KYOTO FUSIONEERING

KYOTO FUSIONEERING: COMPANY, MISSION & TECHNOLOGIES

Dr Richard J. Pearson | Co-founder, Chief Innovator & UK Director

Nuclear Academics Meeting | London, UK | 6-7 September 2023

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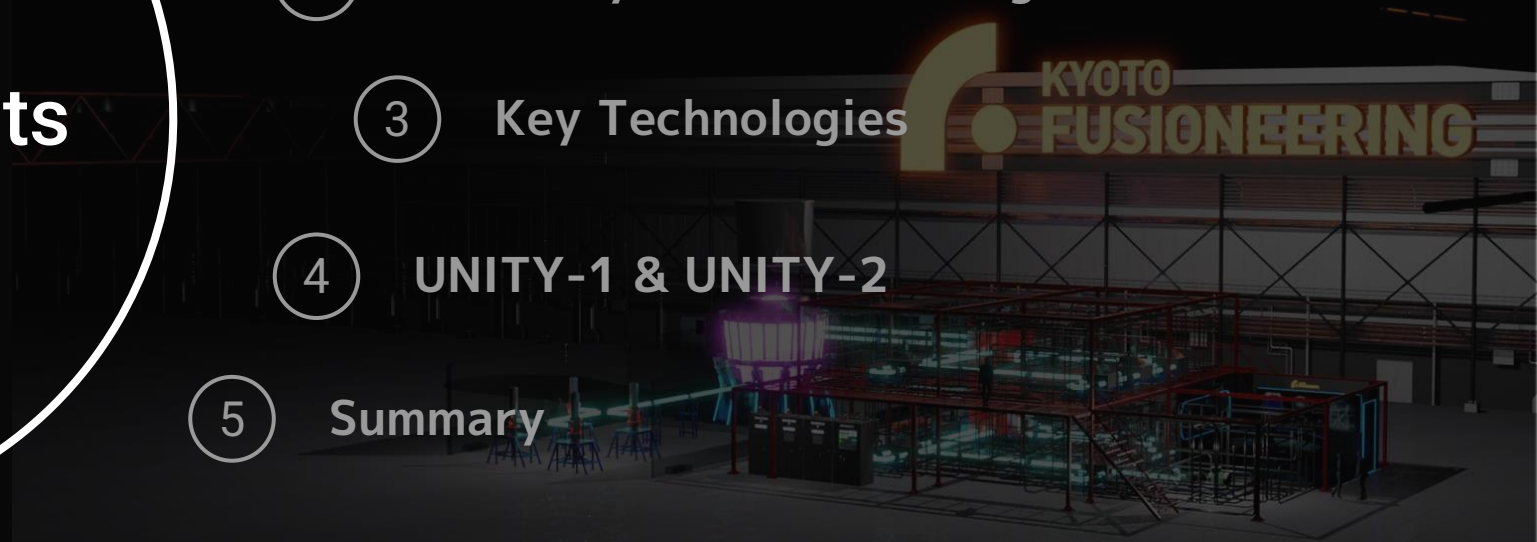

The Backdrop

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Climate Change

Current warming rates not seen in 10,000 years.

Net-zero by 2050

Energy Poverty

13% without electricity

40% without clean cooking fuels

Energy Insecurity

27% of US households having difficulty meeting energy needs

Energy Dependence

Global energy supply controlled by few nations

Supply – Key World Energy Statistics 2021 – Analysis - IEA

A vision of future society realised by fusion energy

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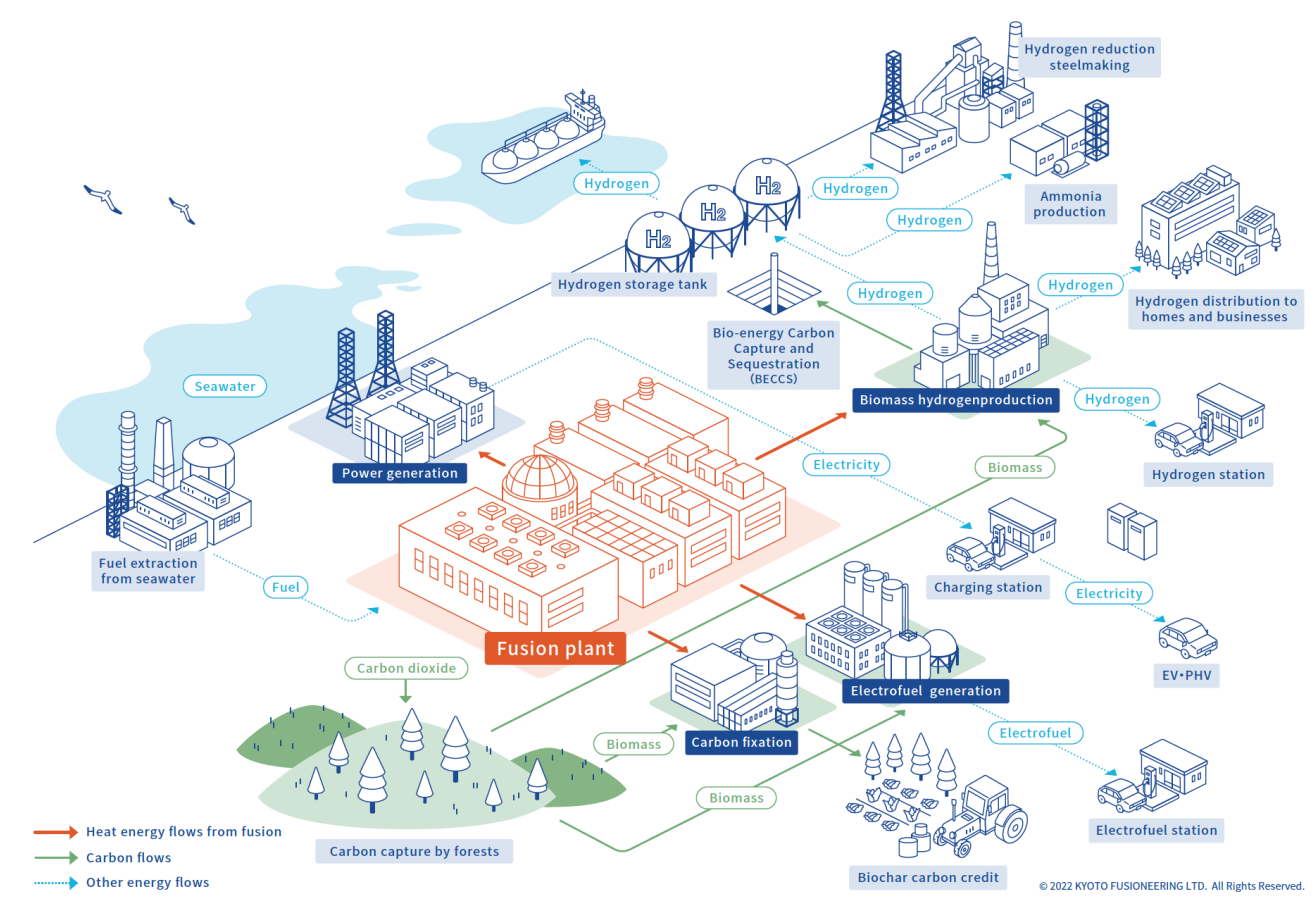
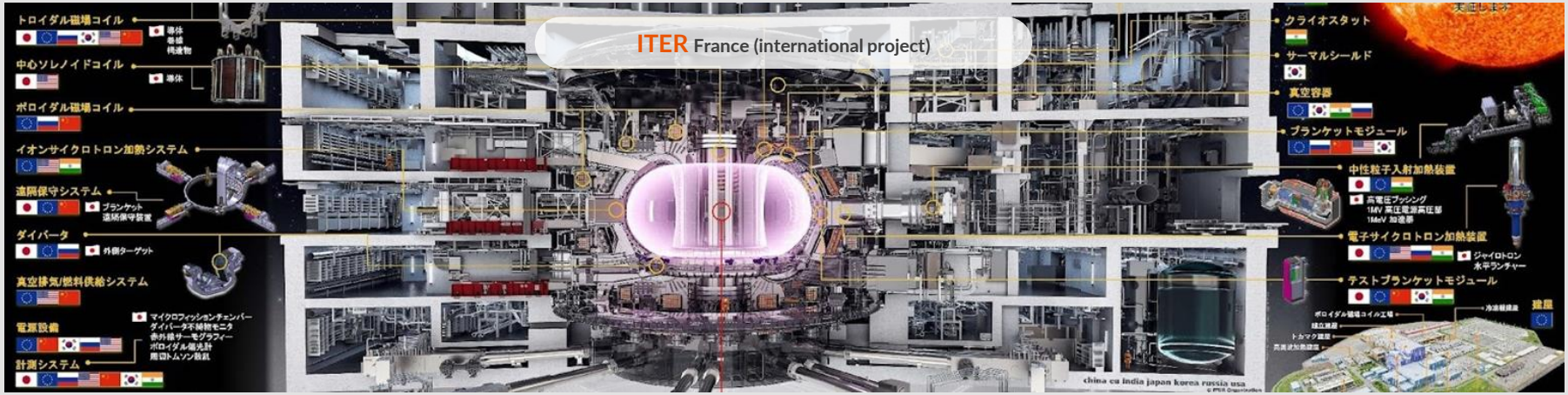


