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Overview of Floating Seismic Isolation System (FSIS) Technology for Small Modular Reactors (SMRs) - White Paper on the Design-related Licensing Information, and Draft Licensing Topical Report on Quality Assurance for FSIS Design Activities

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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

Objectives for this presentation

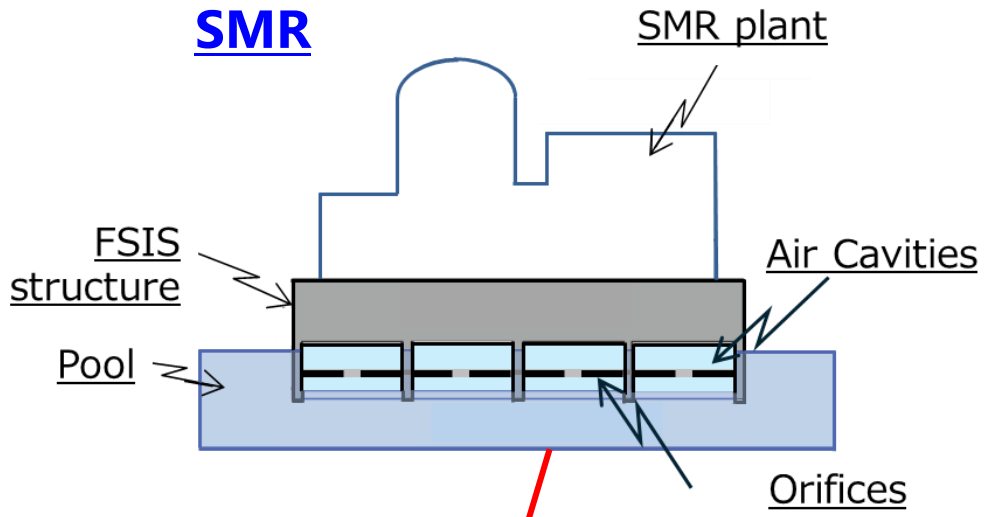
1. FSIS Technology Overview
2. White Paper (WP) : Design-related Licensing Information for the paired FSIS/SMR (FSIS-R) Plant
3. Draft Licensing Topical Report (LTR) : Quality Assurance Program Description (QAPD) for the FSIS Design Activities

