Toward Realistic Fusion Pilot Plants by Enabling Technology and Available Supply Chain

KYOTO FUSIONEERING

Presented by Satoshi Konishi

CEO an Chief Fusioneer

FUSION for the FUTURE

KYOTO FUSIONEERING

Kyoto Fusioneering
Is a Unique company that provides Ingegrated Fusion Plant technology to the World developers of fusion commercial energy.

Founded in
2019

100+
Team members

$90m+
Raised

3
Countries

JP
US
UK

We emphasize
Energy Conversion Systems,
Fuel Cycle,
Nuclear Technology, and
Supply Chain for the fusion energy cycle.

Shareholders: Global companies' support

KYOTO FUSIONEERING

We are supported by not only VCs, but Industry, Financials and Public.

We also introduce our sponsors to other Fusion Companies to promote Fusion Supporing Funds.

Kyoto Fusioneering: The Leadership Team

Prof. Satoshi Konishi

Co-founder CEO, Chief Fusioneer

Prof. Satoshi Konishi co-founded Kyoto Fusioneering in 2019 and serves as the Chief Fusioneer, steering its technological vision. With a Ph.D. from the University of Tokyo, his 40-year expertise spans fusion technology, nuclear design, and tritium engineering, especially the ITER project. A tenured professor at Kyoto University, he's chaired the Test Blanket Program for ITER since 2009. Prof. Konishi leads Kyoto's Institute of Sustainable Science and holds affiliations with multiple atomic and fusion societies. His insights bolster Kyoto Fusioneering's trailblazing ambition.

We are organizing a Strong Team of Business, Financial And Technology

Prof. Keishi Sakamoto

CTO, Director, Head of Technical Development

Prof. Keishi Sakamoto, joining Kyoto Fusioneering in 2021 as Executive Officer, has decades of R&D experience in plasma heating, notably at Japan's National Institute for Quantum Science. He significantly advanced gyrotrons, achieving a world-first in output energy and efficiency. Recognized with awards from MEXT Japan and the European Physical Society Plasma Division, Keishi now serves as a Special Professor at Kyoto University's Institute of Advanced Energy and holds a Ph.D. from Kyushu University.

Mr. Kiyoshi Seko

COO, Director

Kiyoshi boasts a comprehensive background in strategic investments and business development. Formerly with Mitsubishi Corporation, he orchestrated significant M&As and JVs, such as alliances with Princes, Alfa Group, and Toyo Tire, cumulatively worth billions. An MBA from IE Business School, Spain, and with dual M.S. degrees from Kyoto University and the University of Tokyo, he transitioned to Coral Capital, executing venture investments in diverse tech sectors before joining Kyoto Fusioneering. He's an avid reader and tech enthusiast.

We transfer Senior Technology and Knowledge to Young Generation and Newly joind Industry.

Dr. Colin Baus

Vice President of Plant Technology

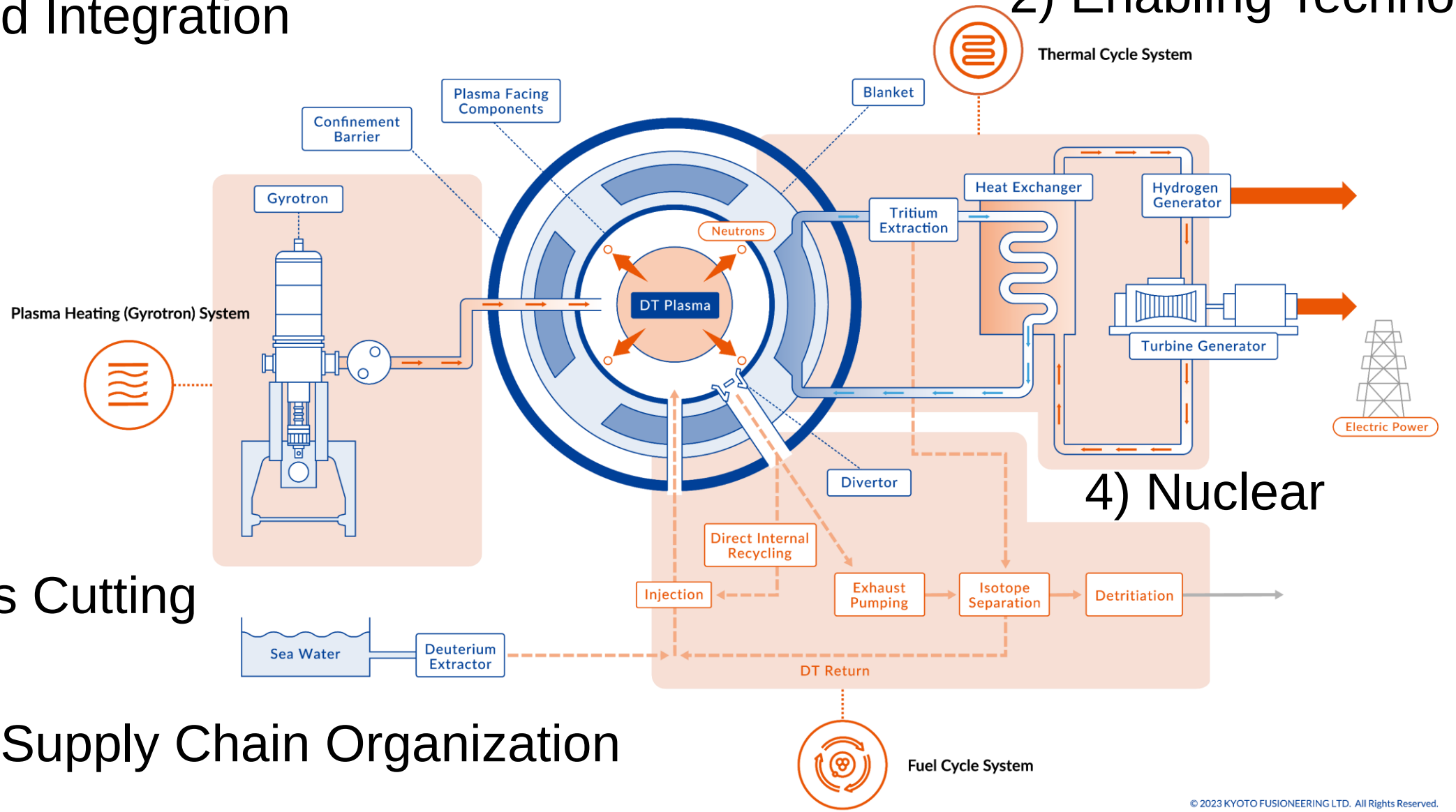
Colin is a physicist with a PhD at the Large Hadron Collider at CERN (CMS experiment) on heavy-ion cross sections and the connection to astroparticle physics. As co-author of the hadronic interaction tool CRMC, he has deep knowledge in nuclear physics. After several years in the private industry, Colin joined Kyoto Fusioneering. Here, he is author of the high-temperature fusion blanket SCYLLA design and currently oversees technical development of the UNITY programme for fusion thermal cycle and fusion fuel cycle in Japan. He is also a visiting researcher at Kyoto University.