Fusion Historically Led by Public Sector



ITER France (international project)

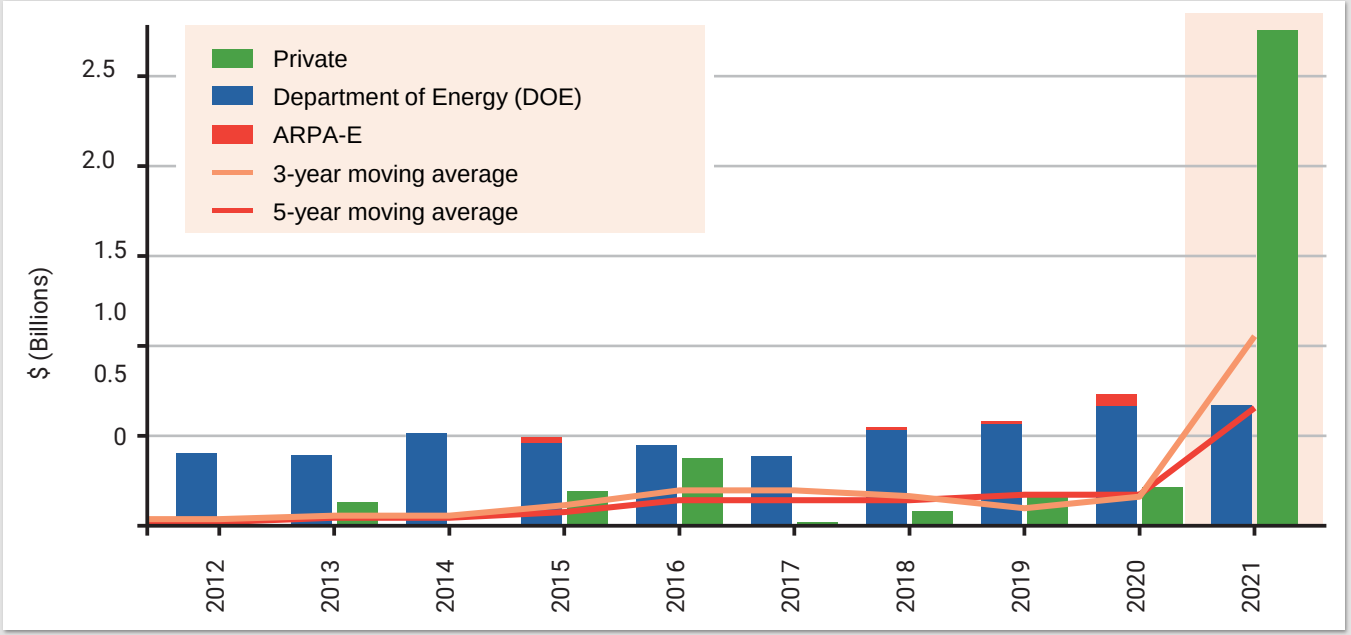

Joint European Torus UK


National Ignition Facility U.S.


JT 60SA Japan

A New Dawn for Fusion Energy

$5+ billion invested in 40+ private fusion companies.



Bloomberg: **Fusion could grow to a $40 trillion industry.**

Credit: Sam Wurzel (U.S. DoE - ARPA-E)

New Paradigm

Governments developing national strategies to promote private fusion through public-private-partnerships.

Nov 2020 – The UK government: **“Ten Point Plan for a Green Industrial Revolution”**

“Aims to build the commercially viable fusion energy plant in the UK by 2040”
15 sites are shortlisted for the UK fusion energy plant (June 2021)

Mar 2022 – US government: **“Bold Decadal Vision for Commercial Fusion Energy”**

“Accelerate the viability of commercial fusion energy in coordination with the private sector”
NASEM “Have a viable design by 2028 and initial pilot plant operation in 2035~2040”

Apr 2023 – Japanese government: **“Fusion Energy Innovation Strategy”**

“Our strategy for the next 10 years is to ‘industrialize fusion energy,’ … the world’s next-generation energy source.
It is necessary to promote further participation of Japan’s private sector and cooperation between industry, academia, and government, and to develop a national strategy that includes specific actions that will attract private investment.”

Deep Tech Innovation Through Public-Private-Partnership

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COTS Program (NASA + SpaceX) being replicated for fusion by White House and U.S. Department of Energy.

Public Program

Strategic projects based on long-term vision

Public Private Partnership

Innovation that combines a long-term vision with an agile, iterative approach

Private (Startups)

Agile, iterative approach with risk-tolerant private capital

Fusion Devices

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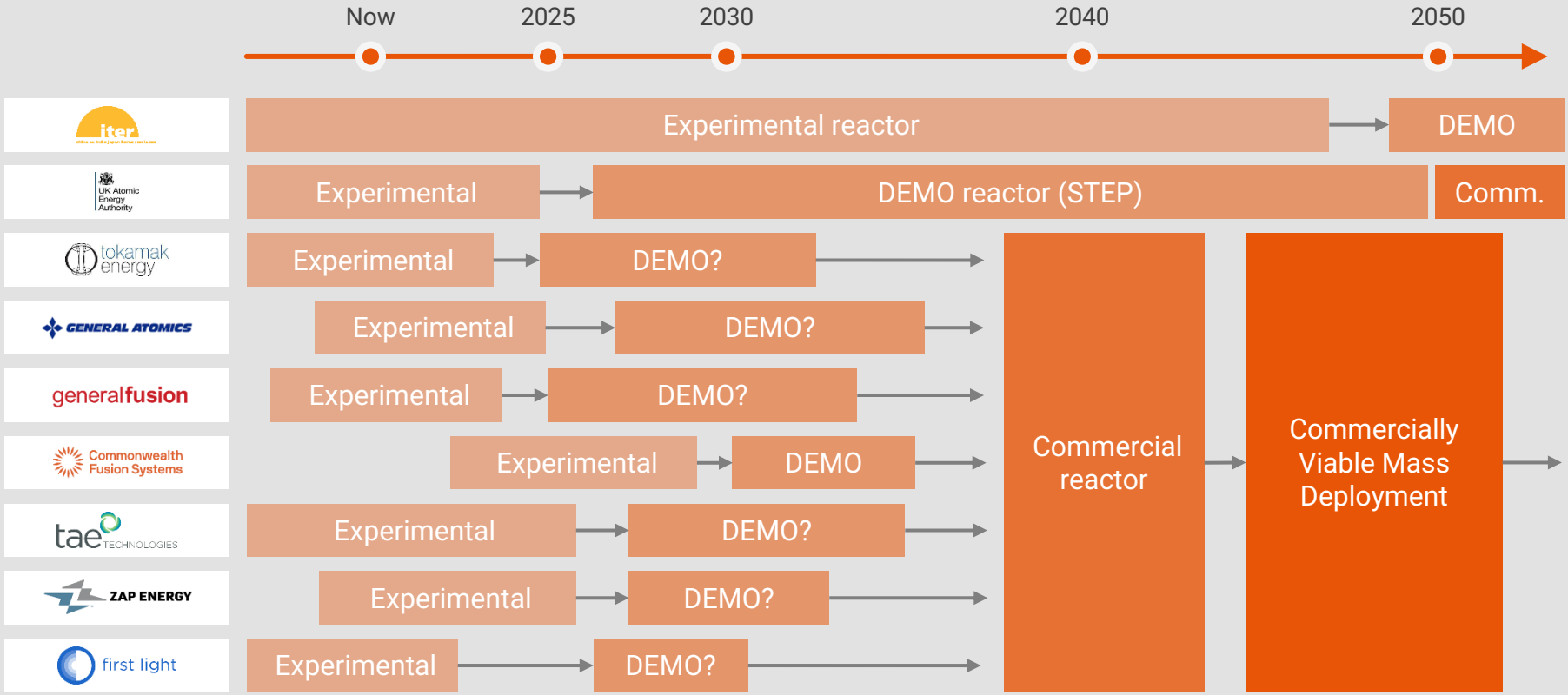
A snapshot of the road ahead



