Chunghwa Nuclear Society
2024 Annual General Meeting
December 16, 2024

NuScale VOYGR™ technical features and safety

December 16, 2024

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Resources, Energy & Environment Business Area
IHI Corporation

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1. Overview of IHI

Company Profile

Year of establishment
1853

Number of employees
(consolidated)
28,237

Business Development Bases
(As of April 1, 2024)
21

Capital
107.1 Billion yen

Works
6

Group companies in Japan
60 [Subsidiaries: 41 Affiliates: 19]

Revenue (Consolidated)
1,322.5 Billion yen
(fiscal 2023)

Branches in Japan
8

Overseas Group companies
135 [Subsidiaries: 113 Affiliates: 22]

Business Area of the IHI Group

Resources, Energy & Environment Business Area

Contribute to carbon-free and recycling societies by providing optimal integrated solutions for each region and customer

- Power Systems
- Carbon Solutions
- Nuclear Energy

Large-scale tower type boiler

Social Infrastructure & Offshore Facilities Business Area

Contribute globally and across life cycles to materialize safe and secure social infrastructures, centered on bridges and tunnels

- Bridges and Water Gates
- Transport Systems
- Shields
- Concrete Construction Materials
- Urban Development

Osman Gazi Bridge across Izmit Bay

Industrial Systems & General-Purpose Machinery Business Area

Contribute to industrial infrastructure progress by thoroughly optimizing operational lifecycles with customers

- Turbochargers for Vehicles
- Parking System
- Rotating Machinery
- Heat Treatment and Surface Engineering
- Materials Handling System
- Logistics and machinery

Turbochargers for vehicles

Aero Engine, Space & Defense Business Area

Leverage advanced technology to open new vistas for air transportation, defense systems, and space utilization, and help materialize social comfort and safety

- Aircraft Engines
- Rocket Systems and Space Exploration
- Defense Equipment and Systems

GEnx turbofan engine

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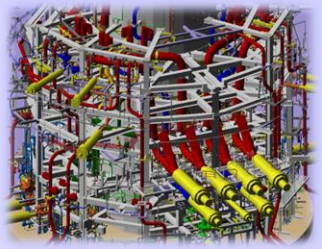
IHI nuclear business for Total & Global solutions

- *Track Record in Nuclear field - for 70 years*
- *One Stop Supply Chain - Engineering to Installation*
- *Solution for Nuclear Lifecycle - New Build to Back-End*

NPP Components & Engineering

BWR

Reactor Pressure Vessel



System Engineering

PWR

Containment Vessel

Structural Module

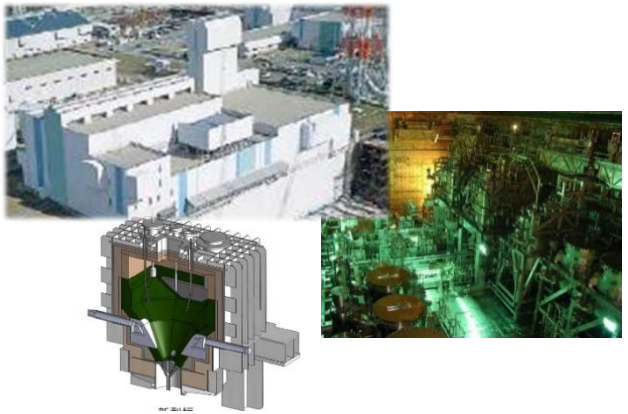
【Photo Source: Southern Nuclear Operating Company Website】
https://vogtlegallery.georgiapower.com/

Operation & Maintenance

Primary Piping Replacement

Nozzle-Shell Weld Inspection Service

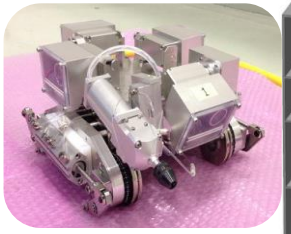
Nuclear Fuel Cycle Plant



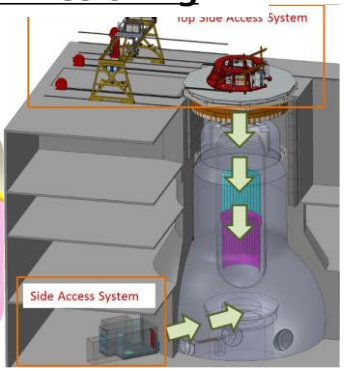
HLW Vitrification & Storage Facility

De-Contamination & De-Commissioning

Source :
Proceedings of WM2015,
Fukushima Inspection Manipulator – 15485



Remote Equipment



Fukushima Fuel Debris Retrieval

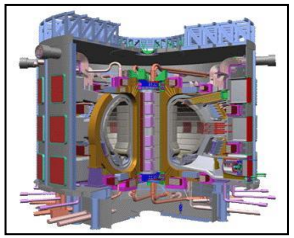
Source :
Proceedings of WM2016, Conceptual Study of Fuel Debris Retrieval System for Fukushima Daiichi Reactors – 16111

Advanced Reactor/Small Modular Reactor

SMRs (NuScale VOYGR)

