SFR Development in JAEA / US-Japan Collaboration on SFR

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Policy for SFR development

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The government of Japan determined policy for FR development

"Strategic roadmap for fast reactor development" was revised on 22nd Dec., 2022. by the government.

- "Sodium" is the most promising candidate for the fast reactor.
- Schedule for the demonstration plant;

Summer 2023:
Reactor concept and developer are selected.

JFY2024～28:
Conceptual design

～JFY2026:
Fuel technology study

JFY2028:
Decision for transition to basic design and licensing phase

JAEA policy for SFR development

- JAEA strongly contributes to the SFR development.
- JAEA provides technologies and infrastructures to the SFR development.
  - ✓ Evaluation methods
  - ✓ Code & standard
  - ✓ Experimental fast reactor Joyo
  - ✓ Sodium experiment facility
- To demonstrate reduction of HLW volume is an important function of SFR in short term.
- International collaborations are important for promoting R&Ds.
- JAEA pursues nuclear innovations for SFR and by using SFR.
  - ✓ RI production for medical use
  - ✓ New technology development for future FRs

JAEA activities for SFR

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Demonstration SFR development from JFY2024.

- Plant system design
  - ✓ Coordination
  - ✓ To support vendors technically
- Fuel & core design
- Fuel development
  - ✓ Irradiation in Joyo
  - ✓ Transient test in TREAT
- Material test
- Sodium tests
- Experiments for demonstration
  - ✓ Experiments in AtheNa
- Restructuring of supply chain
  - ✓ Cladding, wrapper tube, etc.

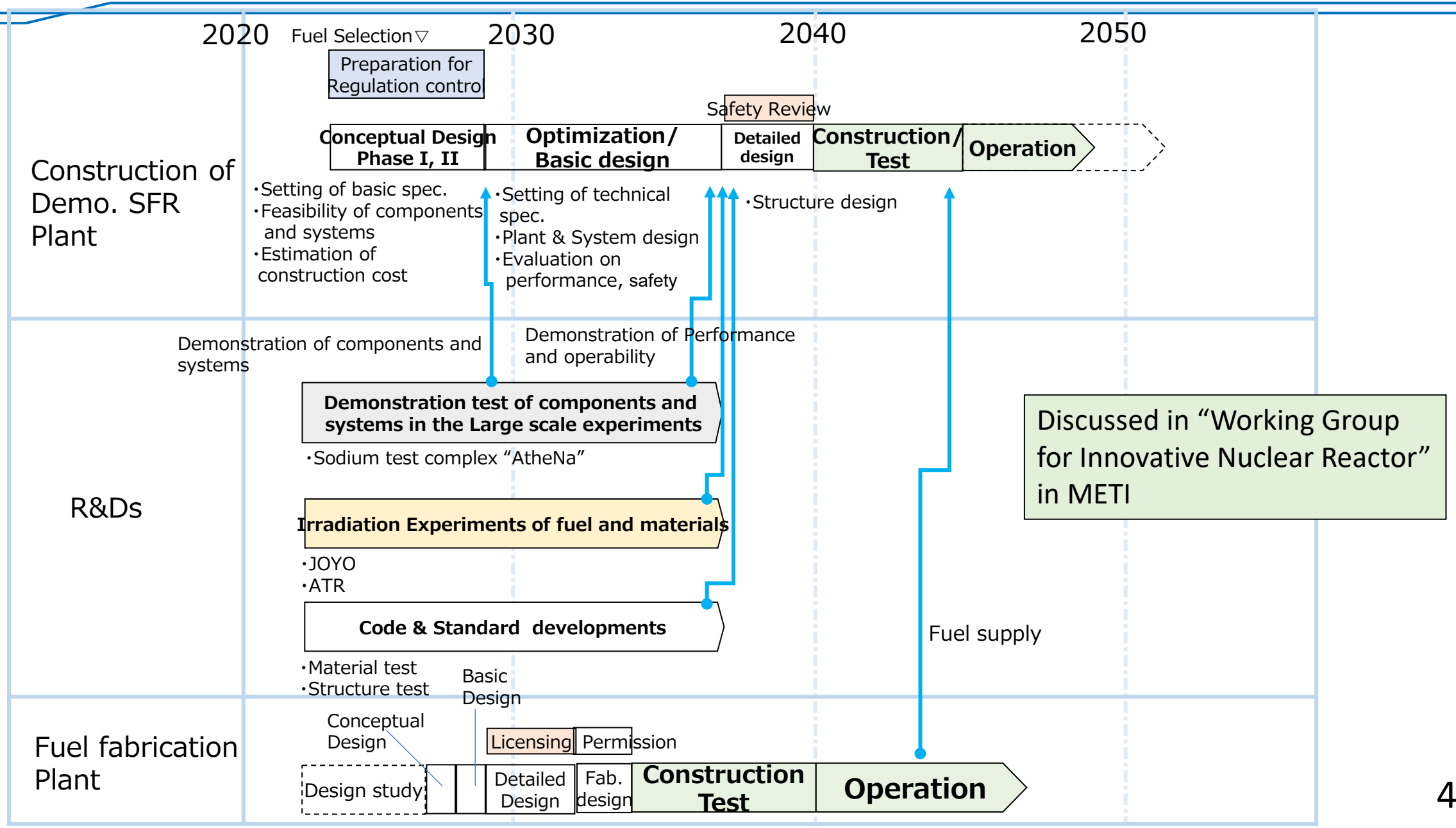
Technologies and infrastructures for SFR R&Ds