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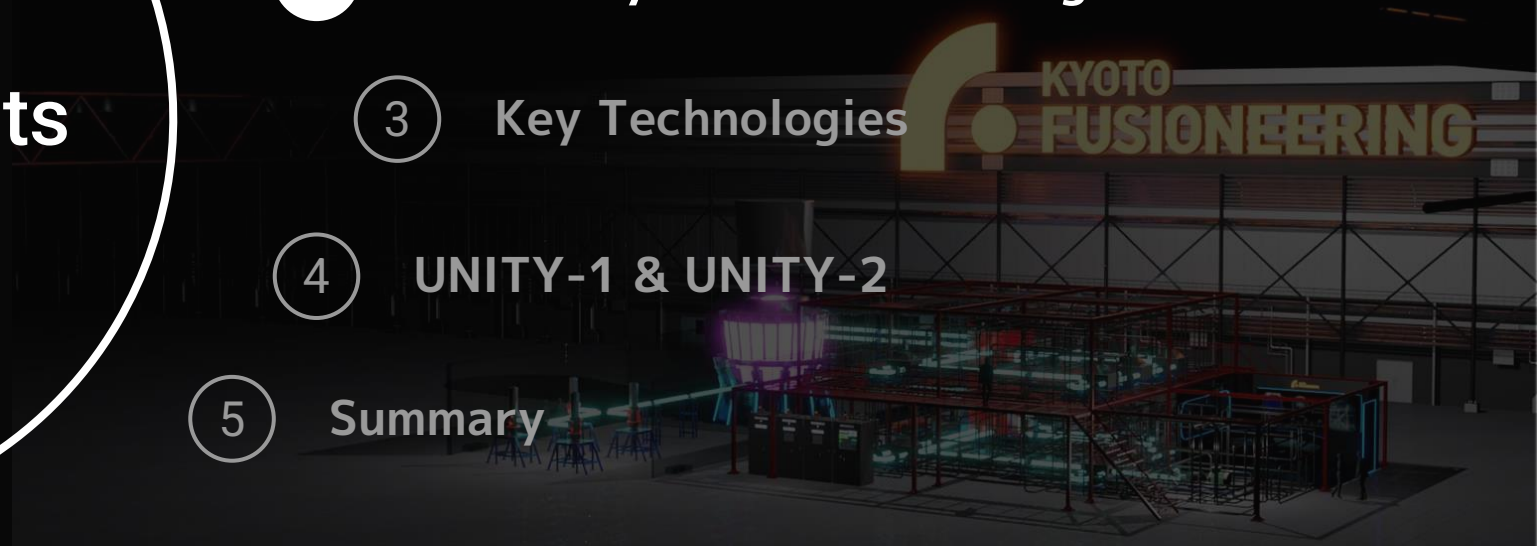


KYOTO
FUSIONEERING
Founded in
2019
90+
Team members
$90m+
Raised
3
Countries
JP
US
UK

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Japan's fusion research gets $79m boost

Jonathan Spencer Jones - May 18, 2023

Facebook Twitter Linkedin

Image: Kyoto Fusioneering

Japanese fusion start-up Kyoto Fusioneering has raised 10.5 billion yen (US$79 million) in a Series C funding round.

NUCLEAR ENGINEERING INTERNATIONAL

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Kyoto Fusioneering secures more funding

23 May 2023

Print Email

Japan's Kyoto Fusioneering (KF) has raised JPY10.5bn ($79m) in an oversubscribed Series C funding round led by existing investor, JIC Venture Growth Investments. The round attracted a total of 17 investors, including 11 new supporters. KF said this latest capital infusion brings total funds raised to JPY12.2bn.

The new capital and the expertise of its investors will be used to accelerate research and development for KF's core products, including in-vessel components of fusion reactors and fusion plant engineering. KF also aims to expand its business expansion in the US and UK in order "to be at the forefront of the practical application and industrialisation of fusion energy".

In Japan, the "Expert Committee on Fusion Strategy" has been active since September 2022. In April, during the government's Integrated Innovation Strategy Promotion Conference, the committee unveiled a "Fusion Energy Innovation Strategy calling for the wider participation of the private sector in fusion energy research & development.

Kyoto Fusioneering was spun out of Kyoto University as Japan's first fusion start-up in 2019 co-founded by Taka Nagao, Satoshi Konishi, Richard Pearson and Shutaro Takeda. Its mission is to tackle reactor engineering and technology challenges, whilst cooperating with fusion developers around the world, to rapidly accelerate the growth of the fusion industry. The company's business model is to conduct R&D and design of innovative fusion reactor technologies, and to provide these alongside engineering solutions to both private fusion enterprises and publicly funded fusion programmes at global research institutions. Satoshi Konishi, was the first and second chairman of the International Coordinating Committee for the ITER Blanket programme.

KF has initiated strategic partnerships with various stakeholders both domestically and internationally. Earlier this year it signed a memorandum of understanding with Canadian Nuclear Laboratories (to collaborate on the development and demonstration of fuel cycle systems and to share scientific information. A collaborative agreement was also signed with the United Kingdom Atomic Energy Authority (UKAEA) to develop fusion related technologies.

Kyoto Fusioneering nets $79M Series C to make parts for fusion startups

Commercial fusion power has never felt closer. It's not going to happen next year or the year after, but plenty of investors think it'll be sooner than later. Even Microsoft has placed a bet, inking a deal with Helion that requires the startup to bring a plant online by 2028.

There are at least half a dozen other companies vying with Helion to supply fusion power to the grid. Many of them are developing a significant fraction of their technology in house, but Kyoto Fusioneering is betting that there's plenty of stuff

TechCrunch+

Japan-based nuclear fusion firm powers up with $79m raise

Photo credit: Kyoto Fusioneering

Kyoto Fusioneering, a Japan-based energy company, has raised US$79 million

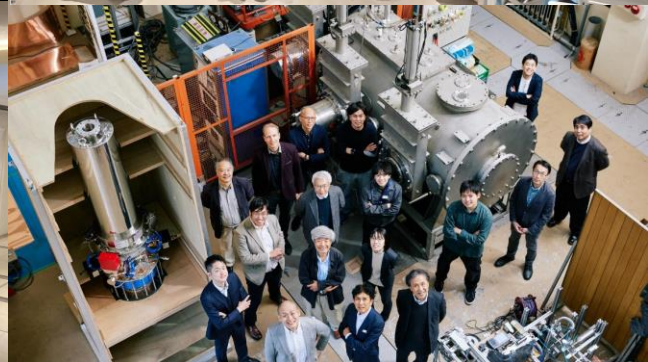
JIC VENTURE GROWTH INVESTMENTS · INPEX · SMBCベンチャーキャピタル · mol plus · 関西電力グループ power with heart · CORAL CAPITAL · JAFCO · DBJ · J-POWER · JGC · global brain · 三菱商事 · MUFG 三菱UFJキャピタル · MUFG 三菱UFJ銀行

大和企業投資 Daiwa Corporate Investment · DBJ · KYOTO-iCAP · KYOTO UNIVERSITY INNOVATION CAPITAL Co.,Ltd.

