Kyoto Fusioneering's Progress and Approach for the Early Testing of Fusion Energy Extraction

FUSION POWER ASS0CIATES

45th Annual Meeting and Symposium

3rd, Dec 2024

KYOTO FUSIONEERING

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CEO & Chief Fusioneer
Kyoto Fusioneering

KYOTO FUSIONEERING

Founded in

2019

140+

Team members

$100m+

Raised

5

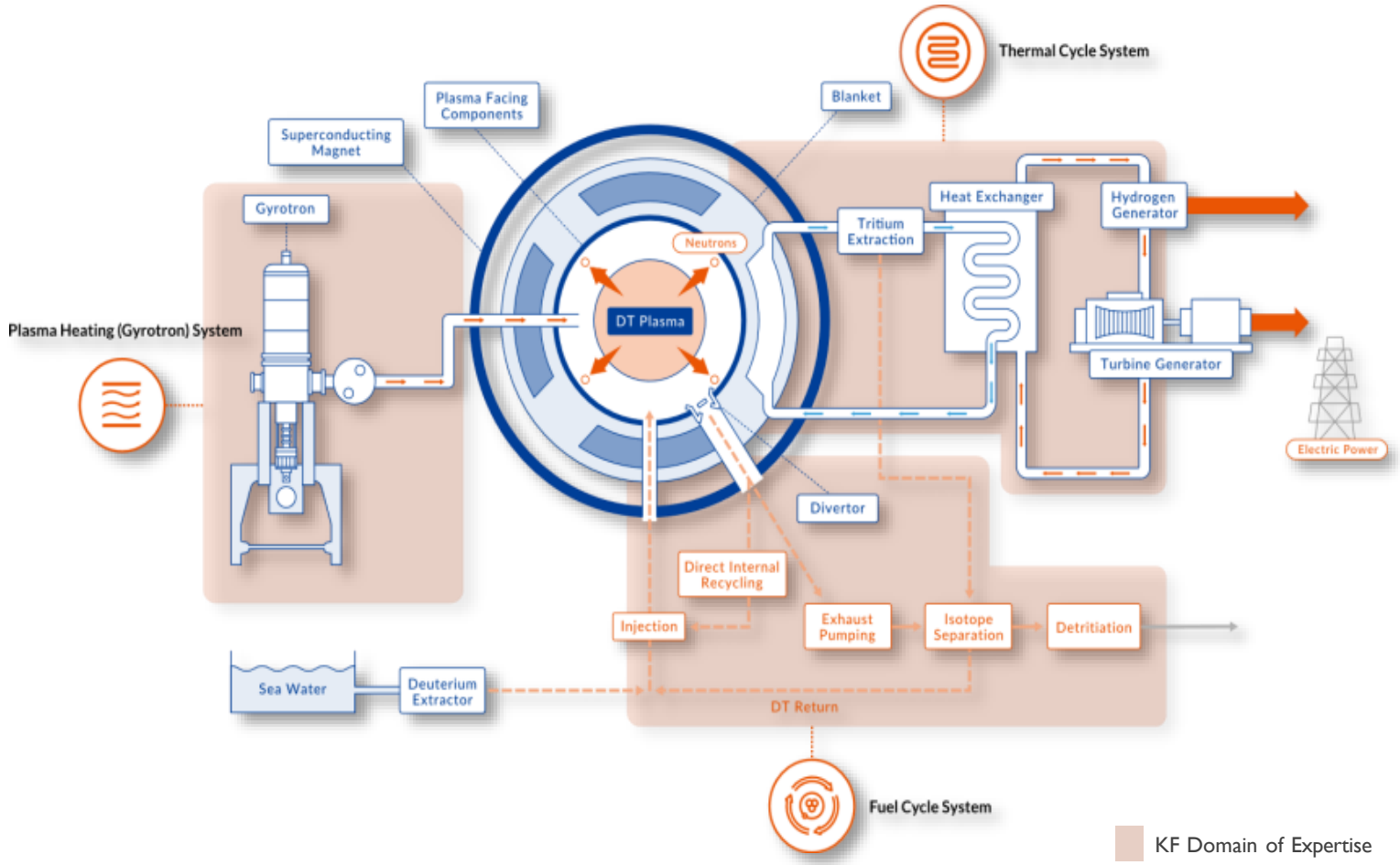
Countries

- JP
- US
- UK
- GE
- CA

Complementary Business Model

A pick-and-axe strategy for fusion development

With a **confinement concept-agnostic** approach to fusion plant technology development, KF is **complementary to the other private fusion programs** and is uniquely positioned to **generate revenue during each phase of development** while **avoiding the risks** of betting on a concept.



KF ECH Activities

UKAEA: Delivered gyrotron tube and main components. Finalizing ancillary parts procurement while waiting for UKAEA's main power supply.

KFE: Completed design review process and started gyrotron aging and testing.

Tokamak Energy: Completed gyrotron tube FAT at QST, ready for shipment.

General Atomics: Completed preliminary design review; preparing for gyrotron testing in 2025.

