**Technical Support – Work Order Specification**

|  |
| --- |
| **Title: Provision of Technical Support to Perform an Independent Analysis of the UK HPR1000 In-Vessel Melt Retention by External Reactor Vessel Cooling Strategy** |
| 1. Background to the project
	1. In January 2017 the UK Government formally asked ONR and EA to begin the Generic Design Assessment (GDA) of the UK HPR1000. The UK HPR1000 is a reactor design proposed for deployment at Bradwell-on-Sea, Essex. General Nuclear System LTD (GNS) is a UK-registered company that was established as the Requesting Party (RP) to implement the GDA on the UK HPR1000 reactor on behalf of three joint requesting parties, i.e. China General Nuclear Power Corporation (CGN), EDF and General Nuclear International (GNI).
	2. The GDA process calls for a step-wise assessment of the RP’s safety and security submissions with the assessments increasing in detail as the project progresses. Step 1 of the UK HPR1000 GDA commenced in January 2017 and Step 2 finished in November 2018. Step 3 commenced thereafter and will last for approximately 13 months. Step 4 is currently planned to last for 24 months, starting in December 2019.
	3. In-vessel melt retention (IVMR) by external reactor vessel cooling (ERVC) is a key aspect of the UKHPR1000 severe accident mitigation strategy. The RP has performed an assessment of in-vessel retention (IVR) using the integral code, ASTEC, in combination with MOPOL, which is an in-house statistical uncertainty code that employs a two-layer melt model.
	4. The RP has used the ASTEC code to perform several calculations of severe accident scenarios (challenging to the IVR strategy) which are used to derive probability density functions of corium mass, steel mass, ZrO2 fraction and decay heat. The monte-carlo code, MOPOL, is then used to determine the margin to the measured critical heat flux (CHF). In this approach, the RP does not demonstrate acceptable heat fluxes to the Reactor Pressure Vessel (RPV) using the ASTEC code. This contract seeks to perform independent calculations to demonstrate success of the UK HPR1000 IVR strategy.
	5. The ASTEC code will also be used by the RP to determine / verify assumptions made in the Level 2 PSA (such as validating SA measures, determining / verifying timings of operator actions and determining the probability of SA phenomena).
	6. The high level objective of the contract is to provide confidence to ONR that the analysis performed by the RP is sufficient to demonstrate the claims made on the success of the IVR strategy for the UK HPR1000 design. With this in mind, the purposes of this contract are to:
* Perform independent analysis to assess if the HPR1000 IVR strategy is successful following a severe accident;
* Perform analysis to test the sensitivity of the success of IVR, in order to provide confidence to ONR that significant uncertainties / assumptions in the RP’s analysis are acceptable;
* Gain an understanding, and insights into, the RP’s methodologies for determining success of the IVR strategy through investigating differences in analyses and results;
* Gain an understanding of any weaknesses / shortfalls of the RP’s analysis; and
* To provide ONR with a tool to test assumptions made in the Level 2 PSA.
 |
| 1. SCOPE OF THE SERVICES REQUIRED