95+

Members

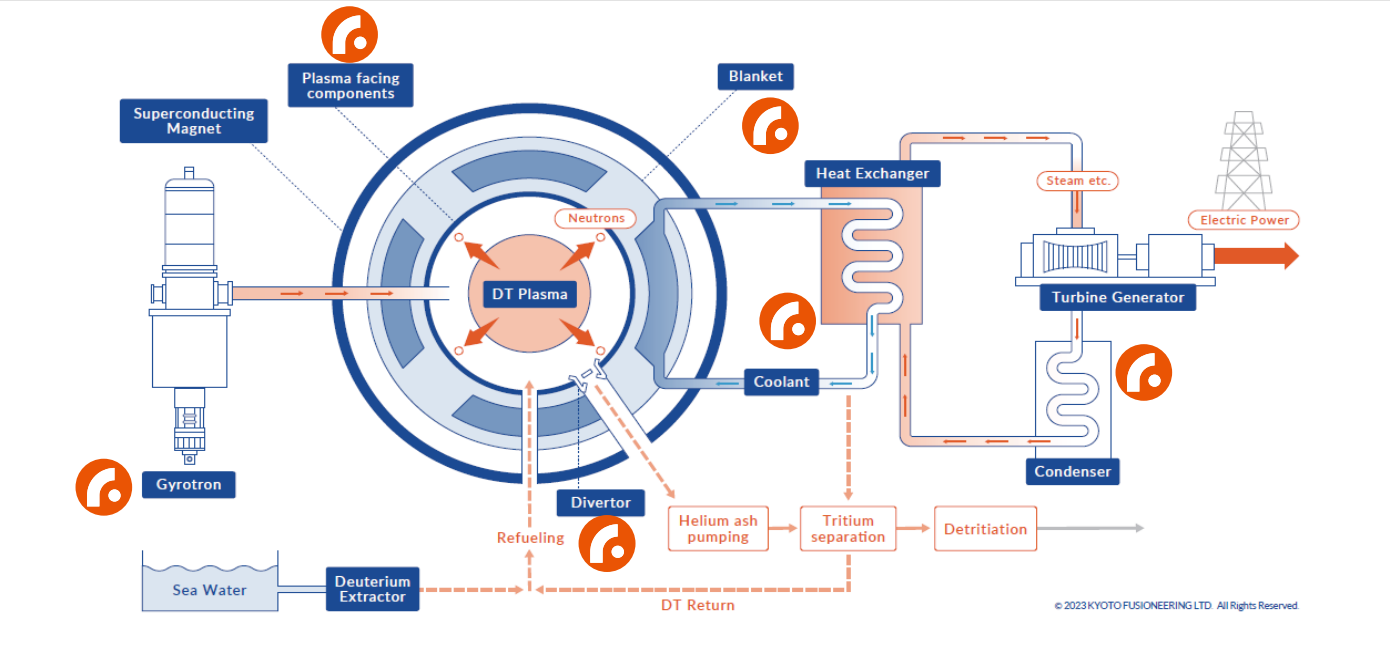
As of June 2023



Complementary Business Model

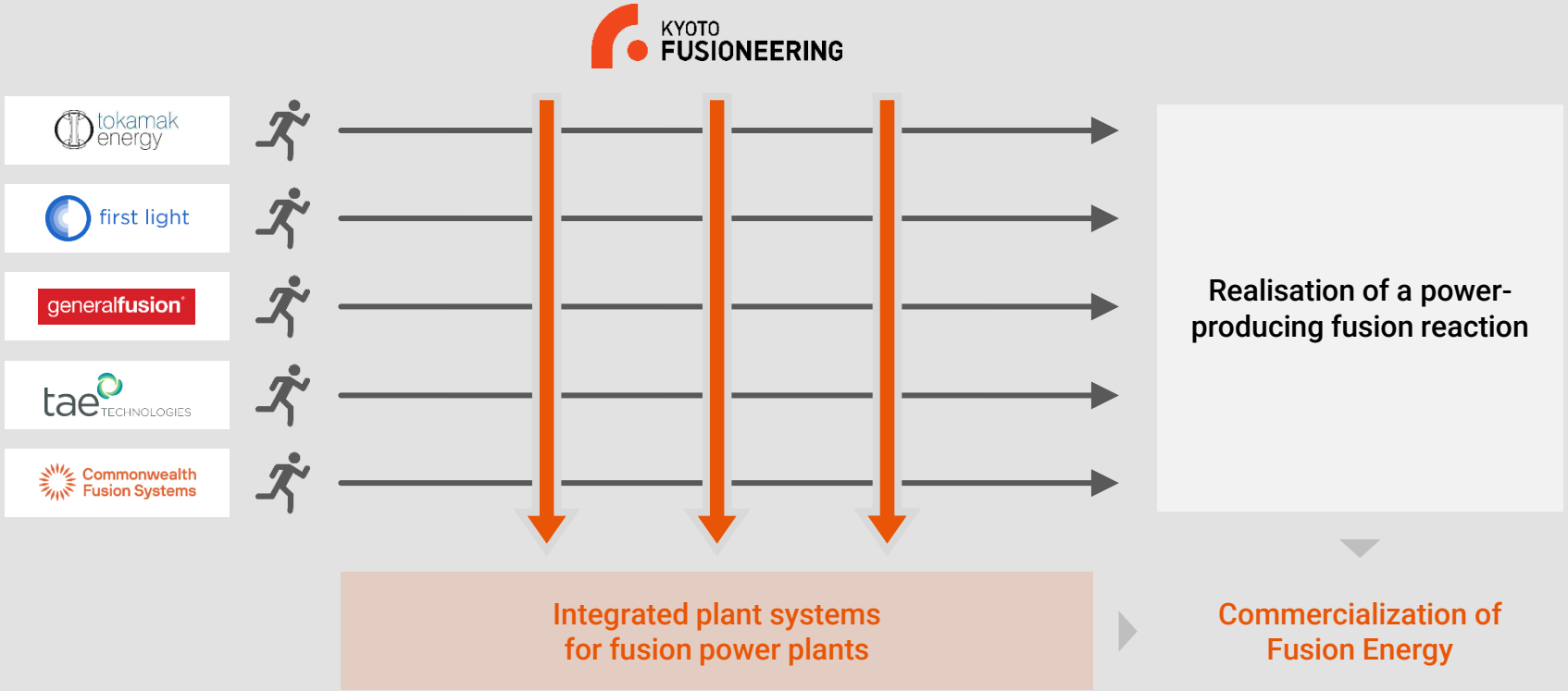
KF focuses on fusion plant engineering – **an enabler for all fusion players like** Levi's

Other fusion companies focus on developing a power-producing fusion reaction…



… KF focuses on key fusion power plant integrated systems and components, principally: plasma heating systems, power production, fusion fuel cycle.

Supporting industry growth; same vision, different mission



Forging a Global Supply Chain; bringing Japanese manufacturing to the fusion market

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Canon CANON ELECTRON TUBES & DEVICES

Nimblox. 助川電気工業株式会社

JASTEC SUPERCONDUCTOR

YAMATO

MTC Metal Technology Co. Ltd.

MIKUNI JGC TYK

And many more....

OAK RIDGE National Laboratory

Savannah River National Laboratory

PPPL PRINCETON PLASMA PHYSICS LABORATORY

MIT

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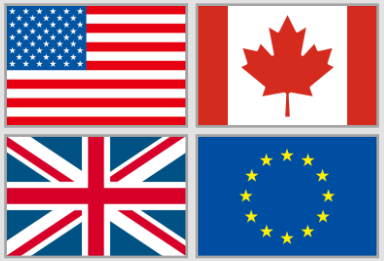
Canadian Nuclear Laboratories



Fusion Developers

Public sector programs, private start-ups

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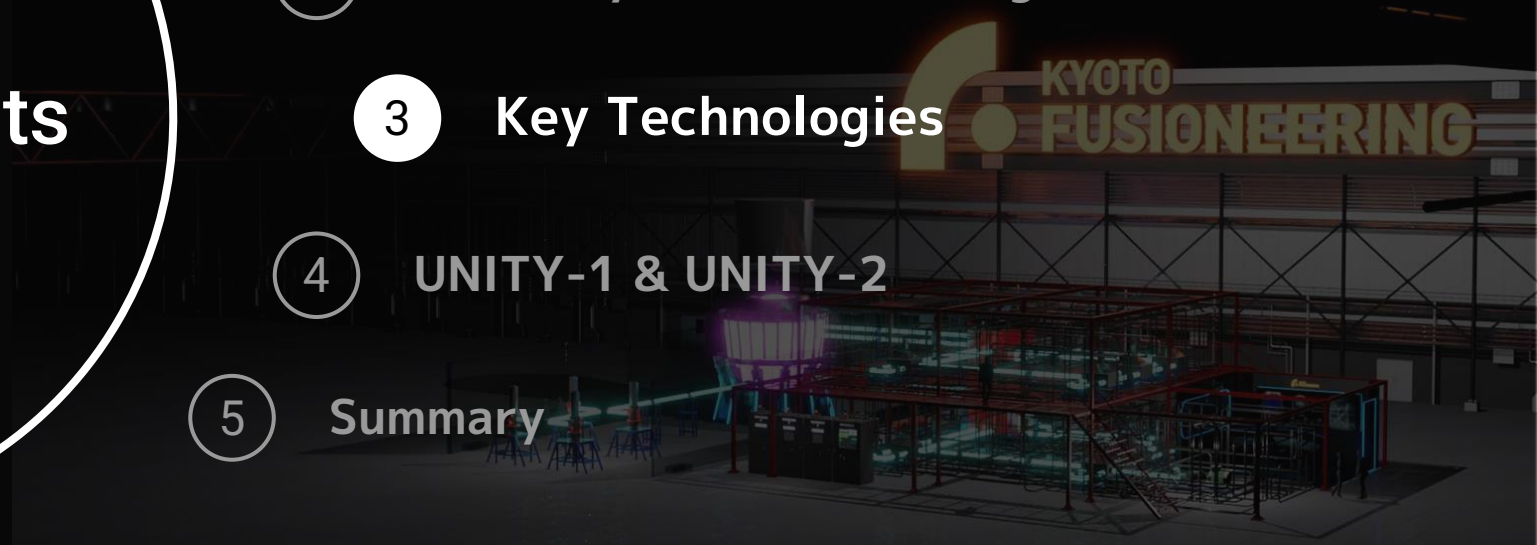
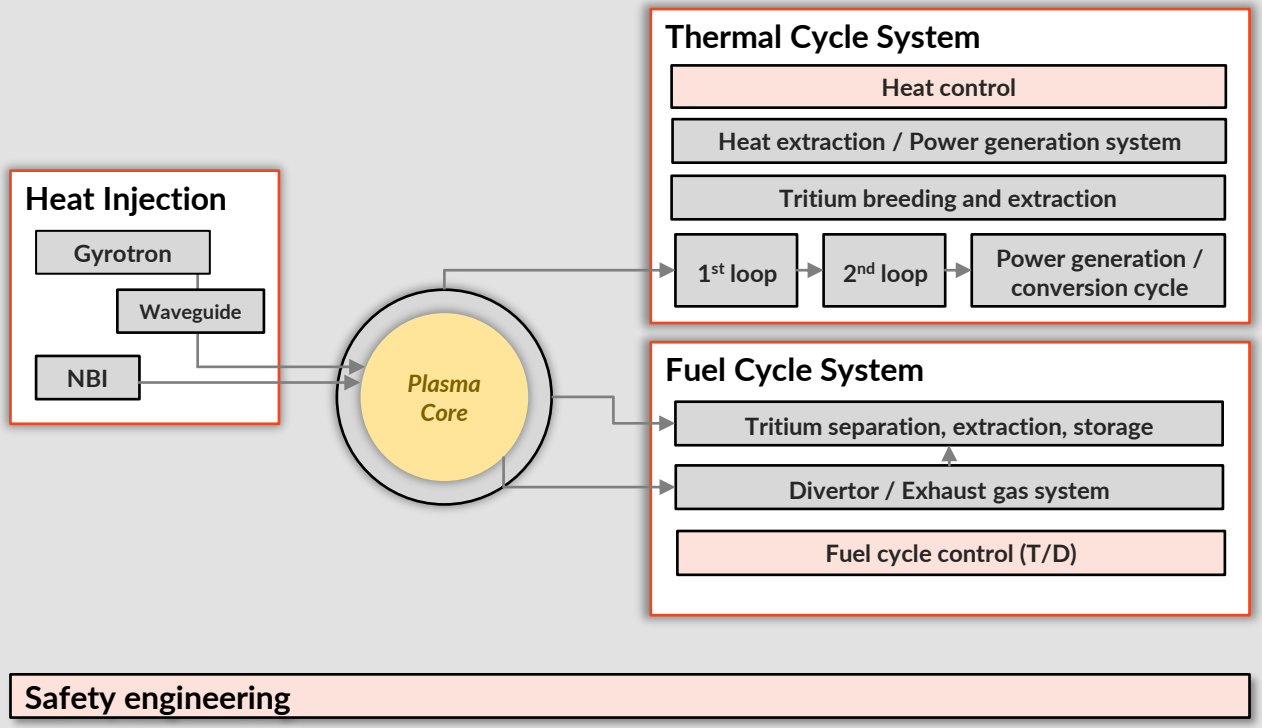
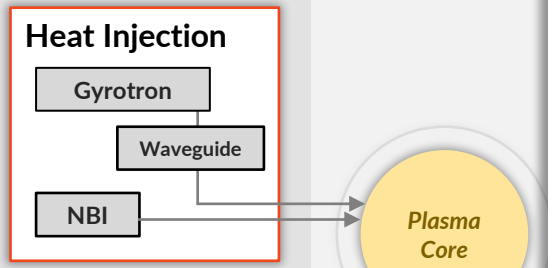
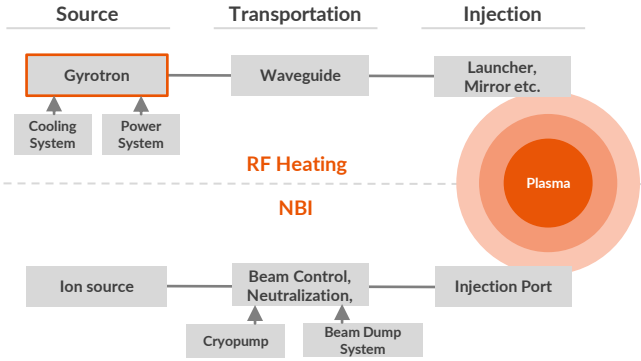


