

Current status of Sodium cooled Fast Reactor Developments in JAEA

Sodium Experiments

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Strategic Roadmap of FR Development

5 years (Evaluation)

10 years

2019~

Innovative technologies to be collected from the public to advance fast reactor concepts (Phase I)

Study of selected design concepts (Phase II)

Development of Technology Base

1. Integrated evaluation method (a risk-informed system for plant life-cycle design) including design support tools.

2. Codes & standards to be met by design by making practical use of the evaluation system.

3. Safety technologies that rapidly improves the safety of fast reactor design concepts.

- R&Ds for selected design concepts
- Global standardization to be promoted
- Design basis to the concepts to be provided

↳ Regulatory bodies

Experiments and studies using irradiation test facilities (e.g. Joyo), PIE facilities, hot labo, **AtheNa, and liquid metal test facilities**

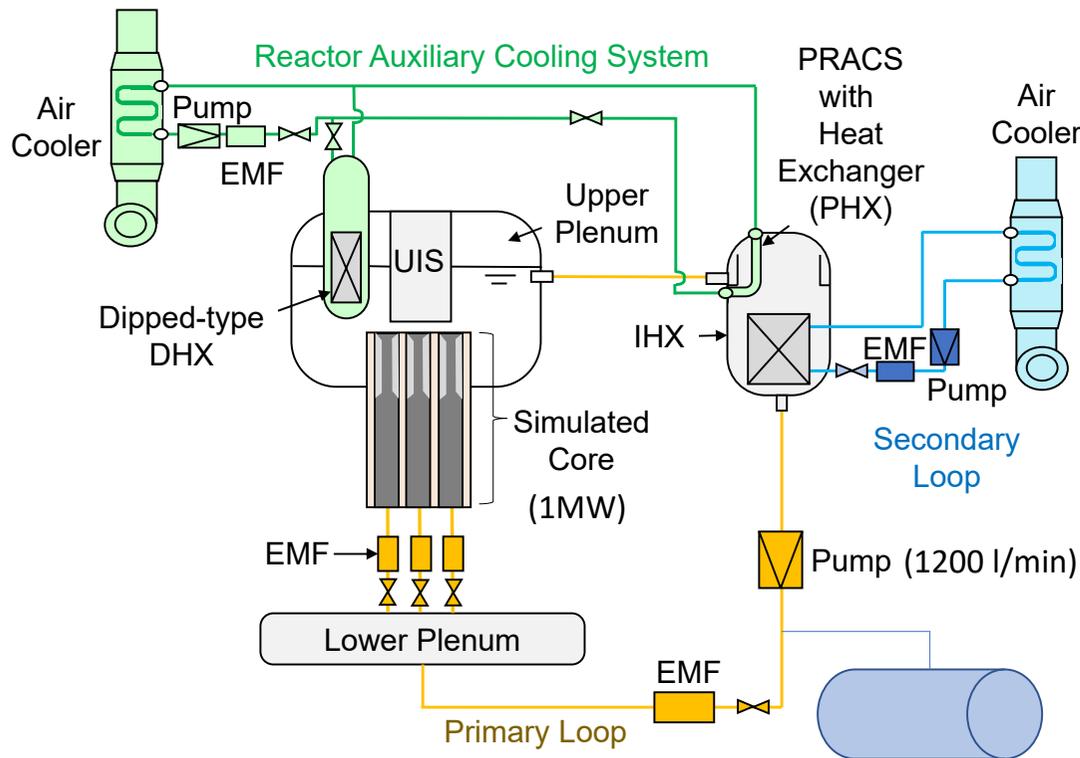
Global standardization

Development by joint works

Bilateral collaborations on R&D of Major Technologies of FR; Evaluation methods, Safety measures, System and component designs

