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Overview of JAEA Floating Seismic Isolation System (FSIS) for SMRs - White Papers on Seismic Design Methodology, Seismic Analysis Methodology Verification & Validation, and Preliminary Plant Standard Design Information

Meeting with USNRC OAR/DARL
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Objectives for this presentation

1. **Who Are We?**
2. **FSIS Technology Overview**
3. **Outlines of White Papers (WPs)** regarding :

"Seismic Design Methodology for Floating Seismic Isolation System (FSIS)"

"Validation and Verification of Seismic Analysis Methodology for FSIS-R Plant"

"FSIS-R Plant Preliminary Standard Design Information"

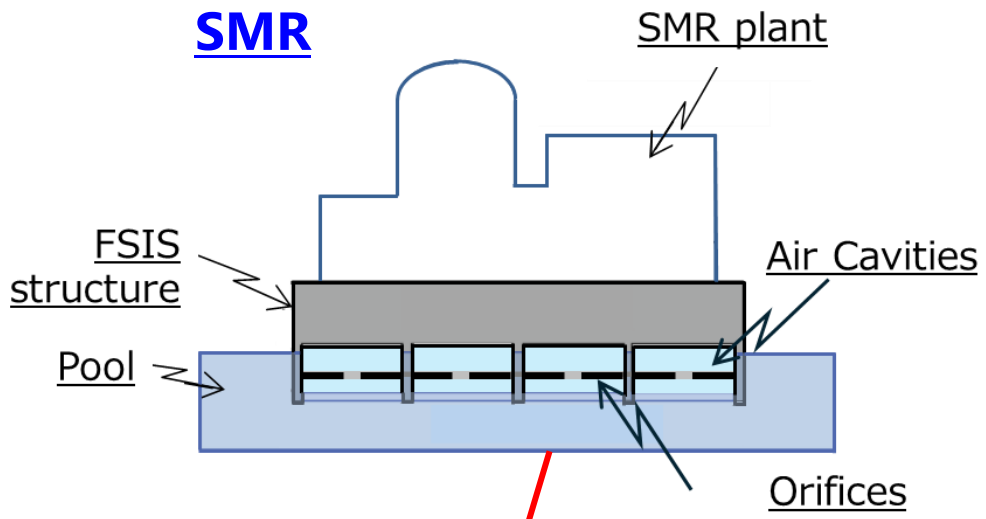
1. Who are we?

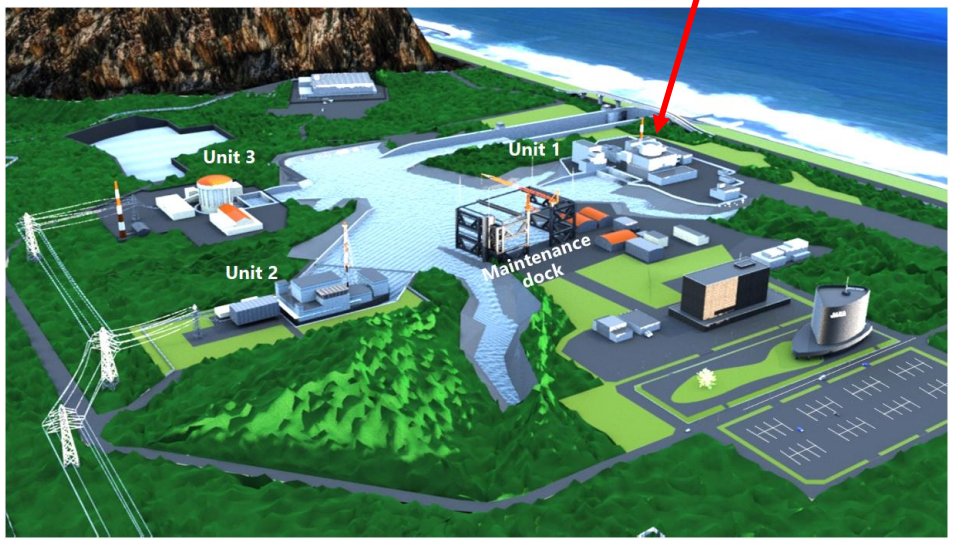
- Japan Atomic Energy Agency (JAEA) and its corporate partners (collectively, JAEA Consortium) are developing the FSIS concept, paired with a SMR design or designs, for possible deployment in the U.S., Japan, and elsewhere.
- Each organization brings specific strengths and competencies, and each will have specific roles in various project stages
  - » JAEA – national nuclear energy research and development authority, project leader for FSIS technology development, conceptual design, and pre-application engagement with the US NRC.
  - » IHI Corporation – engineering and manufacturing expertise for nuclear plant equipment; FSIS design, engineering, and quality assurance
  - » JGC Corporation – engineering and construction expertise for large energy projects including floating plants; FSIS paired reactor design and analysis
  - » Other partners – nuclear civil engineering & construction; shipbuilding