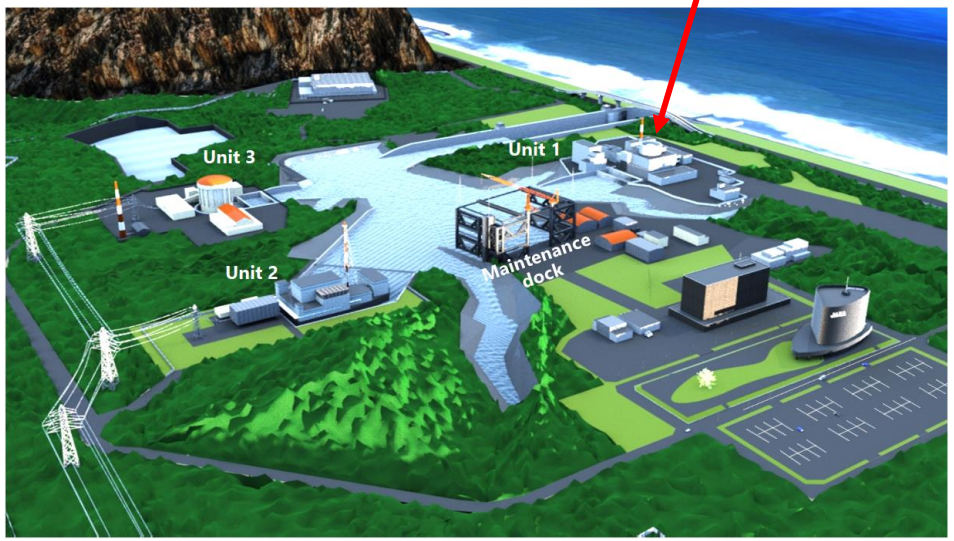
1. FSIS Technology Overview

FSIS Technology Concept

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

A notional FSIS paired SMR





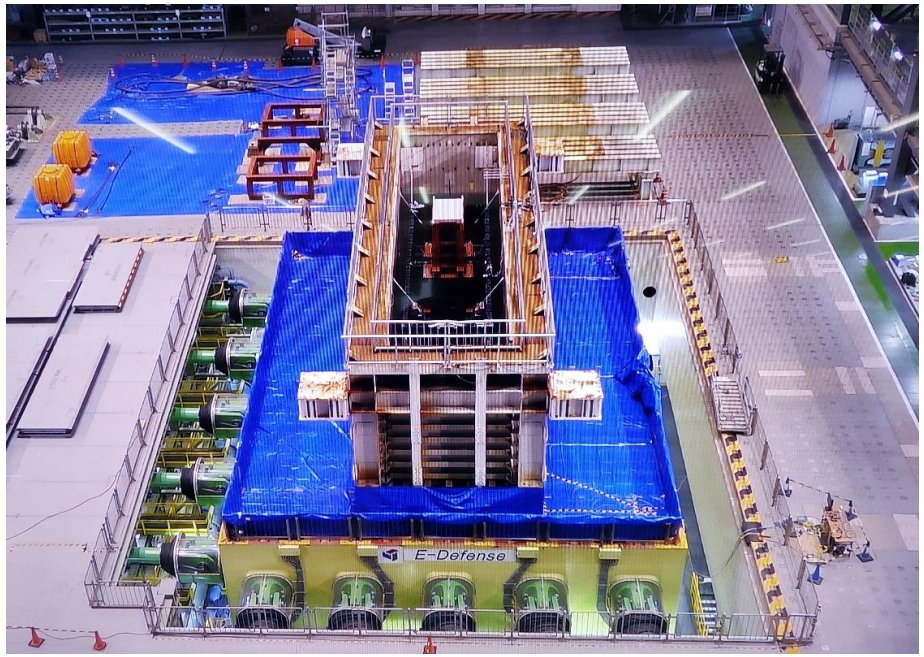
Notional Site Installation of SMR units 1~3

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

Proven Seismic Isolation by Large-Scale Tests

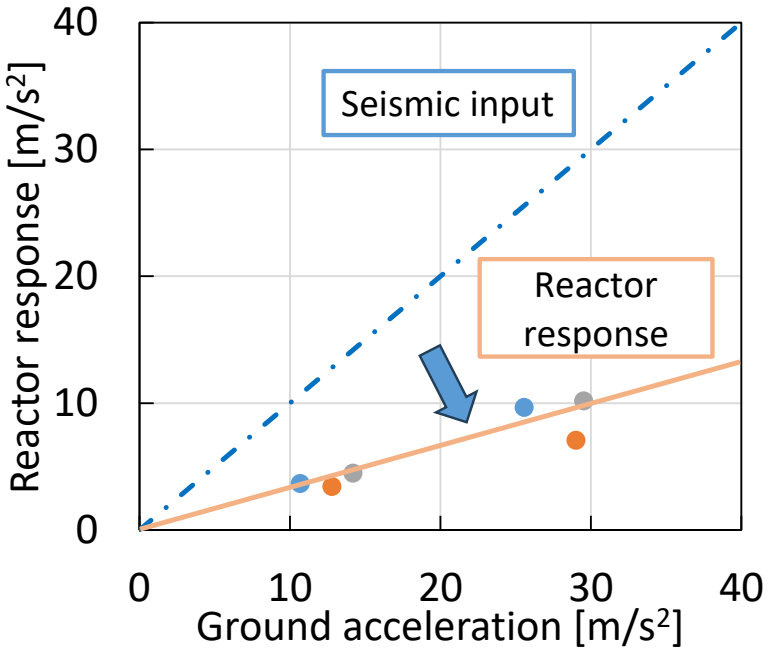
- Tested on a 1/15 scale mockup of the structure of an SMR
- Data applicable to SMR seismic isolation design