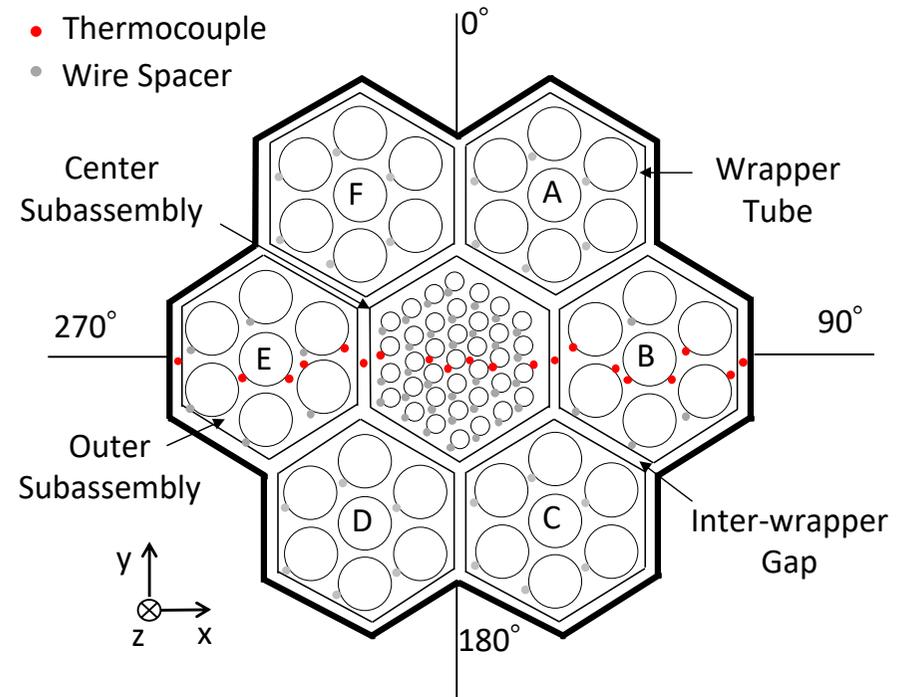
GIF, IAEA: international standardization of codes and standards, safety design criteria

- ❑ Sodium test facility with major components and circuits in SFRs
 - ✓ Sodium Loop: 4 inch. pipe diameter, 1200 l/min of EM pump, 20t of sodium
- ❑ Evaluation of core thermal hydraulics during decay heat removal under natural circulation condition
 - ✓ Cold sodium from DHX flows into subassemblies and inter-wrapper gap