Kyoto Fusioneering's Role in the Fusion Industry

KYOTO FUSIONEERING

1) Pland Integration

2) Enabling Technology

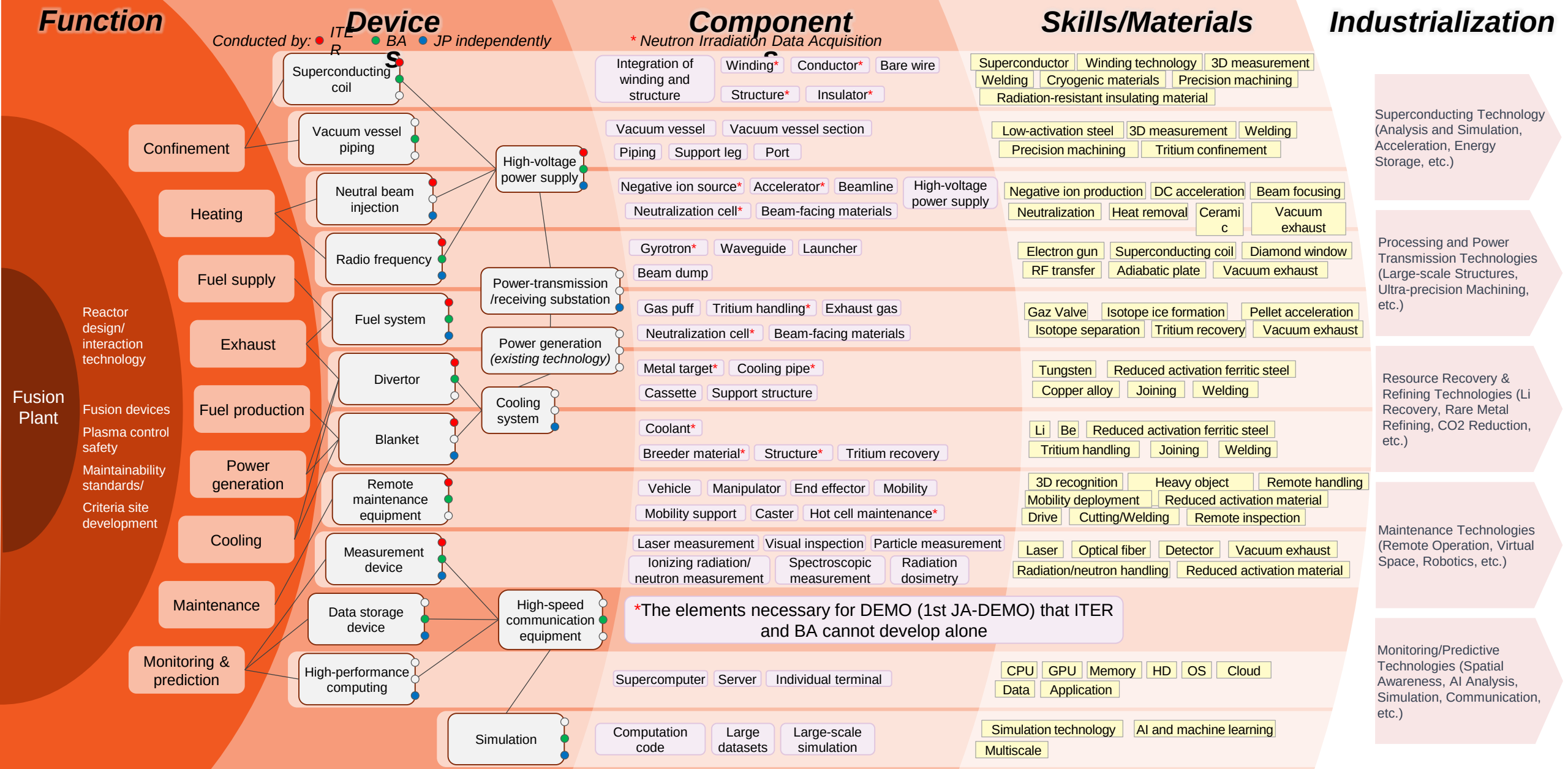


3) Cross Cutting

4) Nuclear

5) Supply Chain Organization

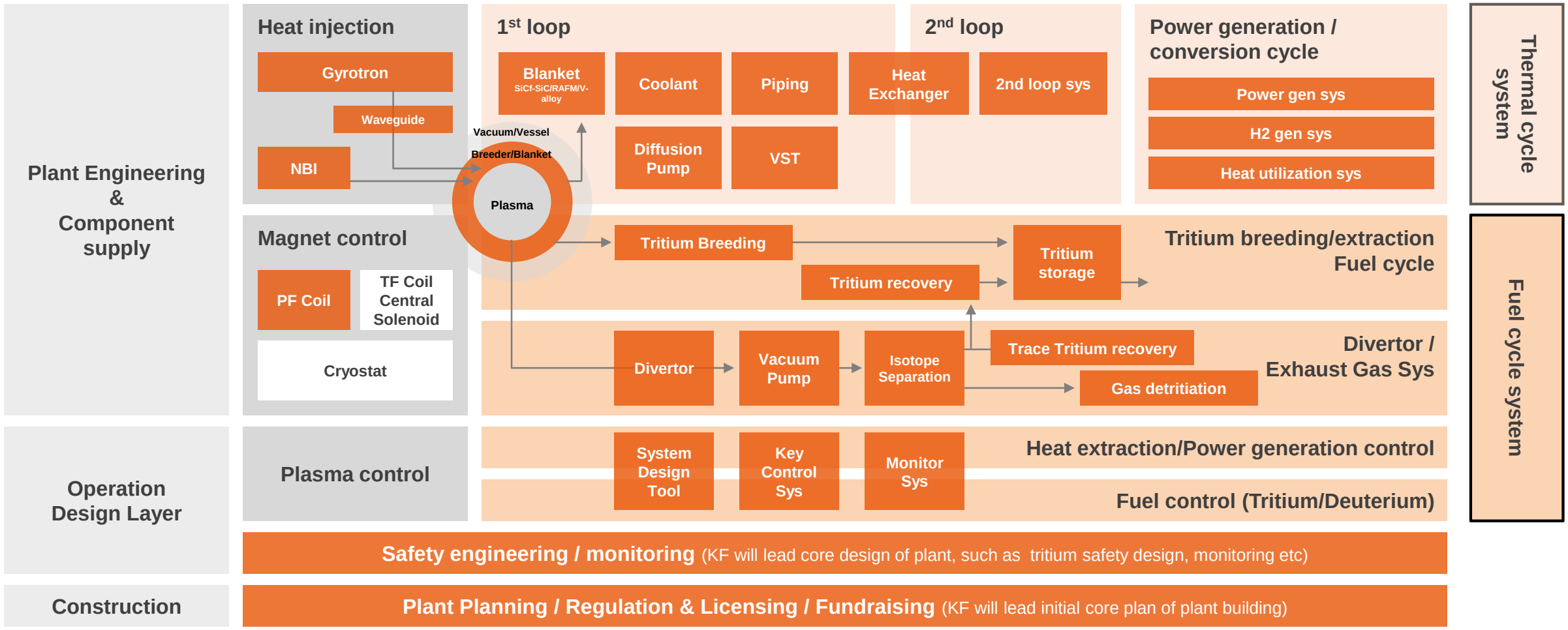
Industrial Fusion Network to be Organized by KF



