Temperature

Parameter	GB GSE Parameter	
	Present Day	Year 2100
Maximum Peak Hourly Dry Bulb Temperature	42.1°C	49.1°C
Minimum Peak Hourly Dry Bulb Temperature	-31.1°C	-
Maximum Peak Hourly Wet Bulb Temperature	27.8°C	33.1°C

21.7.1.1.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design an environmental envelope of ambient conditions has been specified to envelope prospective nuclear sites located on the North American Continent, as defined in the Holtec SMR-300 Specification – Environmental Conditions [19]. Derivation of the environmental envelope is based on the guidance of Electric Power Research Institute (EPRI) Technical Report Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document [49], with portions of the environmental envelope derived from the nearest airport weather station (South Haven) [51] for the licensing activities at the Palisades site.

The environmental envelope defines a range of ambient conditions temperature sets applied in the GDA Reference Design, such as 0%, 1%, and 5% annual exceedance values. These bounding conditions are generally applied to portions of the generic SMR-300 design for which safety claims are made or for those SSCs that are critical to reliability and protection of the plant asset.

A preliminary assessment of this hazard and the temperature values between the GDA Reference Design and the GB GSE has been conducted in the External Hazards US-UK Gap Analysis report [30]. The report presents an evaluation of the temperature sets applied in the generic SMR-300 against GB GSE values that represent Anticipated Operational Occurrence (AOO), DBE, BDBE, and year 2100 climate change adjusted values, and evaluates the temperature sets against the design basis of the generic SMR-300 structures and system groups.

In this preliminary evaluation it is recognised that the GDA Reference Design temperature values are derived for a sustained duration of at least 24 hours. It is also recognised that the derived GB GSE Parameters represent peak maximum and minimum hourly temperature events in the UK and are considered instantaneous short-term events that would unlikely be sustained for a duration of 24 hours.

At the site-specific stage, using the site-specific characterisation of the extreme ambient air temperature hazard, an instantaneous event, a short-term event, and long-term heatwave profiles (where possible) will be established, to enable the derivation of hazard curves for each event type. This will use a detailed analysis of the UKCP18 data to better understand projected increase in severity and frequency with climate change over the lifecycle of the plant.

The preliminary evaluation undertaken in the External Hazards US-UK Gap Analysis report [30] recognises the need for a strategy to account for potential increases in design basis temperatures due to climate change. This strategy may involve uprated SSCs when they need to be replaced to cope with the higher temperatures projected at the time, i.e. a managed adaptive approach to climate change as defined in Use of UK Climate Projections 2018 (UKCP18) Position Statement [26]. As noted within System Design Description for Class 1 DC Power Distribution System [109] there is a requirement on the Class 1E Direct Current (DC) power system, that support systems such as the Passive Safety System (PSS), to remain operation and provide power for at least 72 hours following the loss of forced cooling or ambient cooling (HVAC). This requirement provides further DiD for the protection against extreme ambient air temperature. Substantiation of this requirement is beyond the timescales of the GDA.

A managed adaptive approach involves building flexibility into options and decisions so that the design can accommodate uncertainties associated with climate change. The Requesting Party's (RP) approach to extreme ambient air temperatures is to manage the potential changes to the magnitude of design basis events through re-assessment and margin assessments. As the GDA Reference Design is a first of a kind plant, the design uses more conservative methods and assumptions than is necessary for the next-of-kind plants. During plant life, the reassessments shall factor in real plant performance and testing data to potentially offset increased temperatures without design change. At the site-specific stage, should SSCs require design modifications (i.e. HVAC), there is a high level of confidence that they can be accommodated within the design.

21.7.1.1.4 Cliff Edge and Beyond Design Basis Assessment

Extreme ambient air temperature has been identified as a Category 2 BDB External Hazard, whereby a 10^{-5}/yr value, or lower frequency value has been derived.

The External Hazards US-UK Gap Analysis report [30] presents a preliminary assessment of the GDA Reference Design against the 10^{-5}/yr events derived for the present day extreme ambient air temperature values. These have been analysed by following the methodology outlined in Eurocode BS EN 1991-1-5 [83] and the associated UK National Annex [84]. 'Cliff-Edge' (10^{-5}/yr) events were not derived for the year 2100 scenario as the climate change projections cannot be currently sufficiently quantified by a hazard curve as there is insufficient data to derive an accurate BDBE factor. Doing so would result in additional conservatism applied to the already conservative year 2100 climate change adjusted values.

21.7.1.2 Humidity

21.7.1.2.1 Hazard Characterisation

Extreme humidity is typically grouped with extreme ambient air temperature as an External Hazard in terms of characterising the impact of the hazard on safety related SSCs. Humidity, along with extreme ambient air temperatures and enthalpy, is a key design parameter in the design of HVAC systems[13], which may be providing cooling to safety related SSCs. Extreme humidity can also adversely impact the functionality of I&C equipment.

21.7.1.2.2 Derivation of GB GSE Parameter

The GB GSE Parameters for maximum, minimum, and average relative humidity are presented in Table 10 below. These values are based on Met Office Annual Average Relative Humidity Map for the temporal period of 1991-2020 [85]. Further explanation of the derivation can be found in the GSER [3].

Table 10: GB GSE Parameters for Humidity

Parameter	GB GSE Parameter
Maximum Relative Humidity	100%
Minimum Relative Humidity	12%
Average Relative Humidity	84%

21.7.1.2.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design an environmental envelope of ambient conditions has been specified following the guidance of EPRI Technical Report Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document [49], relative humidity has been considered in combination with the ambient temperature values defined for the GDA Reference Design.

The GDA Reference Design does not currently consider a 100% maximum relative humidity event and a 12% minimum relative humidity event. However, once the assessment is undertaken, there is confidence that these events can be accommodated within the design,

13 The term HVAC includes heating which for the SMR-300 is fulfilled by Air Handling Units (AHU). For extreme low ambient air temperatures, should heating be required, this will be fulfilled by the AHUs.

with further assessment to be undertaken at the site-specific stage to incorporate any minor design adjustments. This is discussed further in the External Hazards US-UK Gap Analysis report [30].

21.7.1.2.4 Beyond Design Basis Assessment

Humidity has been identified as a Category 3 MCE BDB event within the BDB Strategy for External Hazards report [28], whereby humidity levels cannot exceed 100% relative humidity. A MCE of 100% relative humidity has been defined in the development of the GB GSE. At this stage of the GDA, further preliminary assessment of the GDA Reference Design against this MCE has not been conducted. For the low humidity GB GSE value of 12%, this shall also be assessed beyond step 2, however, there are no significant concerns regarding this value.

Thus, at the site-specific stage the hazard shall be evaluated for potential impacts on the generic SMR-300. In addition, it is judged that humidity has no effect upon the SMR-300's ability to use its passive safety systems. This is due to humidity having an insignificant impact upon the ability for decay heat to be rejected from the reactor to the Annular Reservoir (AR) via the Containment Structure (CS), and from the AR to the atmosphere.

21.7.1.3 Extreme Cooling Water Temperature

21.7.1.3.1 Hazard Characterisation

Extreme cooling water temperature is typically a key design parameter for cooling systems which rely on a large body of water for cooling.

The hazard is typically highly correlated with the External Hazard of extreme ambient air temperature. However, this correlated relationship is complex and largely site-specific as it depends on the body of water subject to the extreme ambient air temperatures. For example, closed bodies of water such as lakes and reservoirs, may be more susceptible to warming and cooling than the sea because of the shallower depth of water and limited volume.