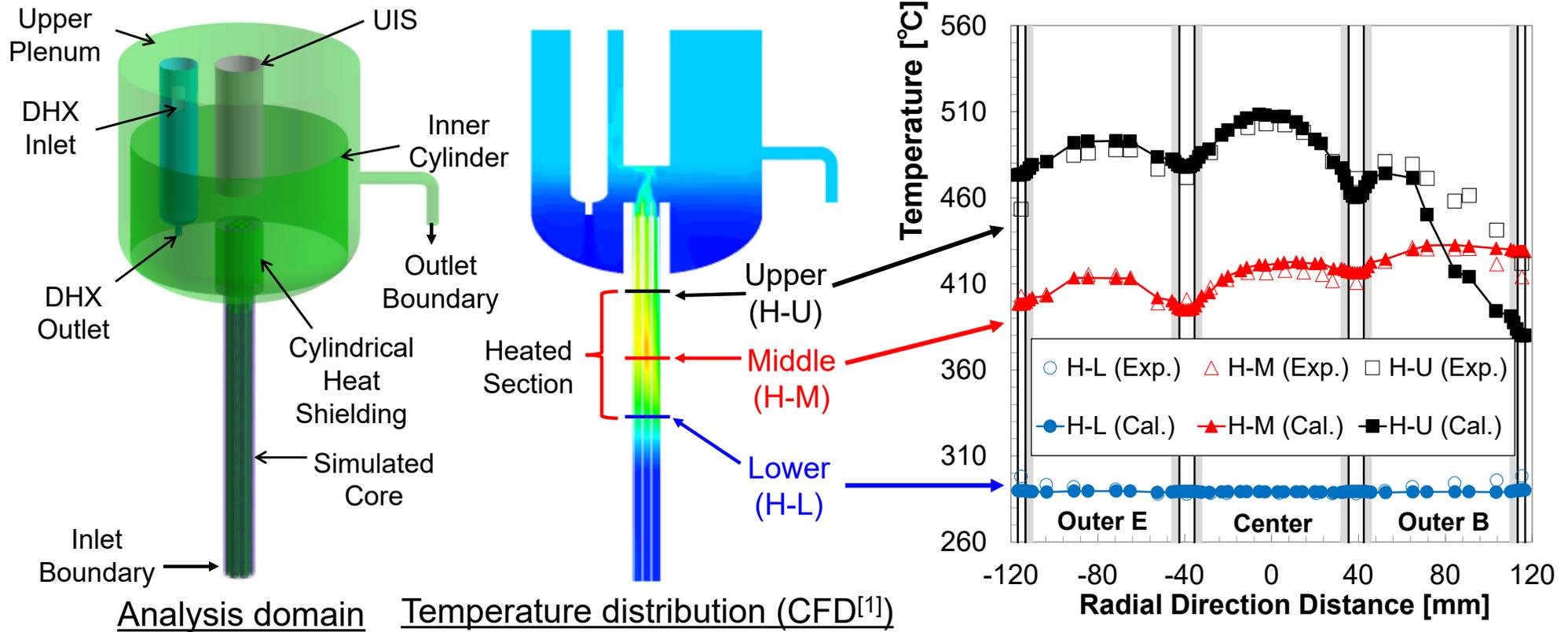
PLANDTL-1 test loop

Dump Tank (20t of Na)

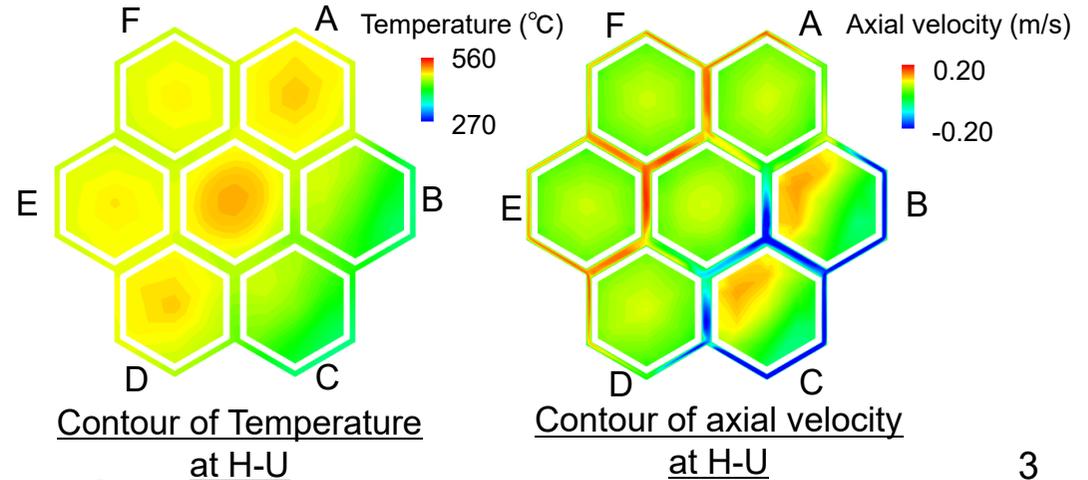


Transverse cross section of simulated core

3-D numerical modeling for RV using CFD code (FLUENT)



- ✓ Calculation conditions
 - DHX operation
 - Power: 2.0% of rated conditions
 - Flow rate: 1.0% of rated conditions
- ✓ Core temperature distribution can be predicted.



- PLANDTL-2: Test section was modified to simulate the core in PLANDTL facility.
 - Sodium experiments have been performed from 2017.

2m Diameter of Sodium Plenum

100mm

300mm

DHX

T/C Tree

Heat Transfer Tube

Inside of Upper Plenum

Test Section

Top of the Simulated Core

Heated Channel

Non-heated Channel

- ✓ Core - upper plenum thermal interaction
- ✓ Multiple rows of core cooling behavior with Inter-wrapper flow
- ✓ Temperature distributions obtained from 500 of thermocouples