Kyoto Fusioneering's Capability and Coverage

KYOTO FUSIONEERING

Kyoto Fusioneering is focused on plant technologies and systems - covering the majority of systems **agnostic to the plasma concepts**



Accelerating technology development

- to improve the TRL of the thechnology to make Pilot Plants Possible

		KF's R&D domain	TRL today	TRL 2026	Market by 2026	Market by 2030
Plasma Heating	Gyrotron	ITER spec	7	9	$500M	$1B
		Higher frequency (> 236GHz)	4	7		
		Continuous wave operation	4	7		
Magnet Control	Coil	PF Coil	7	9	$100M	$300M
Thermal cycle system	Blanket/1st loop	SCYLLA© Blanket	3	6	$300M	$700M
		Molten salt(FLiBe) Blanket & Loop	3	6		
		Lithium Blanket & Loop	3	6		
		Solid Propagation Material & H Permeation Properties	3	6		
		Li-Pb Impurity control	3	7		
		Low activation ferritic steel / Fluid material coexistence	3	7		
		Simulation of Tritium production	5	9		
		SiC-Hydrogen isotope permeation diffusion behaviour	3	7		
		Li-Pb-Hydrogen/ Li-Hydrogen isotope behaviour	4	7		
	2nd loop	SiC Heat Exchanger	5	7		
		GNOME Reactors	2	6		
Fuel cycle system	Exhaust	High tritium compatible roughing pump	7	9	$300M	$1B
		Hydrogen Isotope Separation Pump	3	7		
		Proton Conductor Pump	3	7		
		Tritium tracing	3	8		
	Tritium breeding & extraction	Liquid Metal Diffusion Pump	7	9		
		Droplet Thermal Tritium Recovery	4	7		
		Tritium storage	3	7		
Power Gen/ Conversion Sys	Power Generation	Innovative brayton cycle	5	8	$150M	$300M
		Supercritical Carbon dioxide turbine	5	8		
	Hydrogen	Biomass gasification	3	7		
		Membrane Reactors	2	5		
	Carbon fixation	Biomass carbonization	2	5		

TRL: Technical Readiness Level

Our Depth of Expertise- from design, materials to plants

We operate across various levels in our areas of focus.

Pilot Plant Design & Development

For several Milestone-Based Fusion Development Program awardees and other fusion developers, KF:

- Is **designing** the plasma heating, fuel cycle and thermal cycle system in conjunction with the overall plant.
- Will **supply components and systems** in these areas to the FPP and CPP programs during the construct phase.
- Will continue to **supply consumable components** (e.g., blanket) throughout operations.
- And more (see 2. FPP Development Support)

Clients/partners

Several, undisclosed

Integrated Testing

Designing and **overseeing EPC** of two integrated testing facilities to demonstrate thermal and fuel cycle systems.

UNITY-1 in Kyoto for **thermal cycle**:

- 1000° C Li-Pb, Li, FLiBe loops with blanket test.
- MHD testing with SiC_f/SiC insulators.
- 1st ever electricity gen from blanket module.
- DIR testing with proton conductor pump

UNITY-2 in Ontario for **fuel cycle**:

- ~40g of T, ~50L Li-Pb loop w/ VST T extraction
- Dual storage system (dU, ZrCo)
- Dual ISS (TCAP, CD), outer cycle (WDS, ADS)
- Centrifugal Pellet Injection

Plasma heating system test facility:

- Gyrotron
- Power Supply
- (Waveguide)
- (Launcher)

In partnership with

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

and delivery partners.

Engineering & Manufacturing

Designing and **developing** a suite of fusion-grade components and systems.

- **Plasma heating** system (see gyrotrons)
- Self-cooled lithium-lead **blanket modules** (see blankets)
- Tritium compatible metal diffusion, roughing, turbo molecular **pumps** (see roughing pump)
- **Direct internal recycling** system
- Tritium **storage beds** (see storage)
- TCAP and CD **isotope separation systems**
- Vacuum Sieve Tray for **Tritium extraction**
- Li, Li-Pb, FLiBe loops and technology
- And more (see Components & Systems)

With dozens of the 100+ fusion-relevant suppliers in Japan, including:

Canon, JGC, YAMATO, MTC Metal Technology Co. Ltd., Nimblox, MIKUNI, JASTEC SUPERCONDUCTOR

and 70+ more.

Scientific Discovery & Experimentation

Developing fusion materials & manufacturing methods.

- New grade of **SiC_f/SiC** with liquid phase sintering and particle dispersion composite manufacturing process.
- New joining methods for similar and dissimilar material bonding with **SiC_f/SiC**
- **Mo alloys** for novel heat exchangers.
- **FLiBe** purification techniques & compatible materials.
- **Proton Conductor Pump** for DIR and selective pumping
- **RAFM steels** (F82H) as structural materials
- **New alloys** for storage beds.
- **Impurity and cold trapping** studies for Li-Pb
- And more (see Material Development)

In collaboration with

PPPL, PSFC, QST, Kyoto University Founded 1897, Oak Ridge National Laboratory, SRNL, CCFE

and more.

Plasma Heating System (Gyrotrons)

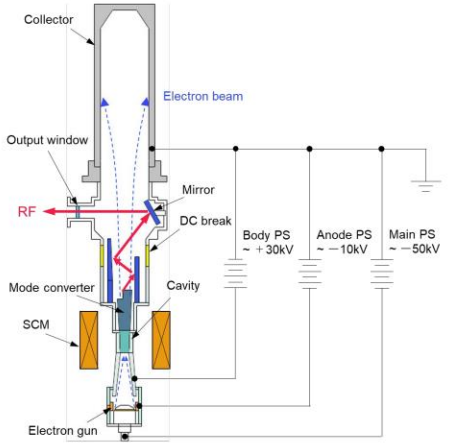
KYOTO FUSIONEERING

Overview

Kyoto Fusioneering's gyrotron is a large vacuum tube capable of continuous 1 MW-class output power with high-power millimeter waves, which consists of the gyrotron body, a superconducting magnet, and a DC power supply. The cavity resonator inside the gyrotron oscillates 1 MW-class millimeter waves, which are reflected by an internal mirror and output to the outside through a vacuum-sealed window.

