REGULATORY OBSERVATION Resolution Plan	
RO Unique No.:	RO-UKHPR1000-0003
RO Title:	Suitable and Sufficient Severe Accident Analysis Safety Case
Technical Area(s)	Severe Accident Analysis
Revision:	Rev 0
Overall RO Closure Date (Planned):	
Linked RQ(s)	
Linked RO(s)	
Related Technical Area(s)	9. Fault Studies 15. Probabilistic Safety Analysis
Other Related Documentation	
Scope of Work	

Background

ONR's guidance (Safety Assessment Principles (SAPs)) requires that "Fault analysis should be carried out comprising suitable and sufficient design basis analysis, PSA and severe accident analysis (SAA) to demonstrate that risks are as low as reasonably practicable (ALARP)" [1]. Therefore, fault sequences beyond the design basis that have the potential to lead to a severe accident should be analysed. ONR have indicated that they consider there are currently a number of gaps between ONR expectations and the current approach and intentions for the UK HPR1000 SAA safety case proposed by GNS during GDA, both in terms of the content and timing. ONR therefore issued RO-UKHPR1000-0003 to address the identified gaps in expectations for the SAA safety case. This resolution plan is provided as a response to ONR's expectations on step 2 deliverables and overall strategy for following GDA steps.

Scope of work

A series of reports will be produced in response to RO-UKHPR1000-0003 to demonstrate that the SAA is suitable and sufficient. The reports will show that the SAA will be suitable and sufficient by providing examples of the analysis performed and by undertaking a gap analysis of the current approach against RGP and producing a plan to address any shortfalls identified. The reports will describe the process that will be used for demonstrating that the risks are ALARP.

The reports will also show that the SAA will not be carried out in isolation of the other fault analysis areas and that links with other assessment areas, that either the SAA supports or from which the SAA requires support, are captured and managed. Because the SAA is not being carried out in isolation, the

reports produced in response to this RO will need to draw on and refer to other documents being produced for the GDA and the key documents of these are listed in the Resolution Plan below.
This Resolution Plan describes the scope and intent of the reports to be produced in response to each of the Actions and provides the schedule for their delivery.

Deliverable Description

RO-UKHPR1000-0003. A1 - SAA Strategy

In response to this Regulatory Observation Action, GNS should provide the strategy for the GDA program. ONR would expect GNS to:

- *Provide the objectives for the SAA*
- *Identify the Relevant Good Practice (RGP) considered by GNS, including learning from the fukushima accident and the Vienna declaration*
- *Provide a justification for how GNS intend to demonstrate compliance with UK regulatory expectations and international RGP. This should include how GNS plans to show that the SAA has been used to:*
  - *Identify any further reasonably practicable preventative or mitigating measures;*
  - *Form a suitable basis for accident management strategies;*
  - *Support the preparation of emergency plans for the protection of people;*
  - *Determine the magnitude and characteristics of radiological consequences;*
  - *Support the PSA of the facility's design and operation; and*
  - *Demonstrate adequate understanding of the severe accident phenomena and accident progression.*
- *Provide information on how a coherent safety case for UK HPR1000 will be produced*
- *Define the scope and objectives of the intended radiological consequence analysis*
- *Identify the criteria used for SAA against which the performance of the engineered features, strategies and procedures can be judged*
- *Define the scope of the severe accident safety case for GDA (i.e. emergency procedures, SAMGs, SBERGs, etc.). If assumptions are made on the future Licensee's emergency capabilities or procedures these should be clearly stated.*
- *Provide a clear detailed outline of work that is required to produce a SAA safety case for UK HPR1000. This should be with accurate dating for Step 2 of the GDA, and with approximate dating for Step 3.*

Report *Safety Case Strategy of Severe Accident Analysis* will be produced in response to Actions 1. The Strategy Document will be submitted before June 15th 2018.
The Strategy Document will describe strategy for the safety case that will be used in the SAA to achieve the objectives of the Severe Accident Analysis (SAA) performed for the UK HPR1000 GDA - namely to demonstrate that the nuclear safety risks from severe accidents are tolerable and As Low

As Reasonably Practicable (ALARP).