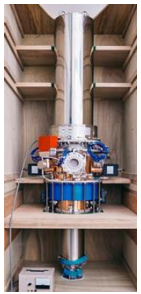
Focus Areas



Focus Areas: Gyrotrons for plasma heating







Key System: Gyrotron

- 28/35 GHz (EBW), 100-236 GHz (world record frequency held by our scientists formerly working at JP National Lab)
- Long pulse up to CW

Delivery to UKAEA, Tokamak Energy, Korean National Lab all on track

Plant System
Plant Component
Operations / Controls

Focus Areas: Thermal Cycle

Advanced Materials HEX, Blanket

- Minimal Tritium permeation heat exchanger
- High temperature (~1000C) heat extraction
- SiC composite technology

Liquid metal/Molten Salt loop and thermal cycle

- Demonstrated ~1000°C heat extraction
- LiPb, Li, FLiBe
- Dual coolant loop

Thermal Cycle System

- Heat control
- Heat extraction / Power generation system
- Tritium breeding and extraction
- 1st loop → 2nd loop → Power generation / conversion cycle

lasma Core

GOV.UK

Home > Scientific research and development

Press release

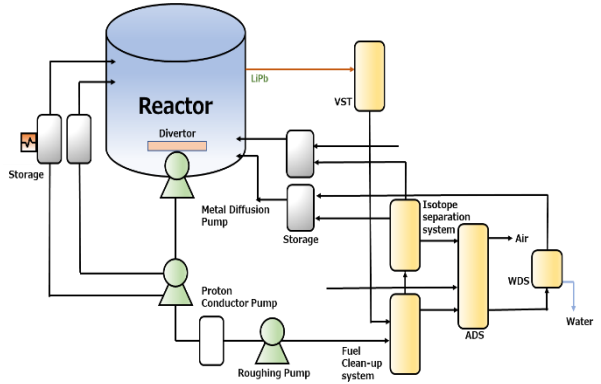
UKAEA and Kyoto Fusioneering to advance fusion materials

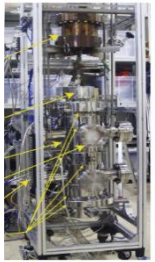
Collaboration agreement signed by UKAEA and Kyoto Fusioneering to advance materials for commercial fusion energy.

From: UK Atomic Energy Authority

Published 23 March 2023

Focus Areas: Fuel Cycle





VST for T Extraction

Roughing pump

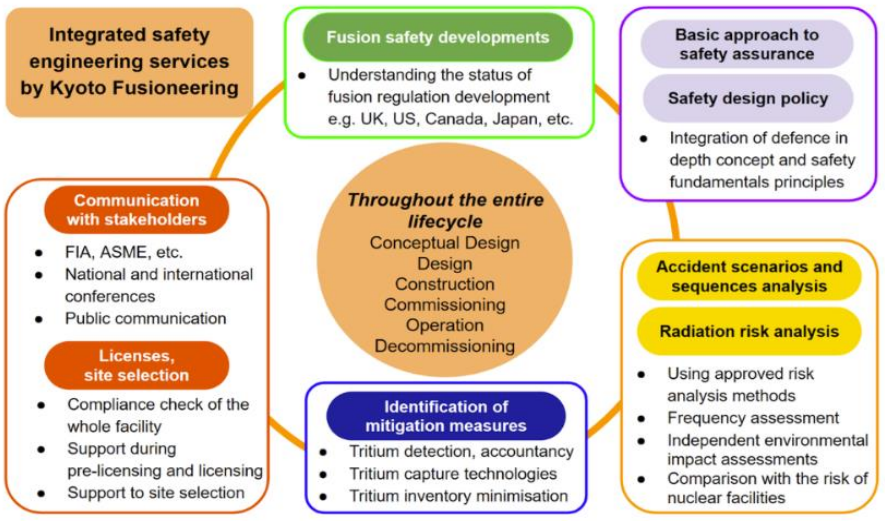
Plasma Core

Fuel Cycle System

- Tritium separation, extraction, storage
- Divertor / Exhaust gas system
- Fuel cycle control (T/D)

Plant System
Plant Component
Operations / Controls

Focus Areas: Safety



Integrated safety engineering services provided by Kyoto Fusioneering

Safety engineering

Plant System
Plant Component
Operations / Controls

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UNITY programme: integrated fusion technology testing