- "Joyo" operation restart
  - ✓ MA bearing fuel irradiation
  - ✓ Metal fuel irradiation
  - ✓ Medical RI production tests
- Post irradiation experiment facilities
- Volume reduction of HLW
  - ✓ MA partitioning
  - ✓ MA bearing fuel
- Evaluation methods development
- Codes and standards
- Large scale sodium experiment complex "AtheNa"
- "New" fast neutron irradiation facility study

Nuclear innovations for future

- Medical RI production by SFR
- Integrated energy system study
- 3D printing technology for nuclear fuel
- Floating seismic isolation system

Technical Roadmap for demonstration SFR



JOYO: Licensing approach

- Applications of Safety Assessment Codes
  - Fast Reactor Licensing: “Joyo”

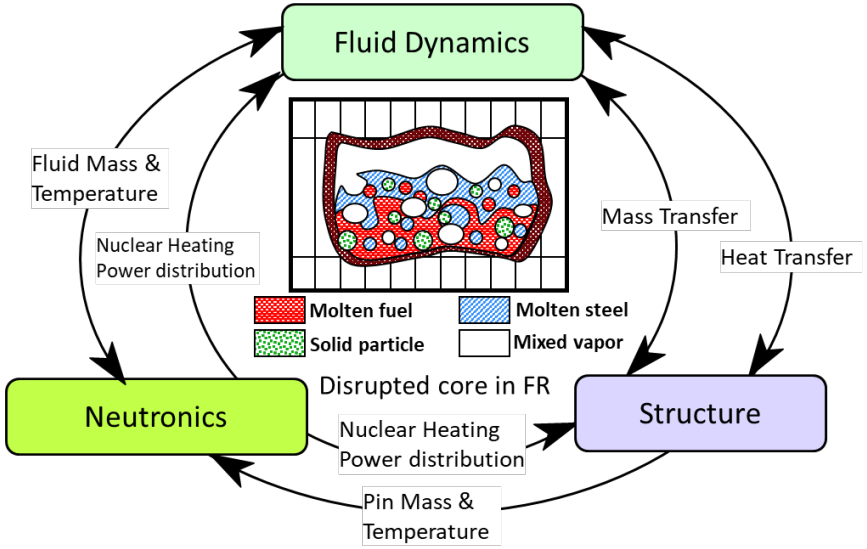
    Expectation of “Permission of Reactor Installation” under “New Regulation“, in the near future
  - Fast Reactor Development
    “Monju” & Future SFR (incl. JSFR)

- List of codes* for Beyond DBA events
  (JAEA original codes underlined)
  - Plant dynamics/Thermal-hydraulics

    Super-COPD, ASFRE, FLUENT
  - Severe Accident

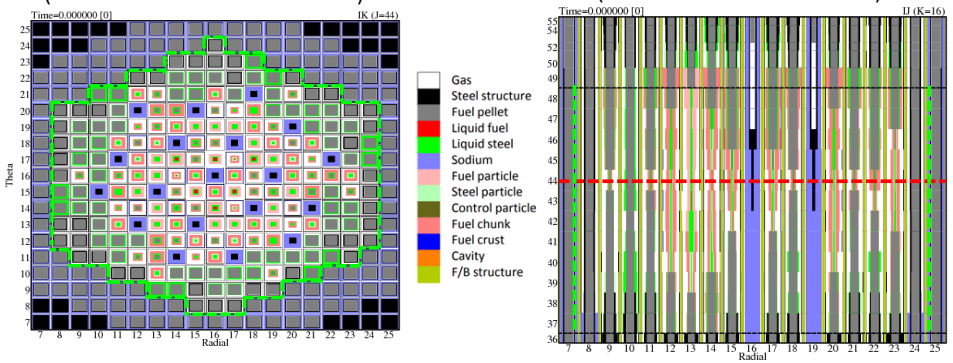
    SAS4A, SIMMER-III/IV, CONTAIN-LMR

SIMMER-III/IV code



Snapshot of accident progression

(horizontal cross-section) (vertical cross-section)