This SAA safety case strategy is to show that with the above severe accident management approach, the principal objective can be achieved; the contents in strategy are listed below:

- The SAA will:
  - Demonstrate the severe accident phenomena are adequately understood
  - Analyse the performance of the severe accident engineered mitigation measures
  - Demonstrate that the engineered measures are effective in preventing or mitigating each phenomenon. Claims that need to be substantiated in other assessment areas or other links will be captured and managed to ensure a coherent safety case.
  - Demonstrate there are no cliff-edges or that the margin to any cliff-edge is sufficiently large.
- The results of the analysis above will provide input to the entry condition and development of Severe Accident Management Guidelines (SAMG).
- The SAA will calculate source terms for a set of release categories which will be an input to the Level 3 PSA which will calculate the radiological consequences for comparison with ONR's numerical targets and provide input to the Emergency Response Plan.
- ALARP assessment will be carried out which will seek to identify potential improvements in the design or accident management strategy or further measures that could either reduce the frequency or mitigate the consequences.
- The SAA will demonstrate that those potential severe accidents states that could lead to early or large release have been 'practically eliminated'.
- If the Level 3 PSA has shown that by comparison with numerical targets the risks are tolerable and the ALARP assessment has shown that there are no practicable measures to reduce the risks further and it is shown that potential severe accidents states have been 'practically eliminated' then the SAA will have achieved its objective.

The scope of the SAA will include the reactor and spent fuel pool in all operating states and configurations. Other facilities such as waste stores and operations such as fuel handling will be assessed for the potential for severe accidents and considered if necessary. Internal and external hazards initiators will be considered and the impacts on and off-site will be assessed.

The approach used to date will be assessed against ONR's SAPs and TAGs and RGP (IAEA Standards, WENRA, NEA, EUR, other GDA submissions, and other sources) [2-13]. This will also include lessons learned from Fukushima. Specifically, a Gap Analysis for the current SAA against TAG-007 [14] is an input for the Strategy Document. For any gaps identified, a forward action plan will be developed to fill these gaps and included in the PCSR Chapter 13.

The Strategy Document will include a programme for the remaining GDA period listing the documents, their scope, and the dates when they will be submitted to ONR.

RO-UKHPR1000-0003.A2 - SAA Methodology

In response to this Regulatory Observation Action, GNS should provide the methodology for all aspects of the technical work that is required to be performed for the SAA.

This methodology should clearly identify "how" GNS intend to undertake the activities identified in Response to Action 1, in order to provide the SAA safety case for UK HPR1000.

ONR would expect that this methodology will cover the full scope of SAA and include topics such as:

- *A description of the overall strategy to deal with severe accidents at a UK HPR1000, that will serve as the basis for the development of severe accident management guidelines and which should be underpinned by severe accident analysis*
- *A description of the computer codes used, their purpose and an outline for how the verification and validation information on the relevant computer codes will be provided*
- *Information on the uses of these computer codes in the analysis of SAA sequences*
- *Comprehensive list and description of all relevant severe accident phenomena including a justification of any known severe accident phenomena that have been excluded from consideration*
- *Comprehensive list and description of possible release paths and the behaviour of radionuclides for the UK HPR1000, including:*
  - *Claims on fission products to be retained within the containment and a description of the behaviour of radionuclides (in-vessel and ex-vessel) following a severe accident.*
  - *A description of the containment failure mode/s assumed in the analyses.*
  - *A description of all other possible release paths following a severe accident considered for the UK HPR1000*
- *A description of the optioneering process which has been, or will be, done to consider what severe accident design measures are reasonably practicable for the UK HPR1000. This should include how GNS will justify that the design of the UK HPR1000 represents RGP and follows the ALARP principle in relation to severe accident engineered measures.*

Report *Overall Methodology of Severe Accident Analysis* will be produced in response to Action 2. The first version of this Methodology Document will be submitted before June 15th 2018.

The Methodology Document will describe the severe accident progression with no mitigation measures to illustrate the severe accident phenomena considered and to demonstrate understanding of the phenomena. The computer codes used in the analysis will be listed along with a description of their strengths and weaknesses and when they would be used. The status of the Validation and Verification of each of these codes will also be described.

The overall severe accident management strategy will be outlined in the Methodology Report. The basic severe accident management approach adopted in the UK HPR1000 design is as follows:

- for the reactor – to maintain as many barriers between the core and the environment as possible for as long as possible.
- for the spent fuel pool – to keep the water level above the top of the fuel.