Scope of work* 1. The RP has performed its own assessment of IVR using the severe accident integral code, ASTEC, combined with MOPOL, an in-house statistical uncertainty code which is dedicated to calculate heat flux to the RPV using a two-layer corium model.
	2. The contractor is initially required to review safety case documentation provided by the RP to ensure that the strategy proposed in response to this work order specification remains valid. A strategy to best achieve the objectives set out in Para 1.6 will be then agreed with ONR.
	3. Whilst the RP’s severe accident analysis of the IVR strategy combines deterministic sequence based analysis and monte-carlo methods, it is assumed that the bidder will, as a minimum, develop a computer model of the UK HPR1000 using an integral code in order to achieve the objectives stated in Para 1.6. The specification is therefore written on the assumption that an integral severe accidents code will be used to model several severe accident scenarios.
	4. A pragmatic approach to the development of the model should be taken to ensure the model can simulate a selection of severe accident sequences without expending unnecessary effort developing capabilities that are not required for the purpose of this contract. In order to facilitate this, the severe accident sequences to be simulated will be agreed towards the beginning of the contract, informed by the TSCs expert judgement.
	5. The simulation model should:
* Be capable of modelling the fault from initiation, through core melt and relocation to the lower head and RPV failure or steady state. This will require the model to include a thermal hydraulics model of the primary circuit, capability of modelling early and late phase core relocation severe accident phenomena, and be capable of modelling the IVR recirculation loop (if necessary).
* Include a basic consideration of containment response. A more detailed containment model is not envisaged at this time but there is value in providing the capability and flexibility to develop and couple such a modelling if containment behaviour emerges as an area of regulatory interest.
* Be capable of providing an input / coupling with fission product transport models for potential future development. However, it is not envisaged that source term analysis will be performed as part of this contract.
	1. Once the model is built, the TSC is required to analyse the severe accident progression and compare the results to the RP’s analysis in order to verify the model. Significant differences in severe accident progression should then be assessed and discussed with ONR and the RP, as required.
	2. A range of severe accident sequences will then be simulated using the TSC’s model. The TSC is required to use its expert judgement to identify areas of greatest uncertainty and/or sensitivity, in order to further scrutinise assumptions / methodologies employed by the RP (e.g. melt compositions, decay heat, emissivity etc.).
	3. ONR will also look to use the model to inspect the Level 2 PSA (referred to as test cases here on). Examples of these test cases may be as follows:
* Importance of timing of activating passive reactor pit flooding, and the available time to switch to active reactor pit flooding;
* Importance of timing of severe accident depressurisation;
* Likelihood of success of IVR (currently IVR is assumed to succeed if IVR reactor pit injection and depressurisation has occurred in a timely manner)
* Sensitivity to timing of containment heat removal initiation;
* Whether IVR can be achieved without reactor pit injection (e.g. by restoring safety injection).
	1. The development of the above models is to be informed by the information supplied by the RP during GDA. Information readily available upon project initiation is as follows:
1. A list of severe accident sequences is contained in the PSCR Chapter 13 (a redacted version is available on-line at <http://www.ukhpr1000.co.uk/>).
2. The Overall Methodology of Severe Accident Analysis report
3. Information on the assessment of In-Vessel Retention Strategy
4. Information on the depressurization capacity analysis of the Severe Accident Dedicated Valve
5. Reactor plant, safety systems and fuel and core design descriptions can be found in PCSR Chapters 2 -10 (available online)
6. More detailed information on RPV internals
7. Documentation on the ASTEC and MOPOL codes used by the RP
8. Specific details of the Level 1 and Level 2 PSA may be provided upon request
9. More detailed system information is available in System Design Manuals
10. Details of C&I systems will be provided by the RP upon request

**WORK BREAKDOWN*** 1. The contractor is required to:
	2. Agree with ONR a strategy to independently confirm the validity of claims made on in-vessel retention ex-reactor vessel cooling strategy, based on the response to this specification. This includes the severe accident scenarios to be modelled. This should occur shortly after award of the contract.
	3. Request from the RP the information needed to develop independent computer models (which ONR will formally submit to the RP as written Regulatory Queries (RQs)). For planning purposes the contractor should assume that data will be provided 6 weeks after each request. It is likely that several information requests will be required in order to ascertain all data required to build the model and run the SA scenarios.
	4. Develop a UK HPR1000 model capable of modelling severe accident scenarios from initiating event to RPV failure or steady state. The model should include an appropriately detailed core and RPV lower head, a containment, a primary circuit thermal hydraulics model and an IVR tank and recirculation loop (if necessary).
	5. Perform confirmatory analysis on a range of severe accidents scenarios. The following severe accident scenarios should be assumed for the purpose of the bid:
* Loss of coolant accident with loss of active safety injection
* Anticipated transient without scram (ATWS) with successful emergency boron system actuation but failure of secondary heat removal.
* Station black out (SBO) with loss of SBO diesel generators.
	1. Discuss the developing model and preliminary results with the RP, via RQs and face-to-face meetings as necessary.
	2. Advise ONR on significant areas of uncertainty that should be targeted for sensitivity studies and areas of interest for test cases.
	3. Perform sensitivity studies and test cases on those areas agreed with ONR.
	4. Document the severe accident integral code model.
	5. Report the results of the analysis and the comparison with the equivalent case run by the RP. The report should include significant findings, key insights gained during the analysis and recommendations to ONR for further investigations.
	6. The sensitivities of the models and assumptions may come to bare as part of performing the base case confirmatory analyses. The contractor should therefore be flexible in its approach, and be pragmatic when performing sensitivity analysis.

**INPUTS*** 1. The initial list of information available to the TSC is detailed in Paragraph 2.9.
	2. Additional data necessary for the models preparation will be delivered by the RP upon request (via ONR). In the cases of missing/uncertain details the TSC shall apply justified conservative assumptions based on similar reactor designs.