21.7.1.3.2 Derivation of GB GSE Parameters

A review of sea water temperatures has been used to derive the GB GSE Parameters for extreme cooling water temperature [86]. It is acknowledged that these temperatures may not be representative of a prospective site which intends to utilise a closed body of water or lake for cooling purposes.

The present-day maximum sea water temperature adopted for the GB GSE is 28°C. Maximum sea water temperatures are projected to increase with climate change through the lifecycle of the generic SMR-300. The 50^{th} percentile of the RCP8.5 scenario projects an increase in temperature of approximately 4.3°C [81]. Applying this factor to the present-day maximum sea water temperature results in a temperature of 32.3°C. A minimum water temperature of -2.0°C has been adopted for GB GSE [86].

The GB GSE Parameters for maximum, minimum, and average sea water temperatures are presented in Table 11.

Table 11: GB GSE Parameters for Extreme Cooling Water Temperature

Parameter	GB GSE Parameter
Maximum Sea Water Temperature (Present Day Value)	28°C
Maximum Sea Water Temperature (Climate Change Adjusted Value)	32.3°C
Minimum Sea Water Temperature	-2°C
Average Sea Water Temperature	13°C

21.7.1.3.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design, for the licensing activities at the Palisades site, systems utilising Lake Michigan as a source of water have been designed for the maximum postulated elevated temperature of Lake Michigan, which has been derived from analysis published by the National Oceanic and Atmospheric Administration (NOAA) Lake Michigan Average Great Lake Surface Environmental Analysis [57]. Within the current generic SMR-300 design, active equipment within the nuclear island is cooled by cooling towers with the non-classified[14] turbine cooling being provided by lake or sea water cooling, depending upon the prospective site. During DB events that initiate the PCC systems, there is no requirement for external cooling water to be supplied to the reactor to support safe shutdown. Consequently, extreme cooling water temperatures only impact the operational limits and efficiency of the plant during normal operations.

Further evaluation of the extreme cooling water temperature hazard for the GDA Reference Design against the GB GSE has been undertaken in the External Hazards US-UK Gap Analysis report [30]. For maximum cooling water temperature, there is confidence that the GDA Reference Design can accommodate the GB GSE Parameters. For minimum cooling water temperature, no minimum temperature value is specified for the GDA Reference design. The intake system for the plant will be inherently site specific, although the GDA Reference Design utilises water from Lake Michigan, the RP has confidence that the existing design can accommodate, or be adapted, to suit a seawater site if required, following site-specific assessment. This is discussed further in the External Hazards US-UK Gap Analysis report [30].

21.7.1.3.4 Beyond Design Basis Assessment

Extreme cooling water temperature has been divided into high and low temperature within the BDB Strategy for External Hazards report [28] to enable a more detailed assessment to be undertaken. The following BDB categories have been assigned:

- High Extreme Cooling Water Temperature: Category 1.
- Low Extreme Cooling Water Temperature: Category 3.

High Extreme Cooling Water Temperature

[14] Formal classification of the turbine cooling shall be subject to DBAA outside the scope of GDA Step 2.

High extreme cooling temperature has been identified as a Category 1 BDB External Hazard as the Service Water System (SWS) design water intake temperatures are in the same order of magnitude of the climate change values for the GB GSE maximum cooling water temperature. Further assessment is not required as the margin for the GDA Reference Design Parameter is considered sufficiently bounding of the present-day GB GSE Parameter to preclude the possibility of 'Cliff-Edge' failures due to extreme high cooling water temperatures. This will be further confirmed by site-specific assessment of the generic SMR-300 against the extreme cooling water temperatures.

Low Extreme Cooling Water Temperature

Low extreme cooling water temperature has been identified as a MCE, as water temperature cannot fall below the freezing point, consequently no further 'Cliff-Edge' evaluation of low extreme cooling water temperature is required beyond the further evaluation outlined within sub-chapter 0.

21.7.1.4 Extreme Wind

21.7.1.4.1 Hazard Characterisation

Extreme wind may cause damage to the plant by the effect of wind loads on external SSCs. In addition, the associated pressure can impact upon HVAC systems as well such that any required cascade of pressure can be maintained.

21.7.1.4.2 Derivation of GB GSE Parameter

A maximum 10-minute mean extreme wind speed of 36.5 m/s has been derived for the GB GSE in accordance with the method outlined in Eurocode BS EN 1991-1-4 [87] and the associated UK National Annex [88]. The GB GSE Parameters for extreme wind are presented in Table 12 below. Further explanation on the derivation of the extreme wind GB GSE Parameters is provided in the GSER [3].

21.7.1.4.3 Preliminary Evaluation of GDA Reference Design

The extreme wind speed for the GDA Reference Design was derived to ASCE/SEI 7-16 [52] and envelopes the continental US. All structures and systems with exterior elements important to safety consider extreme wind loading in the design [19]. A comparison of the extreme wind parameters is provided in Table 12 to demonstrate that the GDA Reference Design parameter bounds the GB GSE Parameter with significant margin present.

Table 12: Comparison of Extreme Wind Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter[15]
10-minute mean	36.4 m/s	[REDACTED]
3-second gust	52.3 m/s	[REDACTED]

[15] ASCE/SEI 7-16 [52] adopts a three second gust measurement of wind speed whereas Eurocode BS EN 1991-1-4 [87] and the associated UK National Annex [88] adopts a ten-minute mean wind speed. Figure C26.5-1 of ASCE/SEI 7-16 provides a method to convert between the two measurements.

21.7.1.4.4 Beyond Design Basis Assessment

Extreme wind has been identified as a Category 2 BDB External Hazard, whereby a 10^{-5}/yr value, or lower frequency value has been derived. The following 'Cliff-Edge' Parameters have been derived for extreme wind within the BDB Strategy for External Hazards report [28]:

- 10-minute mean: 39.2 m/s.
- 3-second gust: 56.4 m/s.

The margin of the GDA Reference Design Parameter to both the GB GSE and GB GSE 'Cliff-Edge' Parameters provides confidence that the GDA Reference Design has capacity to account for any potential increases in wind speed. This margin is considered sufficient to preclude the possibility of 'Cliff-Edge' failures due to extreme wind.

21.7.1.5 Tornadic Wind

21.7.1.5.1 Hazard Characterisation

Tornadic wind concerns are due to the potential damage to external SSCs due to the direct impact of strong tornadic wind pressure and rotating wind. Internal SSCs can also be affected by pressure differences. This hazard differs from other straight wind hazards due to the special characteristics of duration, wind speed, and occurrence frequency.

Similar to extreme straight wind covered within sub-chapter 21.7.1.4, the primary protection against tornadoes is through the provision of SSCs that can withstand the required wind speeds and overpressures.

Tornado generated missiles are covered within sub-chapter 0.

21.7.1.5.2 Derivation of GB GSE Parameter

The design basis tornado for the GB GSE has been derived from US NRC Regulatory Guide 1.76 [42]. 'Region III' has been adopted for the GB GSE, which presents a design basis tornado equivalent to a T5 tornado on the International Tornado Intensity Scale. A tornado of this intensity is considered very conservative in the GB context.

The influence of climate change on tornado intensity and frequency is currently unknown. Holtec are confident that the design basis tornado assumed for the GB GSE is sufficiently conservative to account for any future projections.