Product Details

Product Index	
Pulse Width	CW operation
Efficiency	>50% from input power to output RF
Mode Purity	>90% from TE mode to HE11 mode
Aging (Conditioning)	Shall be operated by KF
Leadtime	~approx. 20 moths from the order to delivery



Frequency	236 GHz	203.1 GHz	170 GHz	137 GHz	104 GHz	35 GHz	28 GHz
Oscillation Mode	TE43,15	TE37,13	TE31,11	TE25,9	TE19,7	TE10,6	TE8.,5
Output Mode	Gaussian Beam						
Magnet	9.2T	7.98T	6.63T	5.32T	4.08T	--	--
Power (>1s)	1MW (to be tested)	1MW	1.2MW 1MW (300s)	1MW	1MW	1 MW	1 MW

Experts at KF

- Keishi SAKAMOTO, PhD, Nuclear Engineering
- Yosuke HIRATA, PhD, Engineering, Energy Science
- Kenichi HAYASHI, M.E., Electronic Engineering

Expert Advisors

- Tsuyoshi IMAI, PhD
- Yasuhisa ODA, PhD

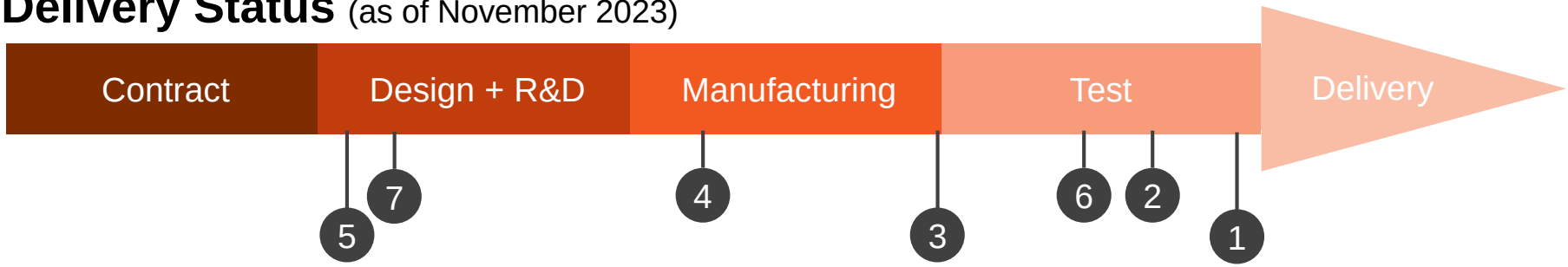
Gyrotron Ongoing Projects

KYOTO FUSIONEERING

Kyoto Fusioneering is currently supplying gyrotrons to public and private fusion industry leaders

	Client	Qty	Frequency (GHz)	Power (MW)	Pulse (s)	Status *(as of Nov 2023)*
1	**Ministry of Economy Trade and Industry**	1	236			Under test at Amagasaki lab
2	**UK Atomic Energy Authority**	2	28 35	0.9	3	FAT@NIFS -> Kyoto Research Ctr.
3	**European Private Fusion Program**	1	104 137	1.0	2	FAT@QST (Dec 2023~)
4	**Asian Public Fusion Program**	1	104 137 170	0.8 0.9 0.9	5 10 300	Design Review, Manufacturing
5	**U.S. Department of Energy's DIII-D National Fusion Facility (General Atomics)**	2	104 137 170	1.0	10	Design Review, Manufacturing
6	**KF R&D 1**	1	236	1.0	CW	Test
7	**KF R&D 2**	1	137	2.0	CW	R&D

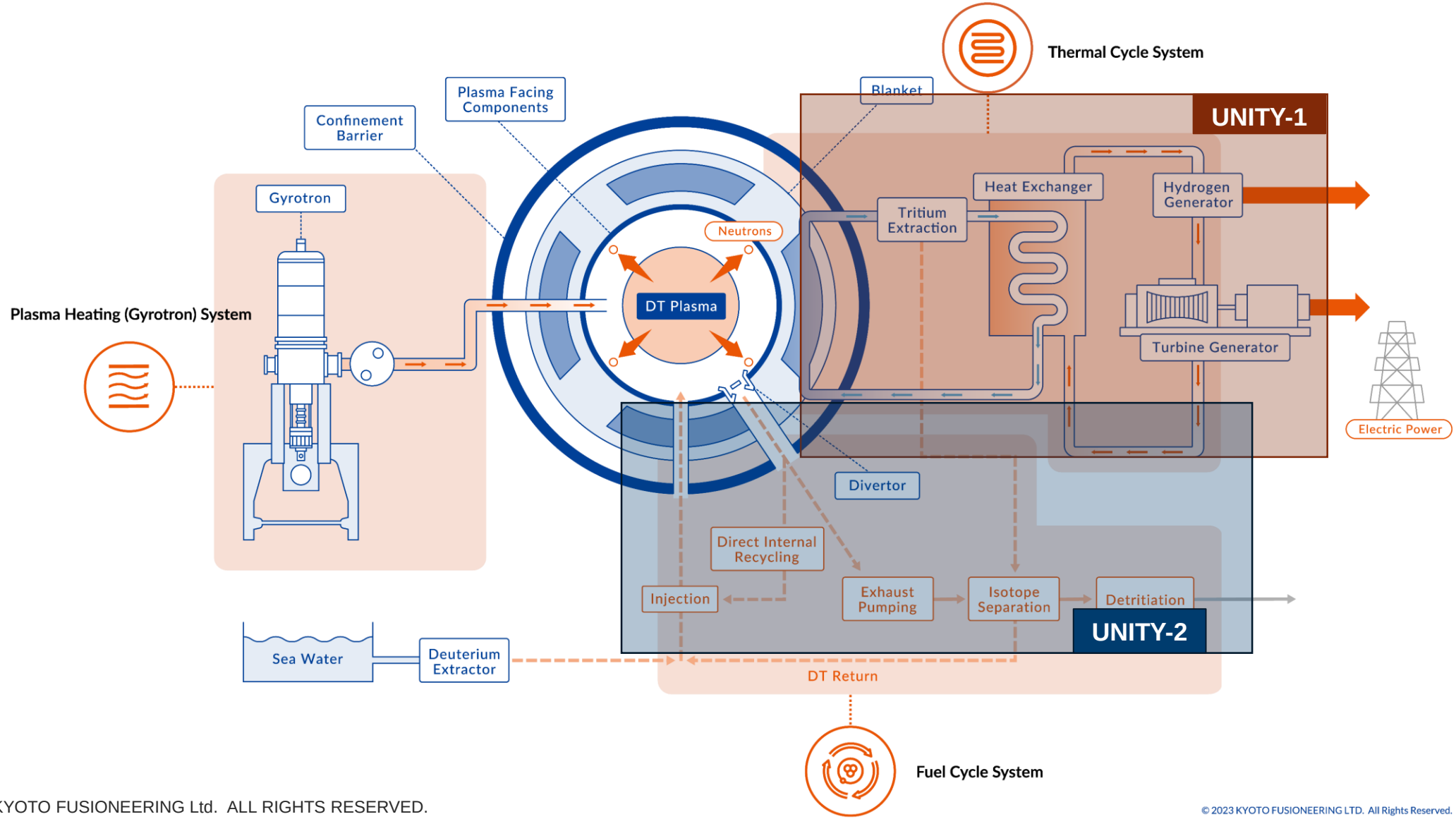
Delivery Status (as of November 2023)