**DELIVERABLES*** 1. The contractor shall provide regular updates to ONR throughout the contract via face to face (or video conference if appropriate) progress meetings. The progress meetings should be include the following milestones:
* progress on the developing model, and any preliminary results for the confirmatory analysis;
* updates to confirmatory analysis, and progress with sensitivity analyses; and
* an overview of all work performed, the model built and the results of both the base case analyses and sensitivity analyses
	1. At the end of the contract, the contractor shall deliver the model that has been developed as part of this work and a report which should include the following:
1. A description of the severe accident simulation model and description of the independence of analysis from that of the RP’s (e.g. different code, different models within code etc.)
2. A description of the assumptions made by the TSC in the analysis, and any boundary conditions / assumptions taken from the RP.
3. A description of the results from the SA analysis base cases performed by the TSC and a comparison of the results with the RP’s submissions.
4. A description of sensitivity analysis of the success of IVR and a reflection on the results of the sensitivity analysis (i.e. what implications it has on the adequacy of the RP’s claims)
5. A description of the test cases and any important findings through comparisons with the RP’s Level 2 PSA.
6. Any insights gained and potential shortfalls in the RP’s methodologies and assumptions used in the SA analysis that may be of be of regulatory interest going forward.
7. A summary of interactions with the RP, and exchanges of technical information.
	1. Prior to the report drafting stage, the TSC will propose to ONR a structure of the report for agreement with ONR. The report should be made available for one round of ONR comments one month prior to final delivery.

**TIMESCALES*** 1. The following table presents an indicative timescales of key project milestones for the contract:

Table 1 - indicative timescales for deliverables and milestones

|  |  |
| --- | --- |
| **Deliverable / milestone** | **Date** |
| Start of Contract | X |
| Initial Review of RP’s safety case documents and present strategy to ONR | X + 3 weeks |
| Request detailed information from RP | X + 3 weeks |
| Update on model progress and any preliminary runs of base cases | X + 4 months |
| Agreement of sensitivity cases and other test cases with ONR | X + 6 months |
| Update on preliminary results of sensitivity and test cases  | X + 9 months |
| Update on final results of base cases and sensitivity cases and test cases | X + 11 months |
| Draft report sent to ONR for comment | X + 12 months |
| Final report submitted to ONR | X + 13 months |
| End of contract | Dec 2020 |

* 1. Whilst the dates between the start of the contract and the final report should be considered as indicative, completion of this contract is required by December 2020. The TSC should propose key project milestones and delivery dates and these will be agreed and fixed when the contract is awarded.