*NRA home page: https://www.nra.go.jp/data/000382064.pdf (in Japanese), dated 2022/Feb./24

JOYO: Irradiation capability and Plan

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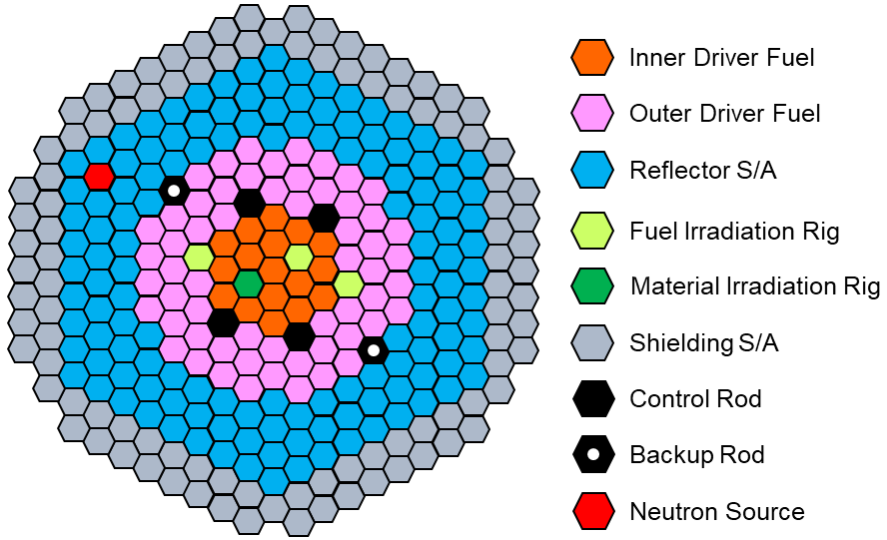
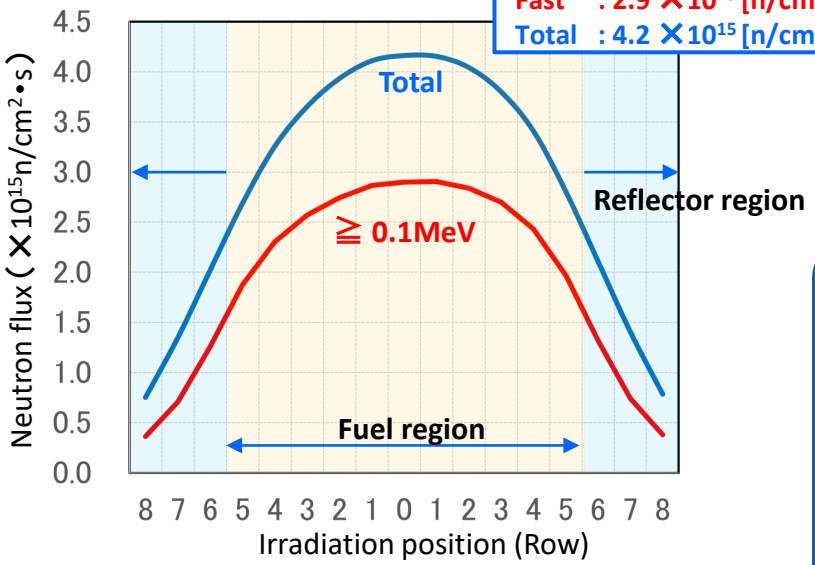
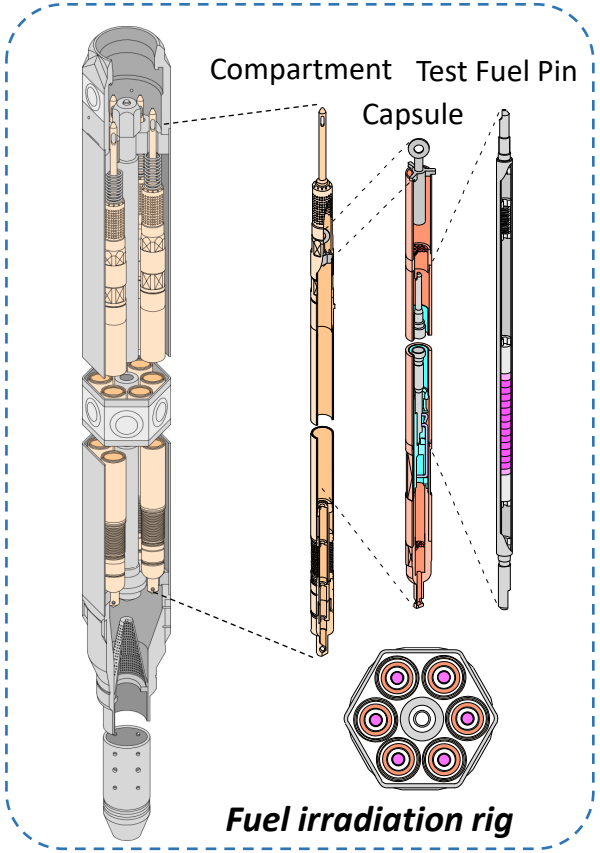