2. FSIS Technology Overview

- A seismic isolation (SI) platform structure, integrated with air cavities and orifices
- The platform supports an SMR plant (all or major safety-related SSCs) and floats in a water pool
- Operates passively – no activation is required
- Uses conventional materials for construction

A notional FSIS paired SMR





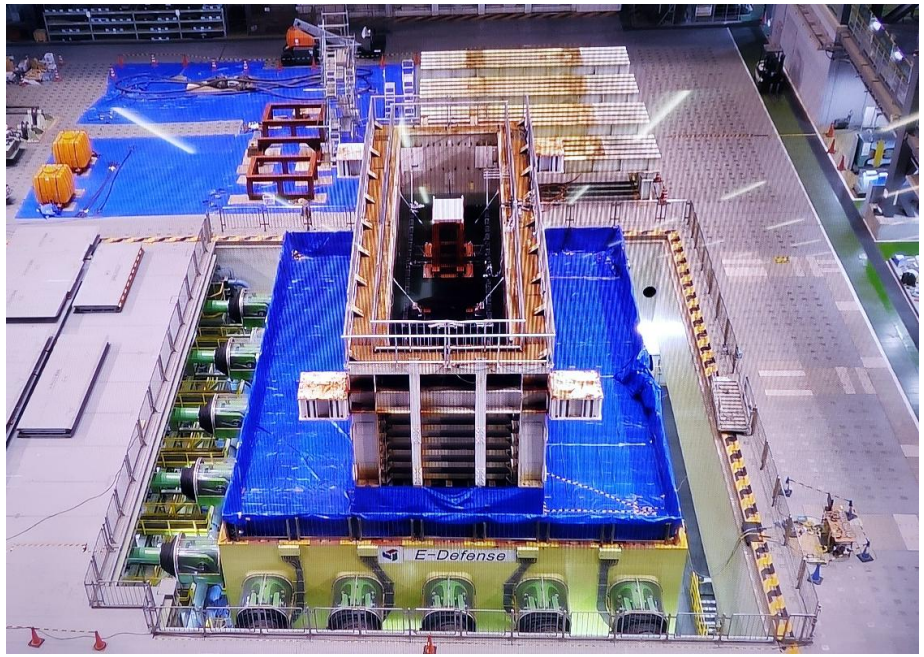
Notional Site Installation of SMR units 1~3

https://www.nrc.gov/reactors/new-reactors/smr/licensing-activities/pre-application-activities/jaea-fsis.html

Proven Seismic Isolation Performance

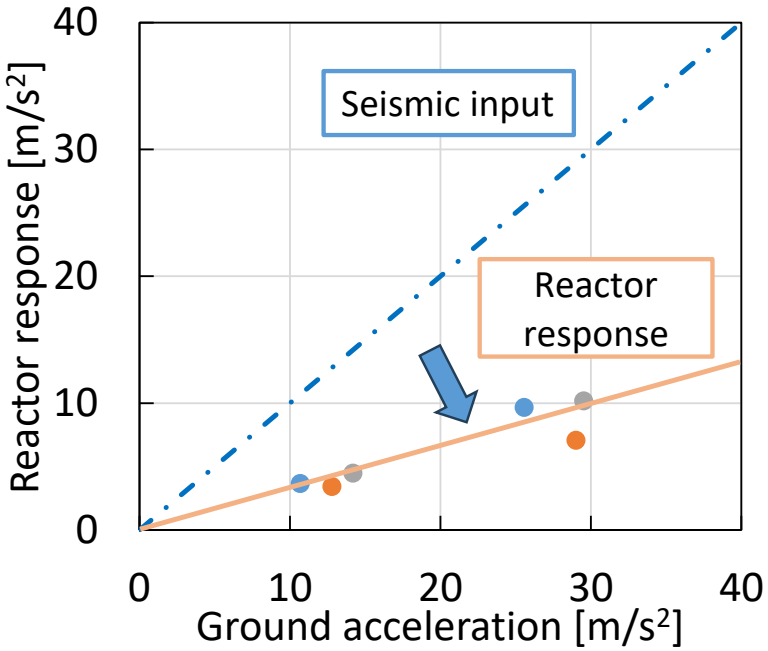
- Tested using a large-scale mockup of the FSIS-R
- Data obtained applicable to seismic isolation design and validation