The GB GSE Parameters for tornadic wind are presented in Table 13 below. Further explanation on the derivation of the tornadic wind GB GSE Parameters is provided in the GSER [3].

21.7.1.5.3 Preliminary Evaluation of GDA Reference Design

The design basis tornado for the GDA Reference Design has been derived from US NRC Regulatory Guide 1.76 [42]. 'Region I' has been adopted for the design basis tornado for the GDA Reference Design, which is the geographical region of the US with the most severe tornadoes. This is equivalent to a T8 tornado on the International Tornado Intensity Scale and therefore is conservatively bounding of the GB GSE. It is noted that hurricanes are also considered for the GDA Reference Design, and these bound the tornado wind speeds.

All structures and systems with exterior elements important to safety, consider tornadic wind loading in the design. Additionally, all structures and systems with exterior elements important to safety, consider hurricane wind loading in the design [19].

A comparison of the tornadic wind parameters is provided in Table 13 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE Parameters.

Table 13: Comparison of Tornadic Wind Parameters

Parameter	GB GSE Parameter (Region III)	GDA Reference Design Parameter (Region I)
Rotational Wind Speed	57 m/s	[REDACTED]
Maximum Wind Speed	72 m/s	[REDACTED]
Translational Speed	14 m/s	[REDACTED]
Radius of Maximum Rotation Speed	45.7 m	[REDACTED]
Atmospheric Pressure Drop	4.1 kPa	[REDACTED]
Rate of Pressure Drop	1.4 kPa/s	[REDACTED]

21.7.1.5.4 Beyond Design Basis Assessment

Tornadic wind has been identified as a Category 1 BDB External Hazard, as stated within the BDB Strategy for External Hazards report [28], such that the GDA Reference Design is sufficiently bounding of the GB GSE Parameter to preclude the possibility of ‘Cliff-Edge’ failures due to tornadic wind with no further BDB assessment required. This is because the GDA Reference Design utilises the most onerous classification (of the US NRC Regulatory Guide 1.76 [42]), Region I, versus the less severe ‘Region III’ adopted by the GB GSE.

21.7.1.6 Tornado Generated Missiles

21.7.1.6.1 Hazard Characterisation

The tornado generated missiles hazard is defined by the damage to the plant due to the impact of tornadic-wind-blown missiles. The primary protection against tornado-generated missiles, is through the design of structures to provide sufficient protection to SSCs important to safety. Within the GSER [3], hurricane generated missiles are grouped under tornado generated missiles, as hurricane generated missiles are bounding of tornado generated missiles within the US, comparison of the GB GSE values to both tornado and hurricane generated missiles has been undertaken for completeness.

21.7.1.6.2 Derivation of GB GSE Parameters

Tornado generated missiles for the GB GSE have been derived from US NRC Regulatory Guide 1.76 [42]. ‘Region III’ has been adopted for the GB GSE to align with the approach undertaken for tornadic wind.

21.7.1.6.3 Preliminary Evaluation of GDA Reference Design

Tornado generated missiles for the GDA Reference Design have been derived from US NRC Regulatory Guide 1.76 [42]. ‘Region I’ has been adopted for the GDA Reference Design to align with the approach undertaken for tornadic wind.

In addition to Tornado generated missiles, within the US, Hurricane generated missiles are also a threat. Hurricane generated missiles are significantly bounding of tornado generated missiles and have been included in Table 14 for completeness. Hurricane generated missiles for the GDA Reference Design have been derived from US NRC Regulatory Guide 1.221, Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants [41].

All structures and systems with exterior elements important to safety, are analysed and designed for the defined missiles hazards [19].

A comparison of the tornado generated missile parameters is provided in Table 14 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE Parameters.

Table 14: Comparison of Tornado Generated Missile Parameters

Parameter	Mass	GB GSE Parameter (Tornado: Region III)	GDA Reference Design Parameter (Tornado: Region I)	GDA Reference Design Parameter (Hurricane)
Schedule 40 Pipe: 0.168 m diameter x 4.58 m long	130 kg	24 m/s	[REDACTED]	[REDACTED]
Automobile: 4.5 m x 1.7 m x 1.5 m	1178 kg	24 m/s	[REDACTED]	[REDACTED]
Solid Steel Sphere: 2.54 cm diameter	0.0669 kg	6 m/s	[REDACTED]	[REDACTED]

21.7.1.6.4 Beyond Design Basis Assessment

As with tornadic wind, tornado generated missiles has been identified as a Category 1 BDB External Hazard, as stated within the BDB Strategy for External Hazards report [28], such that the GDA Reference Design is sufficiently bounding of the GB GSE Parameter to preclude the possibility of 'Cliff-Edge' failures due to tornadic wind with no further BDB assessment required. This is because the GDA Reference Design utilises the most onerous classification (of the US NRC Regulatory Guide 1.76 [42]), Region I, versus the less severe 'Region III' adopted by the GB GSE. In addition, the hurricane generated missiles are significantly more energetic than the tornado Region I missiles.

21.7.1.7 Icing

21.7.1.7.1 Hazard Characterisation

There are many types of ice to be considered in the assessment of NPPs such as frazil ice, rime ice, clear ice, and glaze ice.

Frazil ice is the formation of loose needle-shaped ice crystals within a turbulent body of water. The resulting slush has been attributed to several issues at NPPs, such as blocking the screening system within the water intake. Frazil ice has been screened as site-specific in the GSER [3] as the formation of frazil ice is dependent on the salinity of the water source and any solution developed should be tailored to the site.

The American Society of Civil Engineers (ASCE) journal publication, "Prevention of Water Intake Blockage by Ice during Supercooling Events" [110] is a state-of-the-art review on preventing water intake blockage by ice. Typical solutions include:

- Avoidance (i.e., locating the intake such that it is never exposed to a supercooling event).
- Prevention (i.e., stopping supercooled water entering the intakes).
- Mitigation (i.e., modifying the intake such that the degree of blockage is minimised).
- Remediation (i.e., removing blockage once it has formed).

Rime, clear and glaze ice all form on surfaces and need to be accounted for in the design of lightweight external structures. The formation of ice on the surface of structures applies an additional load to the structure whilst also increasing the total applied wind load because of the increased surface area.

21.7.1.7.2 Derivation of GB GSE Parameters

Eurocode BS EN 1993-3-1 [89] and the respective UK National Annex [84] have been used to derive the GB GSE icing parameters. Further explanation on the derivation is provided in the GSER [3]. A summary of the GB GSE icing parameters is provided in Table 15.

Table 15: GB GSE Parameters for Icing

Parameter	GB GSE Parameter
Radial Ice Thickness, r_o (without wind)	117.1 mm (AFoE = 10^{-4})
Radial Ice Thickness, r_w (with wind)	25.7 mm (AFoE = 10^{-4})
Unit Weight of Ice (without wind)	5.0 kN/m^3
Unit Weight of Ice (unfavourable action with wind)*	9.0 kN/m^3
Unit Weight of Ice (favourable action with wind)**	5.0 kN/m^3

* An unfavourable action refers to the case where the unit weight of ice increases the resultant stress in a structural element.
** A favourable action refers to the case where the unit weight of the ice acts to reduce the resultant stress in a structural element.

21.7.1.7.3 Preliminary Evaluation of GDA Reference Design

In the US, ASCE 7-10, Minimum Design Loads for Buildings and Other Structures [111] is typically used in the design of ice-sensitive structures and covers the atmospheric ice loads caused by freezing rain, snow, and in-cloud icing. This code of practice is considered RGP and is aligned with the approach outlined in Eurocode BS EN 1993-3-1 [89].