HTGR Intermediate HX

ITER Equipment



Source : ITER Organization HP

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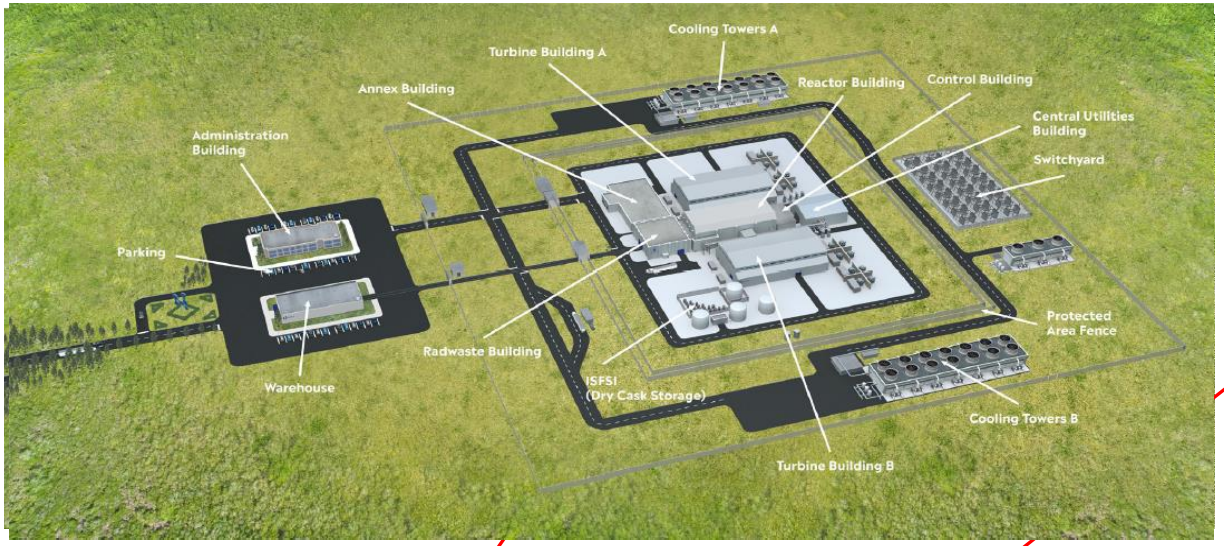
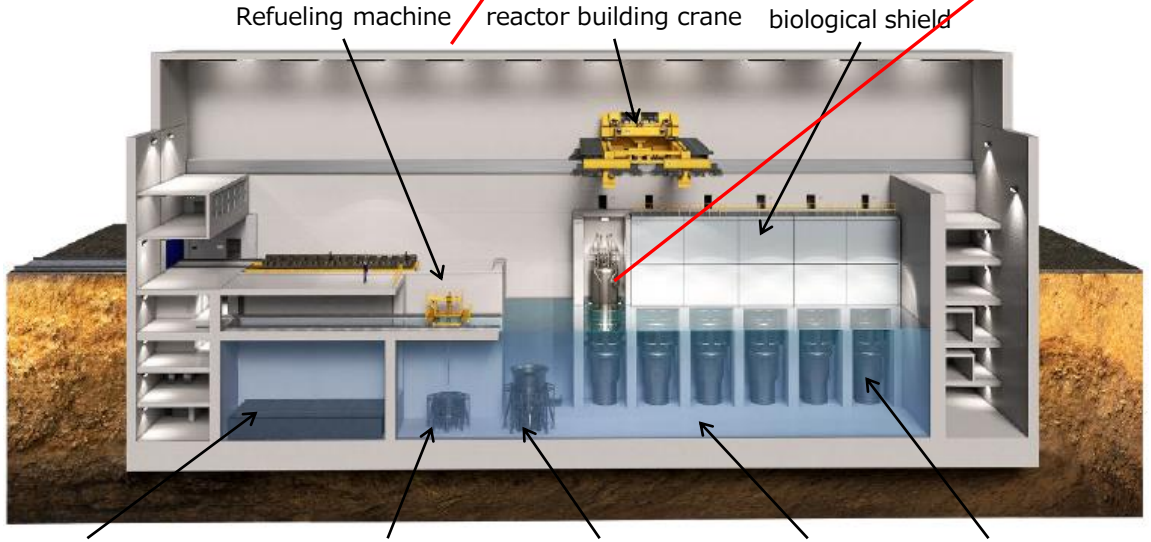
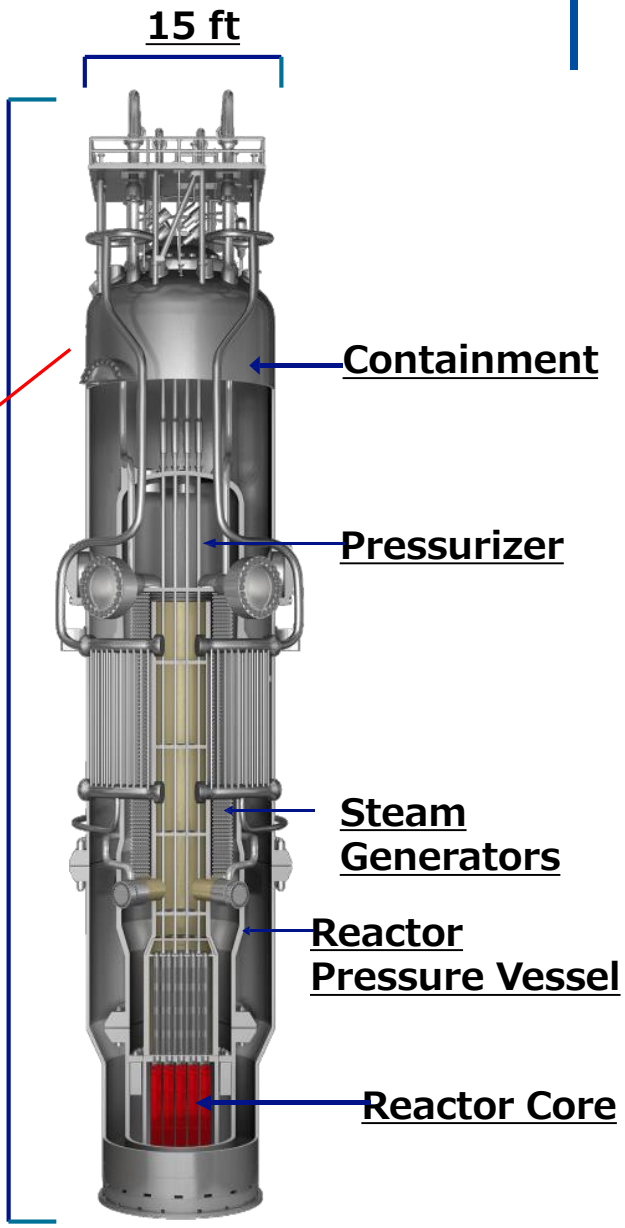
1.Overview of VOYGR™ SMR Power Plant

Plant Layout (Site Area: Approx. 14 ha)



Reactor Building (Cross-Section)