Tests conducted at Japan`s E-Defense facility – the world`s largest 3D shaking table in 2024



Sample of test results

Observed significantly reduced seismic response in tests

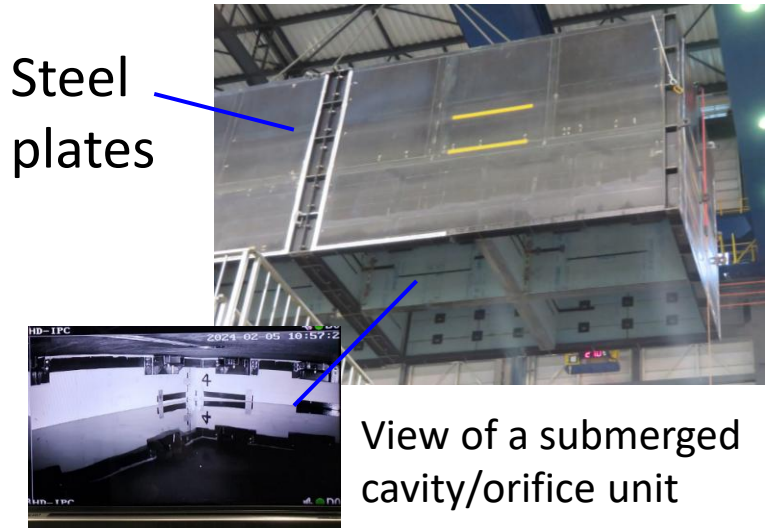


WNN Article:
https://world-nuclear-news.org/Articles/Japan-demonstrates-floating-seismic-isolation-syst

FSIS Benefits for SMR design and safety

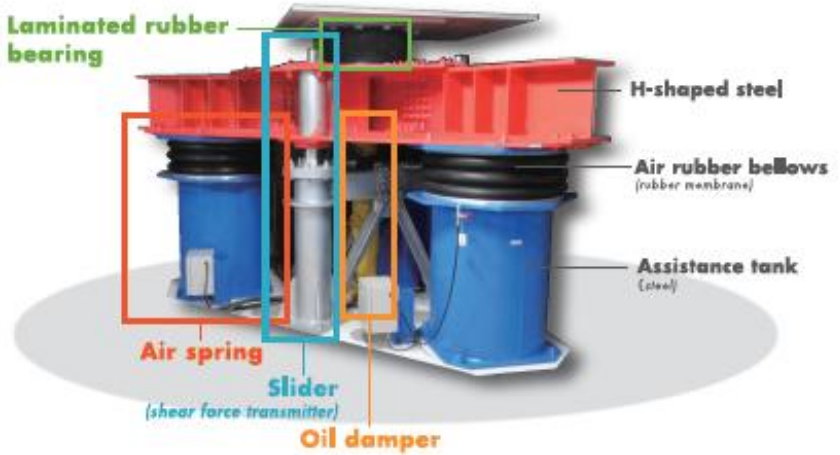
- **Provide complete 3D seismic isolation (SI)**
  - Permit SMR design standardization independent of site seismic conditions
  - Expand siting availability and flexibility
- **Provide greater reliability than other SI options**
  - Separate the function of instantaneous seismic isolation by cavities/orifices from the function of long-term weight support by natural buoyancy.
  - Use few devices and conventional materials of ordinary steel, water and air, making the FSIS relatively simple to design, manufacture, operate and maintain

■ **A FSIS system**



View of a submerged cavity/orifice unit

■ **For comparison: an existing 3D seismic isolation system**



3. Outlines of White Papers (WPs)

WP - “Seismic Design Methodology for Floating Seismic Isolation System (FSIS)”