As noted within the External Hazards US-UK Gap Analysis report [30], with respect to the icing hazard, a preliminary assessment of the GDA Reference Design has not been undertaken at this stage due to the maturity of the design. The RP has confidence that the SMR-300 will be capable of withstanding icing events due to the severity of historic ice storms within the US in comparison to the UK, however a review of the icing hazard and the design of all chimney, stack, and cooling tower structures shall be undertaken once the design has reached sufficient maturity. This is discussed further in the External Hazards US-UK Gap Analysis report [30].

21.7.1.7.4 Beyond Design Basis Assessment

Icing has been identified as a MCE within the BDB Strategy for External Hazards report [28], consequently, no further BDB assessment is required within the scope of GDA, beyond the further evaluation outlined within sub-chapter 21.7.1.7.3.

21.7.1.8 Snow

21.7.1.8.1 Hazard Characterisation

Extreme snow loading can lead to damage of safety related SSCs, particularly the roofs of structures, due to overloading and potential disruption of power delivery systems (e.g., due to the build-up of snow and ice pack on power lines). In addition to 'normal' snow, snow drift is an important consideration especially where one building abuts another. Snow drifts have the potential to apply greater snow loading than 'normal' snow and can result in the burying / clogging of SSCs, e.g., substations and HVAC intakes.

Where SSCs do not have sufficient capacity to withstand snow loading, or the formation of snow drift, there is a risk of collapse or blockage. Typically, SSCs are qualified to withstand the design basis snow loading plus additional margin to accommodate credible beyond design basis occurrences. Protection from snow drifting is typically site specific such that barriers / wind breaks can be installed away from SSCs in the orientation of the prevailing wind to prevent snow build up on key SSCs.

21.7.1.8.2 Derivation of GB GSE Parameter

An extreme snow load has been derived for the GB GSE in accordance with the methods outlined in Eurocode BS EN 1991-1-3 [91] and the respective UK National Annex [92].

The design basis ground snow load for the GB GSE has been determined as 1.50 kN/m^2. Further explanation of the derivation is provided in the GSER [3].

21.7.1.8.3 Preliminary Evaluation of GDA Reference Design

A design basis 'normal' snow load has been derived for the GDA Reference Design following the guidance provided in EPRI Technical Report, Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, [49].

An extreme snow load has been also derived for the GDA Reference Design [50]. This extreme snow load considers the combination of a 100-year snowpack and weight of probable maximum winter precipitation accumulation.

All structures for which by design snowpack cannot practically accumulate with concurrent rainfall, the normal snow load is applied for defining snow load in lieu of the extreme load [19].

A comparison of the snow parameters is provided in Table 16 to demonstrate that the GDA Reference Design parameter is bounding of the GB GSE Parameter. This margin also provides confidence that the GDA Reference Design has the capacity to account for any potential increases in UK snow load due to climate change which have not been accounted for within the derivation of the GB GSE Parameter.

Table 16: Comparison of Snow Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
Snow Loading	1.50 kN/m^2	[REDACTED]
Extreme Snow Loading	-	[REDACTED]

21.7.1.8.4 Beyond Design Basis Assessment

Snow has been identified as a Category 1 BDB External Hazard, as stated within the BDB Strategy for External Hazards report [28], such that the GDA Reference Design is sufficiently bounding of the GB GSE Parameter to preclude the possibility of 'Cliff-Edge' failures due to snow loading with no further BDB assessment required.

21.7.1.9 Lightning

21.7.1.9.1 Hazard Characterisation

The Met Office defines thunderstorms as a series of sudden electrical discharges resulting from atmospheric conditions [112] with frequency and intensity varying regionally across the UK.

Lightning can impact the plant directly, causing structural damage, impacting grid components, inducing EMI on plant equipment, or resulting in a LOOP through the production of EMI, or indirectly through fire started by lightning.

The typical protection measure for lighting strikes is a robust lighting protection system to arc primary strikes to the ground. For secondary strikes, surge protection and suitable grounding is the typical form of protection to prevent the overloading of electrical devices. Additionally, reinforced concrete structures can be designed to act as a faraday cage in the event of a lightning strike providing that the reinforcement is adequately connected and earthed.

21.7.1.9.2 Derivation of GB GSE Parameters

The lightning GB GSE Parameters are presented in Table 17. Further explanation on the derivation is provided in the GSER [3].

BS EN 62305-1 [93] proposes a peak lightning current of 200 kA. European Utility Requirement (EUR) guidance [69] also proposes a design basis lightning current of 200 kA for a first stroke and 50kA for a second stroke.

The CIGRE report [94] and Volume 9 of ETI [95] suggest a maximum credible peak current of 300 kA, this value bounds 99.99% of credible lightning peak currents. Thus, a value of 300 kA has been adopted for the GB GSE.

The UK committee (GEL/81 – protection against lightning) undertook a review of BS EN 62305-2 [97] and provided a UK interpretation of the standard in Annex NF of BS EN 62305-2:2012 [96]. Annex NF presents a global map of the number of thunderstorm days per year based on record information from the World Meteorological Organization for the year 1955. The data shows that the UK is positioned between the five thunderstorm days a year contour and the 20 thunderstorm days per year contour, with the South-East of England shown to experience approximately 15 thunderstorm days per year.

The Flash Density Map 2014 [97], provided as a supplement to [96] shows a maximum flash density of 1.4 flashes per km^2 per year for the UK. This value has been adopted for the GB GSE to conservatively bound all of the sites considered.

Table 17: GB GSE Parameters for Lightning

Lightning Parameter	GB GSE Parameter
Peak Lightning Current	300 kA
Thunderstorm Days	15 days
Mean Flash Frequency	1.40 flashes/km^2/year

21.7.1.9.3 Preliminary Evaluation of GDA Reference Design

In the GDA Reference Design, a ‘codes and standards’-based approach is adopted for the design of the Grounding and Lightning Protection systems (GLP) which are incorporated into the generic SMR-300 design to protect SSCs from potential lightning strikes, as per US NRC Regulatory Guide 1.204 [53].

At the site-specific stage, an assessment of the GDA Reference Design against the GSE peak lightning current shall be undertaken once the design of the GLP has reached sufficient maturity. There is confidence that the GLP can accommodate the GB GSE lightning parameters, and the RP is aware that the GLP will require sizing for local hazard magnitudes and accommodate local norms and standards. This is discussed further in the External Hazards US-UK Gap Analysis report [30].

21.7.1.9.4 Beyond Design Basis Assessment

Lightning has been identified as a MCE as stated within the BDB Strategy for External Hazards report [28], consequently, no further BDB assessment is required within the scope of GDA, beyond the further evaluation outlined within sub-chapter 0.

21.7.2 External Flooding and External Hazards

Argument 2.1.5.4-A2: For all identified sources of External Flooding and Hydrological capable of challenging fundamental safety functions there are suitably qualified safety measures to ensure the plant reaches a safe state for all External Hazards.

21.7.2.1 External Flooding

External Flooding is a site-specific External Hazard, and all types of associated flooding hazards will be assessed at the site-specific stage; no GB GSE Parameters are derived.

In the development of the GB GSE, it has been assumed that the ‘Generic Site’ is ‘dry’ when subjected to flood levels up to the design basis, as such the site operator will develop the site accordingly. The ‘Dry Site Concept’ defined in IAEA, No. SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations [113] and promoted in ONR and EA guidance document, Principles for Flood and Coastal Erosion Risk Management Revision 2 [114] is considered RGP, but it will be up to a future site operator to determine whether to pursue this or a hybrid solution including flood protection barriers.