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



Sample of test results

Demonstrated significantly reduced seismic response on reactor

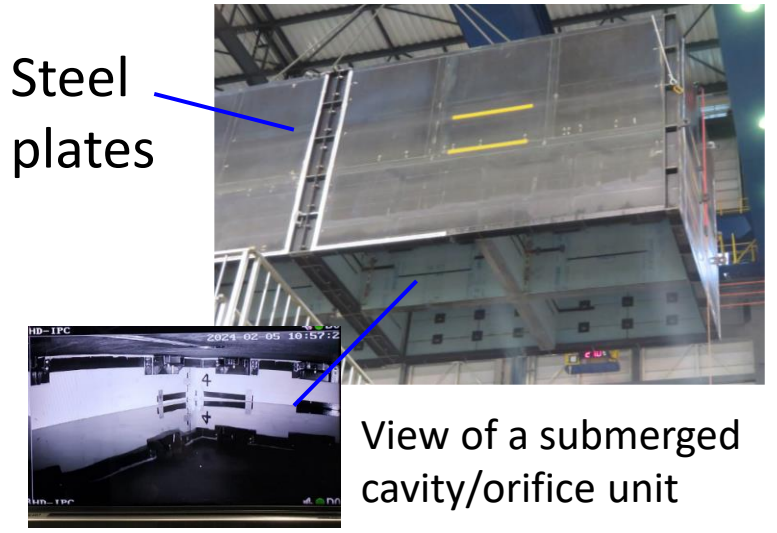


WNN Article:
https://world-nuclear-news.org/Articles/Japan-demonstrates-floating-seismic-isolation-syst

FSIS Benefits for SMR design and safety

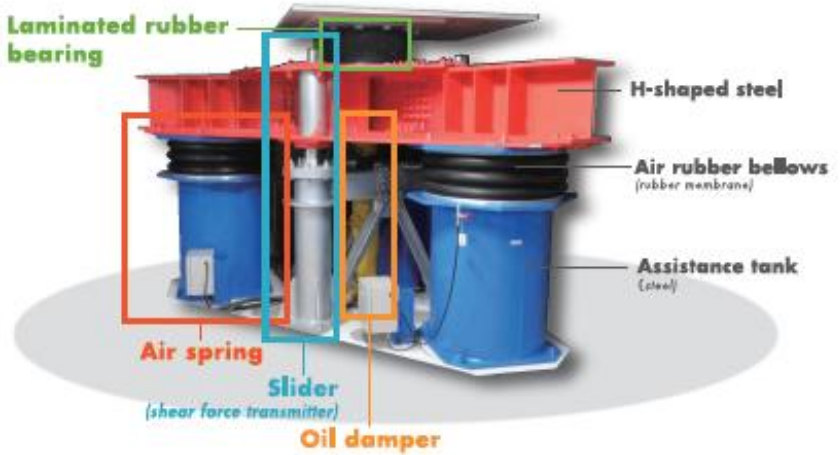
- **Provide complete 3D seismic isolation (SI)**
  - Permit SMR design standardization independent of site seismic conditions
  - Enhance siting flexibility
- **Provide greater reliability than other SI options**
  - Separate the function of instantaneous seismic isolation by cavities/orifices from the 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**

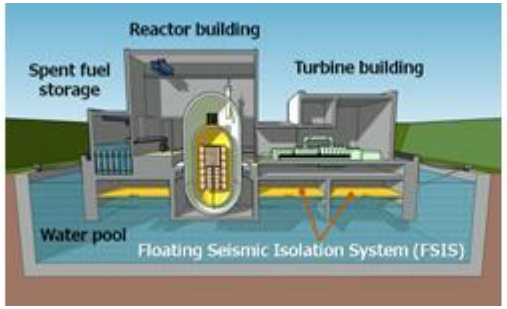


Strategic Approach to FSIS-R Standard Design

Proven Technology

- 3D seismic isolation performance verified by tests on the world's largest shaking table in 2024
- Proprietary technology and reactor interface solutions developed by JAEA and our partner companies

Superior Seismic Safety



- Expand envelope of design base earthquakes to 1.0g vertical direction and 2.0g horizontal direction
- Reduce reactor peak response to 0.5g vertical and 0.5g horizontal direction
- Make static analysis applicable to reactor structure, system, and component (SSC) seismic design

Cost Predictability

- Standardized turnkey plants may be fully built in shipyard and delivered to users
- Factory control of quality, schedule, cost, and inspection, a process that repeats predictably for each plant built
- Significantly reduced lead time due to site-independent design and prefabrication
- Deliverable to coast of 70% of countries worldwide

Siting Flexibility

- Installed, operated and maintained on conventional sites regardless of site seismic conditions
- Modular plants are arranged around a man-made freshwater pool on shore
- More plant modules may be added to meet future demand increase

2. White Paper : Design-related Licensing Information for the FSIS-R Plant

The scope of information provided in the WP includes:

- Design requirements and principal design criteria (PDC)
- Applicable regulatory requirements
- Applicable codes and standards
- Summary-level FSIS-R conceptual standard design
- Planned actions to address design and regulatory gaps in support of issuance of a Standard Design Approval (SDA) for the FSIS-R

Design requirements

In addition to the General Design Criteria of Appendix A to 10 CFR Part 50, the Consortium has identified the following principal design criteria focused on the FSIS and its interface with the paired reactor plant:

1) Safety-related structures, systems and components (SSCs) of the reactor plant are supported on the FSIS floating platform

2) The floating platform provides three-dimensional base seismic isolation in addition to buoyancy weight support and floating stability for the paired reactor plant.