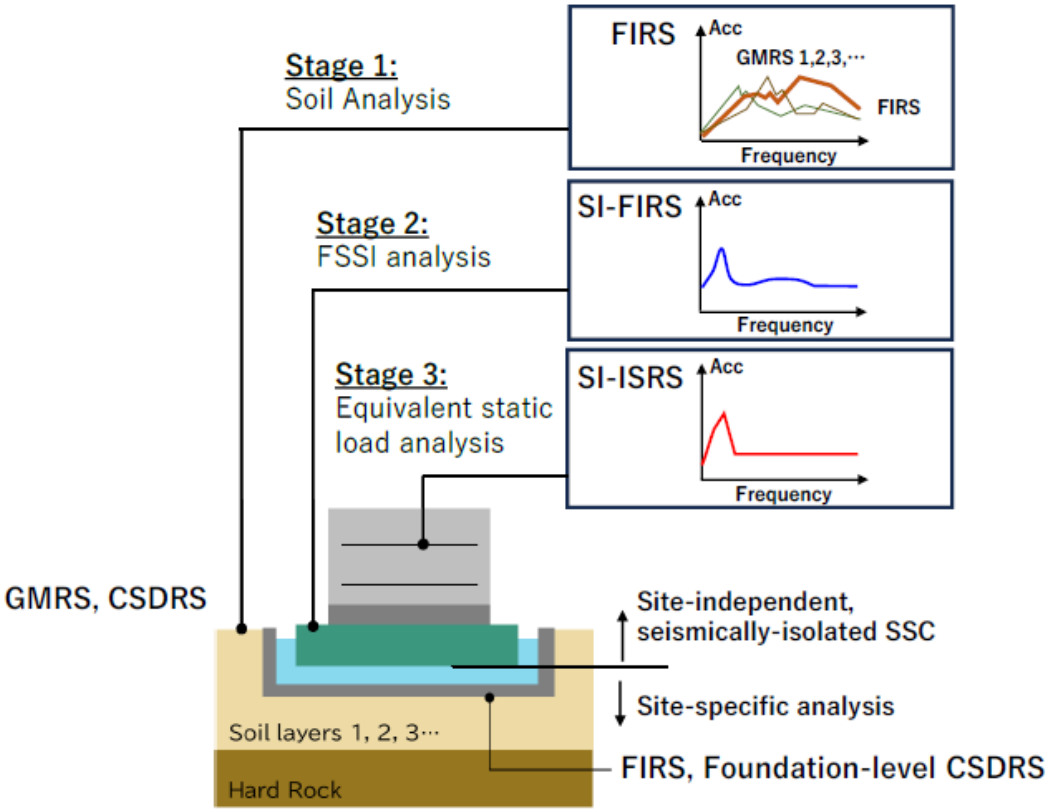
Objective

This White Paper describes a technically rigorous and safety-focused seismic design methodology for the FSIS to support a Standard Design Approval (SDA) pre-application review by the USNRC. Specifically, this document establishes:

- A regulatory pathway, including applicable regulations, guidance, NRC endorsed industrial standards
- A seismic design framework for SMRs pairing with FSIS, a three-stage process and associated design parameters

Technological Basis

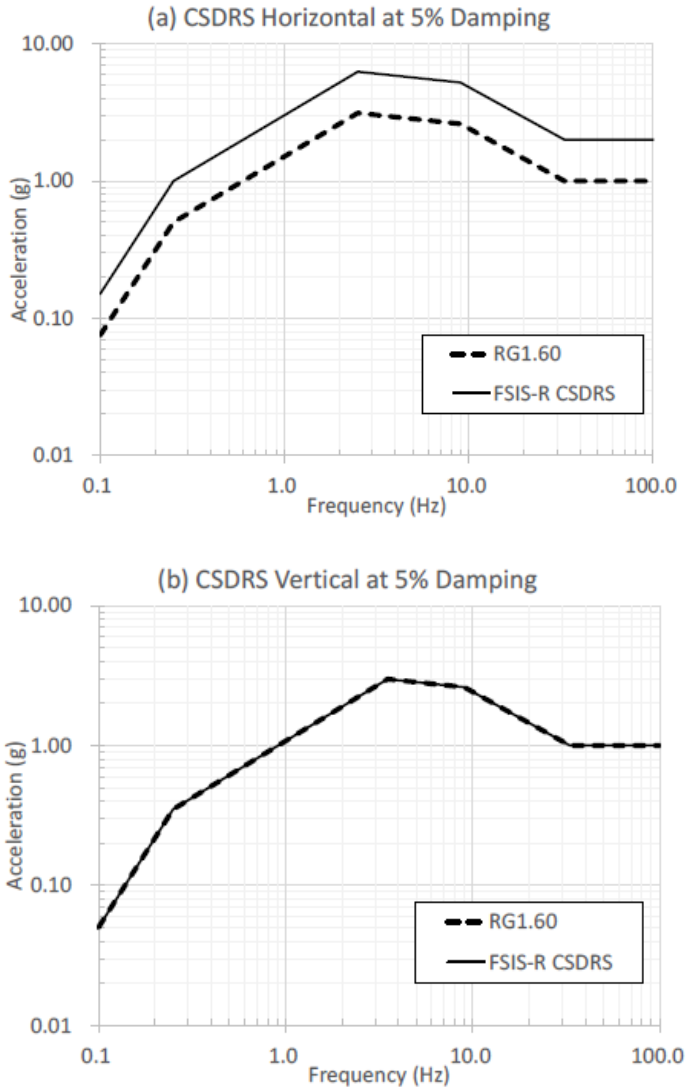
- Derive governing equations of motion and eigenvalue solutions
- Summarize empirical data from three-dimensional, large-scale shaking table tests
- Outline a multistage seismic analysis framework, consisting of
  a. Soil structure interaction (SSI) analysis
  b. Fluid structure interaction (FSI) analysis
  c. Equivalent static load analysis or in-structure response spectral analysis