At the site-specific stage, a detailed assessment will be required to understand the effect of all types of associated flooding hazards relevant to a specific prospective site. Further work has been proposed to outline the methodology and strategy for the consideration of beyond design basis flooding within the BDB report [28] and the following sub-chapter.

Groundwater ingress shall be further investigated at the site-specific stage, as the safety measures employed are dependent upon the site ground conditions. The performance against ingress shall then be part of the surveillance and maintenance regime through the lifecycle of the plant.

These design features selected at the site-specific stage can be combined with additional waterproofing measures to provide multiples lines of protection. The final solution may look to incorporate external/internal membranes, liner walls, cavity drains or a combination of these measures. The appropriate solution will be determined once the site-specific variables are known. For example, a solution involving an external membrane would only be feasible if there is access to the external face of the retaining wall structures. This may be possible if the ground conditions and space available on site permits a battered-back form of construction. However, for some sites it may not be practicable, and an internal membrane or drained cavity solution may be preferred/ required.

Irrespective of the above potential measures to be defined at the site-specific stage, the measures for preventing groundwater ingress shall be through the use of appropriately designed civil structures. For the SMR-300 there is confidence that the provisions for the protection of groundwater ingress for the below grade areas of the CES are suitable, as it is constructed of Concrete Filled Steel Structures (CFSS) which are suitably bonded to the base mat.

All construction joints shall incorporate water stops, and other below-grade Civil structures shall be fitted with water bars. All flood prevention measures shall be subject to shear stress assessment to ensure the suitability of the protection against groundwater ingress.

Similar measures will be provided for the RAB and IB.

21.7.2.1.1 Beyond Design Basis Assessment

External flooding has been identified as a Category 4 BDB External Hazard, as stated within the BDB Strategy for External Hazards report [28], whereby the hazard cannot be categorised by a hazard curve, either within the GDA, or at the site-specific stage. Assessment of such a hazard is undertaken via the assessment of the hazard and consequences, not the estimation of a hazard value.

For external flooding ‘Cliff-Edge’ analysis will consider what would happen if the site-specific design flood defences (unknown at this stage) are subject to flood above the design basis. This will include consideration of features such as site drainage capacity (both topographical and piped water drainage), the height of building door thresholds and the provision of watertight doors and other openings. The preliminary BDB assessment for external flooding [28] identified a number of existing safety measures that provides confidence that at the site-specific stage a BDB assessment will not result in any fundamental design changes. Such safety measures include, but are not limited to:

- ‘Slab’ / Basemat uplift.
- RAB external flood doors.

In addition to these safety measures, the BDB Strategy for External Hazards report [28] outlines the proposed site-specific external flooding assessment that shall be undertaken.

Within the scope of the PSR, the RP has confidence that at the site-specific stage the risks from external flooding shall not pose a fundamental risk to the generic SMR-300.

21.7.2.2 Extreme Rainfall

21.7.2.2.1 Hazard Characterisation

Extreme rainfall can be a hazard to safety related SSCs and their safety functions if the SSCs cannot either withstand the force from standing water or withstand the rainfall (e.g., failure of electrical equipment exposed to rainfall). Typically, mitigation measures for such systems challenged by extreme rainfall include the provision of adequate drainage to prevent the build-up of water, sufficient design load margins for structural SSCs, and suitable Ingress Protection Ratings for any exposed electrical equipment that cannot be housed inside.

21.7.2.2.2 Derivation of GB GSE Parameters

Extreme rainfall events for the GB GSE have been derived using the Flood Estimation Handbook Depth-Duration-Frequency (FEH DDF) models [98], [99] for a 1 in 10,000 year event with an applied factor from the UKCP18 projections to account for reasonably foreseeable climate change over the lifetime of the facility.

The GB GSE Parameters for extreme rainfall are presented in Table 18 below. Further explanation on the derivation of the extreme rainfall GB GSE Parameters is provided in the GSER [3].

21.7.2.2.3 Preliminary Evaluation of GDA Reference Design

Extreme rainfall events applied in the GDA Reference Design have been derived in accordance with US RGP. A five-minute rainfall event and a one-hour rainfall event have been derived in accordance with EPRI Technical Report Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document [49]. A six-hour rainfall event has been derived from the Final Safety Analysis Report for the North Anna 3 Combined Licence Application [50]. A 24-hour rainfall event has been derived from NOAA National Weather Service Hydrometeorological Design Studies Centre [56].

A comparison of the extreme rainfall parameters is provided in Table 18 to demonstrate that the GDA Reference Design parameters are clearly bounding of the GB GSE Parameters.

Table 18: Comparison of Extreme Rainfall Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
5 minute	51 mm	[REDACTED]
1 hour	217 mm	[REDACTED]
6 hour	293 mm	[REDACTED]
24 hour	392 mm	[REDACTED]

21.7.2.2.4 Beyond Design Basis Assessment

Extreme rainfall has been identified as a Category 2 BDB External Hazard, whereby a 10^{-5}/yr value, or lower frequency value has been derived. The following ‘Cliff-Edge’ Parameters have been derived for extreme rainfall within the BDB Strategy for External Hazards report [28] :

- 1-hour: 288 mm.
- 24-hour: 516 mm.
- 48-hour: 553 mm.

The margin of the GDA Reference Design Parameter to both the GB GSE and GB GSE Cliff-Edge margin provides confidence that the GDA Reference Design has capacity to account for any potential increases in extreme rainfall. This margin is considered sufficient to preclude the possibility of 'Cliff-Edge' failures due to extreme rainfall.

21.7.3 Seismic

Argument 2.1.5.4-A3: For all identified sources of Seismic Events capable of challenging fundamental safety functions there are suitable safety measures to ensure the plant reaches a safe state for all External Hazards.

21.7.3.1 Hazard Characterisation

Seismic events are considered site-specific in nature with probabilistic seismic hazard assessments typically undertaken to characterise the hazard for a specific site. At GDA, to the extent possible, a generic seismic hazard can be defined on a "best-estimate" basis utilising regional hazard maps and widely adopted Seismic Design Response Spectra (SDRS).

There are several External Hazards associated with seismic activity, such as liquefaction and capable faulting, that can only be assessed at the site-specific stage and therefore are screened out of the currant scope. Further information on the screening process can be found in sub-chapter 21.5.1.1 of this PSR chapter and in Appendix A of the GSER [3].

The External Hazard of seismic induced vibration presents a significant challenge to nuclear safety because all SSCs may be simultaneously subjected to dynamic loading. A seismic classification system has been implemented across the nuclear power plant to define the performance requirements on SSCs when subjected to a seismic event. The substantiation of SSCs for seismic events shall be undertaken as part of the verification and validation process by their respective engineering disciplines, depending upon the SSC.

A Seismic Equipment List (SEL) is to be developed [115] that identifies the seismically qualified equipment and the representative fragilities.

21.7.3.2 Derivation of GB GSE Parameters

Design basis earthquakes are often defined in terms of a design response spectrum anchored to a Peak Ground Acceleration (PGA) value. The PGA is a function of the geological characteristics of the ground present and the distance of the site from the epicentre of the earthquake.