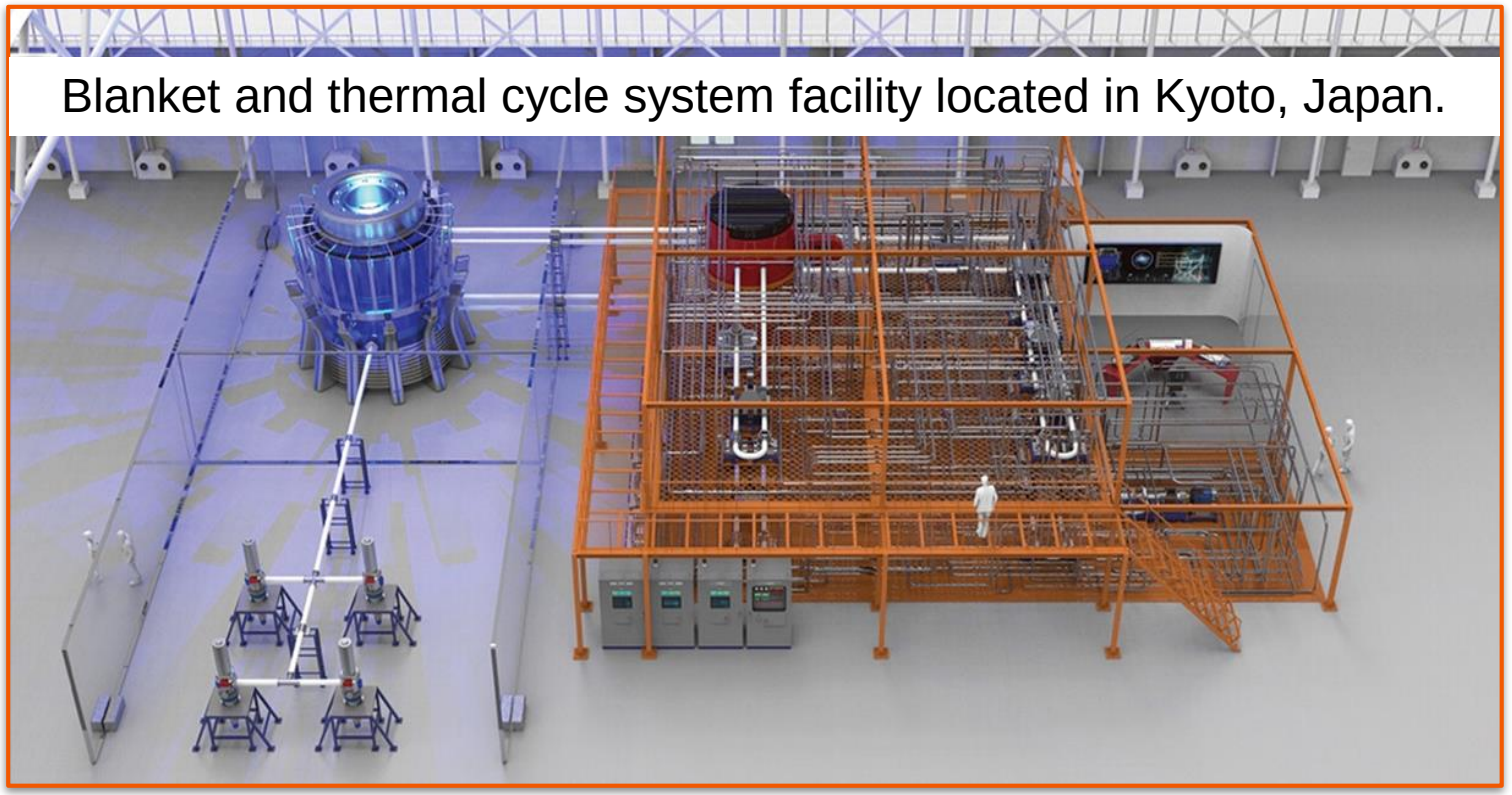
Unique Integrated Testing Facilities

KYOTO FUSIONEERING

- to develop and demonstrate Integrated Pilot Plant Technology



UNITY-1 Overview



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

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

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

2025 — **MHD and hydrogen extraction testing**

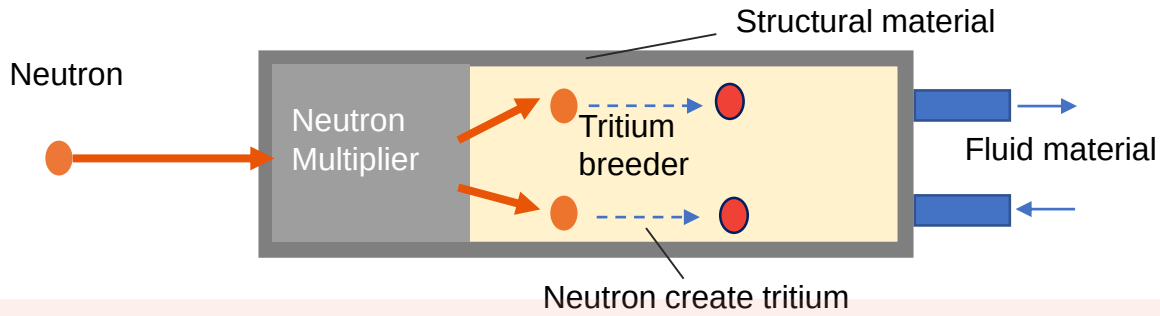
2026 — **Start test of the power cycle demonstration**

Thermal Loop with liquid metal or molten salt

Kyoto Fusioneering is developing technologies of designing and fabricating loops of several candidate breeder fluids to interface MFE,ICF and other pulsed plasma with wet wall/

