Joint CNSC-U.S. NRC First Round of Questions to Terrestrial Energy Inc. and Terrestrial Energy USA, Inc. Under the CNSC-U.S. NRC Memorandum of Cooperation

<u>**Note**</u>:

[[ ]] denotes proprietary information.

Section 1 Articulates a first round of joint CNSC- U.S. Nuclear Regulatory Commission (U.S. NRC) questions based on common discussions around the three documents provided to the U.S. NRC under the White Paper submission and CNSC's experience to date from Phase 1 and 2 Vendor Design Review Activities.

Section 2 Discusses specific U.S. NRC Comments on the Terrestrial Energy USA, Inc. (TEUSA) White Paper -that require further discussion.

Appendix A Documents what Terrestrial Energy, Inc. has requested of CNSC under the Vendor Design Review process.

Introduction

Terrestrial Energy, Inc. (TEI), is currently in Phase 2 of the CNSC's Vendor Design Review (VDR) process for the Integral Molten Salt Reactor (IMSR®) design. TEUSA, is an affiliate of TEI, and is currently engaged in pre application activities with the U.S. NRC. Both companies have submitted documentation associated with the methodology for selection of postulated initiating events (PIE) for the IMSR® design. In December 2020, CNSC and U.S. NRC signed a work plan on cooperation in pre-application review activities pertinent to the IMSR® design. The work plan established as an objective for the CNSC and U.S. NRC to issue a common report of feedback on the Methodology and Selection of PIE for the IMSR® design. The CNSC and the U.S. NRC determined that additional information is needed to support this objective. Therefore, TEI and TEUSA are requested to address the questions below.

SECTION 1. First Round of joint CNSC- U.S. NRC Questions

Current agreed-upon common parameters for memorandum of cooperation (MOC) Discussions:

Using specific documents provided by the vendor along with subsequent discussions and responses to joint requests for information, the CNSC and U.S. NRC will, commensurate with the level of detail provided by the vendor, document:

> *An assessment of the common documents provided both under the PIE White Paper and the CNSC Phase 2 Vendor Design Review to capture the staffs' conclusions in the Joint MOC report. This report will also document:*
>
> 1. *any missing information noted in the assessment and clarifications requested.*
> 2. *conclusions regarding Terrestrial Energy's methodology for selection and identification of initiating events as assessed against fundamental safety principles contained in U.S. and Canadian regulatory requirements*
> 3. *areas of broad agreement between both regulators on key safety objectives and principles used in cooperative activities*

4. *areas where differences exist in regulatory approaches that will need to be addressed by the vendor in regulatory processes in both Canada and the U.S.*

The CNSC and U.S. NRC have agreed that the following questions and the corresponding responses from the vendor may not all be necessary to address specific requirements in the U.S. or, alternatively, in Canada. Responses from the vendor will inform ongoing joint discussions between both regulators.

1. Additional information regarding the approaches

Provide a summary that explains the findings of the different approaches used. Please include the following:

a) A summary (could be in a table form) of the output of different approaches used (e.g., bottom-up and top-down), and how the output of these approaches was compared and integrated in the list of PIE generated.

b) An identification of any limitations in the scope of the analysis and the level of detail used in each approach (e.g., scope of radioactive sources, processes such as fuel processing, etc.). Also describe how they might influence the results.

c) A list of screened-out events and the rationale for screening them out, specifically those events screened out on the frequency basis, knowing that event frequencies quantification is not completed yet.

d) An explanation of the respective similarities and differences between Terrestrial's bottom-up and top-down approaches and how they are consistent with practices of Failure Modes and Effects Analysis (FMEA) and **[[ ]]**.

e) A clarification of whether the top-down approach described by the methodology requires a single expert or a team (which includes multiple disciplines). If performed by a team, describe the attributes of the team and the qualification requirements for team members, if any.

f) A definition and examples of **[[ ]]** as stated in Section 2.2, Page 7 of IMSR400-30800-AR-001 (Rev.1) - *Safety Analysis Postulated Initiating Events List.* Also, describe the spectrum of plant operating states (POS)/operational evolutions where this could occur.

g) The assumptions made related to the first-of-a-kind structures, systems and components (SSCs) and any limitations due to the lack of as-to-be-built and as-to-be-operated details that influence the PIE analysis.

h) The quality assurance (QA) process used for this PIE analysis (if any). Also clarify whether the PIE identification methodology requires an independent assessment or peer review of the PIE list. If so, when would the results of this exercise be available for regulatory review?