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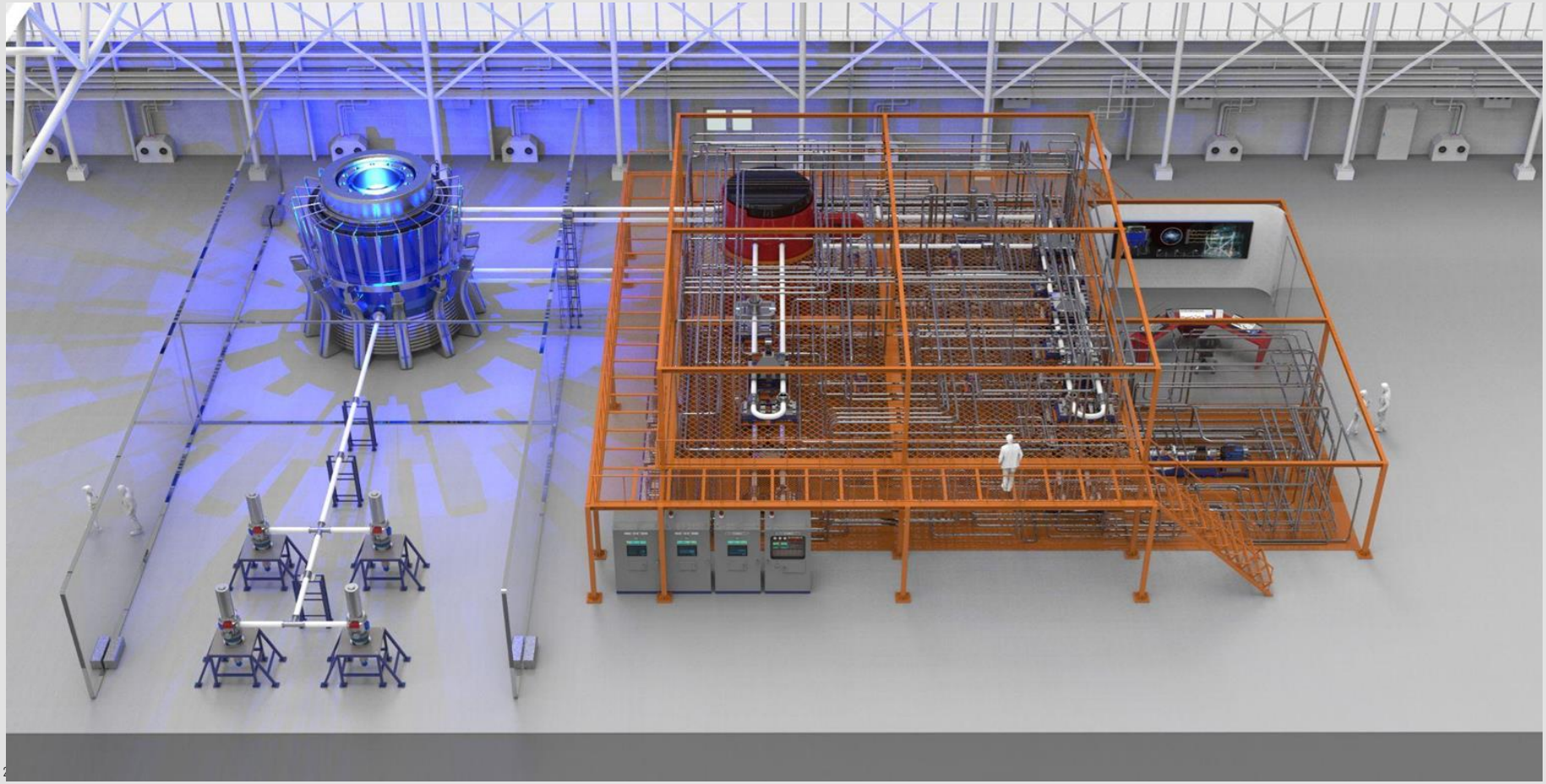

UNITY programme: integrated fusion technology testing

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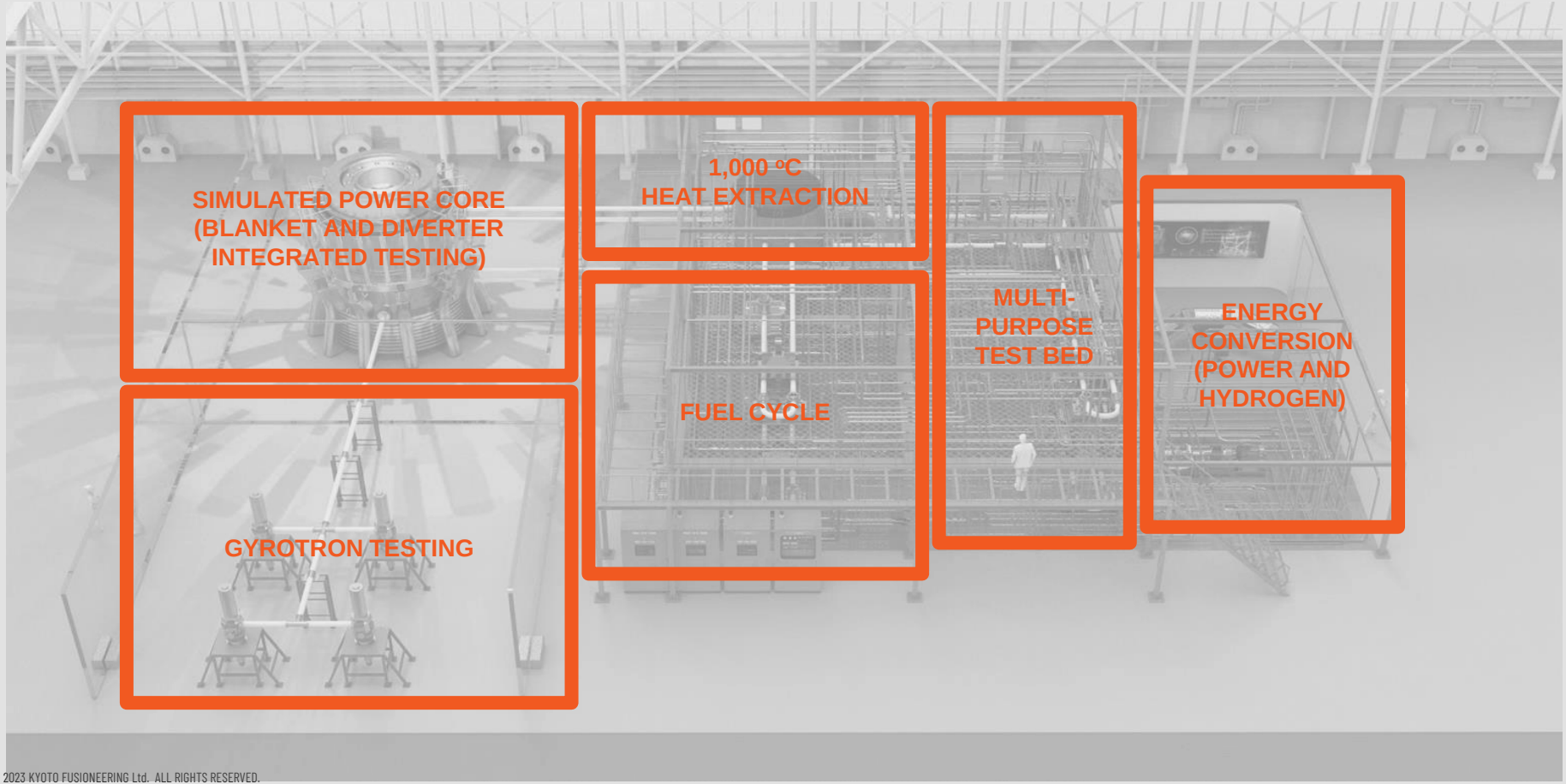

Existing KF products and systems at KF (Kyoto lab)

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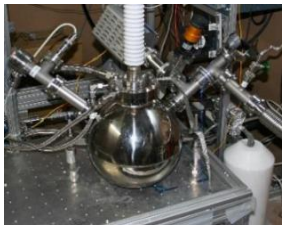
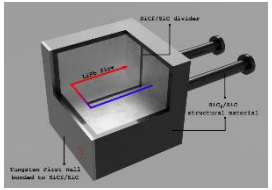
Gyrotron

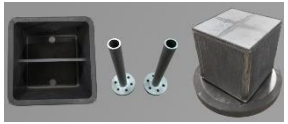
Neutron Source



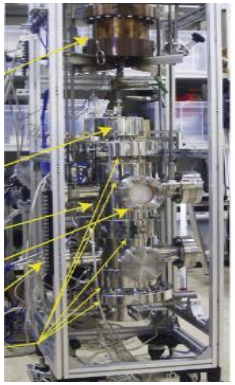
Tritium Processing

Blanket modules





Tritium Extraction



Vacuum Pumps

Li Loop

Under construction;
due for delivery Feb '24

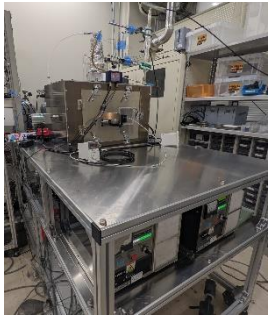
LiPb Loop

FLiBe Loop

FLiBe Refining

Divertor

H2 Generation



Upcoming (under construction) KF products and systems to be integrated…

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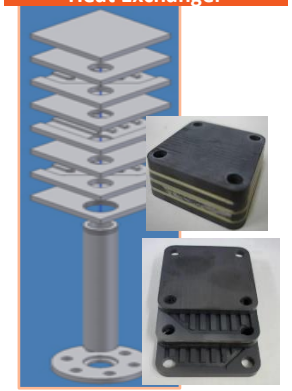
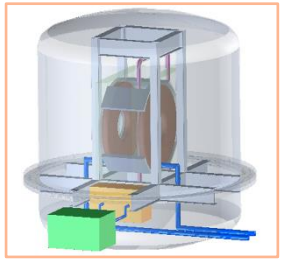
LiPb Loop (scale up)