The engineered severe accident mitigation measures designed to achieve this accident management strategy will be described briefly. The rationale behind the choice of systems and approaches will be discussed. The analysis to be performed to demonstrate that these systems achieve their performance criteria and thereby are effective in achieving the severe accident management strategy will be described.

The Methodology Document will describe how the source terms for reactor building will be calculated - i.e. activities released to the environment, chemical form, and release paths (e.g. from the main stack or through the containment along with any decontamination assumed), etc. The methodology for source term analysis on severe accident of SFP is under development and will be described in next version of the Methodology Document.
The optioneering process planned to be used in the ALARP assessment will be described.

RO-UKHPR1000-0003.A3 - Demonstration of the Adequacy of the SAA Safety Case

In response to this Regulatory Observation Action, GNS should provide sufficient evidence of the various outputs of the work items described in response to Actions 1 and 2 above, to demonstrate that an adequate safety case for SAA will be provided during GDA.

The nature of this demonstration should be defined by GNS, based upon the response to Actions 1 and 2, but this may be in the form of a safety case for a single SAA sequence analysis or by providing elements from different sequences along with a description of how they fit into the overall safety case. However, ONR expect that collectively, sufficient information should be provided for ONR to satisfy itself that regulatory expectations are likely to be met for GDA.

In response to Action 3, Topic Report on the Severe Accident Analysis of a Typical Sequence will be produced to show an example of a complete safety case in SAA and implementation of the Methodology described above. The report will be submitted before 30th April 2019.
A mitigated severe accident sequence (LB-LOCA without active injection) with severe accident mitigation systems available will be analysed to show that the containment integrity can be maintained after fuel melt.
First of all, the results of an unmitigated sequence analysis will be presented to demonstrate that the suite of computer codes available can model the sequence as a whole and the individual severe accident phenomena adequately.
Then, the results of the analysis of sequence where the severe accident mitigation measures function as intended will be presented. This will show that the mitigation systems acting together can achieve the severe accident management strategy for the reactor of maintaining as many barriers between the core and the environment for as long as possible.
The release paths for activity released during this sequence will be described and the source term released to the environment will be calculated. Iodine behaviour in the containment and other key aspects of accident chemistry will be modelled.
The sequence description, analysis assumptions, success criteria, analysis codes, analysis results, and conclusions will be included.

RO-UKHPR1000-0003.A4 - Demonstration of the Adequacy of the SAA Engineered Features

In response to this Regulatory Observation Action, GNS should demonstrate that a systematic approach has

been taken to the identification of safety functions for SAA and that the list of claims made on the severe accident engineered measures (including human actions) is complete.

ONR expects that this demonstration will require the provision of detailed information on the design features and their importance to the severe accident management strategies, for example:

- *The number, type, and location of electrical, and mechanical connection.*
- *SAA system safety classification and withstand capability on all of the proposed severe accident engineered features.*
- *Description of Fukushima related improvements (for example, backup building, mobile components, hydrogen management etc.).*
- *Description of the measures for hydrogen management (and other combustible gases) during a severe accident. This should include addressing the possibility of hydrogen leakage out of the containment building into the spent fuel building, safeguard buildings, etc.*
- *Information on the systems and strategies to control the containment pressure following a severe accident (for example, strategy, system design and filter design).*
- *Details of the strategy and approach for containing a molten core debris (for example, strategy, system design and requirements)*
- *The response to this action should include the outputs from the consideration of optioneering for topics such as:*
  - *methods / technologies for confining a molten core,*
  - *passive methods of core or containment cooling,*
  - *methods for further increasing grace / response times,*
  - *methods of further capturing / reducing fission products inside containment,*
  - *passive methods for flammable gas control.*

A *Severe Accident Engineered Measures Summary Report* will be produced in response to this Action and submitted before 30th September 2019.
This report will draw on and summarize the contents of other reports that will be produced during GDA; these include information from:

- System Design Manuals for each system.
- Chapter 4 of the PSCR describing overall categorization and classification principles and Chapter 6 and Chapter 7 providing categorization and classification information for Structures, Systems and Components (SSCs) claimed in SAA.
- Qualification specifications of equipment as the manufacturers are yet to be decided.
- Function requirement and effectiveness assessment for each system.
- Fukushima Topic Report showing how lessons learnt from Fukushima is addressed in the design of UK HPR1000.