**MEETING REQUIREMENTS*** 1. ONR expects a kick-off meeting to be held between ONR and the contractor on contract award. This should include an introduction of the Contractor’s team and the codes that will be used to develop the models. The contractor should also confirm the initial information that will be required. The strategy for delivering the objective of this contract, including any SA scenarios to be analysed, will be agreed following the contractors review of the safety case. This meeting will take place either at the ONR offices in Bootle, or the contractor offices.
	2. Brief monthly progress meetings between ONR and the TSC should be assumed throughout the duration of the contract. These should be assumed to be by teleconference or videoconference; however they may be face-to-face (if necessary).
	3. During the course of the contract there may be the need to attend meetings with the RP. These could be face-to-face at the RP’s office in London or via videoconference. For planning purposes assume three separate meetings with the RP during the course of the contract; two in the UK and one via videoconference. It is possible that such interactions may be necessary to progress the development of the models, including matters such as clarifying information requests or discussing the RP’s modelling approaches. Importantly the contractor will need to discuss any differences between their own and the RP’s analyses and will need to present the outcomes of the base case runs.
	4. ONR expects that there will be a meeting with ONR when the contractor has developed the UK HPR1000 model sufficiently to make preliminary runs. This meeting will review progress against the specification and confirm the remaining work required. This meeting will take place either at the ONR offices in Bootle, or the contractor offices. Videoconference facilities are also available if necessary.
	5. ONR expects that there will be a further meeting with ONR at a time when preliminary results of sensitivity analyses are available. This meeting will take place either at the ONR offices in Bootle, or the contractor offices. Videoconference facilities are also available if necessary.
	6. A close-out meeting will be held upon completion of the contract. This meeting will take place either at the ONR offices in Bootle, or the contractor offices.
 |
| 1. OBJECTIVES
	1. The purpose of this contract is to:
* Perform independent analysis to assess if the HPR1000 IVR strategy is successful following a severe accident;
* Perform analysis to test the sensitivity of the success of IVR, in order to provide confidence to ONR that significant uncertainties / assumptions in the RPs analysis are acceptable;
* Gain an understanding, and insights into, the requesting party’s methodologies for determining success of the IVR strategy through investigating differences in analyses and results;
* Gain an understanding of any weaknesses / shortfalls of the RPs analysis.
* To provide ONR with a tool to test assumptions made in the Level 2 PSA.
	1. Ultimately, the objective of the contract is to provide confidence to ONR that the analysis performed by the RP is sufficient to demonstrate the claims made on the success of the IVR strategy for the UK HPR1000 design.
	2. The aim of the analyses to be undertaken is not to directly support the RP’s safety case. Rather, it is to assist ONR in coming to a regulatory judgement on the adequacy of the RP’s assessment of its IVR strategy.
 |
| 1. CONSTRAINTS
	1. The following constraints will apply:
* The work is expected to start and conclude on timescales consistent with step 4 of the GDA process, with completion before December 2020.
* The latest versions of the relevant RP’s safety case documentation will be provided at the start of the contract. However, this will not be sufficient to allow the necessary computer models to be developed. Further information will need to be identified and requested by the Technical Support Contractor through RQs (via ONR). The timescales for this processes are largely outside of ONR’s direct control and therefore delays to the receipt of information may occur. Similarly the quality of any response cannot be guaranteed. A pragmatic and flexible approach will need to be adopted to deal with this, both technically and contractually.
* It is expected that the successful contractor will also draw upon their experience, resources and publically available information to perform this work.
* All information received from the RP will need to be treated in accordance with the ONR Technical Support Contact Framework agreement and non-disclosure agreement. The information or a certificate of destruction will need to be returned to ONR at the end of the contract.
* The arrangements for security vetting and IT security established in the Technical Support Contract framework agreement will need to be followed. No information with a security marking above UK OFFICAL - SENSITIVE is anticipated as part of this contract. Most information will carry the RP’s commercial marking.
* The contractor and where applicable, its sub-contractors, will need to provide assurances that it has, or is able to obtain, all necessary export control licenses, where required to transfer relevant information out of the UK and return it.
* Any constraints in relation to completing this work should be declared. Where such constraints exist, the contractor should describe how these will be managed. Examples of such constraints, include, but are not limited to, constraints imposed by code developers on the use of their codes or the availability or use of third-party information.
* The transmittal of all documents between ONR, the RP and the successful TSC will be through ONR's Joint Programme Office (JPO). This will be through encrypted emails using the Egress Switch software, regardless of the security marking (unless the documents are publically available on the internet).
* Any conflict of interest should be declared. Where a potential conflict exists, the contractor should describe how this will be managed.
* The aim of this work package is to inform and advise ONR. However, it is ONR’s intention that the TSC will brief the RP on the conclusions of the work. The RP will also be provided with copies of any reports produced for information and will be invited to comment on their factual accuracy.
* It is not ONR’s intention to publish the reports produced through this contract. However, it is likely they will be referenced in publically available reports and therefore subject to freedom of information requests. This should not constrain or limit the produced reports but should be taken into account with the style and format.
 |
| 1. CONTRACT MANAGEMENT
	1. ONR will require to be kept updated about progress and delivery of the required work in accordance with the Framework arrangements. This should include monthly meetings, to include a contract start-up meeting at ONR’s offices at Bootle, or the contractors’ offices.
	2. The scope of the confirmatory analysis will be kept under review throughout the contract. The TSC should propose appropriate interim milestones during the contract to allow progress to be monitored and controlled.
 |
| **TECHNICAL RESPONSE** |
| 1. Response
	1. In addition to the generic requirements established in ONR’s Technical Support framework, a proposal in response to this specification is required which:
* Clearly addresses all aspects of the specification (including objectives, scope and constraints);
* Describes the computer code(s) and methodology the Technical Support Contractor will utilise to deliver the work package and describes how the analysis will be sufficiently independent from the RP’s analysis;
* Describes any interactions with other contracts awarded to the TSC by ONR (e.g. potential benefits from data / models already available to the TSC at the time of awarding this contract);
* Describes the fundamental information and data that would be required to initiate work on the models;
* Provides a strategy for the development of the model with appropriate milestones and timescales for performing the various aspects of the contract;
* Demonstrates a flexible and pragmatic approach to the application of the models to selected sensitivity studies, and timely and appropriate advice will be provided on progression to achieve ONR’s objectives.
* Describes the capability of the developed model at the end of the work package;
* Details the experience of the organisation and team members in developing and running SA integral code;
* Identifies the anticipated engagement with ONR, including progress meetings;
* Provides an overview of any prior experience with the HPR1000, similar designs with the IVMR ERVC severe accident mitigation strategy, and relevant knowledge of phenomena related to in-vessel retention;
* Provides a description of proposed deliverables and/or outputs;
* Clearly details the proposed cost and associated effort assumptions for development of the models, the analysis of the base case scenarios, the sensitivity studies and any contingencies;
* Provides a project delivery plan showing activities and milestones;
* Provides a planned invoice schedule;
* Details any assumptions or constraints.
 |