KF ECH activities

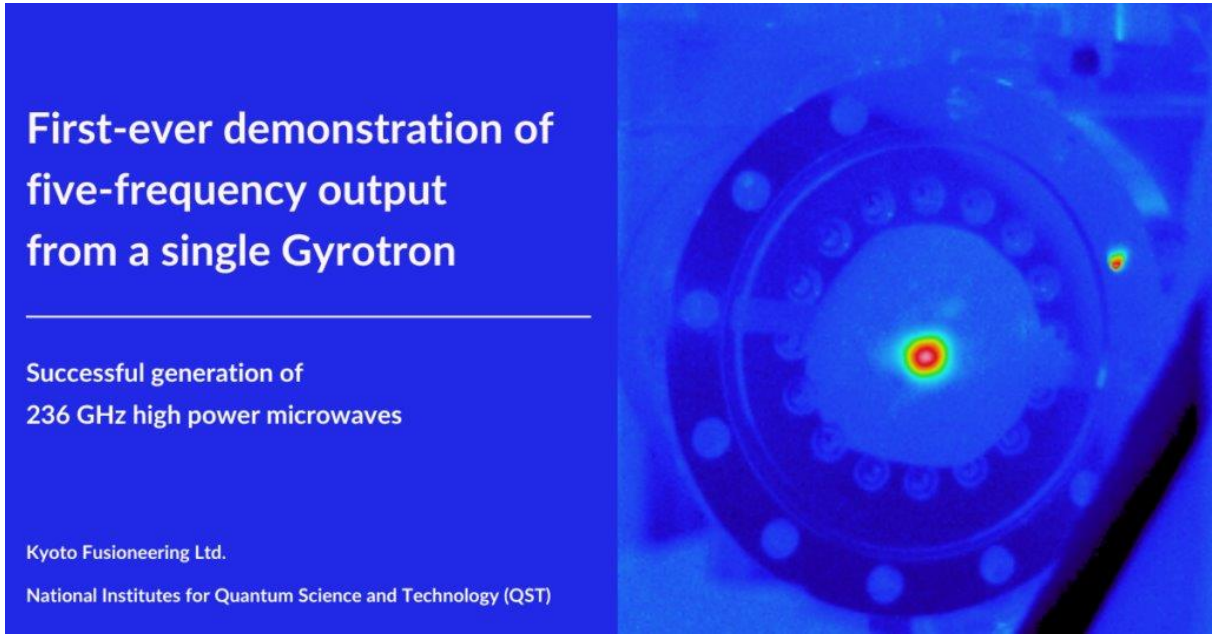
HV main power supply

2024 — Start of procurement

2025 — Completion of detailed design, long lead item procurement

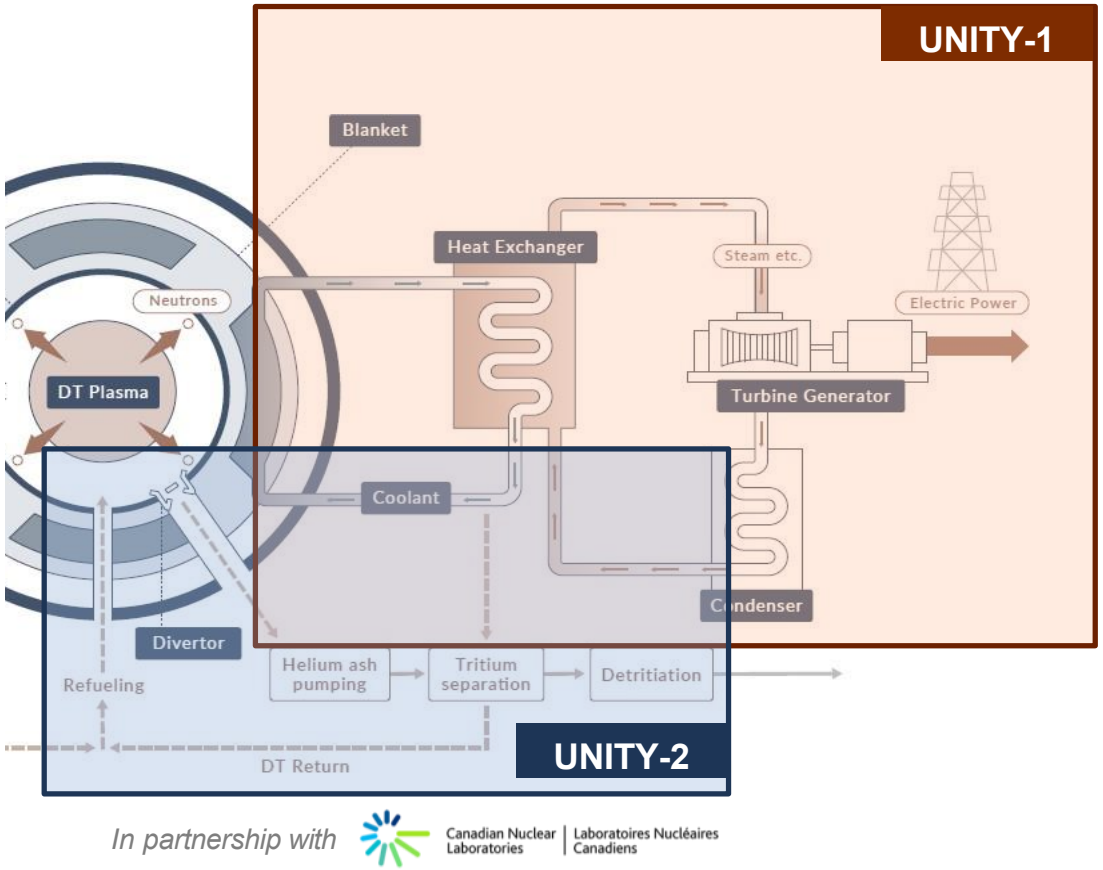
2026 — Installation in new R&D site

236 GHz development: A single gyrotron produces five separate frequencies of electromagnetic beam output.



Unique Integrated Testing Facility (UNITY) Projects

KF and our partners are designing and developing UNITY-1 and -2



In partnership with Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

UNITY-1

Located at our Kyoto Research Centre, UNITY-1 is dedicated to advancing the Fusion Thermal Cycle System, crucial for harnessing fusion's power. It simulates high-temperature and magnetic conditions of a fusion plant to test various power generation systems, employing components like a blanket for heat extraction, liquid metal loops, and an advanced heat exchanger—all without radioactive materials.

UNITY-2

Located at Chalk River Laboratories in Ontario, UNITY-2, in strategic alliance with Canadian Nuclear Laboratories, focuses on the complete deuterium-tritium fuel cycle.

This test loop will pioneer global standards in fuel exhaust, pumping, and tritium handling, among other critical operations.

Together, these facilities underscore our commitment to accelerating R&D to support fusion commercialization.

UNITY-1

Blanket and thermal cycle system facility located in Kyoto, Japan

2023 ✓ — **Completion of lithium-lead loop**

2024 — **Start of the blanket testing campaign**

2025 — **MHD and hydrogen extraction testing**

2026 — **Start test of the power cycle demonstration**

Location: Japan (under construction)

Thermal Cycle and Blanket System:

- Blanket test section (1000°C LiPb, Li, FLiBe)
- 300 L LiPb inventory
- 4T NbTi magnet
- IH heating and surface heating for blanket module 30x30x70 cm
- Two heat exchangers and power conversion (first electricity generation from a blanket module)