NuScale Power Module

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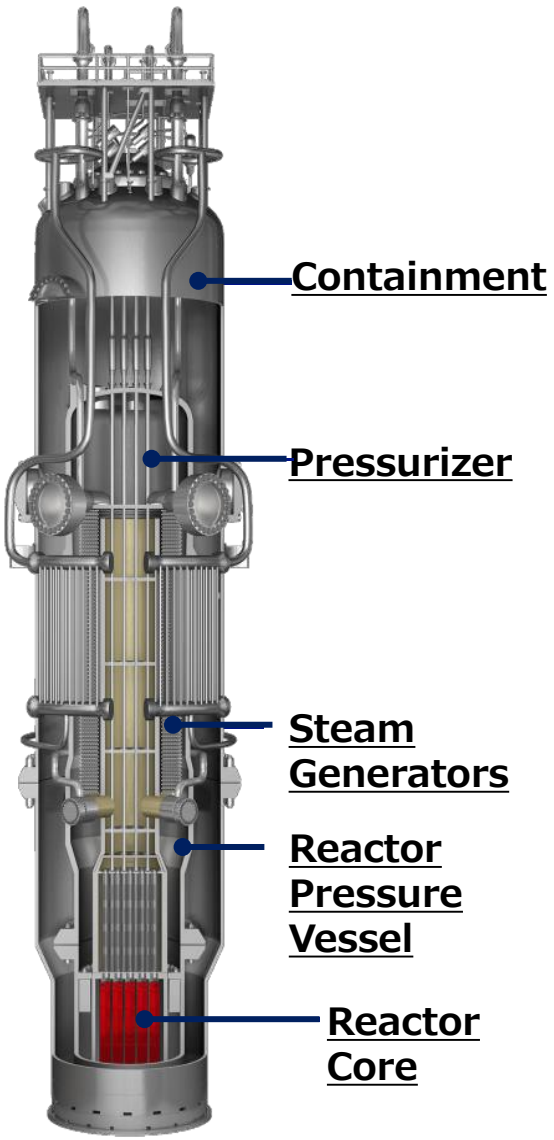
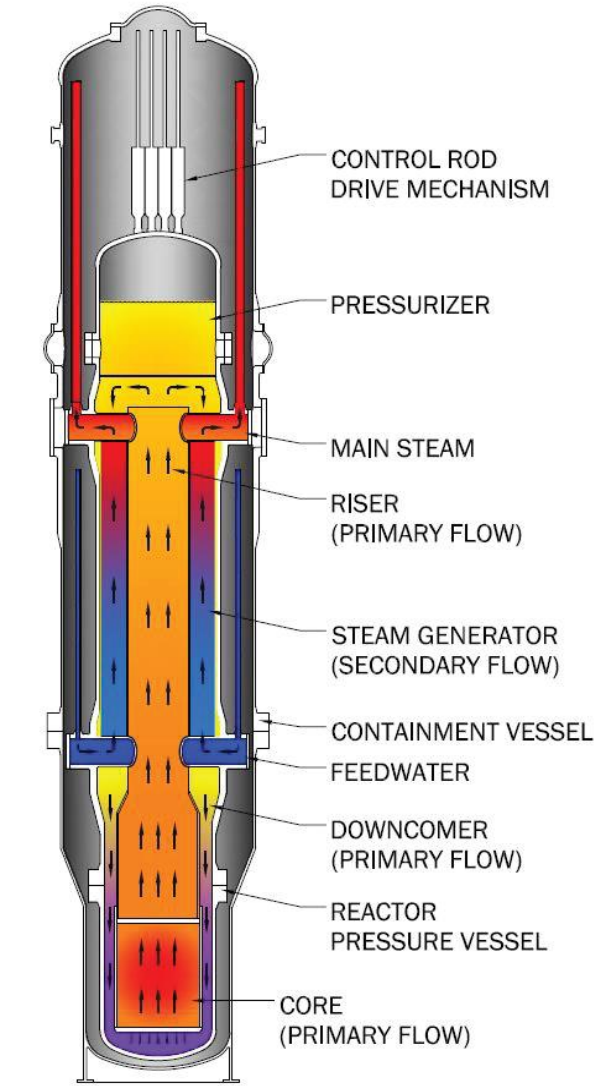
NuScale Power Module™ (NPM)





- The reactor vessel in the NPM contains the reactor core, steam generator, pressurizer, and other reactor-related components. The reactor is integrated with the containment vessel and installed in the reactor pool.
- Through natural circulation, the reactor coolant rises up the riser, descends with heat exchange with the secondary cooling system in the steam generator, and returns to the core.

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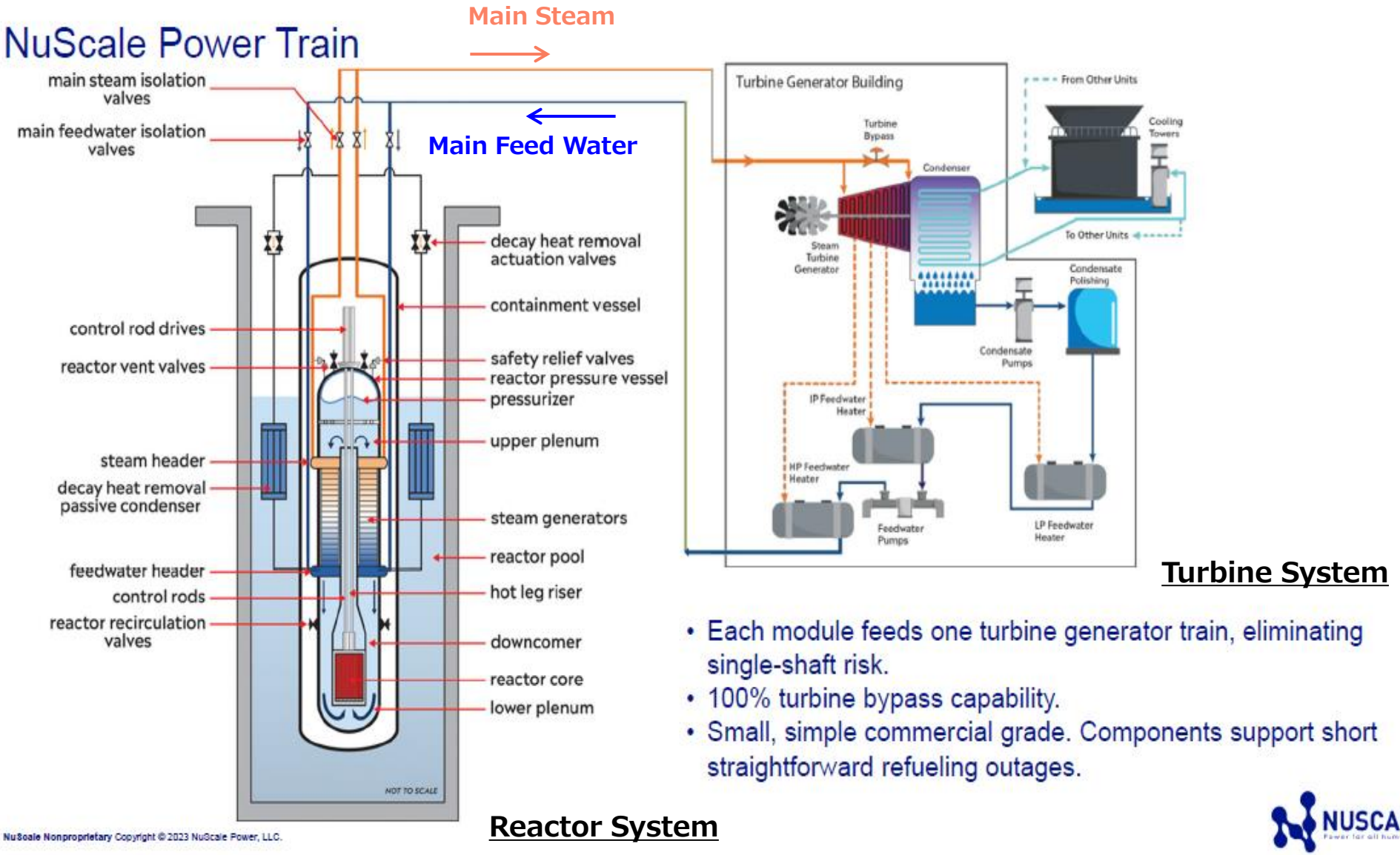
Reactor and Turbine System Configuration