Core configuration of Joyo

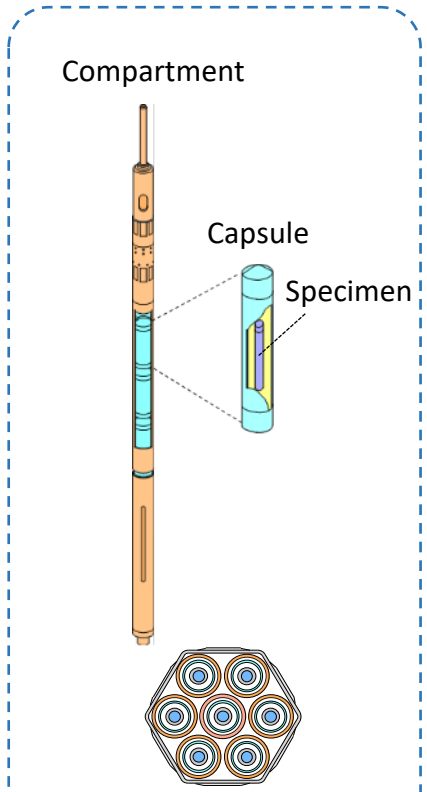
Maximum neutron flux
Fast : 2.9 ×10^{15} [n/cm^2•s]
Total : 4.2 ×10^{15} [n/cm^2•s]



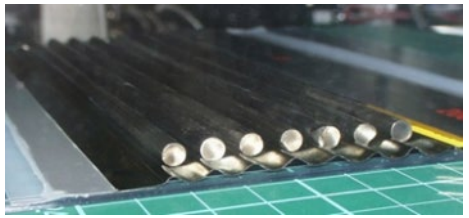
Neutron flux distribution



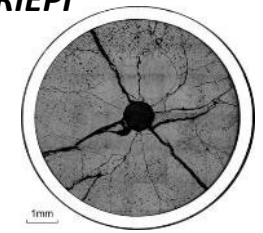
Fuel irradiation rig



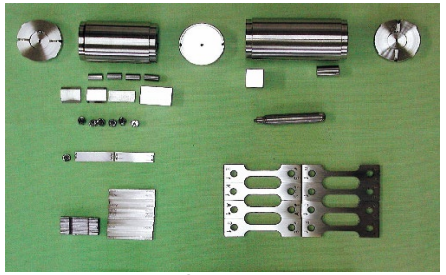
Material irradiation rig



Metal Fuel under collaboration with CRIEPI



Irradiation result of MA-MOX fuel



Material test specimen

Future irradiation test plan

- Various fuel irradiation test for nuclear innovation.
  (MA bearing fuels for high-level radioactive waste reduction, high burn-up fuels, etc.)
- Material irradiation test for FR.
- Demonstration of radio isotope production for nuclear medicine.