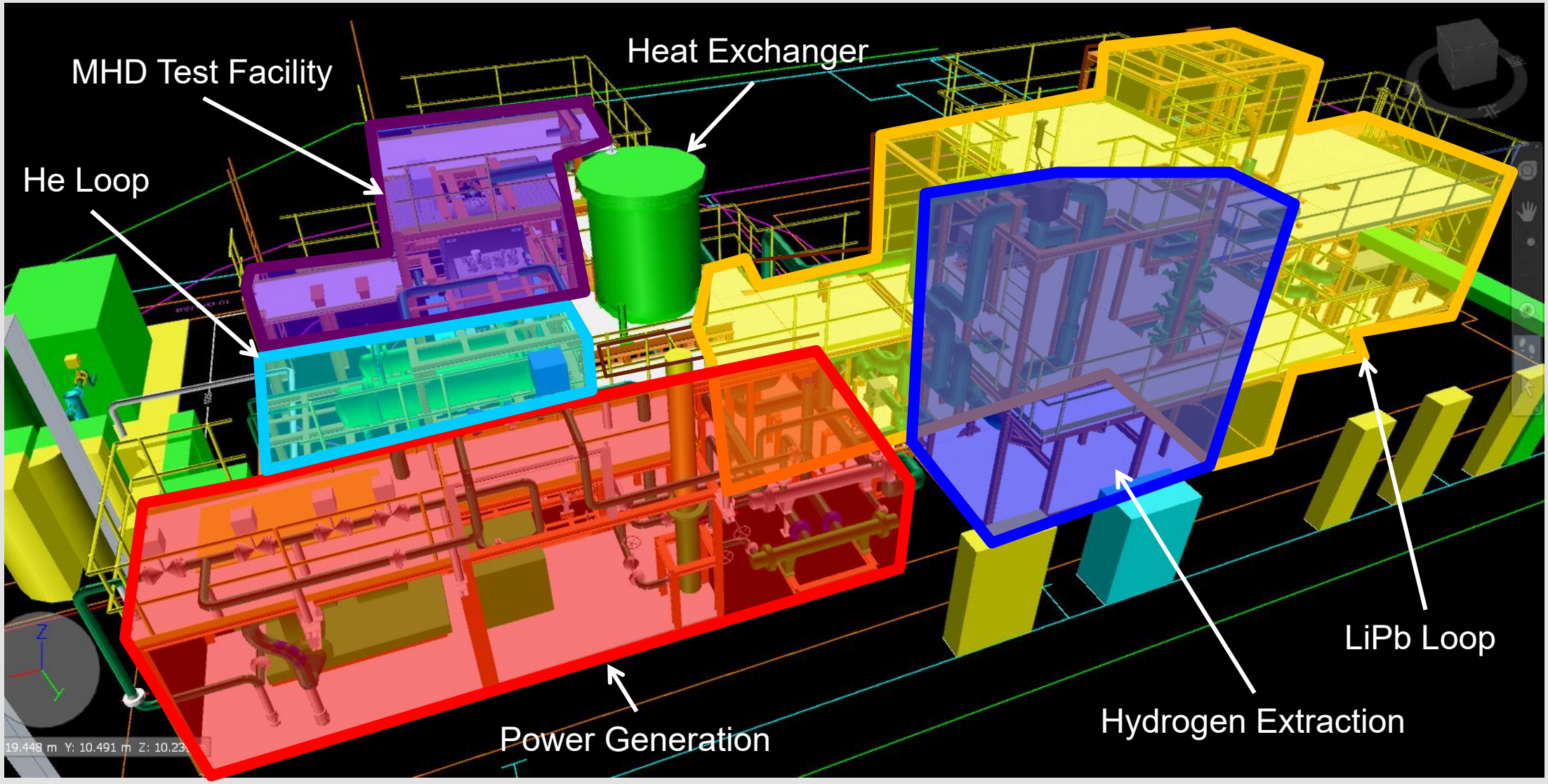
Fuel Cycle:

- Deuterium injection as proxy for tritium
- Tritium extraction via VST, electrochemical
- Exhaust pumping from vacuum vessel (pump train)
- DIR testing with proton conductor pump

Materials:

- Compatibility in flow conditions (up to 50 L/min via 3 EMPs)
- FLiBe and Li piping material tests
- MHD testing with SiCf/SiC insulators

UNITY-1 Update



UNITY-1 Update

Lithium-Lead Coolant Loop and Tritium Extraction System

Kyoto Fusioneering has just commissioned the UNITY-1 LiPb base loop (250 L)

- The loop for UNITY-2 will be redesigned to be made tritium compatible with an innovative vacuum system to keep release rates low at 500°C
- UNITY-2 loop will be ~1/5th of the base loop with 50 L inventory and 10 L/min flow rate

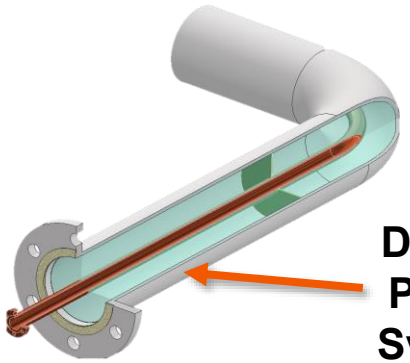
Tritium extraction system based on VST is under construction for UNITY-1

UNITY-2 will demonstrate:

- That performance can be met with T
- Components are tritium compatible

LiPb loop

Multi-Stage VST



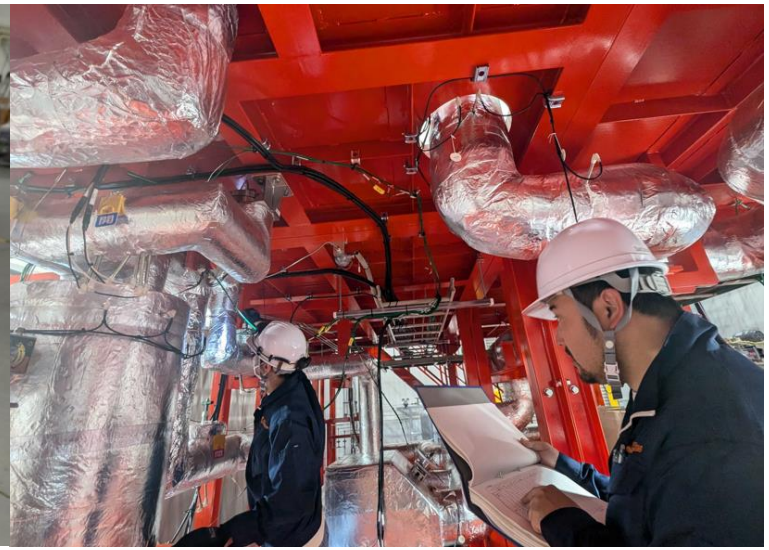
Double Piping System

UNITY-1 Update

Coolant Base Loop Operation

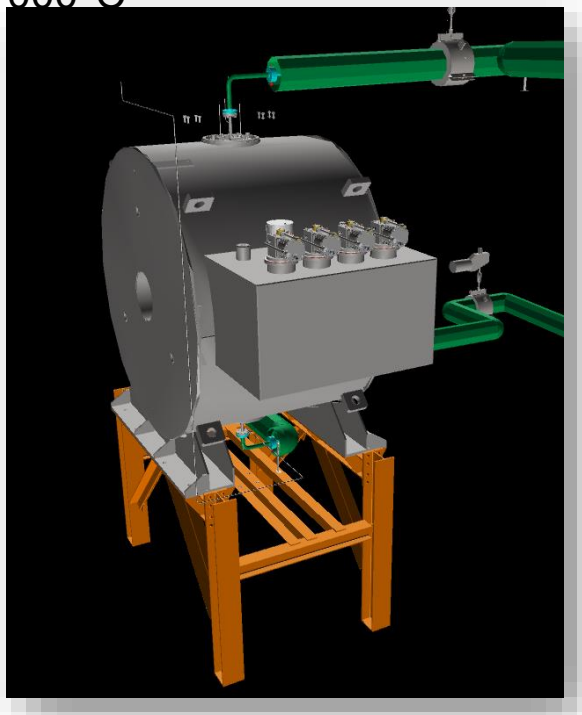
Operation completed successfully

- Operation temperature : 300-500°C, LiPb Flow rate : 0-50 L/min
- Cold trap operation : 280°C – 5 L/min
- Heating operation 400->500°C
- Emergency shutdown operation completed safely