Multistage seismic analysis framework for FSIS-R

Site Seismic Envelope for FSIS-R Design

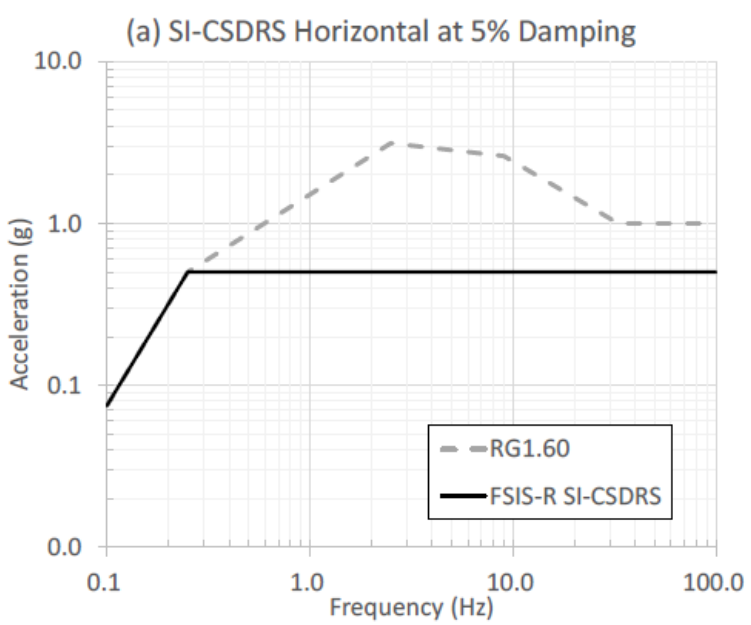
- Define site-enveloping Certified Seismic Design Response Spectra (CSDRS), in accordance with RG 1.60 and RG 1.208
- Select a diverse suite of eight seed earthquakes representative of strong, long period, hard rock, etc. characteristics observed in the US, Japan, and globally for a highly robust and comprehensive representation of seismic hazards, ensuring global siting applicability
- Establish CSDRS-compatible Bounding Design Ground Motion Time Histories and Response Spectra

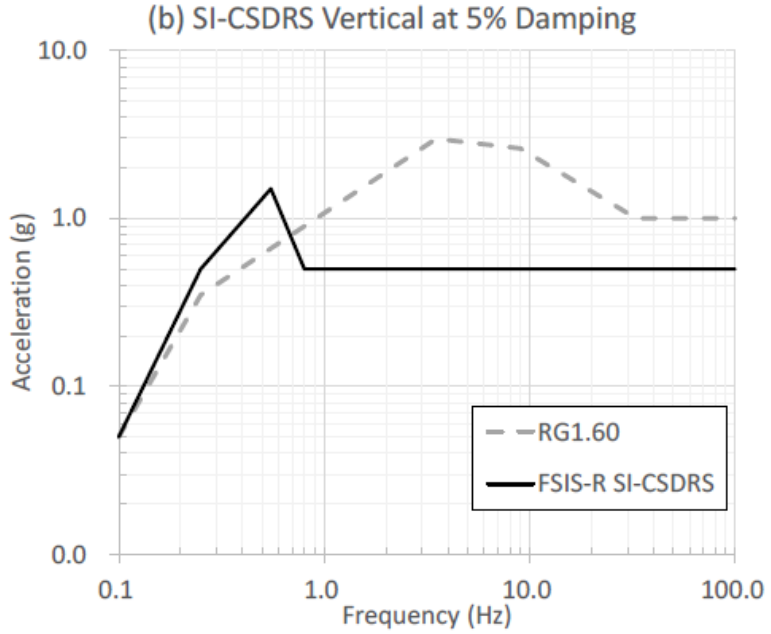


Certified Seismic Design Response Spectra (CSDRS)