Reactor System

Turbine System

- Each module feeds one turbine generator train, eliminating single-shaft risk.
- 100% turbine bypass capability.
- Small, simple commercial grade. Components support short straightforward refueling outages.

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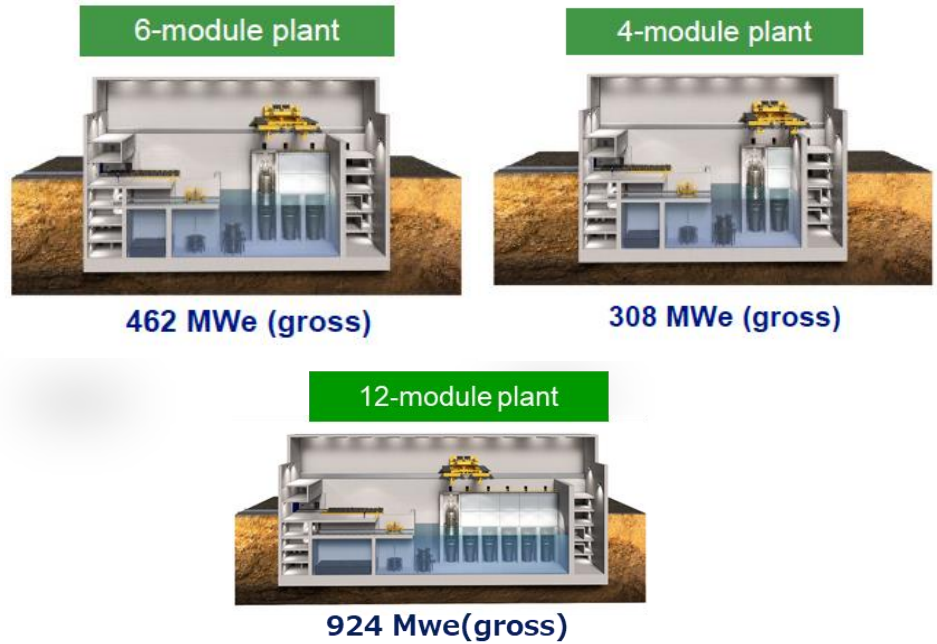
2. Technical features and Safety of VOYGR

【Main Specifications】

Reactor type	Integral PWR
Coolant	Light water
Thermal/electrical capacity	250 MWth / 77 MWe x Max. 12 NPMs
Primary coolant temperature/pressure	321°C / 13.8 MPa
Fuel type/assembly array	UO_2 / 17x17"
Refueling Cycle	18 months
Design life	60 years



【Features】

Features	Advantages
Light-water reactor type	Existing technology can be reused.
Integrated modularization of reactor components	Repeatable factory production is possible, reducing construction risk.
Multiple (4-12) reactor plant configurations	Meets various demands (308 to 924 MWe)
Multiple reactors can be operated independently.	Regulated power supply function, and Operation and maintenance leveling
Cooling of nuclear reactors during accidents without requiring personnel or power	Improved safety
Significantly reduced area of impact in the event of an accident	Improved site location selectivity

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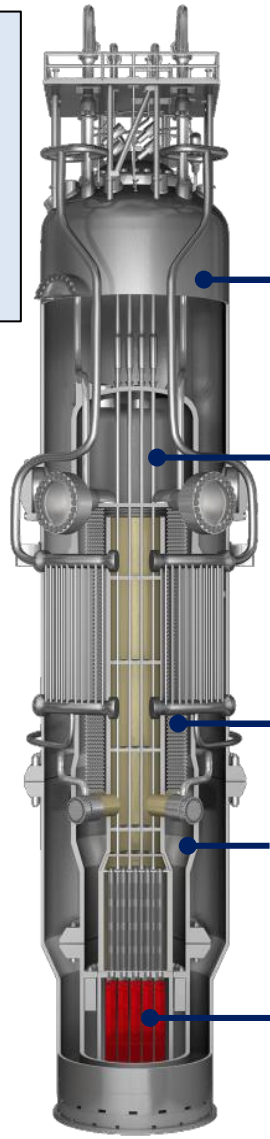
Innovative Design

Integrated NPM design; eliminates the need for large diameter reactor coolant piping loops. Eliminates large break loss-of-coolant accident (LBLOCA) scenarios.