The Summary Report will describe each of the systems, listing all the claims made for each system. Where these claims require substantiation in another assessment area, this will also be taken into consideration. The arrangements for ensuring that these claims are captured and addressed adequately

will be discussed in the Strategy Document produced in response to Action 1. The safety functions delivered by each system will be determined in a systematic way which will be described in PCSR Chapter 4. The classification of each SSC is based on the defence-in-depth concept and their roles in achieving the functions. The qualification specifications for each system will be based on the output of the SAA to ensure that the systems will be able to perform as intended and deliver their safety function under the conditions they will be required to operate.

The rationale for the choice of each of the mitigation measure in UK HPR1000, which derives from HPR1000 (FCG3), will be described in *Severe Accident Engineered Measures Summary Report*.

Detailed ALARP evaluation will be provided if necessary, based on the results of the SAA safety case. They will be described in the *ALARP Evaluation on Severe Accident Measures* report which will be submitted before 30th March 2020. Before the final version, an intermedia version which includes preliminary results on certain system will be produced and submitted to ONR for review.

Reference:

[1] ONR, Safety Assessment Principles for Nuclear Facilities, Revision 0, November 2014.
[2] ONR, Severe Accident Analysis, NS-TAST-GD-007 Revision 3, September 2017.
[3] Fundamental Safety Principles, Safety Standards Series No. SF-1
[4] Safety of Nuclear Power Plants: Design Safety Standards, SSR2/1, Rev. 1
[5] Safety of Nuclear Power Plants: Commissioning and Operation Specific Safety Requirements, SSR2/2, Rev.1
[6] Safety Assessment for Facilities and Activities, Safety Standards Series No. GSR Part 4, Rev. 1
[7] Considerations on Application of the IAEA Safety Requirements for the Design of Nuclear Power Plants, IAEA-TECDOC-1791
[8] Severe Accident Management Programmes for NPPs, Standards Series No. NS-G-2.15
[9] Design of Reactor Containment Systems for Nuclear Power Plants, IAEA Safety Standards Series No. NS-G-1.10
[10] Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants, No. SSG-4
[11] WENRA, Reactor Safety Reference Levels for Existing Reactors, 2014
[12] WENRA, Safety Objectives and Statement for New Power Reactors, 2009
[13] WENRA, Statement on Safety Objectives and Statement for New Power Reactors, 2010
[14] CGN, Gap Analysis with TAG-007, GHX00600178DRAF02GN, June 2018

Impact on the GDA Submissions

The information will be incorporated into PCSR Chapter 13 v0/v1/v2 submitted in the following GDA Steps. Related PCSR chapters and their supporting submissions are also involved in this resolution plan.

GDA Submission Document	Related ROAs	Planned schedule for submission
Safety Case Strategy for Severe Accident Analysis	ROA1	15th June 2018
Overall Methodology of Severe Accident Analysis	ROA2	15th June 2018
Topic Report on the Severe Accident Analysis of a Typical Sequence	ROA3	30th April 2019
Severe Accident Engineered Measures Summary Report	ROA4	30th September 2019
ALARP Evaluation on Severe Accident Measures	ROA4	30th March 2020

Timetable and Milestone Programme Leading to the Deliverables

See attached Gantt Chart in APPENDIX A.

CGN EDF General Nuclear System	REGULATORY OBSERVATION RESOLUTION PLAN RO-UKHPR1000-0003	Rev.: 0	Page: 9 / 10
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PREVIOUS REVISIONS RECORD				
Rev.	**Author**	**Scope/Reason of Revision**	**Date**	**Page**

APPENDIX A RO-UKHPR1000-0003 Gantt Chart

		May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20
RO Action 1																												
	Development of deliverable - [Safety Case Strategy for Severe Accident Analysis]																											
	Submission of deliverable - [Safety Case Strategy for Severe Accident Analysis]																											
RO Action 2																												
	Development of deliverable - [Overall Methodology of Severe Accident Analysis]																											
	Submission of deliverable - [Overall Methodology of Severe Accident Analysis]																											
RO Action 3																												
	Development of deliverable - [Topic Report on the Severe Accident Analysis of a Typical Sequence]																											
	Submission of deliverable - [Topic Report on the Severe Accident Analysis of a Typical Sequence]																											
RO Action 4																												
	Development of deliverables - [Severe Accident Engineered Measures Summary Report]																											
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