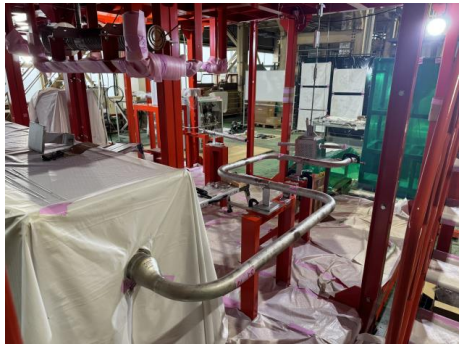
Blankets require materials to serve as:

- Tritium breeder
- Neutron multiplier
- Heat extraction fluid
- Blanket structural material



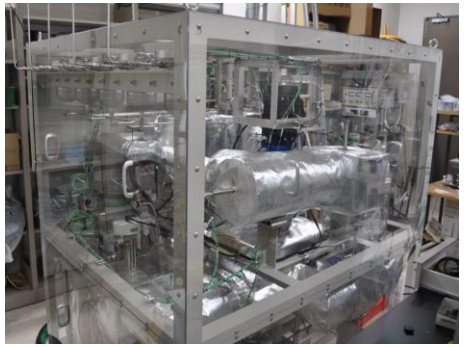
Kyoto Fusioneering can provide solutions for this incredibly challenging system that can achieve **high temperature heat extraction**, **tritium breeding**, **tritium extraction** for several candidate materials:

LiPb



LiPb base loop

FLiBe



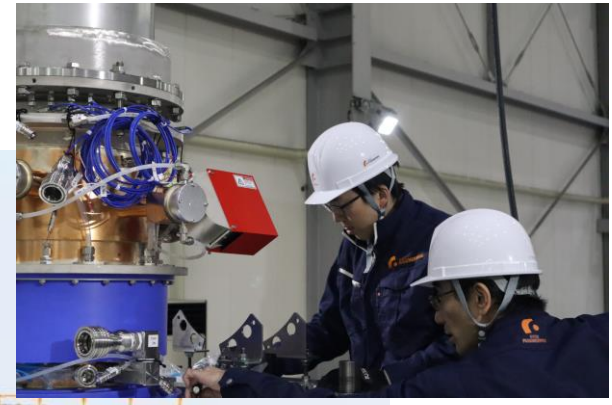
FLiBe test loop benchtop experiment sited at Kyoto University (Inconel 600)

Pure Lithium

IFMIF Lithium Loop (Prof. Sakamoto formerly led this project)

Technical Development

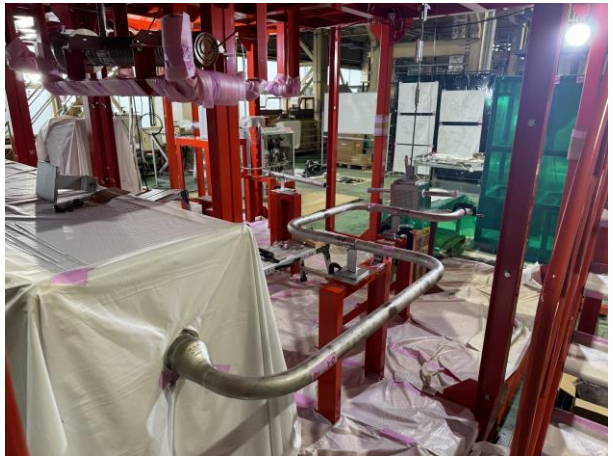
- **Thermal Cycle**



LiPb Loop - Progress



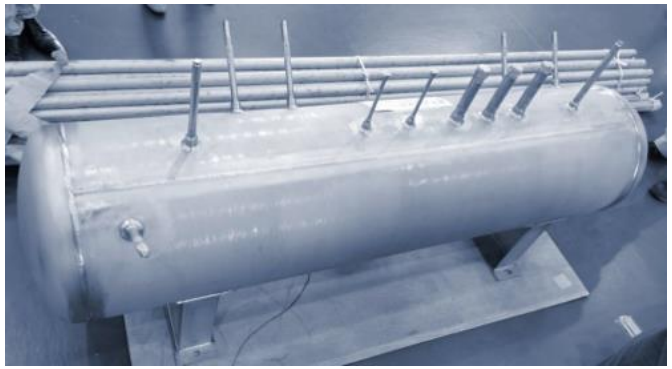




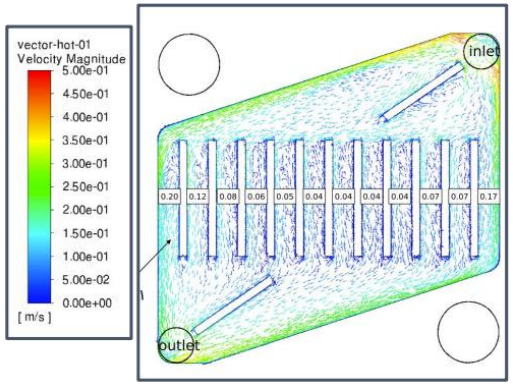
UNITY-1 Thermal Cycle Key Components

Structure

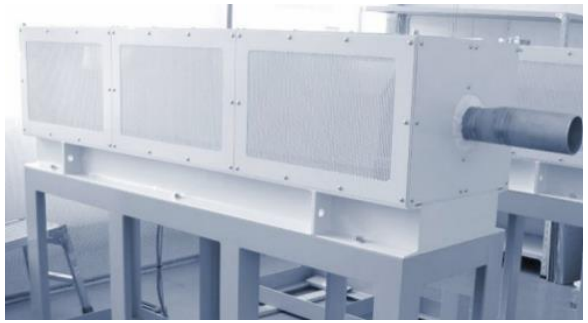
Electromagnetic Flow Meter



Dump Tank



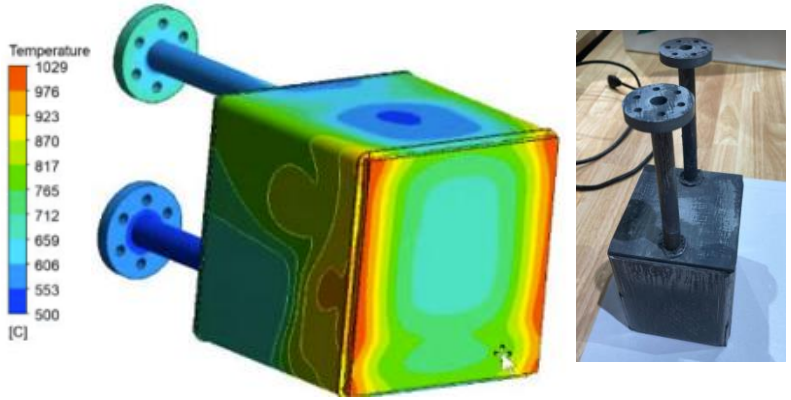
High temperature Heat exchanger



Electrical Magnetic Pumps

Blower

Vapor Trap



Blanket Module Mock-up

SiCf/SiC, Vanadium Alloy, RAFM, Mo for flow path materials and components are developed.