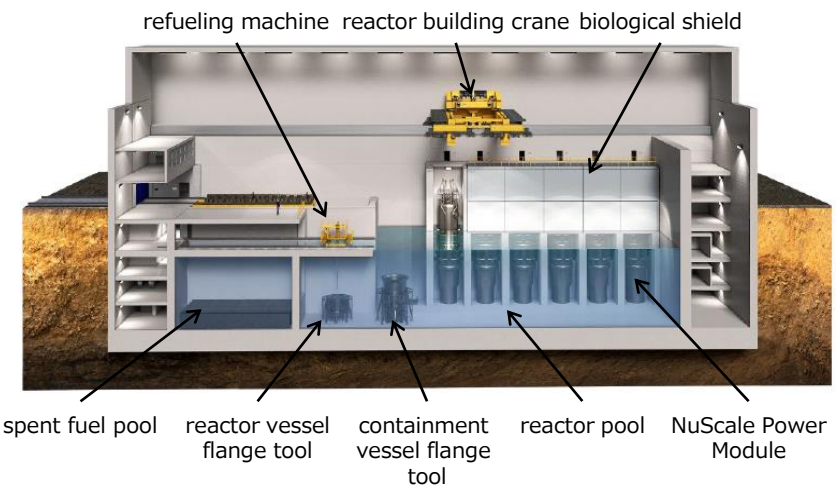
Passive safety system; eliminates need for external power supply in accident conditions

Natural circulation cooled core; no primary coolant pump.
Small core; enhanced molten core retention, low impact area during accidents.



High design pressure containment ; maintain containment integrity, minimize potential release of radioactive material
Vacuum containment; minimized Non-condensable gas generation and oxygen content during operation.

Reactor pool ; NPM installed in the reactor pool. Long-term and passive cooling continues.



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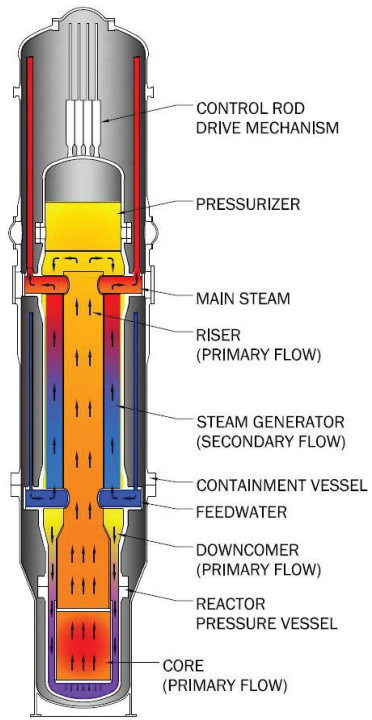
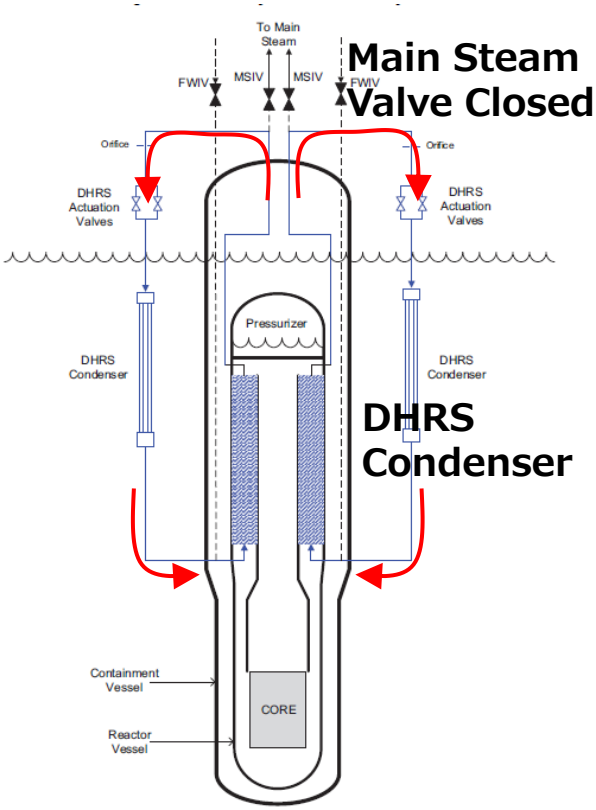
Safety: Passive Safety System

Decay Heat Removal System（DHRS） : DHRS provides reactor cooling when the normal feedwater system is not available. The system is a closed-loop natural circulation cooling system with one system connected to each of the two steam generators.

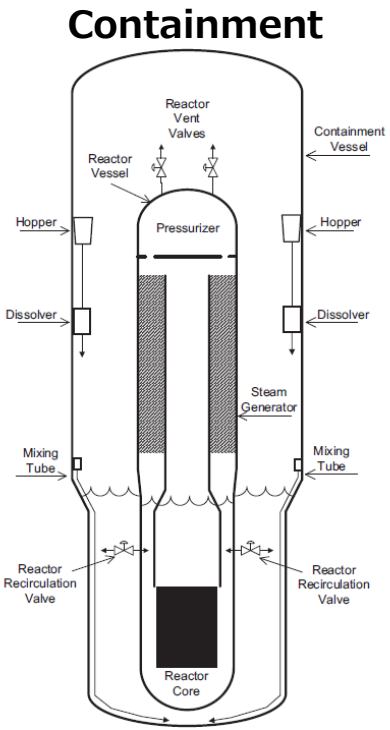
Emergency Core Cooling System（ECCS） : ECCS consists of two independent reactor vent valves and two independent reactor recirculation valves; when the ECCS is activated, the steam is cooled by the reactor pool water through the containment walls. (See next slide)