Seismically Isolated Response Spectra for the Reactor Design:

- Establish an analysis procedure to define the Seismically Isolated Foundation Input Response Spectra (SI-FIRS)
- Establish the Seismically Isolated Certified Seismic Design Response Spectra (SI-CSDRS) as input for design of reactor plant`s safety-related SSCs





Seismically Isolated Certified Seismic Design Response Spectra (SI-CSDRS)

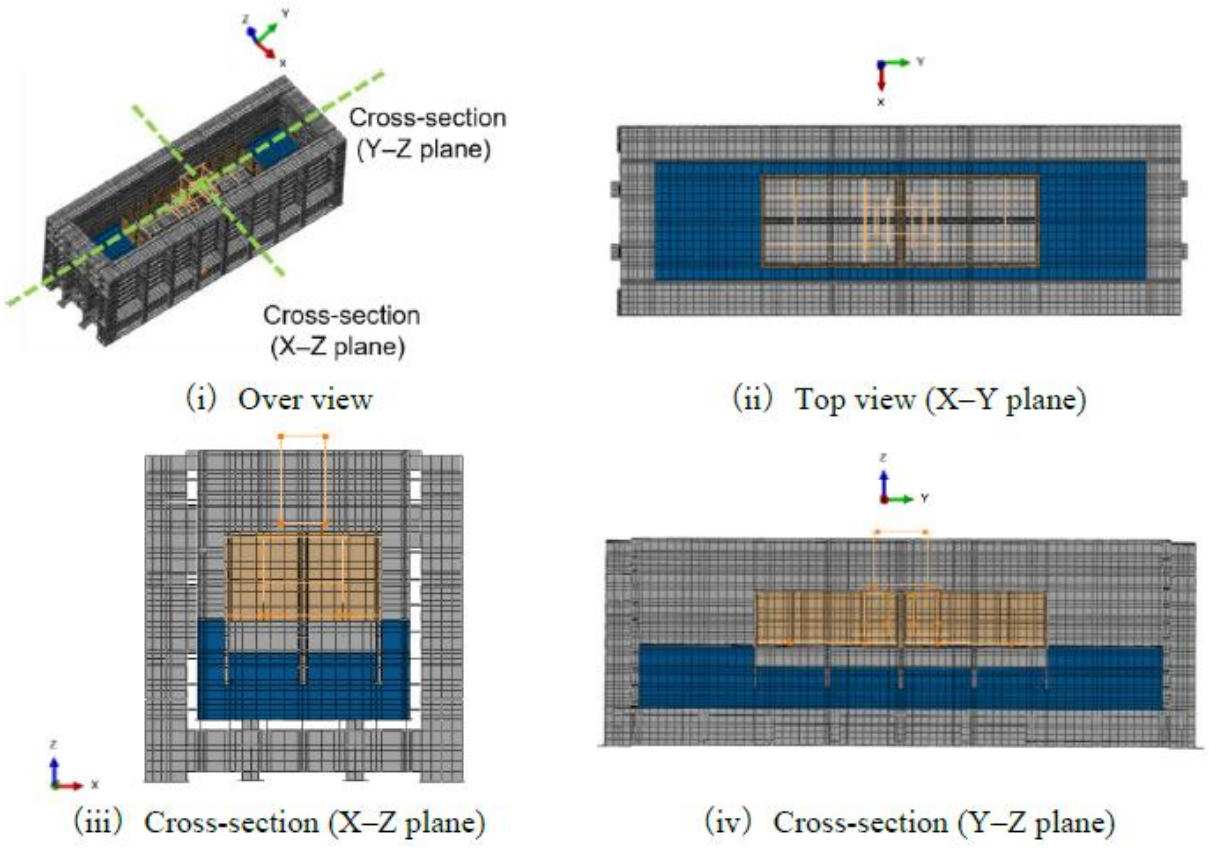
WP -"Validation and Verification of Seismic Analysis Methodology for FSIS-R Plant"