MA fuel: SmART cycle (Small Amount of Reuse Fuel Test Cycle)

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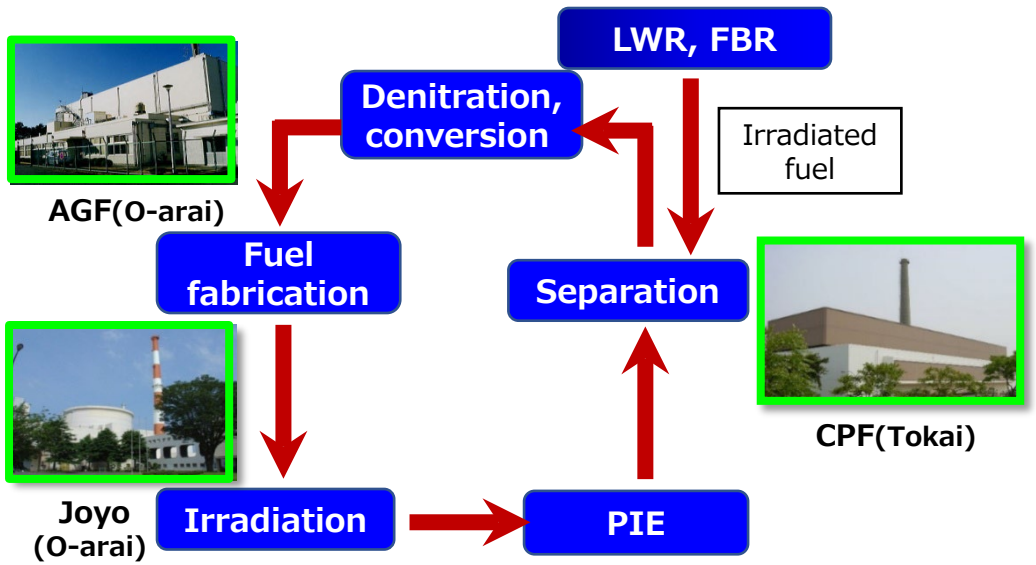
JAEA promotes SmART cycle project which includes MA separation from irradiated fuels and irradiation of the MA-MOX products in Joyo.

【Aim】

- **Separation and transmutation data of MA etc.**
- **Feasibility of small scale of partitioning and transmutation cycle**

Irradiation behavior of MA isotopes in the irradiated MOX will be evaluated for the first time in the world



SmART cycle

【Significance】

- **Effect of FPs on fuel fabrication and irradiation**
- **Effect of MA isotopes on transmutation**
- **Material balance of MA through the cycle**

【MA amounts (plan)】

MA more than 1g is separated from 4 pins of irradiated Joyo fuel

MA yields from irradiated fuel are top level in the world

Recovered MA solution

【Current status】

MA separation of about 2g from the raffinate of extraction was finished at CPF

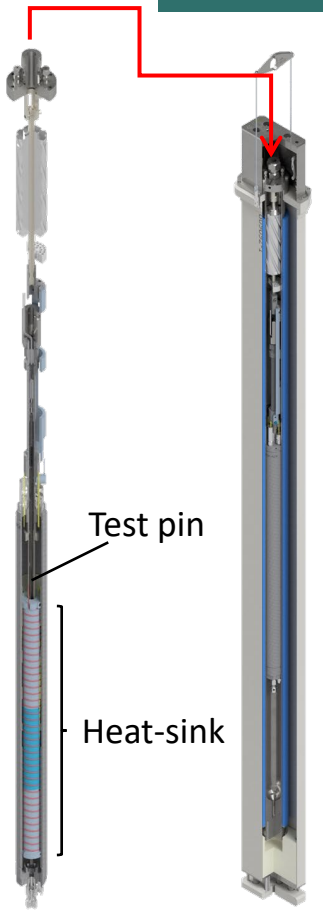
Irradiation behavior of MA bearing fuel is very important to achieve reduction of volume and radiotoxicity of HLW.

Fuel development: Irradiated MOX pin test by TREAT

The experiments will advance global fast reactor fuel safety research and are part of a four-year cost-shared facility sharing initiative being executed between the U.S. Department of Energy (DOE) and Japan Atomic Energy Agency (JAEA) under the Civil Nuclear Energy Research and Development Working Group.