A representative seismic design response spectrum applicable to a GB site and adopted by other generic designs subjected to the GDA process is the EUR spectra [69]. These spectra have been used to define the seismic hazard for the GB GSE with the EUR Hard spectrum anchored at a PGA of 0.275 g, and the Medium and Soft spectra anchored at a PGA of 0.25 g. Further information on the derivation of the PGA values and the justification behind adopting the EUR spectra is provided in the GSER [3].

Paragraph 254 of the ONR SAPs [24] states that an Operating Basis Earthquake (OBE) should be defined where no SSC should be impaired by ground motions at the OBE level.

The EUR code [69] states that the Designer shall provide information on the maximum level of earthquake under which no specific inspection would be required to continue with operation, equivalent to the OBE defined above. The EUR code [69] suggests typical values of horizontal PGA in the range of 0.05 g to 0.10 g. Thus, an OBE of 0.10 g has conservatively been adopted for the GB GSE.

21.7.3.3 Preliminary Evaluation of GDA Reference Design

The SDRS used for the GDA Reference Design is based on a modified version of the NRC Reg. Guide 1.60 spectra [48] anchored at a PGA of [REDACTED] g in each orthogonal direction. Notably, the SDRS are anchored below grade at the base of the Containment Enclosure Structure (CES).

A PGA of [REDACTED] g can be considered very conservative for the UK resulting in a conservative seismic design in the context of the GB GSE. The GDA Reference Design defines an OBE of [REDACTED] g, which is 1/3 of the design basis earthquake. Further information on the seismic analysis methodology is provided in Part B Chapter 20 [15].

A comparison of the seismic parameters is provided in Table 19 to demonstrate that the GDA Reference Design parameters are bounding of the GB GSE Parameters.

Table 19: Comparison of Seismic Parameters

Parameter	GB GSE Parameter	GDA Reference Design Parameter
Design Basis Earthquake, PGA	0.275 g (EUR Hard)	[REDACTED]
	0.25 g (EUR Soft, Medium)	
Operating Basis Earthquake, PGA	0.1 g	[REDACTED]

Figure 4 further demonstrates that the SDRS adopted in the GDA Reference Design is suitably bounding of the EUR spectra [69] anchored at a PGA representative of the sites considered within the GB GSE. Further discussion is provided in the GSER [3].

At the site-specific stage, a seismic Probablistic Safety Assessment (PSA) shall be carried out in line with the methodology outlined within the Seismic PSA Methodology [115].

[REDACTED]

Figure 4: Comparison of GDA Reference Design Horizontal SDRS Against EUR Horizontal Spectra (5% Damping)

21.7.3.3.1 Beyond Design Basis Assessment

The Seismic hazard has been identified as a Category 4 BDB External Hazard, as stated within the BDB Strategy for External Hazards report [28], whereby the hazard cannot be categorised by a hazard curve, either within the GDA, or at the site-specific stage. Assessment of such a hazard is undertaken via the assessment of the hazard and consequences, not the estimation of a hazard value.

For the seismic hazard, the margins present in the GDA Reference Design both in terms of SDRS [REDACTED] and Seismic Margin Assessment (SMA) [REDACTED] compared to the GB GSE (0.275 g EUR Hard) gives confidence that there is sufficient margin to preclude the possibility of 'Cliff-Edge' effects for the seismic hazard in the generic SMR-300 design.

In addition to this, comparison of previous GDA approaches to seismic BDB assessments have been undertaken, where they have assumed a margin above the DBE. Both the HPR1000 and the ABWR assumed a 50% margin over the DBE for seismic BDBE. Taking 150% of the DBE as one that has previously been considered reasonable, this is still significantly less than the SMA value of [REDACTED] g used for the US NRC compliant SMR-300. Again, this provides confidence that the GDA Reference Design is suitably bounding of the GB GSE values to prevent 'Cliff-Edge' effects, however, this shall be confirmed at the site-specific stage.

21.7.4 Human Induced External Hazards

Argument 2.1.5.4-A4: For all identified sources of Human-Induced External Hazards capable of challenging fundamental safety functions, there are suitably qualified safety measures to ensure the plant reaches a safe state for all External Hazards.

21.7.4.1 Aircraft Impact

21.7.4.1.1 Hazard Characterisation

Aircraft impact is a human induced External Hazard to be considered in the safety assessment of any NPP. This safety assessment considers the damage made to the plant including dynamic impact loads applied to structures and any consequential effects such as aircraft impact induced vibrations and fire.

There are two categories of aircraft impact: accidental and malicious. Accidental aircraft impact has been screened as a site-specific External Hazard. At the site-specific stage it should be determined whether the accidental aircraft impact hazard has a total initiating frequency that is demonstrably below once in 10 million years. A method for determining the total initiating frequency of an accidental aircraft impact for a range of aircraft types is provided in the GSER [3] with provisional calculations undertaken within the Aircraft Impact Safety Case Strategy [32].

Malicious aircraft impact (referred to as “malevolent” in the US) is not within the scope of this External Hazards assessment. For the assessment of malicious aircraft, the design information to be used by the designers to characterise the malicious aircraft impact hazard, including maximum take-off weight, impact velocity, and angle of impact, is provided by the US and UK government/regulator and is security classified.

The UK threat definition for malicious aircraft impact is defined by the ONR. The ONR has issued an expectation letter which provides the threat definition and outlines the regulatory expectations for the consideration of malicious aircraft impact on a UK nuclear site. Within the scope of GDA Step 2, malicious aircraft impact is outside the scope of this PSR chapter, and no further assessment is undertaken in this report. Beyond GDA Step 2, a comparison to the GDA Reference Design and the ONR expectations for malicious aircraft impacts shall be undertaken.

21.7.4.1.2 Derivation of GB GSE Parameters

No GB GSE Parameter has been derived for accidental aircraft impact due to the site-specific nature of the hazard. It is also expected that the malicious case will likely govern the design for aircraft impact at the site-specific stage.

21.7.4.1.3 Preliminary Evaluation of GDA Reference Design

Additional work has been undertaken within GDA Step 2 to outline the aircraft impact safety case strategy for the generic SMR-300. The Aircraft Impact Safety Case Strategy [32] undertook preliminary frequency calculations based upon the site plot plan and concluded the accidental aircraft frequencies were within the BDB frequency region, consequently, accidental aircraft impacts shall be assessed as such. The crash frequency shall be reassessed at the site-specific stage.

The GDA Reference Design considers aircraft impact in accordance with US NRC guidance and 10 CFR 50.150(a) [58], which states that any new reactor designed after July 13, 2009, requires a design-specific assessment of the effects on the facility from the beyond-design-basis impact of a large, commercial aircraft used for long-distance flights in the United States.

To satisfy the requirements of 10 CFR 50.150(a) [58] an aircraft impact safety assessment is performed in accordance with the following standards:

- Realistic analyses per NEI 07-13, Methodology for Performing Aircraft Impact Assessments for New Plant Designs [59].
- US NRC Regulatory Guidance 1.217, Guidance for the Assessment of Beyond Design Basis Aircraft Impacts [47].

As noted within the Aircraft Impact Safety Case Strategy [32], the following general plant acceptance criteria apply for a BDB aircraft impact for the generic SMR-300:

a. The containment shall remain intact.
b. Spent fuel pool integrity is maintained.
c. The reactor core shall remain coolable.
d. Spent fuel pool cooling is maintained.

It can be seen that the above acceptance criteria are more onerous than the traditional criteria specified in NEI 07-13 [59], where the designer is given the option of demonstrating that the containment remains intact or that the reactor core remains cooled; and that spent fuel pool cooling is maintained, or that spent fuel pool integrity is maintained.