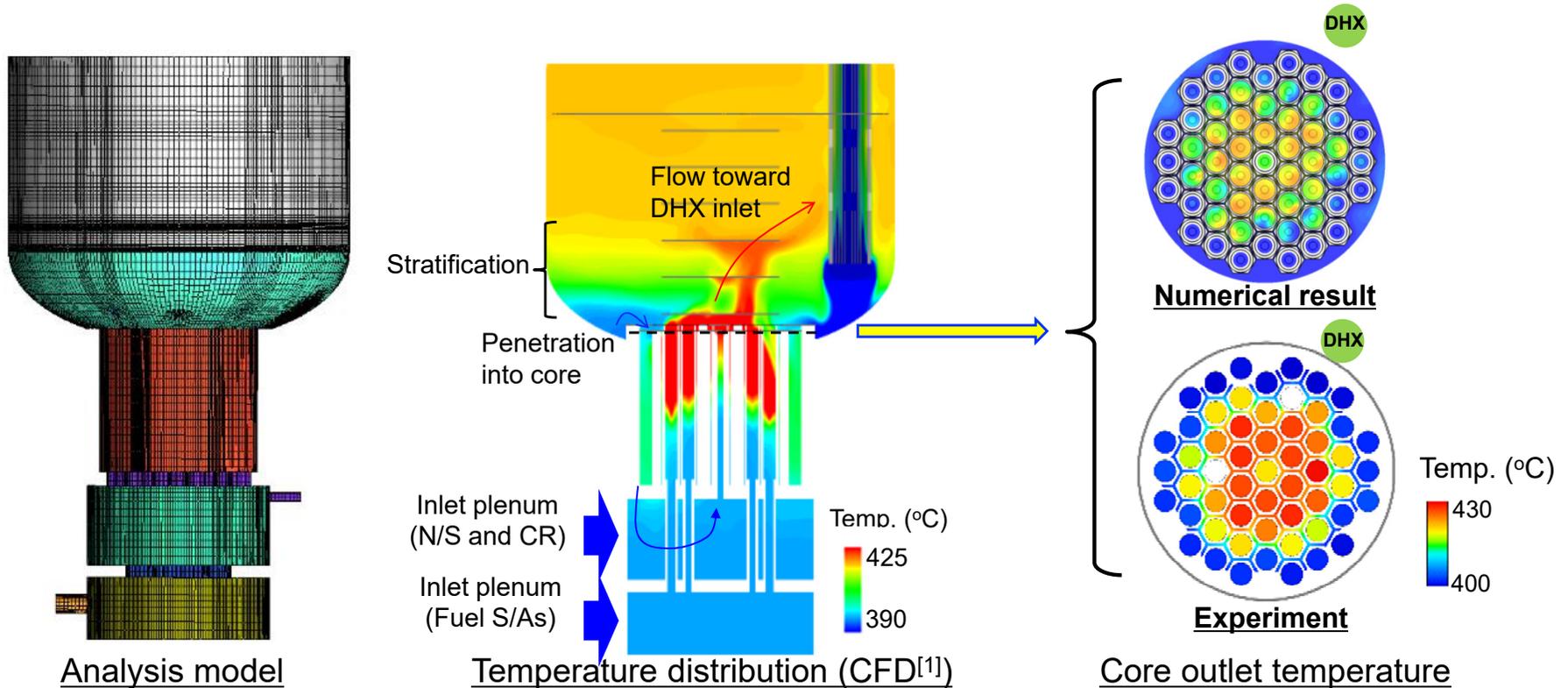
□ Preliminary analysis using CFD code (FLUENT)

● 3-Dimensional numerical modeling for

- ✓ Core: Core - upper plenum thermal-hydraulic interaction with inter wrapper flow
- ✓ DHX: Modeling of multiple heat transfer tubes

(Detailed tube modeling was applied as the reference in below.)

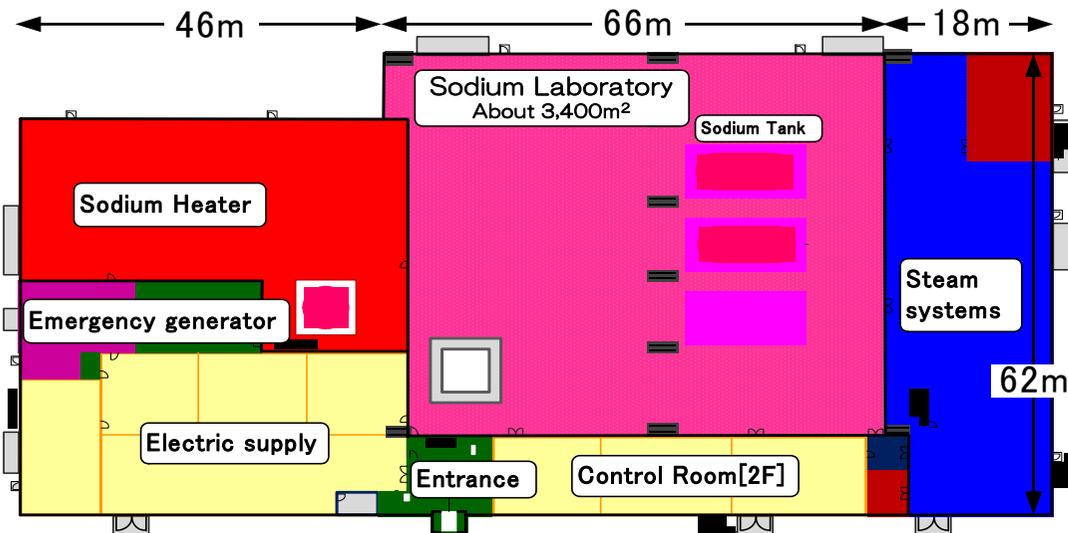
➡ Validation work using PLANDTL-2 data is now on-going.