2. **Use of operating experience (OPEX) and other sources**

   a) Explain how OPEX from the Molten Salt Reactor Experiment is used and whether any PIE is added/removed with the rationale for doing so.

   b) Explain if other sources are used, such as the information from the United Kingdom (UK) Office of Nuclear Regulation (ONR) workshop on licensing basis events identification (May 2019).

3. **Use of Phenomena Identification and Ranking Table (PIRT) Analyses**

   Was the generic PIRT analysis completed by U.S. Department of Energy/ORNL analyses used to generate the PIE list? If so, explain how these analyses influenced the generated PIE list.

4. **Consideration of Plant Operating States (POS)**

   The white paper stated that "*From the perspective of deterministic safety analysis, a comprehensive listing of PIEs should be prepared for all permissible plant operating modes: e.g., reactor startup, at-power and shutdown modes to ensure that the analysis of the behavior of the plant is complete.*" Please provide the listing of PIEs for the different POS. This should include the list of events during the shutdown state, such as module swap, and maintenance.

5. **PIE screening based on dose calculations**

   Explain the rationale used to inform PIE screening based on dose calculations, considering the level of knowledge base for fission product release and transport.

6. **Consideration of uncertainties in PIE frequencies**

   Explain how the uncertainties in PIE frequencies will be used to inform the PIE classification, specifically for those events with a frequency on the border between two classes of events (borderline events).

7. **Supporting information**

   Design details for systems included in the PIE methodology (e.g., instrument diagrams) need to be provided along with identification of system dependencies, if any. Examples include, but are not limited to, the irradiated fuel system, initial fuel system, make-up fuel system, off-gas removal system, and core swap system.

8. **Establishing Confidence in the Completeness of PIE list**

   a) Section 2.1, Page 7 of IMSR400-30800-AR-001 (Rev.1), indicates that considerations have also included human-induced initiating events. However, no human-induced initiating events are found in Figures 2-8 and Section 2.5. Clarification is needed.

   b) Section 2.1 of IMSR400-30800-AR-001 (Rev.1), specifies that the PIE analysis also includes internal common-cause (CC) events; however, some internal CC initiating events are not found in the report (e.g., loss of direct current power, loss of Heating, Ventilation and Air Conditioning). Clarification is needed.

c) Some external hazards (e.g., hurricane, seiche, volcanic, avalanche, landslide, pipeline accident, biological events) are not shown in Figure 3 “Top-Down Flowchart” of IMSR400-30800-AR-001 (Rev.1). Clarification is needed.

d) Figures 2 through 8, “*PIEs Identification Top-Down Flowchart*,” of IMSR400-30800-AR-001 (Rev.1) should be replicated in the TEUSA white paper to support NRC staff review.

9. Multi-reactor/unit plant

Based on the provided plant description, the IMSR® 400 PIE analysis was performed on plants with only one reactor. How would the results of the safety analyses be impacted for a multiple unit facility? For example, it is necessary to understand how initiating events that impact specific combinations of multiple reactors and sources of radioactive material in shared facilities are identified.

U.S. NRC Comments on the TEUSA White Paper, *Postulated Initiating Events for the IMSR®*, that require further discussion

TEUSA is requested to provide responses to the following observations which will inform:

- U.S. NRC's strategy for responding to the White Paper and
- Future collaborative activities with CNSC to inform a Joint Report containing feedback on the subject of the vendor's processes and methodologies for identification and selection of PIE
- Future MOC questions and outcomes to address the above

1. In TEUSA Letter #L201022, dated October 22, 2020 (found in the U.S. NRC's Agencywide Documents Access and Management System (ADAMS) Accession No. ML20318A178), TEUSA transmitted white paper "Postulated Initiating Events for the IMSR®" and requests that the U.S. NRC review the white paper. Additionally, the letter requests that the U.S. NRC approve five specific items based on the information provided. In approval request #2, TEUSA requests the U.S. NRC to approve the methodology used to develop the list of PIE.