The generic SMR-300 safety case strategy is to ensure that all plant acceptance criteria (a) to (d) are simultaneously demonstrated with the aim of producing a highly robust and safe design against the External Hazard of aircraft impact.

Further details on the SSCs required to fulfil safety functions in support of the above acceptance criteria and the protection strategies for each are outlined within the Aircraft Impact Safety Case Strategy [32]. Within the scope of GDA Step 2, due to the ongoing design work within the US, a design challenge has been raised for accidental aircraft impacts. This design challenge is ongoing and will not be completed within the scope of Step 2, consequently, the following commitment has been raised to capture this:

C_Exte_066: The Design Challenge Paper 'Design Challenge – Aircraft Impact' outlines how the SMR-300 US design against aircraft impact differs from UK expectations. This topic is also related to SMR-300 Security assessment for malicious aircraft impact.

[REDACTED]

Further discussion on this commitment is outlined within sub-chapter 21.8.2.4.

21.7.4.2 Malicious Activity

The threat on UK nuclear facilities arising from malicious activities is defined by the UK government in the UK Design Basis Threat (UK DBT) which is a highly classified document. The UK DBT will be used for site specific security studies but for the GDA an alternative DBT based on publicly available information is used instead as discussed in the SMR-300 Security by Design report [116]. The alternative DBT used for the GDA is reported in the Threat Interpretation Report [117].

21.7.5 Electromagnetic Interference and Space Weather

Argument 2.1.5.4-A5: For all identified sources of External EMI and Space Weather capable of challenging fundamental safety functions, there are suitably qualified safety measures to ensure the plant reaches a safe state for all External Hazards.

21.7.5.1 Electromagnetic Interference

21.7.5.1.1 Hazard Characterisation

Electromagnetic Interference is defined in ONR TAG 13 Annex 5, Other External Hazards [118] as "a disturbance that affects an electrical circuit due to electromagnetic radiation emitted from an external source". This disturbance has the potential to interrupt, obstruct or limit the performance of safety related I&C, and electrical equipment.

EMI can be a result of a variety of natural external sources including lightning strikes, electrical storms, and extra-terrestrial events such as solar flares. Other external sources of EMI include human-induced sources such as communication systems and electrical circuits.

EMI sources that originate from within the site are considered as Internal Hazards, which are the subject of Part B Chapter 22 [10].

21.7.5.1.2 Derivation of GB GSE Parameter

EMI, arising from sources external to the site and its processes, has been screened as a site-specific hazard in the GSER [3]. At the site-specific stage, all local sources of EMI should be identified and characterised.

The hazard is still within the scope of GDA but at this stage no DBE has been derived to establish a GB GSE Parameter. A design basis peak lightning current has been defined for the GB GSE with the derivation presented in sub-chapter 21.7.1.8.4.

21.7.5.1.3 Preliminary Evaluation of GDA Reference Design

The GDA Reference Design follows the guidance provided in US NRC Regulatory Guide 1.180, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems [54]. This is an established code of practice used in the design of NPPs in the US and provides guidance for evaluating EMI in I&C systems. This includes guidance on testing procedures to determine whether EMI presents a significant hazard to the plant.

21.7.5.2 Space Weather

21.7.5.2.1 Hazard Characterisation

Space weather is a collective term to describe the effects at or close to the Earth's surface of variations in the sun, solar wind, magnetosphere, ionosphere, and upper atmosphere [119]. There are a variety of associated External Hazards that need to be considered within the design of NPPs.

Large Geomagnetically Induced Currents (GICs) can be produced from solar flares and Coronal Mass Ejections (CMEs). Solar flares are defined as the sudden release of electromagnetic radiation from the Sun. A CME is the ejection of magnetized plasma from the sun, which can drive geomagnetic storms if their magnetic orientation opposes the geomagnetic field. GICs can lead to transformer damage, voltage instability and harmonics triggering protective relays, which could all result in a LOOP event. Infrastructure typically affected by GIC events includes electrical power transmission systems, pipelines, and railways [118].

GIC is a site-specific hazard and is related to the UK power network topology, the geomagnetic latitude of the site, the ground conductivity profile and the proximity to the coast.

Solar Energetic Particle (SEP) events consist of the ejection of protons, electrons, and ions from the Sun. SEPs can cause a Ground Level Enhancement event which can disrupt the performance of I&C and electrical equipment.

21.7.5.2.2 Derivation of GB GSE Parameter

Space weather has been screened as a criterion 5a within the GSER. The hazard is still within the scope of the GDA, but no DBE has been defined for the GB GSE. At the site-specific stage, a detailed hazard assessment will be undertaken alongside a review with the National Grid to ensure the plant design is up to date with the latest RGP.

21.7.5.2.3 Preliminary Evaluation of GDA Reference Design

At Revision 1, a preliminary evaluation of the space weather hazard for the GDA Reference Design has not been undertaken due to the maturity of the PSR and available design documentation. Although no analysis has been undertaken within GDA Step 2, the following high-level methodology documents have been produced which outline future work that will consider the effects of space weather and its associated consequences, these are:

- Electrical Calculation Methodology [120]:
    - Lightning Protection Analysis.
    - Electromagnetic Compatibility Analysis.
    - Geomagnetic Induced Current Analysis.
    - Grounding Analysis.
- Grid Compliance Strategy [121]:
    - Identification of SMR-300 electrical requirements.
    - Identify critical areas that are driven by grid characteristics that necessitate the need for different SSC, analysis, and validation.

21.7.6 CAE Summary

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

The maturity of this claim will develop beyond GDA Step 2 when formal hazard identification and assessments are undertaken alongside the fault studies topic area. The PFS and ultimately the Fault Schedule to be produced at the site-specific stage shall act as the vehicle to capture all of the credible External Hazards, along with their fault progressions, to ensure that sufficient safety measures and lines of protection are in place. Substantiation and validation of these safety measures will be provided by their corresponding disciplines, e.g., Civil Engineering, Mechanical Engineering etc.

At this stage, the application of the US NRC guidance and US-based RGP provides confidence that safety measures in conjunction with operator actions, enable the plant to reach a safe state. The preliminary evaluation of each External Hazard has demonstrated that in many cases significant margin is present between the GDA Reference Design, and the requirements of a generic site in GB bounded by the GB GSE. Further work is planned to address External Hazards where the preliminary evaluation has identified a difference in hazard characterisation and / or design basis magnitude between the GDA Reference Design and the GB GSE.

21.8 CHAPTER SUMMARY AND CONTRIBUTION TO ALARP

This sub-chapter provides an overall summary and conclusion of the External Hazards Chapter and how this chapter contributes to the overall demonstration of ALARP for the generic SMR-300. PSR Part A Chapter 5 Summary of ALARP [122] 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.
    - Evaluation of Risk.
  - Risk Reduction Options.
  - GDA Commitments and Forward Actions.
- Conclusion.

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

21.8.1 Technical Summary

PSR Part B Chapter 21, Revision 1 aims to provide confidence that the GDA Reference Design is suitably designed for the GB GSE parameters such that the in-scope SSCs with External Hazard related safety functions will meet the high-level claims of the SSEC and that the SSCs can be substantiated at Pre-Construction Safety Report (PCSR) stage. This is to be demonstrated through the following claim:

Claim 2.1.5: Risks from External Hazards and their combinations have been demonstrated to be tolerable and As Low As Reasonably Practicable (ALARP).