The Large Scale Sodium Test facility for the Component development & demonstration

Facility Specification

- Dimension: 130 m x 62 m x 55 m
- Cranes: 120 & 100 ton
- Sodium inventory: 240 ton
- Temperature range: ~600°C
- Sodium heater: 60 MW at maximum



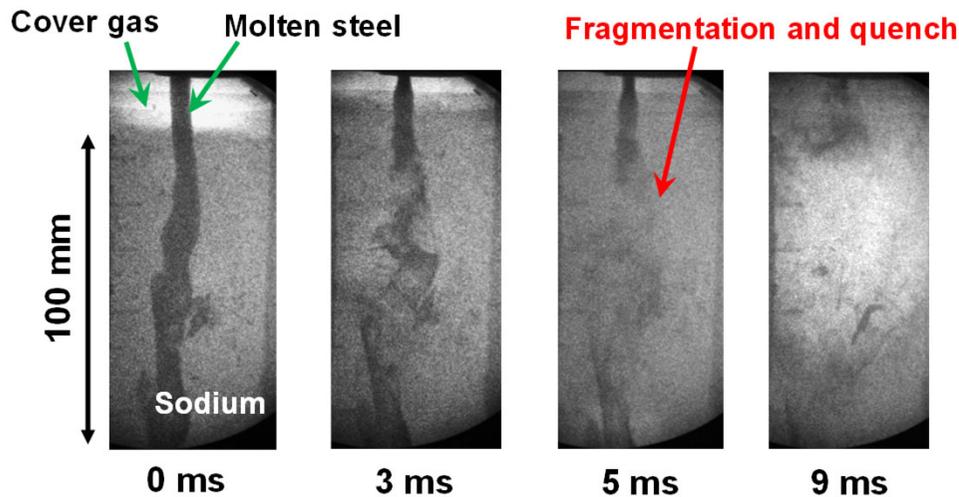
Layout of AtheNa facility

- **“Mother loop”** is available for utility functions, such as sodium storage, charge, drain, and purification. Construction of the sodium heater is on going.
- Expected test items in AtheNa
 - Safety related experiments,
 - Component development and demonstration
 - ✓ Various types of Heat Exchanger, SG, Pump, etc.
 - Verifying heat transfer, flow stability...

➤ Safety

MELT:

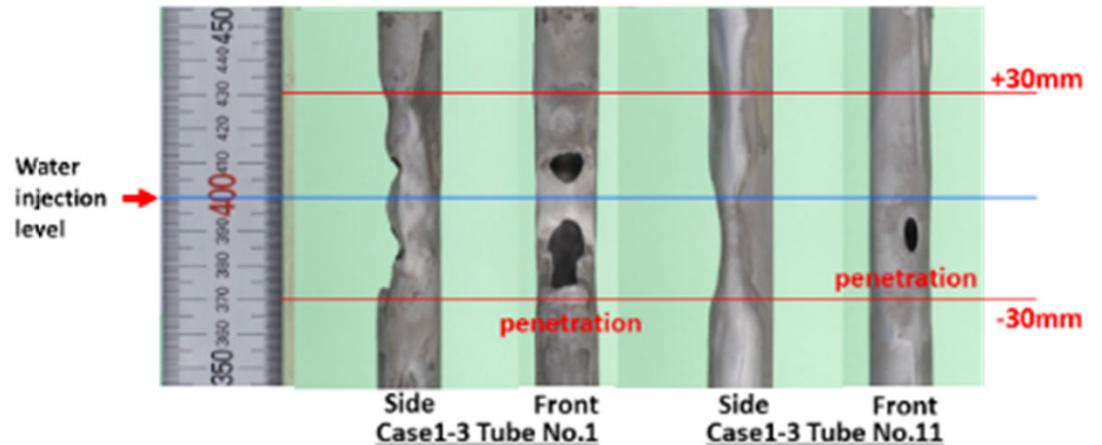
Utilized for experimental studies to clarify the molten-core material behavior during severe accidents of SFR



X-ray images of melt behavior in sodium

SWAT-3R:

Sodium-water reaction (SWAT-3R) test facility with reaction vessel simulating SG



Example of Test results : Penetrating failure tubes

➤ Others (ISI, seismic)

SERF: Sodium Engineering Research Facility (SERF) for technology development of advanced inspection, sodium handling, and so on.