Normal Operation



DHRS（Decay Heat Removal System）



ECCS（Emergency Core Cooling System）

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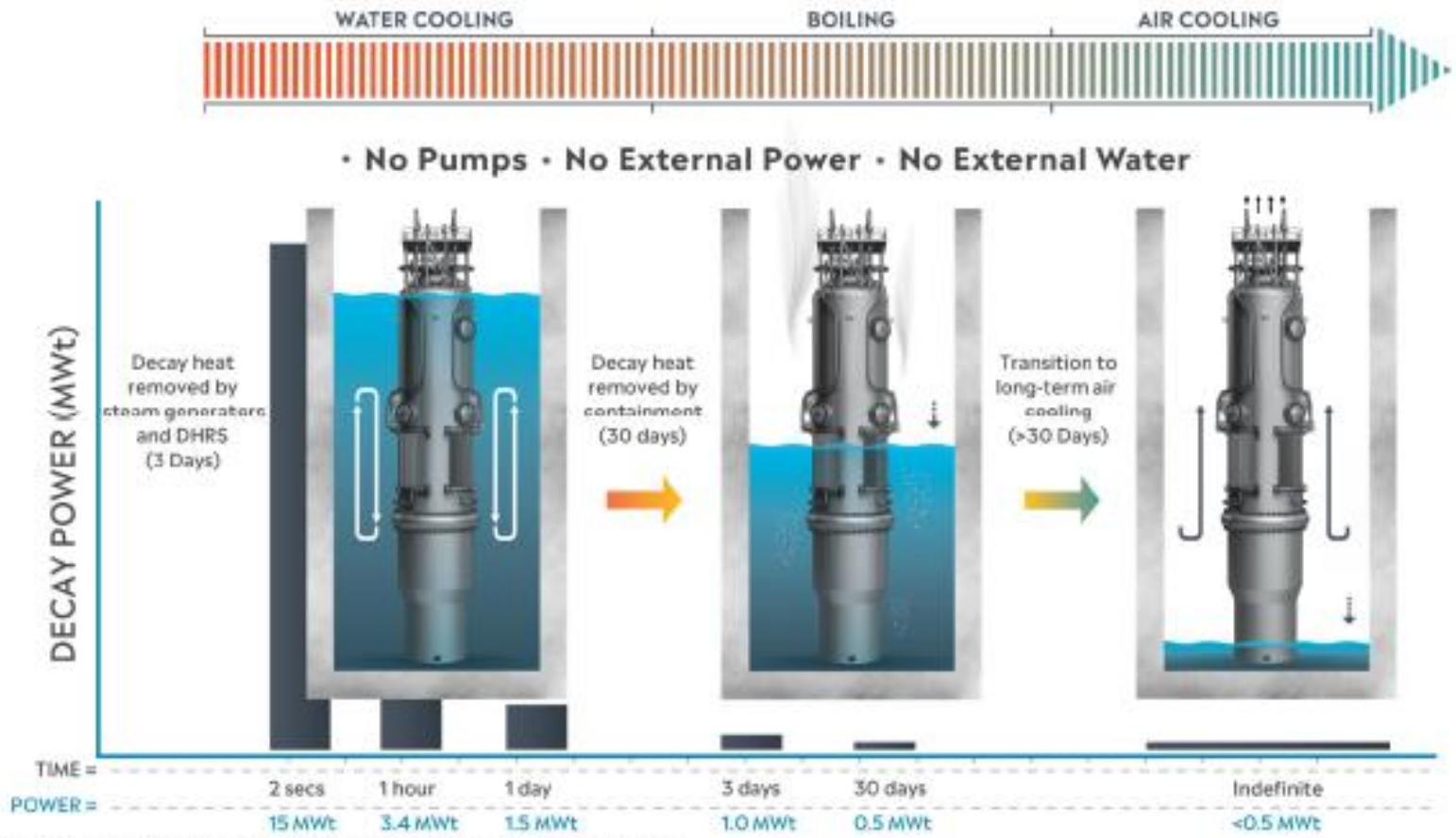
Safety: Passive Safety System

- NPMs achieve a lower core damage frequency (CDF) than conventional reactors by employing two independent, redundant, passive safety systems: DHRS and ECCS (see below).
- The reactor pool water can cool the decay heat generated by up to 12 NPMs for more than 30 days, and after the loss of reactor pool water, cooling can be continued for an unlimited period of time by air cooling.



*Alternate 1E power system design eliminates the need for 1E qualified batteries to perform ESFAS protective functions – Patent Granted

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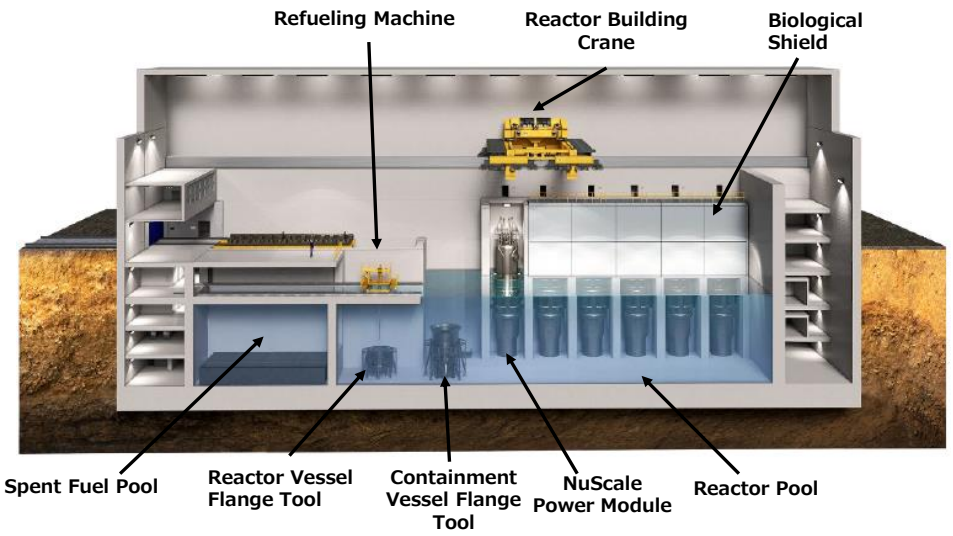
Safety: Response to External Events