A key requirement of the SMR-300 is to protect the reactor and its support systems from all credible identified External Hazards, including their combinations, and to provide containment and shielding to protect people and the environment. Substantiation and validation of these safety measures will be provided by their corresponding disciplines, e.g., Civil Engineering, Mechanical Engineering etc., beyond GDA.

A comprehensive hazard identification and screening methodology has been undertaken in accordance with RGP to identify credible External Hazards that are relevant to the deployment of the generic SMR-300. External Hazards have been identified for a generic site in GB that could affect nuclear safety and are considered on a generic basis. The identified External Hazards have then been characterised following appropriate codes and standards, taking cognisance of RGP and OPEX, to establish the GB GSE Parameters.

All the identified and screened External Hazards have been treated as initiating events in the fault studies analysis and where sufficient design detail is available, suitable and sufficient safety measures have been identified for each hazard. This exercise has been undertaken in conjunction with the development of Part B Chapter 14 [7], and the production of the PFS [108].

At Revision 1 of the PSR, where possible, a preliminary evaluation of the GDA Reference Design has been undertaken for each of the identified External Hazards. This preliminary evaluation has demonstrated that for many of the identified External Hazards there is significant margin present between the GDA Reference Design parameters and the GB GSE Parameters providing confidence in the robustness of the generic SMR-300 in the context of a UK deployment. This evaluation has also identified hazards which require further investigation at the site-specific stage.

For Revision 1 it is deemed that the maturity of the safety justification presented in this chapter (Part B Chapter 21) is appropriate for a PSR. The comprehensive hazard identification process and the preliminary evaluation of the GDA Reference Design provide confidence that Claim 2.1.5, will be substantiated in future safety submissions and risks evaluated as tolerable and ALARP.

21.8.2 ALARP Summary

21.8.2.1 Demonstration of RGP

The approach to External Hazards inherent within the generic SMR-300 design complies with RGP and NRC requirements applicable in the US. The design adopts nuclear-specific codes and standards endorsed by the US NRC and internationally recognised bodies such as the IAEA. The codes, standards and international regulatory guidance applied to identify and characterise External Hazards in the GDA Reference Design are presented in sub-chapter 21.4.

The GB GSE has been established in accordance with RGP and international regulatory guidance. The hazard identification process undertaken in the GSER [3] consisted of a comprehensive literature review of UK and International Regulatory Guidance documents, RGP, previous GDA submissions and previous work undertaken by Holtec International to define a “Universe of External Hazards”, which consisted of an extensive unscreened list of External Hazards. This included guidance from the ONR [17], [24], IAEA [60], WENRA [61], [62], SKI [63], ASAMPSA [64], the Organisation for Economic Co-operation and Development (OECD) [65], [66] and the US NRC [67]. This extensive list of External Hazards has then been screened applying a criteria developed in accordance with RGP from the ONR [17], [24] and the IAEA [68].

21.8.2.2 Evaluation of Risk and Demonstration Against Risk Targets

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

- By undertaking proportionate safety assessments in line with Target 4 of the ONR SAPs [24], whereby the level of assessment correlates to the frequency and unmitigated consequences of the hazard. Figure 2 of TAG-13 [17] provides a visual representation of Target 4 of the SAPs.
- By ensuring the cumulative risk from the identified External 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, External Hazard fault progressions shall be bounded by plant faults and utilise the associated risk values from these progressions.
    - The External Hazards PSAs (currently seismic, high wind and external flooding are envisaged) will demonstrate that the risks from these three key External Hazards are below the required targets 4-9 and are ALARP. These assessments are included in the commitment C_Faul_103, as described in Part B Chapter 14 Design Basis Analysis [7].
- 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 (BSOs) are considered broadly acceptable; however, the RP is still required to identify further risk reduction measures in line with the ALARP approach. Risks between the BSOs and Basic Safety Levels (BSLs) require a consideration of risk reduction options.

For External Hazards the evaluation of the normal operations and accident risks against Targets 1-9 has not been provided at this stage of design, however, this information will, when developed, be presented in the following chapters:

- Part B Chapter 10 Radiological Protection [123] for normal operations.
- Part B Chapter 14 Design Basis Analysis [7], Part B Chapter 15 BDBA, Severe Accidents Analysis and Emergency Preparedness [8] and Part B Chapter 16 Probabilistic Safety Assessment [9] for accident conditions.

21.8.2.3 Options Considered to Reduce Risk

A single design challenge has been raised in relation to the External Hazards topic area. In line with the Design Adaptation Committee (DAC) process, once raised, design challenges are required to progress through a number of ‘gates’ prior to acceptance. Within the scope of GDA the External Hazards design challenge has yet to complete the DAC process and is 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 [20]. Part A Chapter 5 [122] considers the holistic risk-reduction process for the generic SMR-300.

The design challenges relating to External Hazards for the aircraft impacts, C-Exte-066, has not yet completed the DAC process, however, a commitment has been raised to capture this post Step 2, further information on this commitment is outlined in the next section.

21.8.2.4 GDA Commitments

At Revision 1, a single GDA commitments have been identified for Part B Chapter 21 to capture the aircraft impact design challenge:

- **C_Exte_066** – The Design Challenge Paper 'Design Challenge – Aircraft Impact' outlines how the SMR-300 US design against aircraft impact differs from UK expectations. This topic is also related to SMR-300 Security assessment for malicious aircraft impact.
  [REDACTED]. Target for Resolution – Issue of Pre-Construction SSEC.

21.8.3 Conclusion

The conclusion of Part B Chapter 21 is that:

- The chapter claims identified have been met to a maturity aligned with a PSR at this stage of GDA.
- The approach to External Hazards inherent to the generic SMR-300 design complies with RGP and US NRC requirements applicable in the US.
- All credible External Hazards that can affect nuclear safety, are relevant to the deployment of the generic SMR-300 on a generic site in the GB and can be considered on a generic basis, have been identified and characterised in accordance with RGP.
- An appropriate methodology is proposed for the identification, screening, and categorisation of hazard combinations, to a level of maturity aligned with a PSR.
- External Hazards have been assessed within the PFS to a level appropriate for a PSR. This PFS identifies safety functions and safety measures which are provisionally categorised and classified to provide suitable and sufficient lines of protection.
- All in-scope SSCs identified in Appendix B of Part A Chapter 2 [4] are considered as SSCs with External Hazard safety functions as all have been seismically classified. As the fault studies topic area progresses, protection measures are to be identified for each External Hazard. A provisional strategy for categorisation and classification is provided within Part B Chapter 14 [7] and its supporting deliverables.
- The preliminary evaluation of the GDA Reference Design has demonstrated that for many of the External Hazards, significant margin is present between the GDA Reference Design parameters and the GB GSE Parameters providing confidence in the robustness of the design in the context of a UK deployment.
- The preliminary evaluation of the GDA Reference Design has also identified where there are deltas in hazard characterisation and / or design basis magnitudes that require further assessment at the site-specific stage.
    - The undertaking of this site-specific work is deemed business as usual as the design develops. A single commitment has been raised for External Hazards in relation to aircraft impacts that will be progressed via the design challenge process as outlined within [20] beyond Step 2.

Part A Chapter 5 [122] 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.

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21.10 LIST OF APPENDICES

Appendix A PSR Part B Chapter 21 CAE Route Map

Table 20: PSR Part B Chapter 21 CAE Route Map

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