MHD Testing Module

- 4T magnetic field for piping
- Bore size : f300mm
- 1T magnetic field for blanket
- 2 Coils distance : 810mm
- LiPb temperature : 300-1000°C

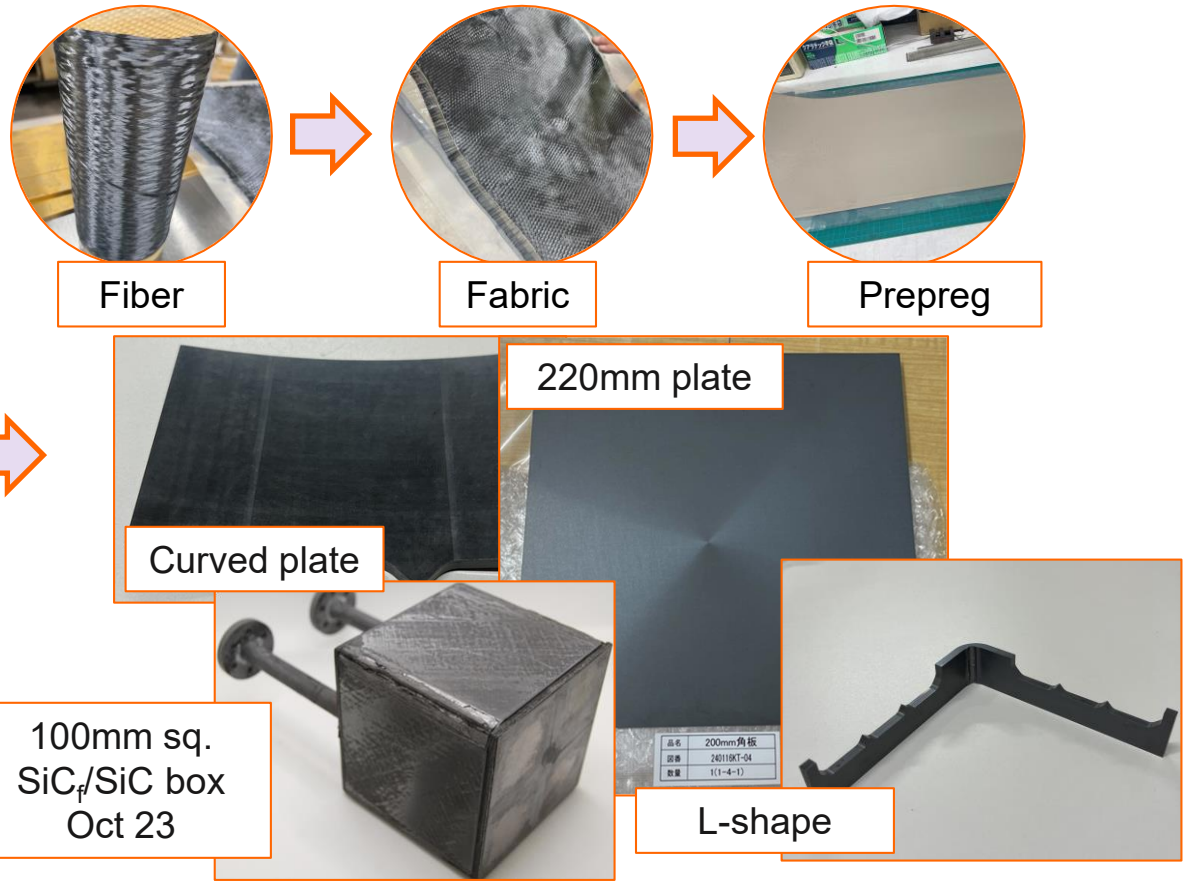


UNITY-1 Update

KYOTO FUSIONEERING

Blanket Module

- SiCf/SiC Blanket module
- To confirm feasibility of using SiCf/SiC for Blanket
- To organise the whole supply chain from fiber to SiCf/SiC
- To confirm parts can be combined to make larger module



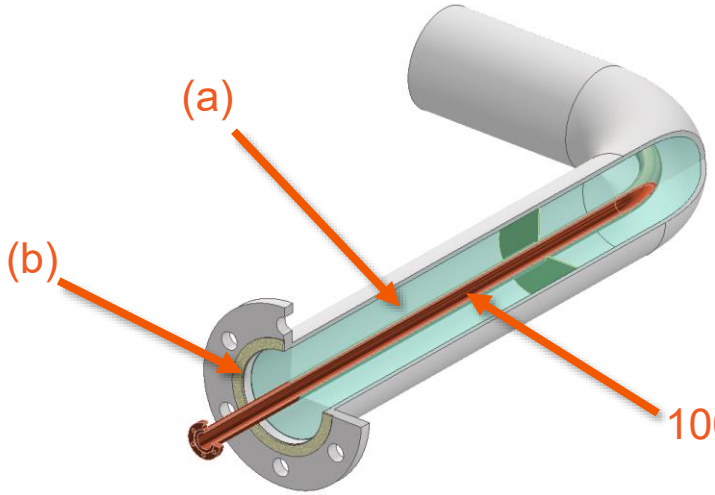
1000°C Test Section

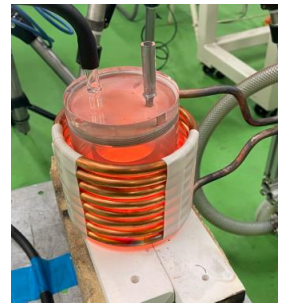
- Heating system
- IH heater applied in the system
- Double piping system
- Vacuum thermal insulation system applied