   The U.S. NRC staff notes that the document "A Regulatory Review Roadmap for Non-Light Water Reactors" (ADAMS Accession No. ML17312B567) provides a description of various preapplication options available to applicants for communicating plans and soliciting feedback from the U.S. NRC staff. It states that white papers can be used "to request general feedback, to obtain preliminary regulatory responses (e.g., a template could be submitted to propose a reasonable format and content for a submittal), or a more formal regulatory decision (e.g., applicability of a regulatory requirement to the design)." Per this guidance, an applicant can direct the staff to provide a more rigorous assessment of the white paper or provide high level feedback. However, the vehicle for obtaining approvals is a topical report, which receives a stand-alone safety evaluation report, management review, and Advisory Committee on Reactor Safeguards review.

   If TEUSA wishes to obtain approval for the PIE methodology, TEUSA must submit the methodology as a topical report. The topical report should contain a sufficient level of detail for the staff to make a finding that it meets applicable regulatory requirements. Alternatively, TEUSA can direct the staff to perform a thorough assessment of the white paper per the options described above. The staff can review the white paper to identify missing information, request clarification, and capture the staff's conclusions in an assessment report.

2. In approval request #1, TEUSA requests the U.S. NRC to approve the list of PIE included within the white paper. In approval request #5, TEUSA requests that the U.S. NRC approve the list of postulated initiating events in future licensing actions.

   The staff notes that while the methodology is included within the white paper, it is not a previously approved methodology and since it is not submitted as a topical report, the U.S. NRC staff is unable to approve the white paper. Additionally, a completed IMSR® design has not been submitted to the U.S. NRC yet, so the staff cannot determine if all appropriate design considerations were considered when developing the potential initiating event list. Based on the information provided, the staff can perform a detailed assessment of the PIE list information provided and document any potential concerns with the provided list (or conclude that the list appears to be reasonable based on the information provided) in an assessment report.

If TEUSA wishes to obtain staff approval of requests 1 and 5 from Letter #L201022, then the methodology and analysis will need to be submitted as a topical report and the analysis must be based on an essentially complete design. Any design changes between the essentially complete design included in the topical report and the final design, will result in additional review during licensing application reviews.

3. In approval requests #3 and #4 in TEUSA Letter #201022, TEUSA requests the U.S. NRC to approve the threshold used to establish Anticipated Operational Occurrences and Design Basis Events, respectively.

   Similar to the staff's comments regarding "approval" of white papers noted in feedback item (1), the staff can only assess the information provided in the white paper and provide feedback in relation to the information. This does not imply approval; however, it can be used to illustrate information that will be reviewed in a future licensing action.

   Additionally, requests #3 and #4 from Letter #L201022 use Regulatory Guide(RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" as a basis for the values chosen. Section VII of the white paper identifies the threshold for PIE classification for IMSR® but does not provide justification other than to compare it with RG 1.233. The staff notes that RG 1.233 endorses Nuclear Energy Institute (NEI) 18-04, which initially introduced the Failure-Consequence Curve concept along with the associated event classification cut-off values. However, RG 1.233 also states that NEI 18-04, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development" is an integrated methodology. Since it is the U.S. NRC's understanding that TEUSA is not following the licensing modernization project process in its entirety, additional information should be provided to justify the chosen cut-off points for the IMSR® design.

APPENDIX A: Terrestrial Energy Inc. (TEI) Engagement with the CNSC for a Phase 2 Vendor Design Review

On November 30, 2017, following the successful completion of the Phase 1 VDR, TEI requested CNSC to perform a Phase 2 vendor design review of their IMSR® design. A Service Agreement was signed between the two organizations on May 9, 2018.

This review does not certify a reactor design or involve the issuance of a licence under the *Nuclear Safety and Control Act* (NSCA). It is not required as part of the licensing process for a new nuclear power plant or small reactor. The conclusions of a VDR do not bind or otherwise influence decisions made by the Commission Tribunal.

This review process is intended to facilitate the vendor's early identification and resolution of potential regulatory or technical issues in the design process, particularly those that could result in significant changes to the design or analysis. This information can be used by the vendor for discussions with potential customers seeking to reference the use of the design in an application for a license under the NSCA.

The objective of a pre-licensing vendor design review is to provide feedback on a vendor's efforts to address Canadian requirements in their design and safety analysis activities including early identification of key issues and any issues that could present fundamental barriers to licensing.

A Phase 2 review serves to give CNSC a significant level of assurance that the vendor has taken into account CNSC design requirements and is establishing the necessary information to substantiate safety claims.