Objective

- Establish regulatory and technical requirements for V&V: Regulations (10 CFR 50 Appendices A, B, and S); Guidance (SRP 3.7.2, NUREG/CR-7253, DC/COL-ISG-017); and consensus standards (ASCE 4-16, ASCE 43-19)
- Develop V&V frameworks for FSIS-applicable FSI and FSSI analysis methodologies - the methodologies are developed to support the seismic design, analysis, and qualification of safety-related structures, systems, and components (SSCs) for the FSIS and the FSIS-R plant system
- Discuss V&V results

Technological Basis for V&V

- Derive theoretical equations of motion, resulting damping, resonant modes
- Present experimental database from large-scale shaking table tests
- Develop FSI and FSSI analysis models using FEM codes of ABAQUS and ACS SASSI

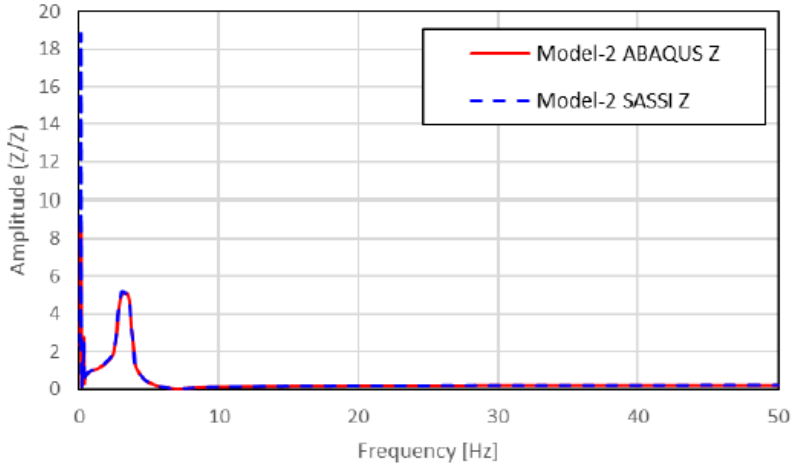


FEM modeled after large-scale FSIS mockup setup
(for benchmark of analysis codes with test data)

Validation and Verification Approach

A three-step sequential finite element V&V execution:

- Step 1 : Benchmark of ABAQUS FSI model with experimental data.
- Step 2 : Benchmark ACS SASSI FSI with ABAQUS
- Step 3 : Evaluate ACS SASSI FSSI methodology, integrating ASCE 4-16 deep-embedment SSI criteria with validated FSI capabilities regarding several FSIS-specific application effects.



A Step 2 Result

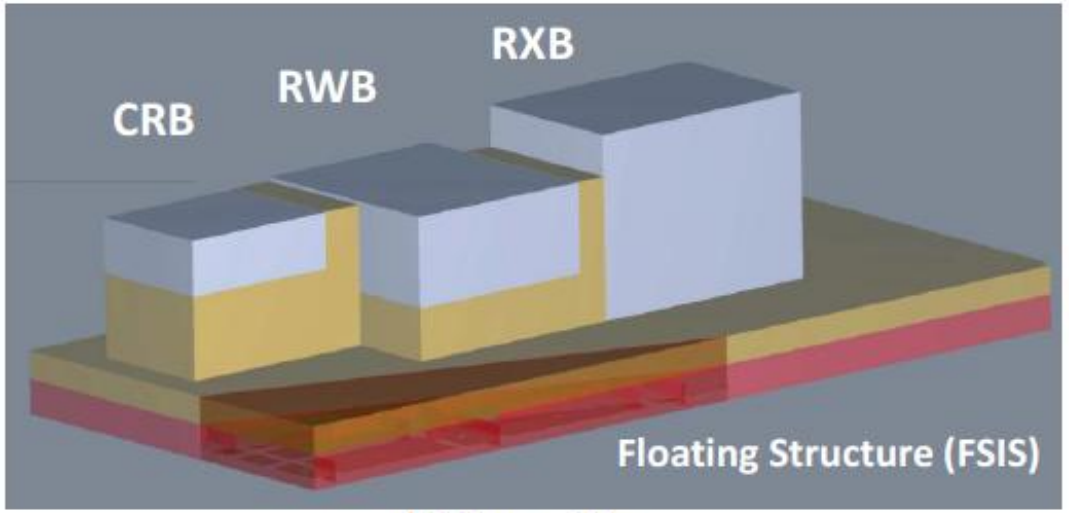
WP -“FSIS-R Plant Preliminary Standard Design Information”