(a) Insulation with super low thermal conductivity

(b) Anti-tritium permeation joint

(c) Flexible support to reduce thermal stress





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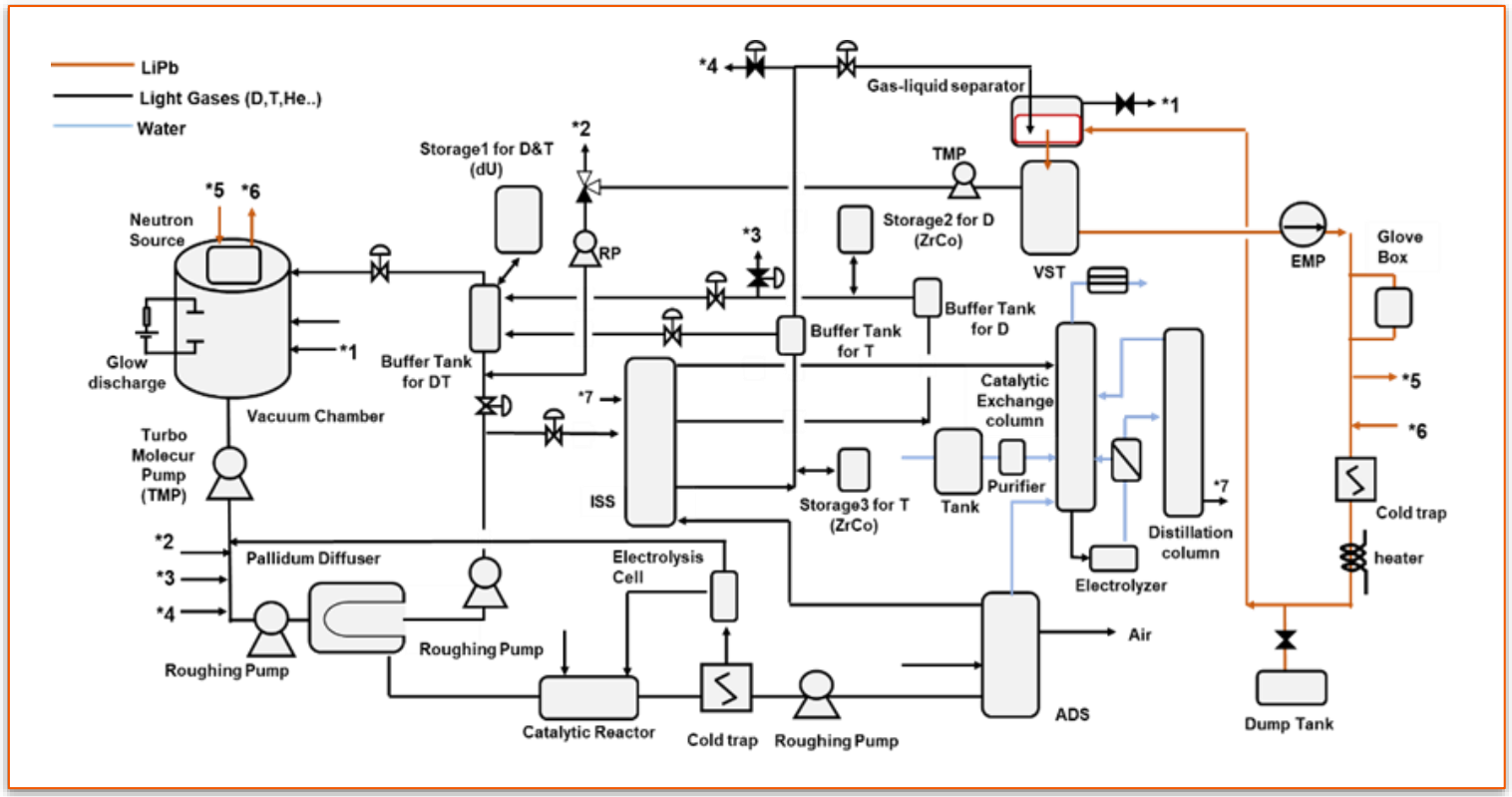
Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

KF and CNL established a new joint venture to accelerate the development and commercialization of fusion fuel cycle technology – with UNITY-2.

Building B215 at Chalk River, Ontario
Licensed for 100g of Tritium

Unity-2

A full deuterium-tritium fuel cycle test loop



2023 ✓ — **2024** — **2026**

Initiation:
Design and individual component testing

Procurement:
Key systems and components

Installation:
Integration of systems. Planned commissioning

Location: Chalk River, Ontario, Canada

Components:
- Tritium Extraction System to be tested with Tritium (~50 L Li-Pb loop)
- Fusion reactor conditions for vacuum chamber (including PEG gases)
- Dual storage system (dU, ZrCo)
- Dual ISS (TCAP, CD)
- Outer cycle included (WDS, ADS)
- Centrifugal Pellet Injection

Tritium:
- Under review, 10 to 40 g inventory
- Fuelling of vacuum chamber at ~2.6 Pa m3 / s

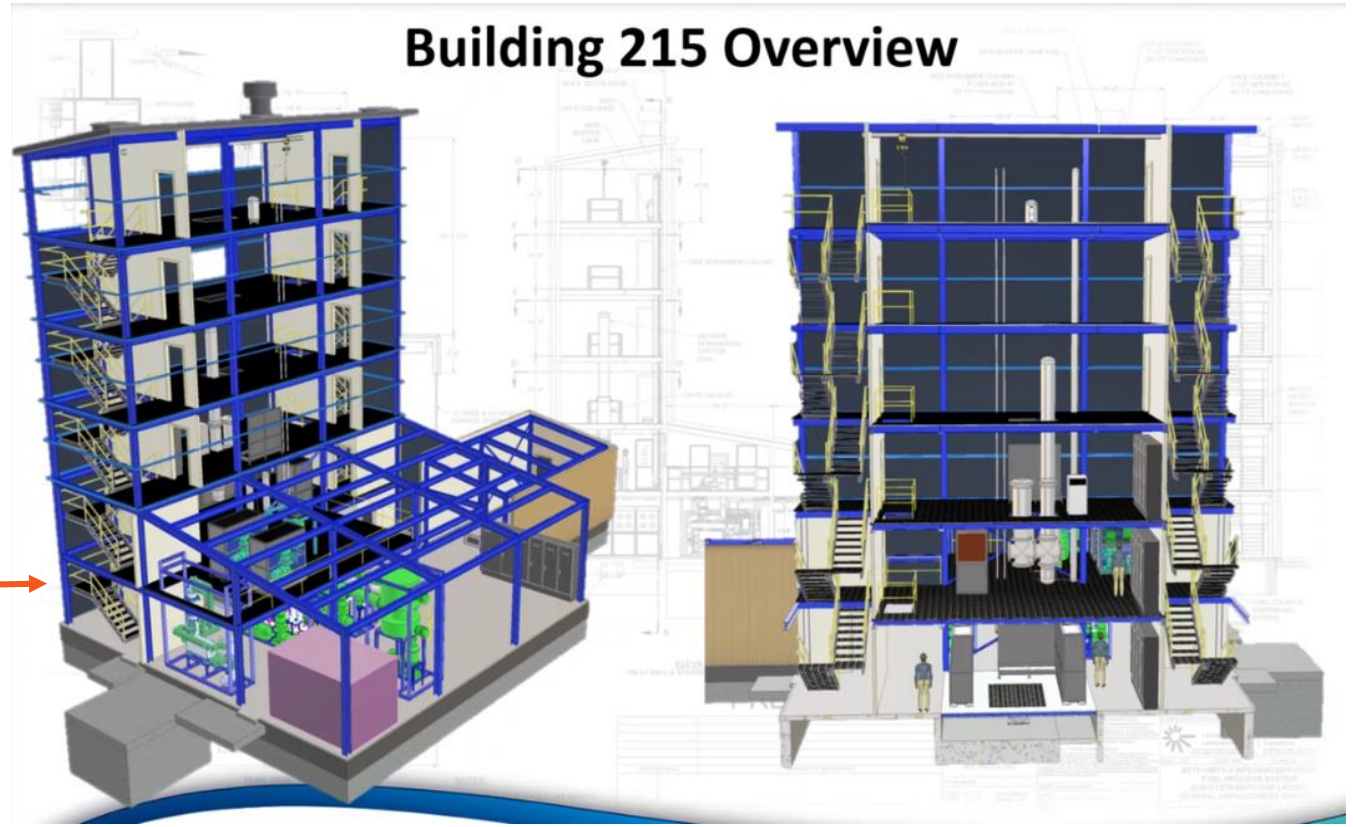
Modelling:
- Dynamic fuel cycle modelling
- Coolant/breeder inventory
- Pumps, Pd diffuser, getter beds, DT delivery mechanism