3) The floating structure isolates the SSCs from the ground motion response spectra (GMRS) found in most if not all areas of the Continental United States and elsewhere.

4) Seismic isolation for the SSCs is provided such that equivalent static analysis may be applied with conservatism to them.

5) The pool in which the FSIS-R floats is a non-safety-related system.

Applicable regulatory requirements

The FSIS-R plant is being designed in compliance with the following major regulations :

1) 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities” , with focus on compliance with design-related requirements from Part 50 that are referenced in Part 52 Subpart E Standard Design Approval, or applicable design-related regulatory requirements referenced in NUREG-0800, the Standard Review Plan

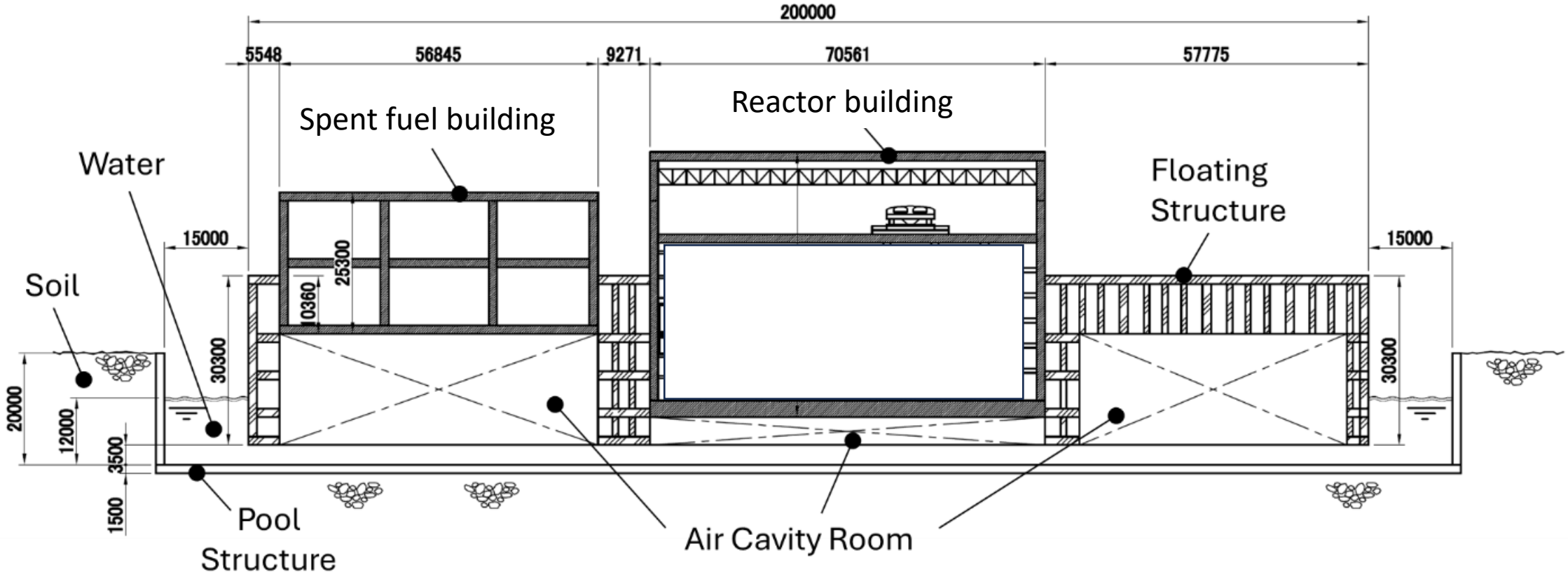
2) 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants” , Subpart E Standard Design Approval

Applicable Codes and Standards

The FSIS-R SSCs are being designed in accordance with the following major industry codes and standards :