UNITY2 - Tritium Fuel Cycle

Tritium handling and management is one of the biggest challenges in fusion plants.

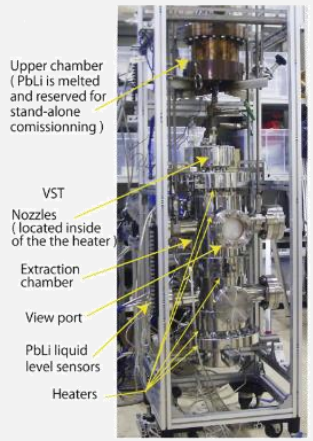
Requirement:

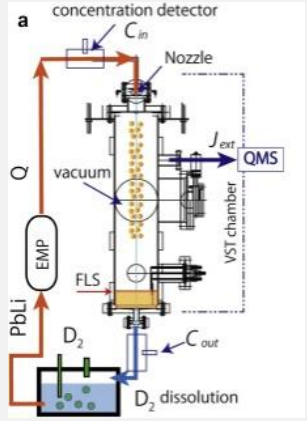
- Continuous operation under high tritium area
- Tritium breeding
- Effective extraction of Tritium
- Low permeability of Tritium
- Low tritium circulating quantity

Key①：Tritium Extraction from Liquid Metal Loop

Tritium extraction from liquid breeders is one of the biggest issues to sustaining a continuous burning fusion plasma, as it is critical for supplying fuel.

KF Capabilities:
Extensive experience in handling tritium extraction from liquid breeders. Demonstration in UNITY-2.

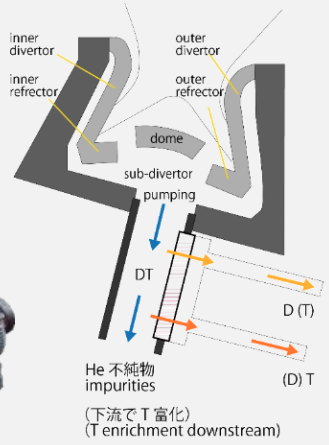




Key②：Plasma Exhaust

Fusion reactors require tritium compatible pumping systems to sustain a continuous burn of fusion plasma with fuel recirculation.

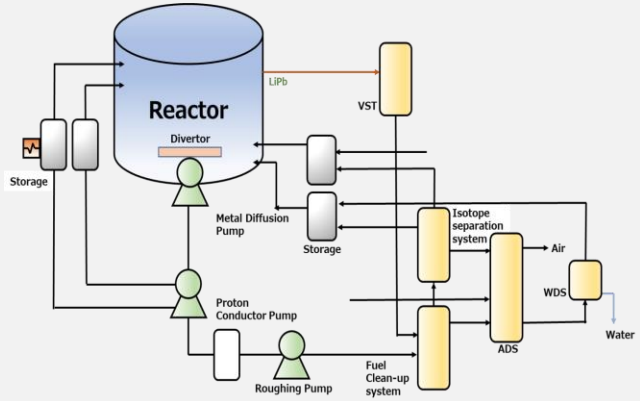
KF Capabilities:
Tritium compatible pumps and optimized design of new plasma exhaust components.



Key③：Overall Fuel Cycle Design

Tritium fuel cycle design needs to be both safe and affordable to sustain fusion reactor operation.

KF Capabilities:
Optimized and cost competitive design for fuel cycle system by professional experience and knowledge. UNITY-2 design underway.

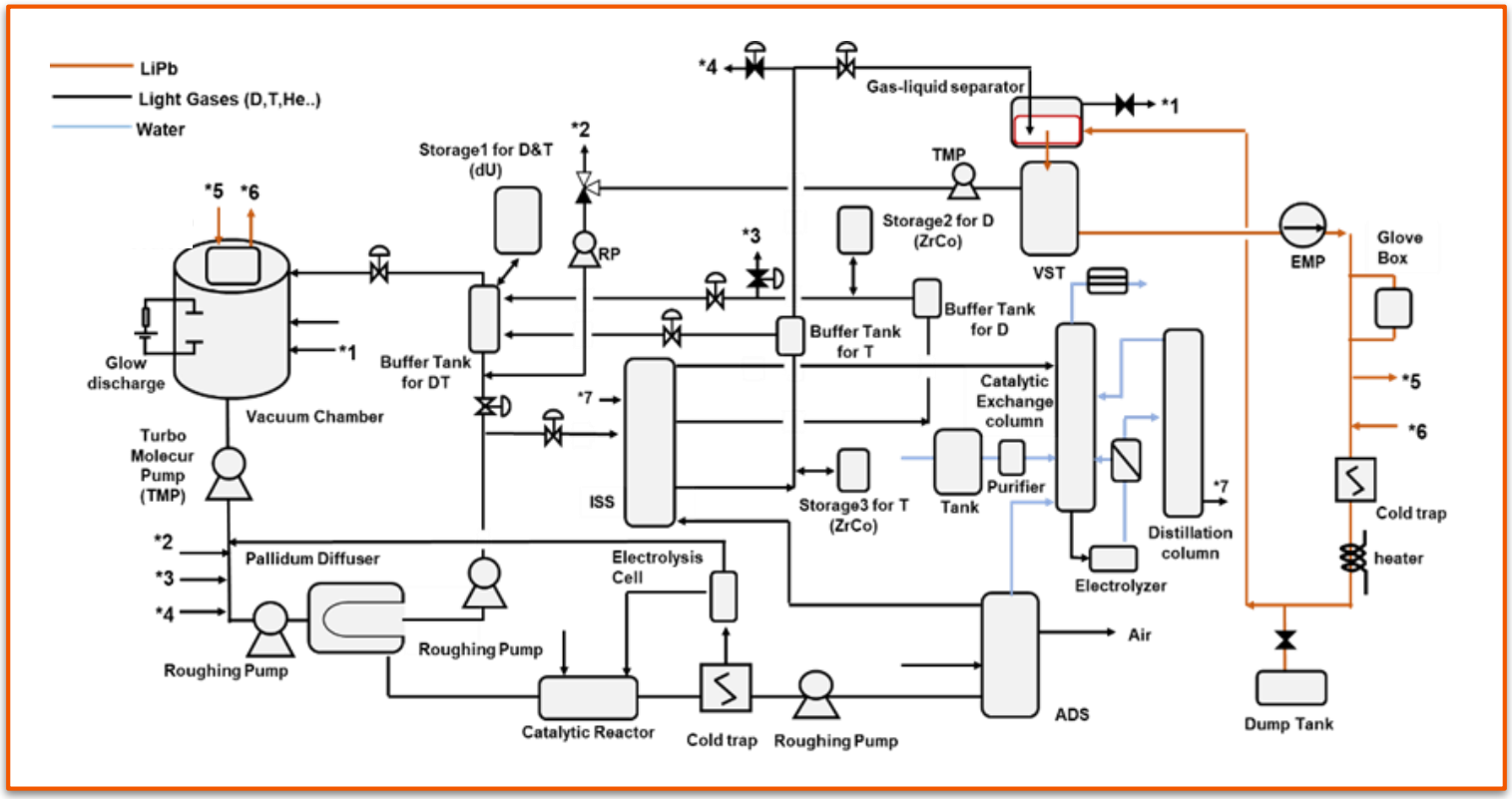


Tritium compatible dry vacuum pump system is now ready to serve.
For wet wall chambers, liquid metal diffusion pump is developed and reported.