Dynamic test facility: need to be refurbished to perform test

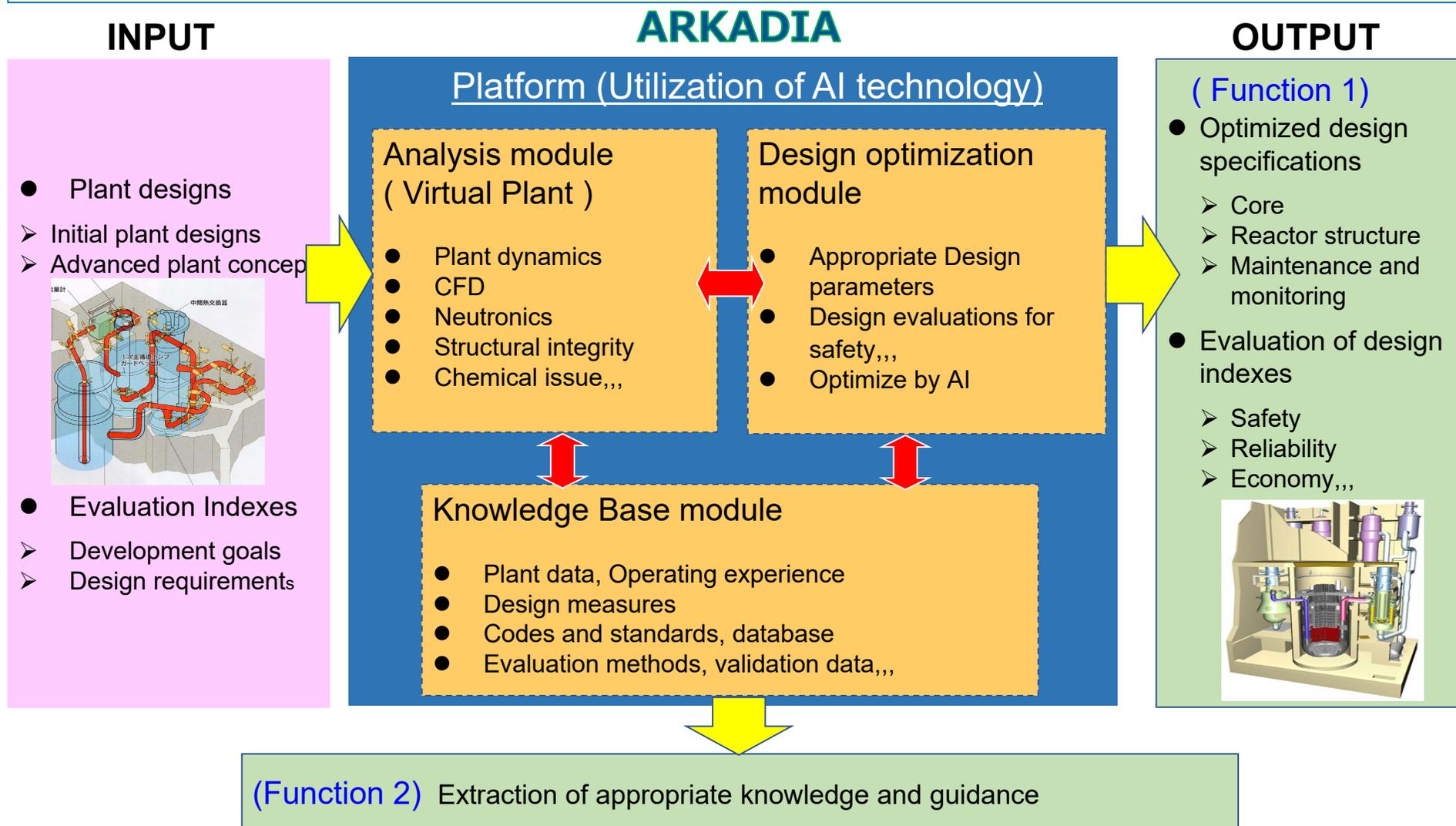


ARKADIA

Advanced Reactor Knowledge- and AI-aided Design Integration Approach through the whole plant lifecycle