1000°C LiPb Heat Exchanger

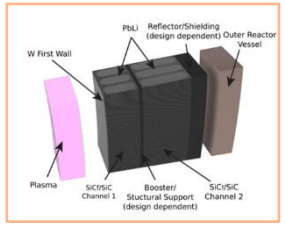


Power Generation

Blanket Test System

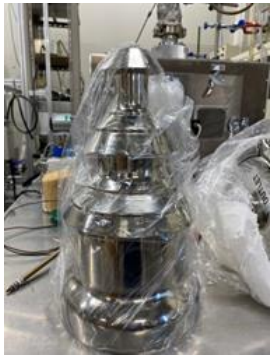


Breeding Blanket Module & Design

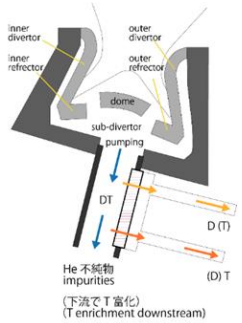


VST (scale up)

Metal Diffusion Pump



Direct Internal Fuel Recycling

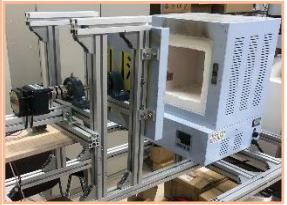


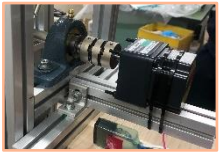
Tritium Handling System

Hydrogen Sensor

Gyrotron (Multi-Frequency)

Li Isotope Separation





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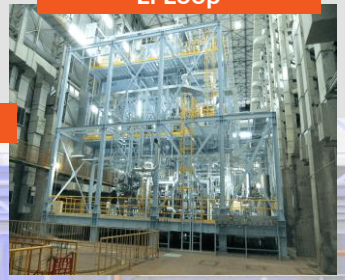
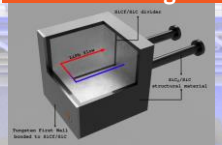
Li Loop



LiPb Loop (scale up)

FLiBe Loop

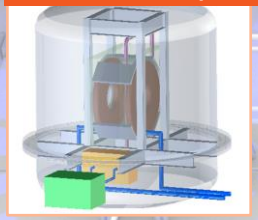
SiCf/Sic Heat Exchanger



Divertor

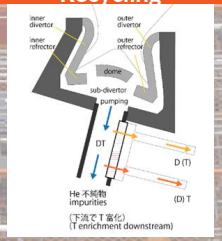
Plasma Simulator

Blanket Test System



Tritium Extraction

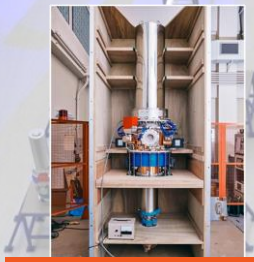
Direct Internal Fuel Recycling



Power Generation

H2 Generation

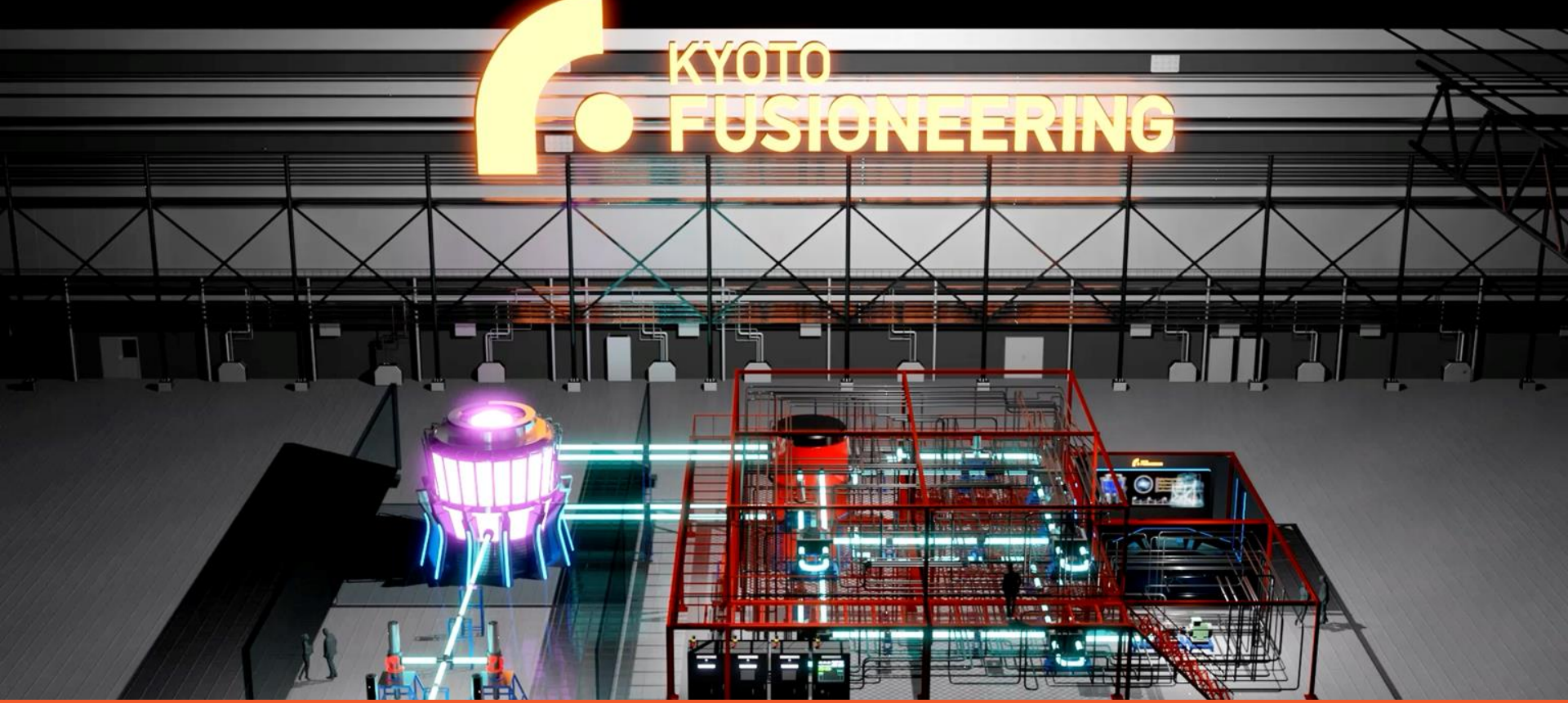
Gyrotron



Metal Diffusion Pump

VST(scale up)

Tritium Handling Sys



UNITY-1 (UNique Integrated Testing facilitY 1: Thermal Cycle)

Announced 2022 (publication). World-first integrated testing facility for fusion power plant equipment. Electricity generation with fusion relevant technologies; operational from 2024.

UNITY-1 Facility

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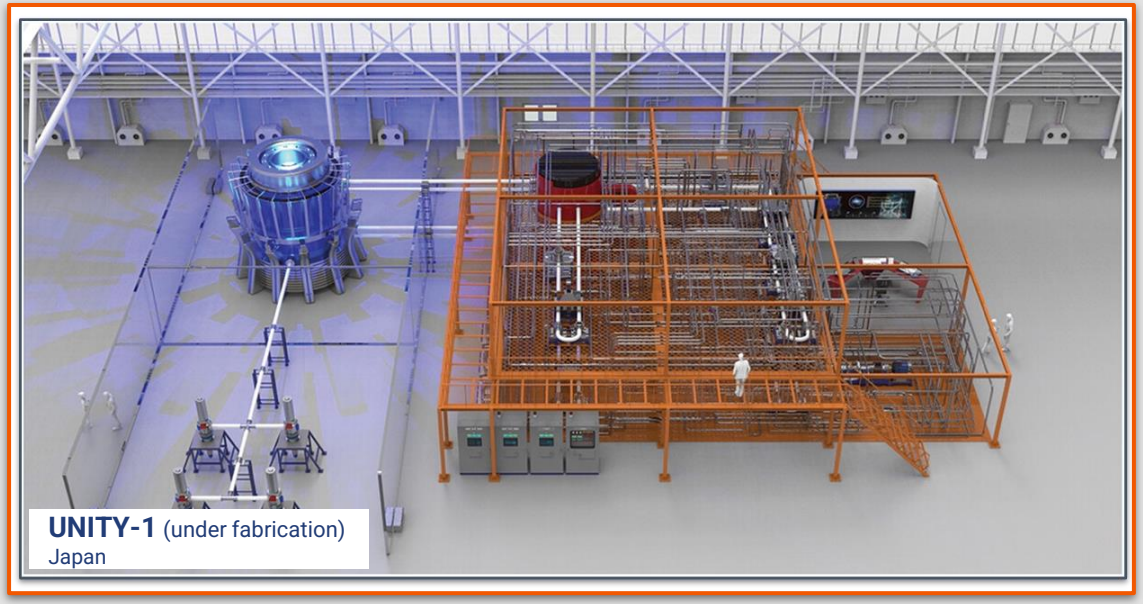
Focused on blanket testing and technology needed to integrate the power and fuel cycle



Location: Kyoto, Japan

Thermal Cycle:

- Blanket test section (1000°C LiPb, Li, FLiBe)
- 250 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
- H isotope 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

KYOTO FUSIONEERING

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

"Both CNL and KF are conducting cutting edge work in fusion, with each organization having built strengths in select areas. By working cooperatively, we can more effectively apply this knowledge and expertise, which will ultimately better serve the needs of the market."