UNITY-2 Overview

Fully integrated DT fuel cycle including breeder interface and effluent control

Will be developed, demonstrated and provide its technology for pilot plants.



2023

Initiation:
Design and individual component testing

2024

Procurement:
Key systems and components

2026

Installation:
Integration of systems.
Planned commissioning

Location: Chalk River, Ontario

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:

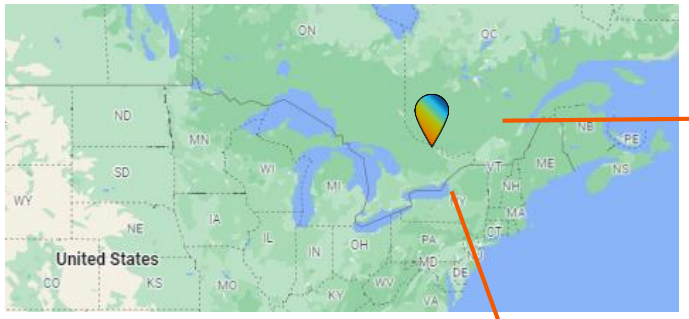
- Under review, 10 to 40 g inventory
- Fuelling of vacuum chamber at ~2.6 Pa m^3 / s

Modelling:

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

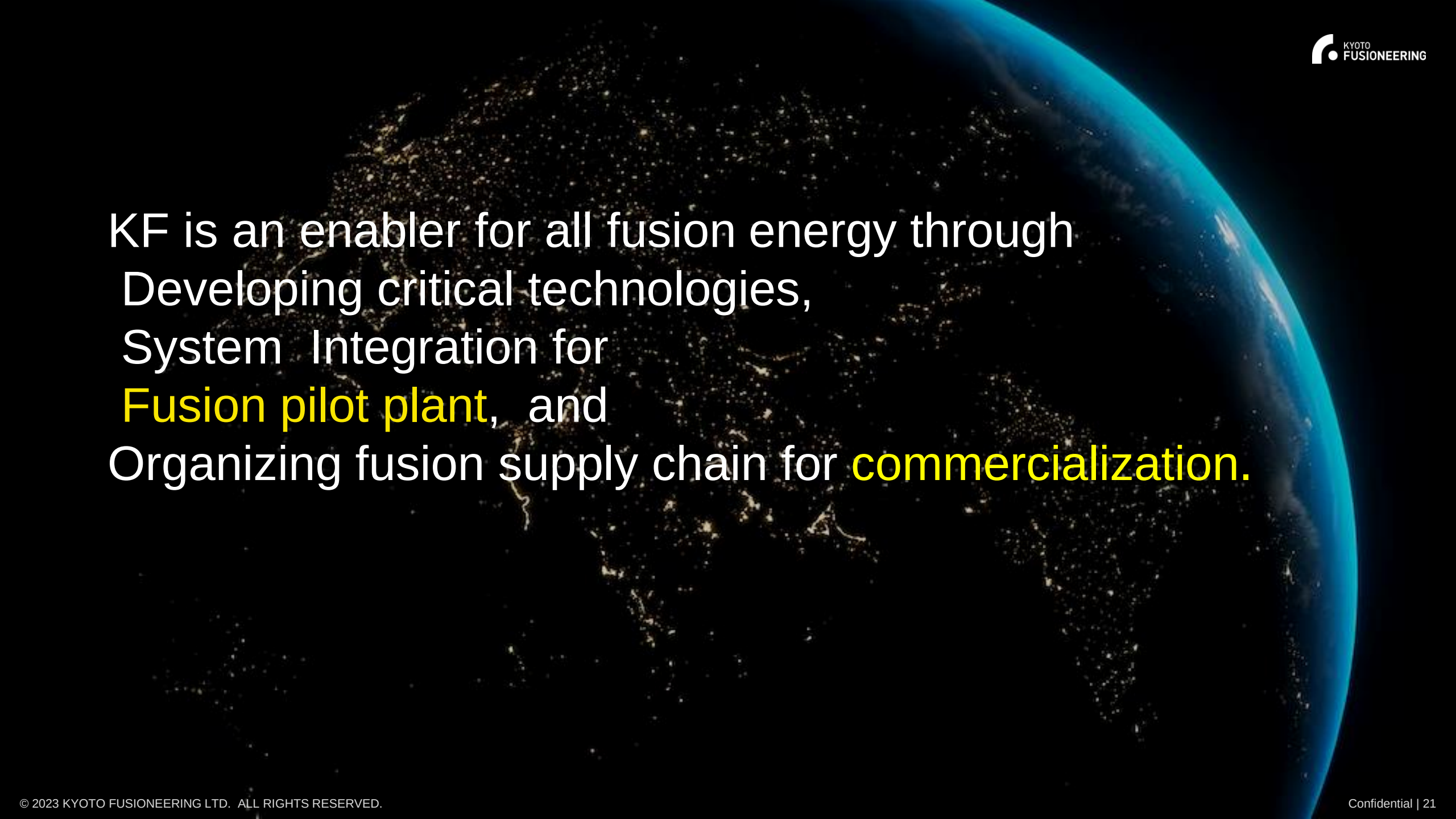
UNITY-2 is constructed under a collaboration with Canadian National Laboratory

UNITY-2 will be housed in CNL's existing Tritium Facility at Chalk River Laboratories, Ontario.



Location of UNITY-2

- Class I licensed Nuclear Facility / Class A Radioisotope Laboratory
- High Level R&D Laboratory with Tritium Dispensing capability
  - Two Inert Atmosphere Gloveboxes (IAGB) one with THA
  - Associated Air Purged Enclosures (APE)
  - Four fume hoods
- Low Level R&D Laboratory with Gas Standards Preparation
  - Two walk-in fume hoods, four fume hoods and 2 APE
- Low Level Counting Laboratory
  - Two Liquid Scintillation Counters
  - Two fume hoods
- Tritium Vault storage for up to 2.5 Mci (~250 g) of tritium



KF is an enabler for all fusion energy through
Developing critical technologies,
System Integration for
Fusion pilot plant, and
Organizing fusion supply chain for commercialization.