ARES project:

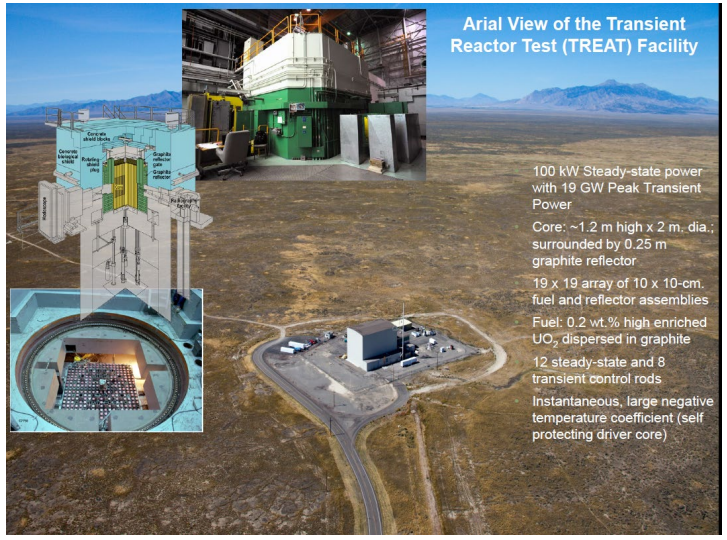
- The purpose of this project is to develop a threshold for fuel-cladding mechanical interaction (FCMI) in irradiated oxide fuels.
- This threshold will be applied during the design of future irradiation experiments that may be conducted in Joyo, and to qualification of oxide fuels for future commercial Sodium Fast Reactors (SFRs).
- 2 MOX annular fuel pins (UW02009, UW02011) irradiated in EBR-II up to high burnup over 100 GWd/t in 1980's to 1990's under the DOE-PNC collaboration are selected as transient test pins in TREAT.
- Specific to the ARES project, the MOXTOP capsule fabrication has been completed as well as three commissioning experiments using fresh metal fuels.
- Assembly of the first MOX test capsule has been started to support MOXTOP testing in late March, 2023.



THOR-MOXTOP capsule

MOXTOP test pins irradiated in EBR-II

Test ID	Fuel	Cladding	Smear Density (%)	Pellet Density (%)	Burnup (at%)
MOXTOP-1 (A,B) (UW02009)	Annular $(U,Pu)O_2$	PNC-1520	80	94	13.7
MOXTOP-2 (A,B) (UW02011)					13.4
Sister pin PIE (UW06024)		PNC-FMS			13.5



Codes and Standards Development

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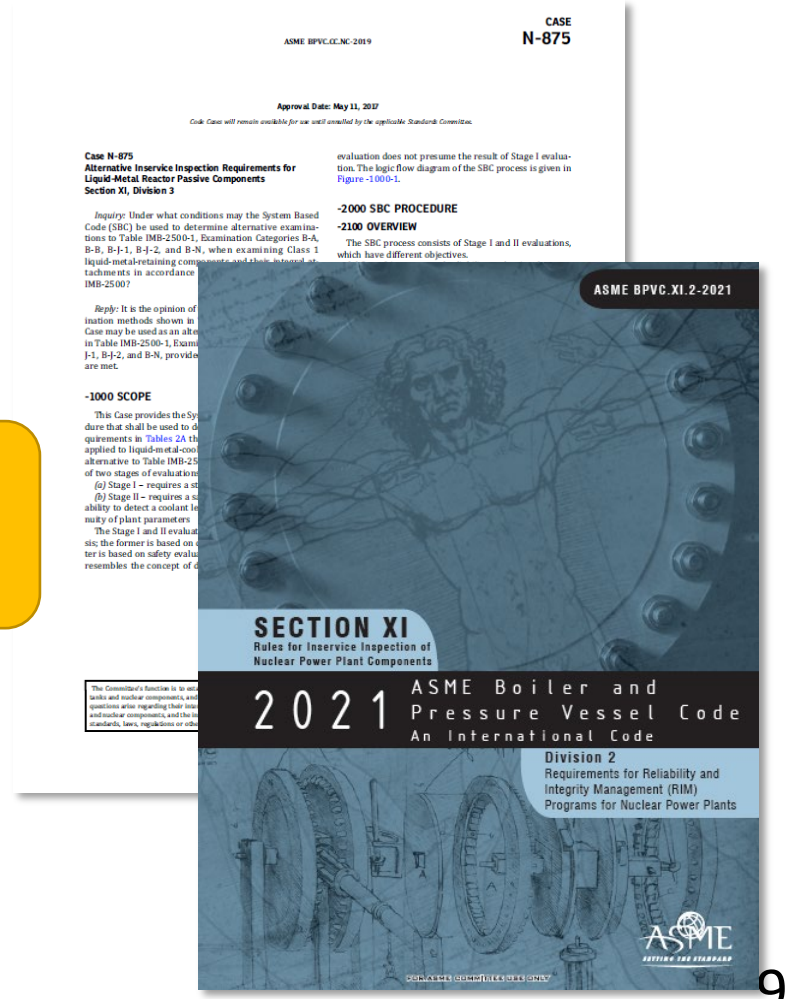
JSME and ASME are actively collaborating on code and standards development for advanced reactors . JAEA is working to facilitate collaboration between JSME and ASME