UNITY-2 Update

Conceptual Design and 3D layout were completed

- UNITY-2 fits within tritium facility operating license at Chalk River, ON.
- Current license allows **up to 100g in process** and **up to 250g immobilised**.
- The precious space is being carefully allocated. **Potential user input is currently being considered**.

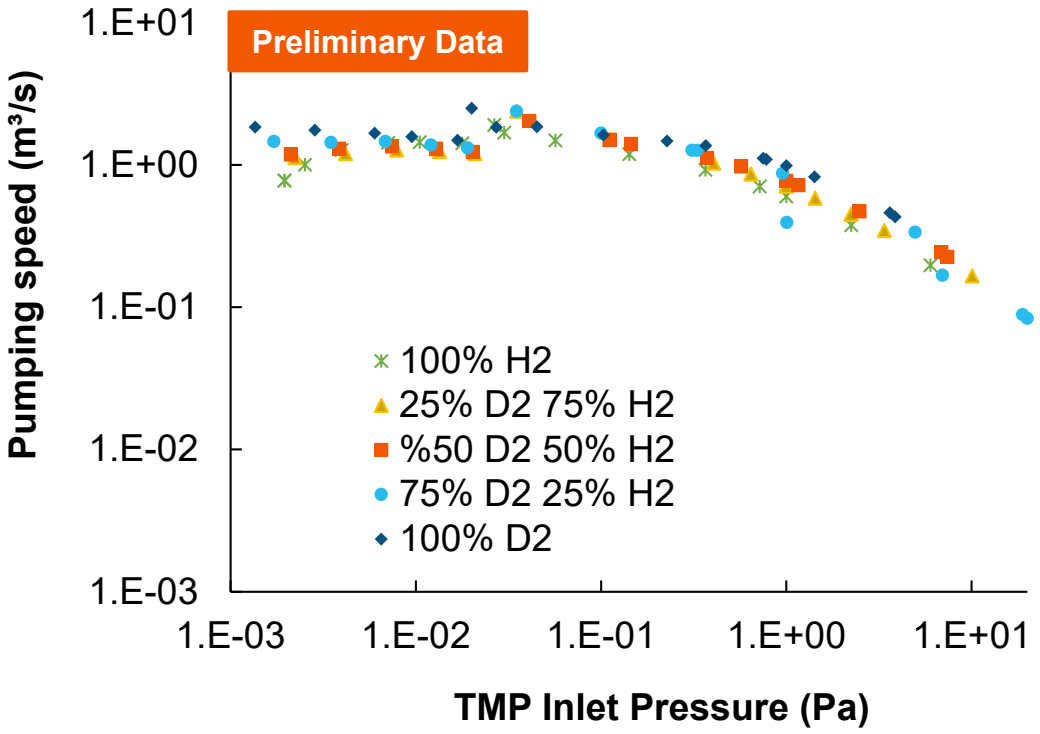
Location of UNITY-2

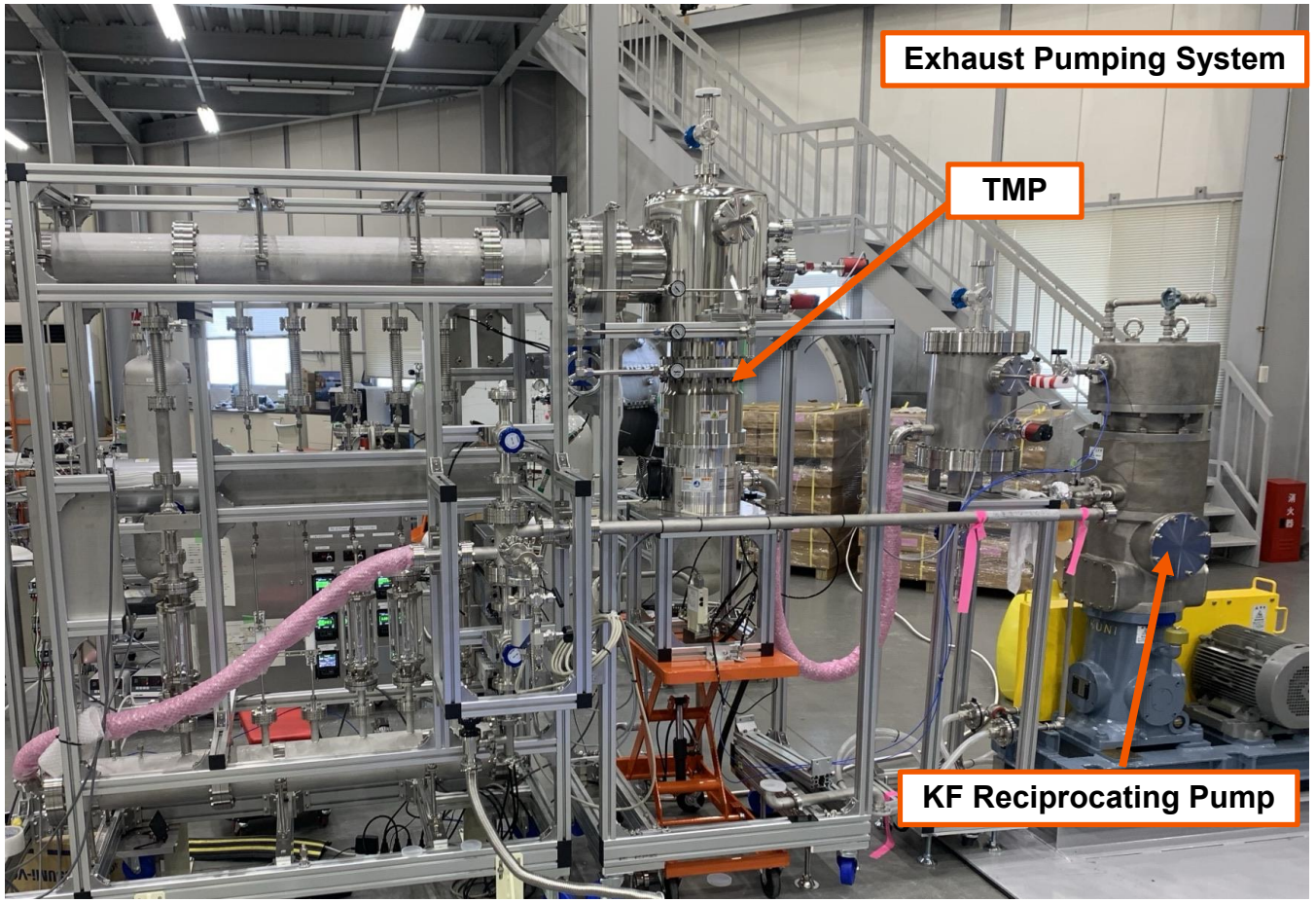


UNITY-2 Update

Primary Pumping System

First tests are being conducted in Japan.