Objective

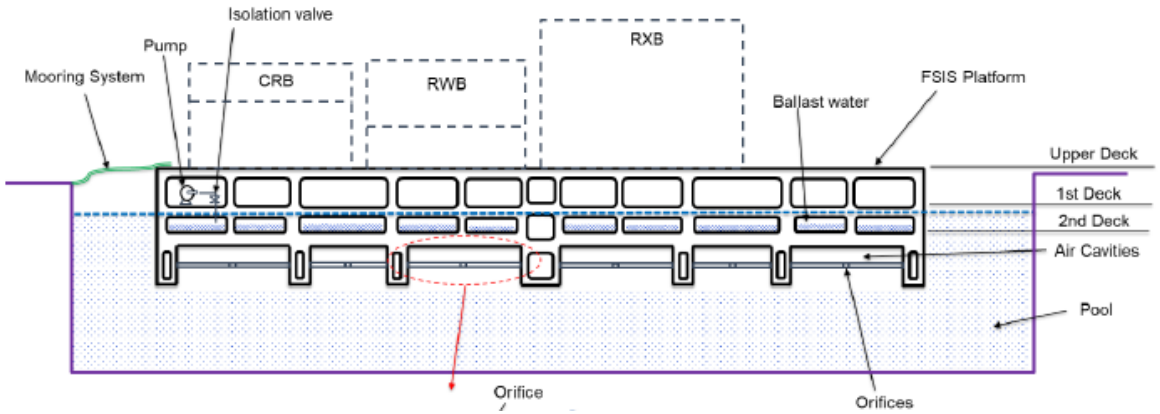
- This White Paper describes the preliminary standard design of the Floating Seismic Isolation System (FSIS) pairing a small modular reactor (SMR), jointly referred as FSIS-R
- The Consortium intends to submit, in accordance with 10 CFR Part 52, an application for a Standard Design Approval (SDA) for the FSIS-R, or for to-be-specified major portions of the FSIS-R
- The White Paper facilitates the ongoing pre-application engagement with the NRC by describing some details of the FSIS-R plant standard design, with the purpose of helping identify aspects of the design that should be further developed to facilitate an efficient review of the SDAA when submitted

Major Contents in the White Paper

- Site parameters
- Design requirements, including a set of FSIS-R specific principal design criteria (PDC)
- Safety and seismic classifications for structures, systems, and components (SSCs)
- Conceptual description of the plant standard design
- Detailed description of structural and seismic isolation designs for FSIS nuclear island (NI) floating platform



Nuclear Island Floating Platform



Cross-section View of NI Floating Platform

Performance Goal : Significantly Reduce Seismic Demands on Reactors

- Site envelope PGA (SSE - Safe Shutdown Earthquake; OBE – Operation Basis Earthquake)

Direction	**SSE**	**OBE**
Horizontal direction	2.0 g	0.67 g
Vertical direction	1.0 g	0.33 g

- Seismically isolated input acceleration levels for reactors supported on FSIS platform

Direction	**SSE**	**OBE**
Horizontal direction	0.5 g	0.17 g
Vertical direction	0.5 g	0.17 g

Major pre-application topics going forward

Topic	Description		Form of Engagement	Date of Engagement
Quality Assurance Program	Topical Report (TR) Quality Assurance Program Description (QAPD) for FSIS Design Activities		Document submittal	March, 2026
			Meeting Web	July, 2026
FSIS Technology Methodology	Seismic Design Methodology: Design requirements, performance basis, site seismic envelope, seismic analysis	White Paper (WP)	Document submittal/Meeting	This week
		TR	Document submittal	Dec 2026
	V&V of Seismic Analysis Methodology: Verification and validation of analysis computer codes	WP	Document submittal/Meeting	This week
		TR	Document submittal	Dec 2026
FSIS-R Standard Design	FSIS-paired reactor (FSIS-R) plant design: Platform structure and reactor integration	WP	Document submittal/Meeting	This week
		TR	Document submittal	2027
	WP: Probabilistic risk analysis (PRA), focused on FSIS-reactor pairing		Document submittal/Meeting	2027
	Draft TR : Safety Analysis Report (SAR) Seismic safety analysis; Analysis of other FSIS-related design and beyond design basis events		Document submittal/meeting	2027
Application Readiness Assessment	WP: FSIS-R design compliance analysis with 10CFR50 Appendix-A GDCs		Document submittal/Meeting	2028