- A state-of-the-art in-service inspection methodology for liquid-metal-cooled reactors was developed by a JSME/ASME Joint Task Group and issued as an ASME Code Case in 2017.
- The concept of “reliability target” in the Case was incorporated into the 2019 Edition of ASME BPV Code Section XI that the U.S. NRC endorsed in 2022

The first ASME Code to implement “reliability target” that allows for more reasonable inspection strategies taking advantage of the enhanced safety features of advanced reactors



✓ *The methodology is consistent with **the technology-inclusive, risk-informed, and performance-based approach**, and would enhance it to explicitly cover the structural aspects of advanced reactor design and maintenance*

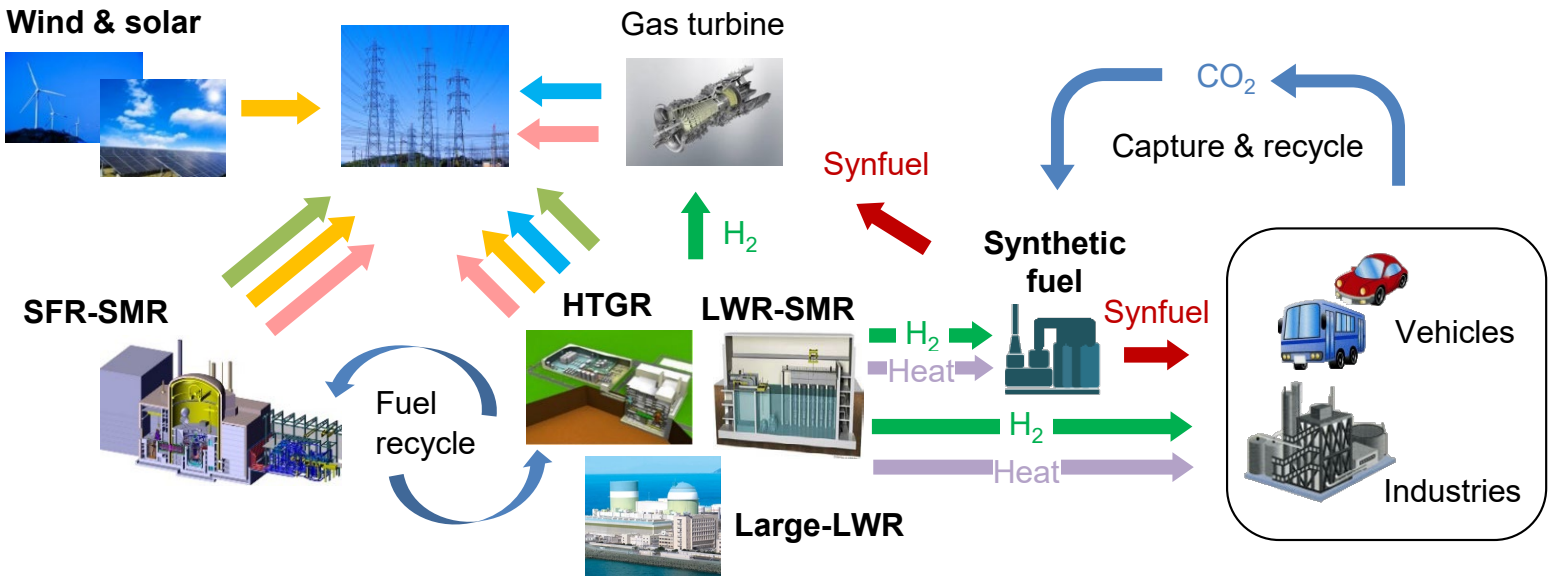
Nuclear Innovation: Sustainable Energy System with HTGR & SFR

■ Objective

- Underscore nuclear energy roles for resilience and net zero with renewables
- Highlight synergy between HTGR (heat, hydrogen, load follow) and SFR (fuel recycle, base & peak load with heat storage)

● Power Grid Resilience

● Net Zero



■ National projects

1. Modeling and simulation for assessing electricity and energy supply best mix scenarios
2. Development of an IES test facility to assist in design and licensing