Non-active testing of vacuum pump train (TMP + roughing pump)

- Fully tritium compatible
- Compression <1 Pa → 1 atm
- Ultimate pressure <5 x 10^{-5} Pa

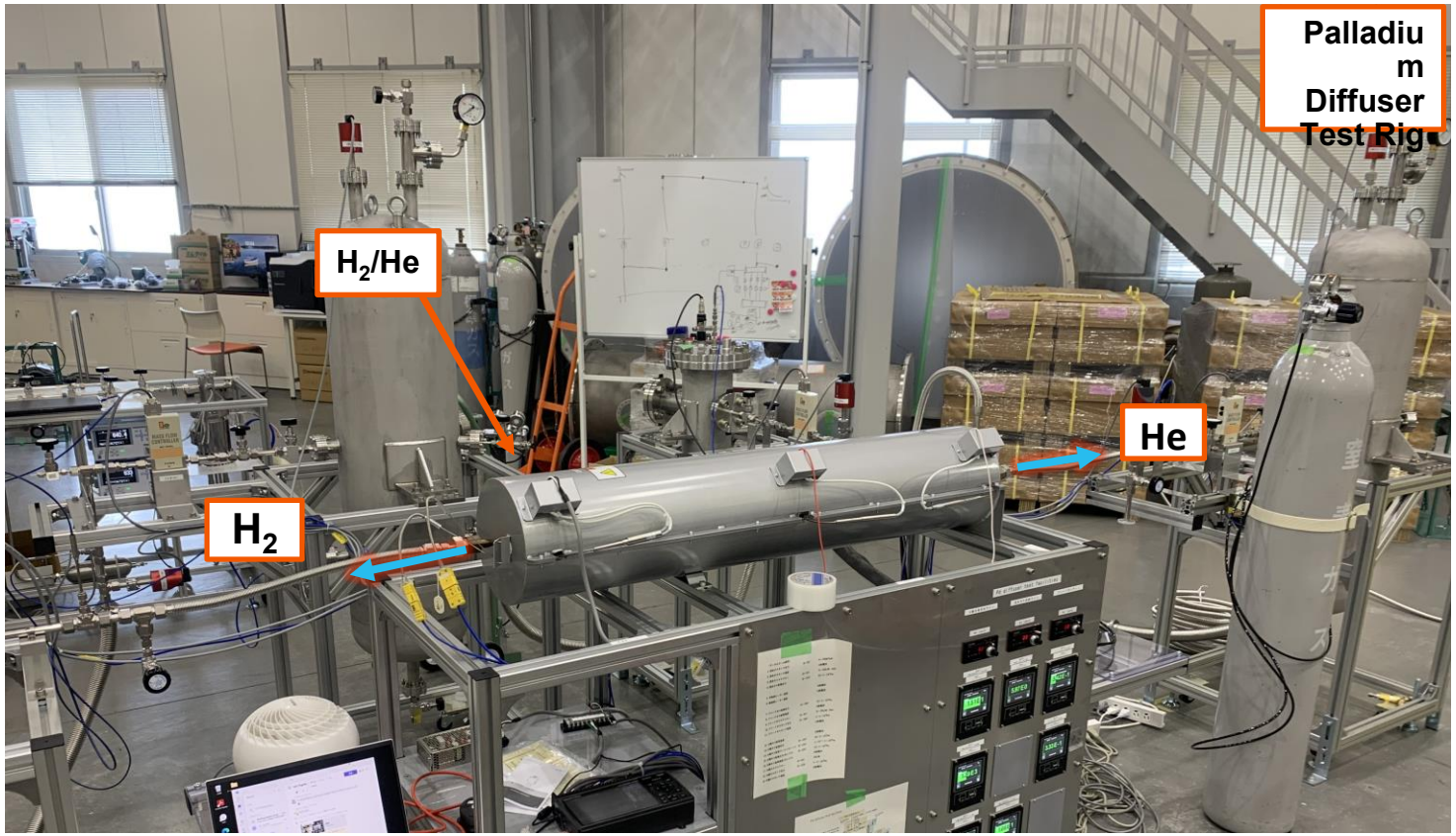
UNITY-2 Update

Fuel Cleanup System (FCUS)

Palladium diffuser (permeator) has many use cases in the fuel cycle.