Earthquakes

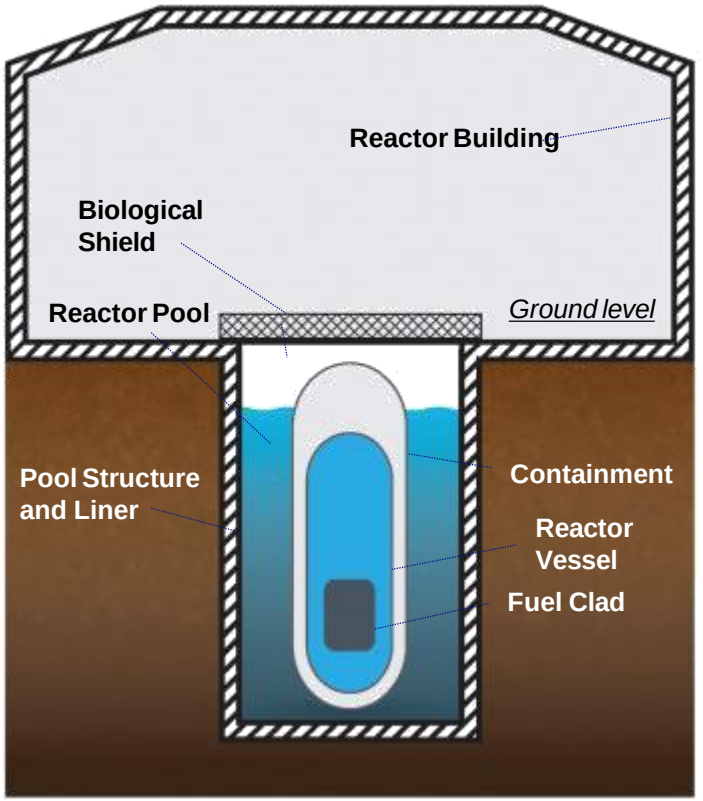
Everything necessary to ensure the safe shutdown of the plant is contained within the reactor building, which has a seismic category I (equivalent to S-class in Japan) according to U.S. NRC Regulatory Guide 1.29. Due to the low height of the reactor building and the underground location of the reactor pool where the NPM will be installed, the reactor building is robust to seismic events and designed to withstand a maximum response acceleration (ZPA) of 0.5 g and a peak acceleration of 1.1 g.

Aircraft impact

Based on 10 CFR 50.150, the impact of an intentional aircraft impact on the facility has been evaluated, and it is assessed that the integrity of the containment vessel, core cooling capacity, and spent fuel pool would be maintained.



【Source: METI Website】
https://www.enecho.meti.go.jp/committee/studygroup/ene_situation/007/pdf/007_005.pdf



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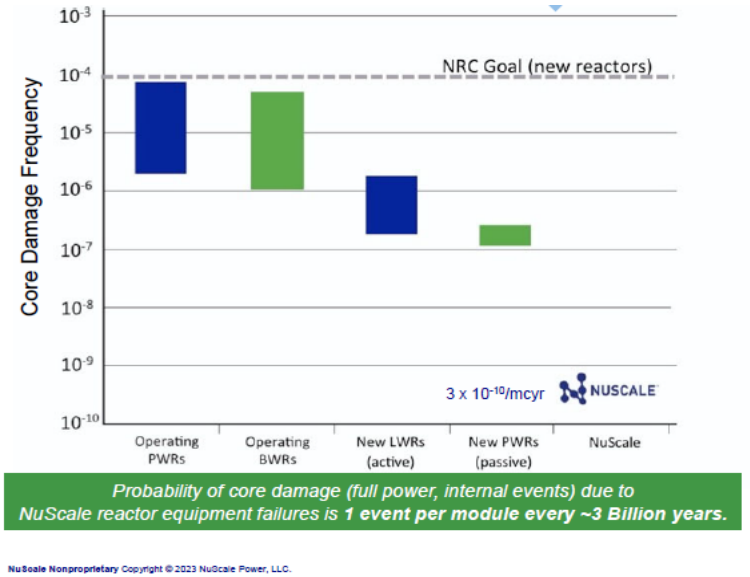
Innovative Safety

- The integrated design of the NPM eliminates the need for large-diameter reactor coolant piping loops, thereby eliminating the large-break loss-of-coolant accident (LBLOCA) scenario.
- The passive safety system eliminates the need for an external power supply under accident conditions.

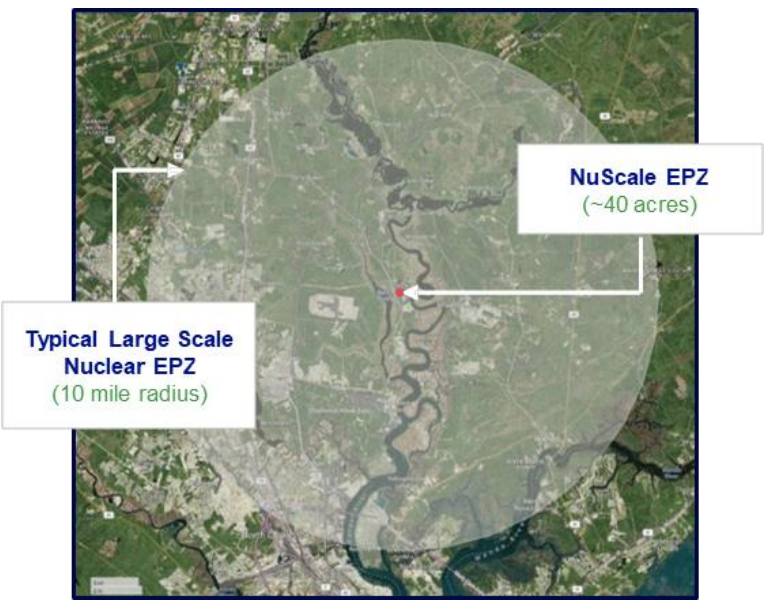
⇒ **As a result, the CDF is lower than that of conventional reactors.**



The core has a much lower fission product invento and slower accident progression than conventional reactors, resulting in a much lower source term during an accident.

⇒ **Based on these characteristics, a sizing methodology was developed to support significantly reducing the plume exposure Emergency Planning Zone (EPZ), as compared to conventional reactors, to the plant site boundary. This sizing methodology was approved by the U.S. Nuclear Regulatory Commission in October 2022.**

For NuScale reactors, the probability of core damage due to failure is less than 1 in 1,000,000,000 years



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Operation and Maintenance

Operating Personnel

Passive safety systems, a fail-safe design, and a high-degree of automation help to optimize operator staffing. The NuScale operational concept requires only 3 operators for up to 12 NPMs, which is approved by the U.S. Nuclear Regulatory Commission and confirmed through our own independent assessment.