1) ASCE/SEI 4-16, Seismic Analysis of Safety-Related Nuclear Structures
2) ASCE/SEI 43-19 “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
3) ACI 349-13 “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary
4) ANSI/AISC N690-18 “Safety-Related Steel Structures for Nuclear Facilities
5) Other applicable standards for design, construction, operation and maintenance for floating structures and ships

Summary-level notional FSIS-R conceptual standard design



Cross-section view of the plant arrangement on the FSIS platform (numbers in the figure are in millimeters)

Seismic Isolation Design Condition

■ Ground motion response spectrum as site seismic envelope

Direction	**DBE (Sd)**	**SSE (Ss)**	**Foundation response Spectra**	Remark
Horizontal direction	1.0 g	2.0 g	1 ~ 33 Hz	Dynamic analysis for seismic design of safety-related SSCs
Vertical direction	0.5~0.7 g	1.0 g	1 ~ 33 Hz	

FSIS Seismic Isolation

■ Seismically-isolated CSDRS level (for SSCs supported on FSIS floating platform)

Direction	**DBE (Sd)**	**SSE (Ss)**	**FSIS response Spectra**	Remark
Horizontal direction	0.3 g	0.5 g	unlimited	• SSCs on FSIS platform appear effectively a rigid body • Static load analysis applicable for design of safety-related reactor SSCs
Vertical direction	0.3 g	0.5 g	≧ 1 Hz	

Planned actions to address design and regulatory gaps

Future planned design-related LTRs and other documents in support of issuance of an SDA for the FSIS-R plant will include:

Submittals	Description	Expected year
Licensing Topical Report	FSIS seismic design method: Design requirements, site seismic envelope, regulations and guidance, codes and standards, and technical bases	2025
Licensing Topical Report	FSIS seismic analysis method: Validation and verification of SSI-based code FSSI for FSIS seismic analysis	2026
White Paper	Probabilistic risk analysis (PRA): Identification of failure modes and sequences for FSIS-specific SSCs, probability and consequence assessment of the identified events.	2026
Draft Topical Report	FSIS-R preliminary standard design: Site envelope parameters, structural design, seismic design and response	2026
Draft Topical Report	Safety analysis report (SAR); Seismic safety analysis; Analysis of other FSIS-related design basis events and beyond design basis events	2027
White paper	FSIS-R standard design compliance analysis with GDCs	2027
Topical Report	Exemptions to be sought	2028
White Paper	FSIS-R SDA application readiness assessment	2028

3. Draft Licensing Topical Report on the QAPD for FSIS Design Activities

The QAPD applies to the FSIS Design Activities affecting the quality and performance of safety-related SSCs, including but not limited to design, procurement, and testing regarding:

(1) Purchase and maintenance of commercial calculation software,

(2) Construction of a model for analysis,

(3) Determination of calculation parameters,

(4) Establishment of analytical procedures for the seismic isolation system, and

(5) Establishment of FSIS design methodologies including FSIS system verification analysis, FSIS design, FSIS-R design, and seismic safety analysis.

Summary: Conformance with NQA-1-1994

- The table summarizes the conformance of the QAP with ASME NQA-1-2017.
- The QAP fully complies with the applicable requirements of ASME NQA-1-2017 without exception.
- Compliance of the QAP with guidance in Section C of USNRC Regulatory Guide 1.28 is also discussed and few exceptions are proposed.

Notes:
- Criteria IX, XIII, XIV are not applicable to SDA applicant.
- The FSIS design does not involve any activities related to Criterion XII.

Criterion	NQA-1 Conformance
Criterion I: Organization	Yes
Criterion II: Quality Assurance Program	Yes
Criterion III: Design Control	Yes
Criterion IV: Procurement Document Control	Yes
Criterion V: Instructions, Procedures, and Drawings	Yes
Criterion VI: Document Control	Yes
Criterion VII: Control of Purchased Material, Equipment, and Services	Yes
Criterion VIII: Identification and Control of Materials, Parts, and Components	Yes
Criterion IX: Control of Special Processes	Not applicable
Criterion X: Inspection	Yes
Criterion XI: Test Control	Yes
Criterion XII: Control of Measuring and Test Equipment	Not applicable
Criterion XIII: Handling, Storage, and Shipping	Not applicable
Criterion XIV: Inspection, Test, and Operating Status	Not applicable
Criterion XV: Nonconforming Materials, Parts, or Components	Yes
Criterion XVI: Corrective Action	Yes
Criterion XVII: Quality Assurance Records	Yes
Criterion XVIII: Audits	Yes