● Nuclear fuel cycle sustainability

kW：Supply capacity
kWh：Power generation
ΔkW：Power adjustability
Moment of inertia

SMR: Small Modular Reactor

Nuclear Innovation: FSIS and 3D printed fuel

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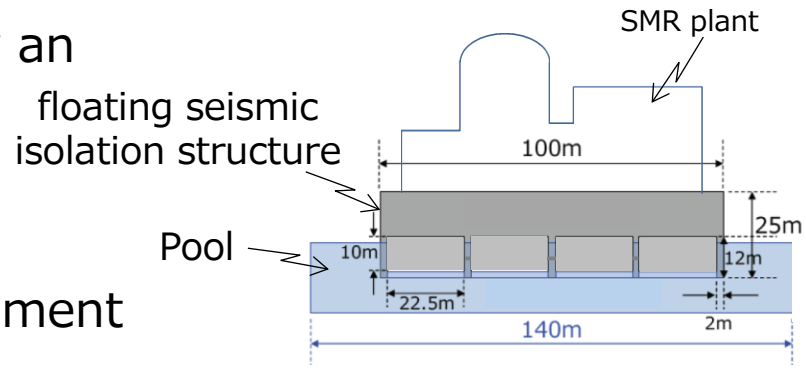
Floating Seismic Isolation System (FSIS)

Development goals

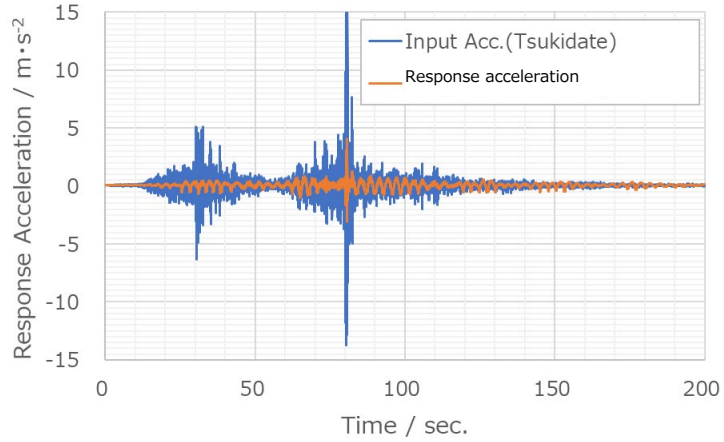
- Three-dimensional seismic isolation
- Reduction of seismic acceleration by an order of magnitude
- Improve safety and standardization

Development project funded by METI

- Large-scale (1/10 SMR scale) experiment and safety analysis code
- Design evaluation & regulatory discussion



Blue : Seismic wave
Orange : Response by FSIS



Seismic isolation performance:

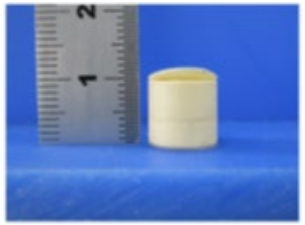
3D printed fuels

Development goals

- A common technology of ceramic 3D printing for SFR and HTGR fuels
- Improving manufacture efficiency and cost

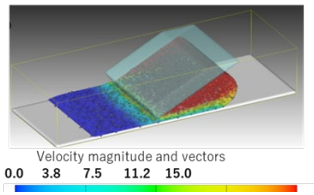
Research funded by MEXT

- Multi-scale multi-physics 3D printing experiment and simulation modeling

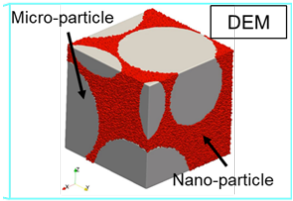


SFR MOX (CeO_2) printed fuel pellet

HTGR SiC/C functionally graded printed fuel matrix



Fuel slurry motion simulation



Nano/micro particles mixing/sintering

Collaborations between US-National Labs. & JAEA

On-going collaboration(CNWG);

- Fast Reactor Materials
- Advanced Reactor Modeling and Simulation
- Metal Fuel Core
- Metal-Fueled Fast Reactor Accident Analysis
- Advanced Fuels: Properties, Performance and Analysis, Transient Test
- Waste Treatment and Electrochemical Reduction

Prospected collaboration areas;

SFR development

- MA bearing fuel production and irradiations
- Advanced fuels and materials irradiations
- Metal fuel and core

Nuclear Innovations

- Seismic isolation
- Integrated energy system study
- Restructuring of supply chain