Simulated Control Room (NuScale In-House Simulator) Consisting of 12 NPMs

Maintenance and Inspection

Maintenance and inspection are performed for each reactor module. By continuing the operation of the remaining units, it is possible to equalize the reactor power, maintenance and operation personnel, and the backup power supply can be equalized through maintenance and inspections.

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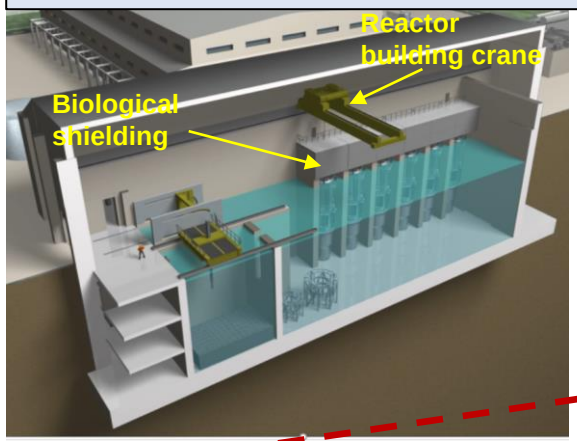
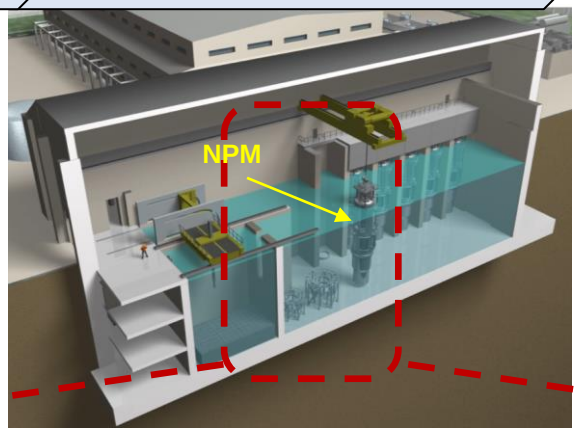
Operation & Maintenance

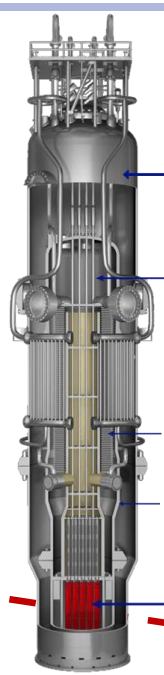
Refueling Procedure

Normal operation

Removal of biological shielding
Reactor module lifting







Installation to Containment flange tool

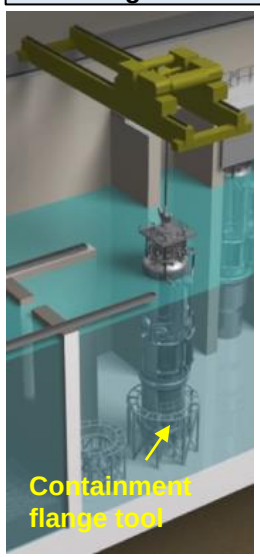
Lower Containment removal

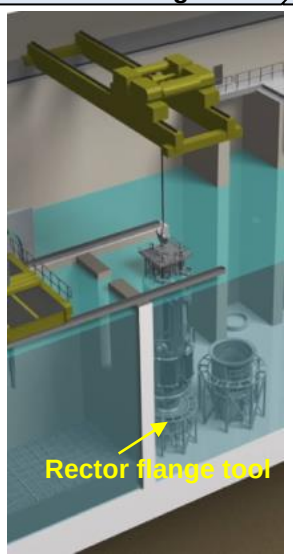
Installation to Rector pressure vessel flange tool

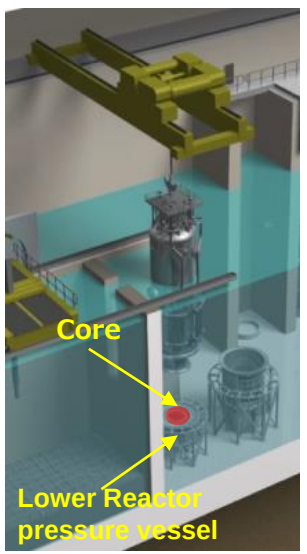
Lower Reactor pressure vessel removal

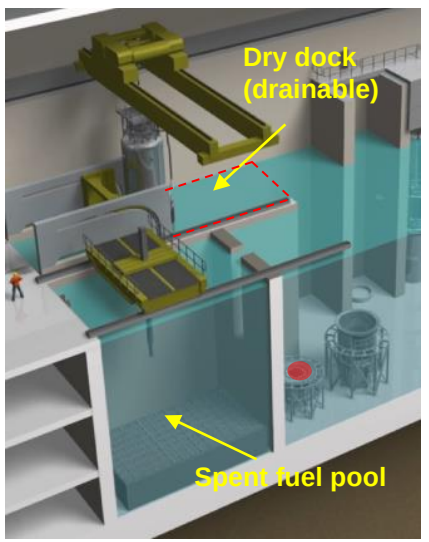
Move upper reactor module to dry dock

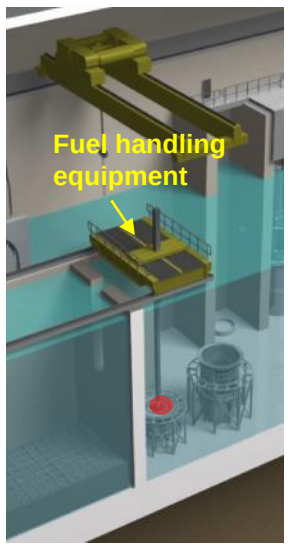
Fuel handling











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4. Summary

IHI Nuclear Business Overview

- 70 Years of Expertise: Extensive experience in the nuclear field, providing comprehensive lifecycle solutions.

VOYGR™ SMR Power Plant Highlights

- Integrated NPM Design: Eliminates large diameter reactor coolant piping loops, preventing LBLOCA.
- Passive Safety Systems: Operates without external power supply, using natural circulation for cooling.
- Seismic Resistance: Designed to withstand seismic events with robust reactor building and underground pool.
- Operation and Maintenance : Allows individual reactor module maintenance while ensuring continuous operation.

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