Dr. Jeff Griffin
Vice-President, Science & Technology, CNL

KF and CNL sign a Strategic Alliance Agreement to collaboratively accelerate the development and commercialization of fusion fuel cycle technology – with UNITY-2: Fuel Cycle.

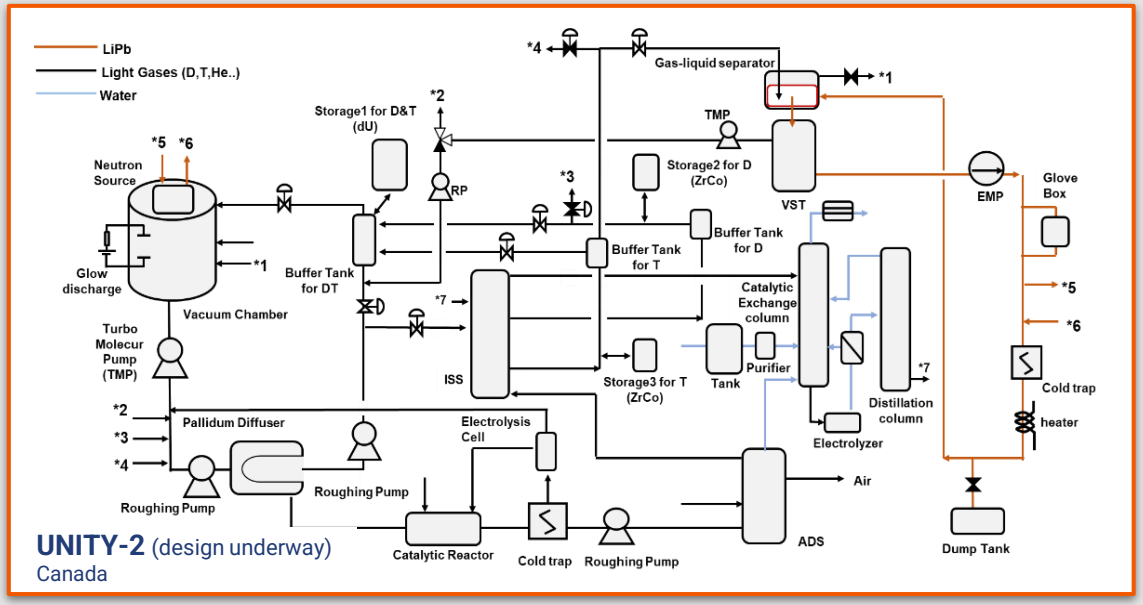
"Fusion energy holds transformative potential for global energy. Our partnership with CNL merges KF's fusion technology with CNL's tritium management expertise, positioning us to tackle some of commercial fusion power's most critical challenges."

Dr. Satoshi Konishi
Co-Founder & Chief Fusioneer, KF

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

UNITY-2 Facility

Focused on demonstrating fusion power plant relevant tritium fuel cycle technologies in an integrated fashion



2023 — 2024 — 2025

Initiation:
Design and individual component testing

Procurement:
Key systems and components

Installation:
Integration of systems. Possible commissioning

Location: Chalk River, ON, Canada (CNL)

Components:

- Tritium Extraction System to be tested with real tritium (~50 L LiPb 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
- Will include DIR

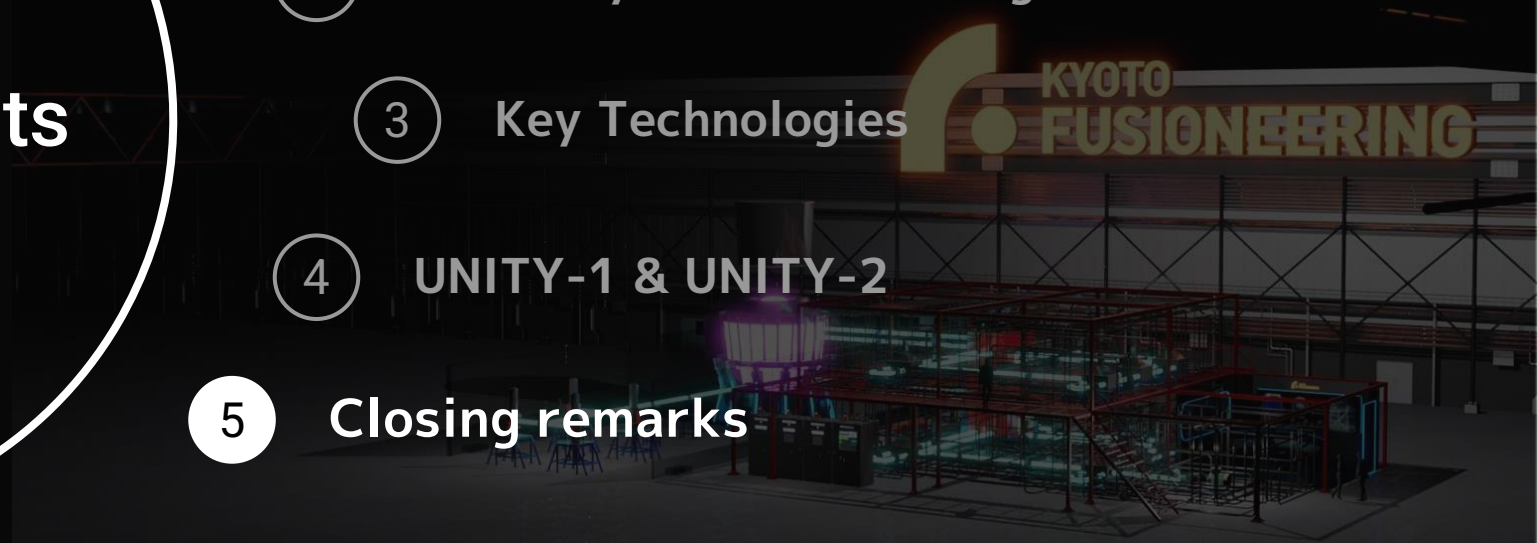
Tritium:

- Under review, 10 to 40 g inventory
- Fuelling of vacuum chamber at ~2.6 Pa m^3 / s

Modelling:

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

Contents



KF's message to the nuclear academic community

- **We are a fusion engineering company**
  - We tackle fusion engineering challenges, aligning closely with the nuclear sector's expertise and concerns.
  - We're not a plasma physics company; we seek expertise in nuclear materials, chemistry, chemical engineering, mechanical engineering, waste handling, and more.
- **Nuclear engineering is where our origins are**
  - Three out of four co-founders are nuclear engineers; we have strong ties to academic foundations in this field.
- **We pride ourselves on being ambitious yet realistic**
  - We know how challenging the road ahead is for fusion – we don't shy away from this, and we don’t pretend it's easy.
  - We approach fusion engineering challenges with ambition tempered by practicality, seeking viable solutions.
- **We see collaboration opportunities with the sector**
  - We welcome collaborations with universities and academics in cross-cutting areas.
  - Your expertise complements our fusion engineering goals.
- **We want to nurture future nuclear talent to unleash cross-cutting potential**
  - We seek talented post-docs, PhD students, and researchers (you!), acknowledging the vital role of academia in shaping fusion's future – *we have both full-time career opportunities and for internships*
  - Your network harbours the future leaders of fusion engineering...

Summary

1. The quest for fusion energy has undergone a **paradigm shift** in the past 5-10 years.
    - Emphasis now on demonstrating commercial viability – going beyond the lab.
    - Numerous public & private developers advancing towards **power plant prototypes**.
    - KF **supports these fusion developers** around the world.
    - KF **shares the vision** but follows a **distinct mission** for achieving commercial fusion.
2. Secured **~$80M (May 2023)** for the next phase, enabling focus on critical technology areas:
    - **H&CD**, **power cycle**, **fuel cycle**, and **safety** (underpinning).
3. Developing **major fusion development facilities** for integrated testing of power cycle and fuel cycle to advance key technologies (“move the dial”):
    - **UNITY-1** (Japan) 
    - **UNITY-2** (Canada) 
4. **Seeking collaboration – from you!**
    - *If you think you can contribute to our mission, reach out!*
5. **We are growing:** hiring in the UK, Japan & N. America (spread the word!)

KYOTO FUSIONEERING

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