Objectives

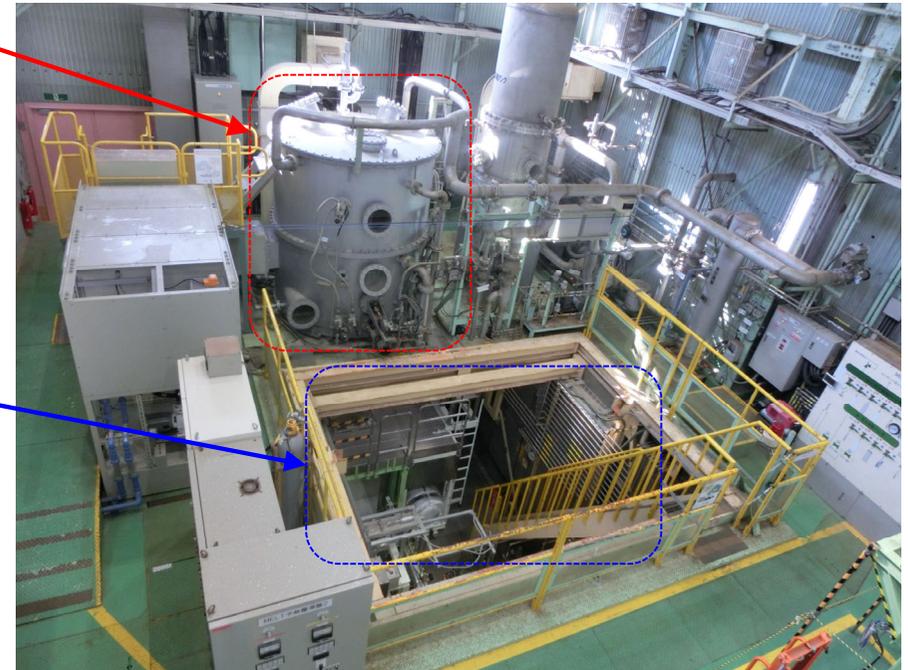
- Design efficiency improvement for plant lifecycle optimization
- Knowledge management to support design innovation and technology transfer



- Sodium experiments for SFR developments are on going.
- Several sodium test facilities are available.
 - AtheNa: component tests
 - PLANDTL-2: core thermal hydraulics
 - MELT: melt behavior in severe accidents
 - SWAT-3R: sodium-water reaction,
 -
- Design support and evaluation method
 - ARKADIA: Advanced Reactor Knowledge- and AI-aided Design Integration Approach through the whole plant lifecycle
 - Validation based on the experiments through the international cooperation
- International cooperation using R&D facilities is significant for the SFR developments.

Appendix

- The purpose of the MELT facility is to experimentally investigate the phenomena that occur at the discharge of molten core materials from the core region during core disruptive accidents in sodium-cooled fast reactors.
- This facility consists of the melting section and the test section to perform various types of experimental studies.
- The **melting section** is capable of melting 20 liters of materials such as alumina and stainless steel at the highest temperature of 2300 °C by the induction heating furnace, which is installed inside the cylindrical containment vessel.
- The **test section** is located in the basement and allows the high temperature melt to react with structures or sodium.
- An X-ray imaging system with high speed camera is available for the visualization of transient phenomena in the test section.



Overview of the MELT facility

Simulation of secondary cooling system
and reaction product release system in real plant

- ❑ Sodium inventory : 15 ton
- ❑ Design temperature/pressure :
 - Max. 555 °C / 1.96 MPa (sodium system),
 - Max. 400 °C / 24 MPa (water/steam system)
- ❑ Maximum flowrate of sodium : 2.3 m³/min
- ❑ Reaction vessel (simulated SG)
 - Inner diameter : 1.3 m,
 - Height : 7.7 m





Sodium circulation loop system



Multipurpose Test cells

■ R&D programs in SERF

- ✓ *In-service inspection and repair technologies for SFRs*
- ✓ *Decommissioning and dismantling technologies for MONJU and future SFRs*
- ✓ *Studies about chemical reactions of sodium including the case of severe accidents*



Glovebox test benches



Miniature sodium Circulation loop system