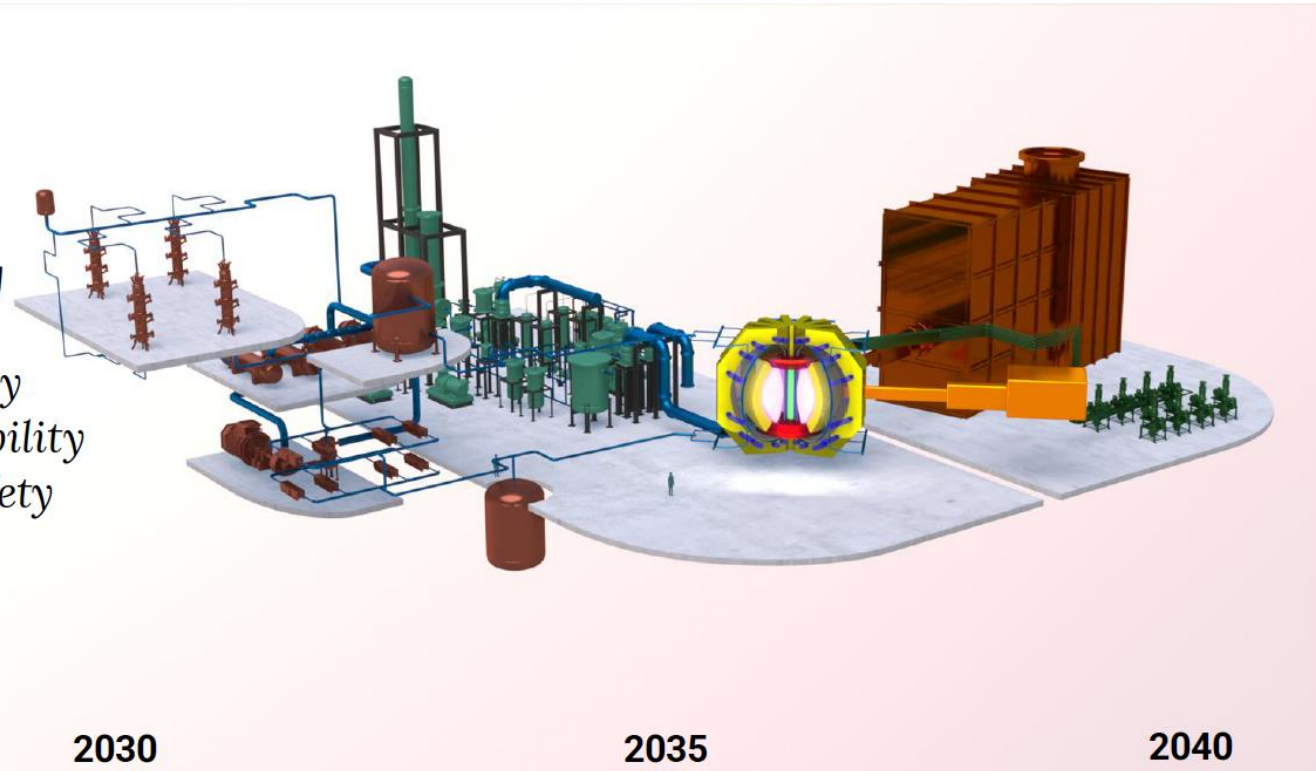
Permeator
- Outside-in configuration, finger tubes
- High throughput
- Continuous operation
- 1 m^2 area
- Ammonia cracking tested, insufficient for our use

FCUS (new design, due to facility limit on tritium concentration in water)
- Nickel bed (CQ_4 processing)
- Shift bed (Q_2O processing)
- 2x nickel bed
- 3x permeators



FAST project

Fill the gaps toward fusion plant/DEMO
Provide Fusion Nuclear Test Environment
Integration of fusion nuclear technology
- *Burning plasma operation for engineering*
- *Transport and control fusion energy flow*
- *Extraction and conversion of fusion energy*
- *Close Dt fuel cycle and test breeding capability*
- *Integrated plant system operation and safety*



2024
Project Launch
Team Organization
PreConceptual Design

2025
Conceptual Design
Key Safety Features
Site Invitation Call
Site Iselection

Engineering Design
Components Procurement
Components R&D
Site preparation
Regulation and License
Application

2030
Assembly and Construction
Tokamak Assembly
Plant Integration
Subsystem commissioning

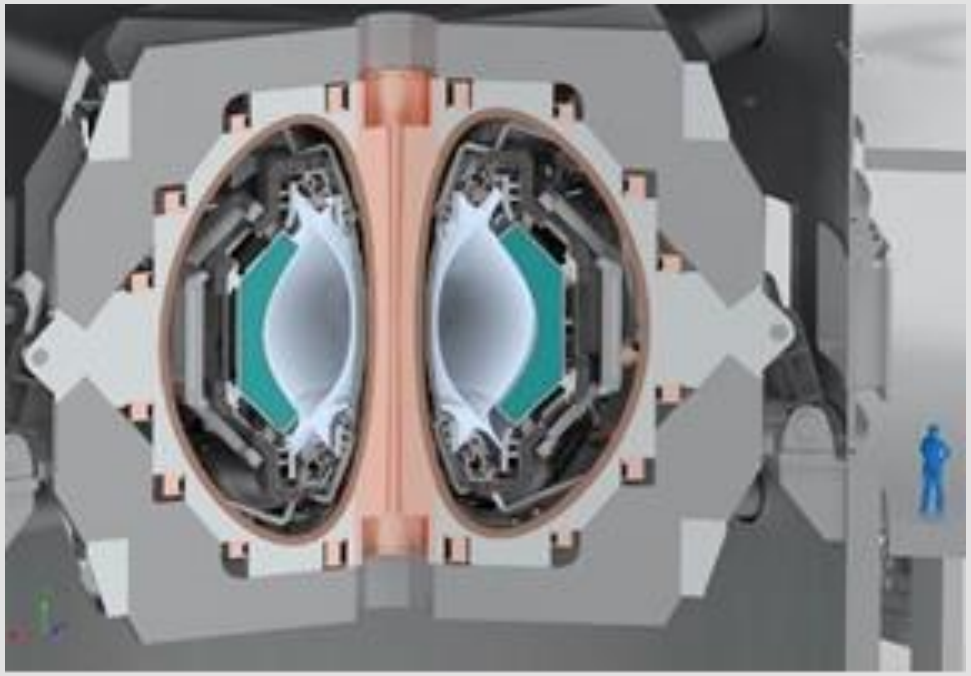
2035
Initial Operation
Initial testing of plant
Nuclear Operation
Function Verification
Plasma Optimization
Power Ascention

2040
Fusion Operation
Sustained Burn
Energy Extraction
And conversion
Tritium Breeding
Providing Fusion
Experimental Services

FAST Objectives and Specification

Power generation demonstration in mid 2030s

- D-T Fusion Reaction
- Energy Conversion
- Tritium Breeding and Fuel Cycle
- Fusion System Integration



Major Radius:	2 - 3 m
Minor Radius:	1 - 1.5 m
Magnetic Field Strength:	3 - 4.5 T (with HTS magnet)
Line Average Density:	1 –2 x1020 m-3
Normalized Beta:	3.5 - 4.5
Ion Temperature:	～20 KeV (200 million degree Celsius)
Plasma Current:	6 - 10 MA
External Heating Systems:	NBI and ECH
Confinement Improvement Factor:	1.2 - 1.5
Fusion Power:	50 - 100 MW (a discharge duration of 1,000 s)

Academia-Industry-International Partnership

Japanese unique public-private partnership model to accelerate fusion energy development

Japanese Industry

Kyoto Fusioneering
Mitsui & Co., Ltd.
Mitsui Fudosan Co., Ltd
Mitsubishi Corporation
Marubeni Corporation
Fujikura Ltd.
KAJIMA CORPORATION
Furukawa Electric Co., Ltd.

Japanese Academia

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Professor Yasushi Ono, University of Tokyo
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Professor Takaaki Fujita, Nagoya University
Professor Atsushi Fukuyama, Kyoto University
Professor Hitoshi Tanaka, Kyoto University

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Dr. Masayuki Ono, Princeton Plasma Physics Laboratory (US)
Dr. Brian Grierson, General Atomics (US)
Dr. Sam Suppiah, Canadian Nuclear Laboratories (Canada)
Dr. Ian Castillo , Fusion Fuel Cycles (Canada)

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