The VDR process includes 19 standard focus areas, selected because experience has shown that issues in these areas can promulgate throughout the design, introduce potentially latent safety issues and should be resolved as early in the design process as practicable. The focus areas are as follows:

Focus Area	Description
1	General plant description, defence in depth, safety goals and objectives, and dose acceptance criteria
2	Classification of SSCs
3	Reactor core nuclear design (Physics)
4	Fuel design and qualification
5	(design for) Control system and facilities: a) main control systems b) instrumentation and control c) control facilities d) emergency power system(s)
6	Means of reactor shutdown

7	Emergency core cooling and emergency heat removal
8	(design provisions for) Containment/confinement and safety-important civil structures
9	Beyond design basis accidents (BDBAs) and severe accidents (SA) – prevention and mitigation (includes Design Extension Conditions)
10	Safety analysis (deterministic safety analysis, probabilistic safety analysis) and internal and external hazards
11	Pressure boundary design
12	(design provisions for) Fire protection
13	(design provisions for) Radiation protection
14	Out-of-core criticality
15	(design provisions for) Robustness, safeguards and security
16	Vendor research and development program
17	Management system of design process and quality assurance in design and safety analysis
18	(design for) Human factors
19	Incorporation of decommissioning in design considerations

The CNSC does not have authority to “approve”, “endorse” or “accept” the PIE methodology in Pre-Licensing Activities. The adequacy of the PIE list is reviewed as part of assessment of a site-specific licence application. Regardless of this, because a Phase 2 review normally looks at a design that is still being optimized using research and development, engineering practices and safety analysis, the CNSC does not expect a PIE list to be complete and understands that it may evolve based on vendor activities. As a result, the Phase 2 review includes examining vendor submitted information to develop a degree of confidence that the vendor processes are producing a traceable and supportable PIE list that is being iteratively informed by safety analysis results as the design is being refined. Feedback to the vendor would indicate the level of confidence (i.e. *sound-ness* of methodology) and any expectations going forward to resolve gaps or issues.

Because the development and use of PIE list cuts across different aspects of design activities, it is addressed from different perspectives within the standardized focus areas of the VDR process. Examples of key focus areas include:

- Focus Area 1: General plant description, defence in depth, safety goals and objectives, dose acceptance criteria
- Focus Area 2: Classification of SSCs

- Focus Area 9: Beyond design basis accidents (BDBAs) and severe accidents (SA) – prevention and mitigation – which includes addressing Design Extension Conditions (DEC)
- Focus Area 10: Safety analysis:
  - deterministic safety analysis
  - probabilistic safety analysis
  - internal and external hazards

Assessments of each of these focus area interface with one another during the review to compare observations and potential issues. Observations are normally conveyed to the vendor as Findings or technical clarifications. The following criteria also apply to identify any potential fundamental barriers to licensing:

REGDOC 3.5.4, *Pre-licensing Review of a Vendor's Reactor Design*:

A fundamental barrier is a shortcoming in the design or the design process that, if not corrected, could have the potential for significant risk to the public, workers or the environment. The barrier is considered fundamental when there is no clear and adequate path to resolution of a significant safety issue. A barrier would also be considered fundamental if there are significant uncertainties associated with the proposed resolution plan, or if the timeline is such that the issue may not be resolved at the time an application for a license to construct is submitted to the CNSC.

The following are considered to be barriers to licensing a nuclear power plant or small reactor design in Canada:

- *non-compliance with Canadian regulatory requirements*
- *unjustified non-conformance with Canadian regulatory requirements, including those in the regulatory document REGDOC 2.5.2 or RD-367, and other applicable regulatory documents and national standards for design and analysis*
- *unjustified non-compliance with design and safety analysis quality assurance standards and procedures*
- *a design that does not address known issues of safety significance (i.e., the design has not taken into account resolution of safety concerns from past regulatory reviews)*
- *a design that does not meet the "as low as reasonably achievable" (ALARA) principle*
- *unproven engineering practices for new or innovative design features (i.e., not adequately supported by analysis, research and development, or both)*
- *a design introduces unacceptable operational complexity in order to meet operation compliance (i.e., to meet regulatory requirements, the system or technology would be so complicated as to introduce complexities that may cause other events due to human factors)*