Canadian Nuclear Laboratories & Kyoto Fusioneering

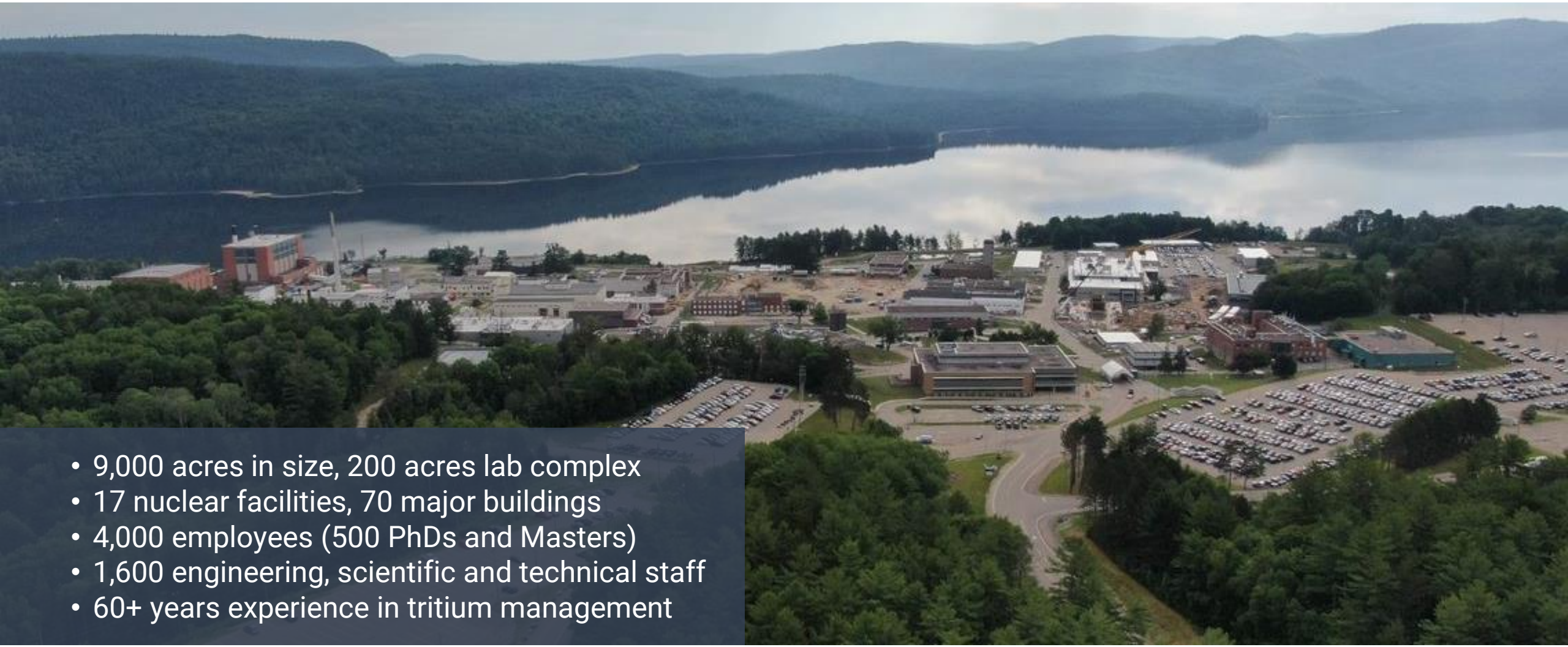
Offering Tritium Compatible Fusion Fuel Cycles

KYOTO FUSIONEERING

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

Canadian Nuclear Laboratories

The Largest Science and Technology Laboratory in Canada



- 9,000 acres in size, 200 acres lab complex
- 17 nuclear facilities, 70 major buildings
- 4,000 employees (500 PhDs and Masters)
- 1,600 engineering, scientific and technical staff
- 60+ years experience in tritium management

Kyoto Fusioneering

Designing and developing critical path fusion power plant systems

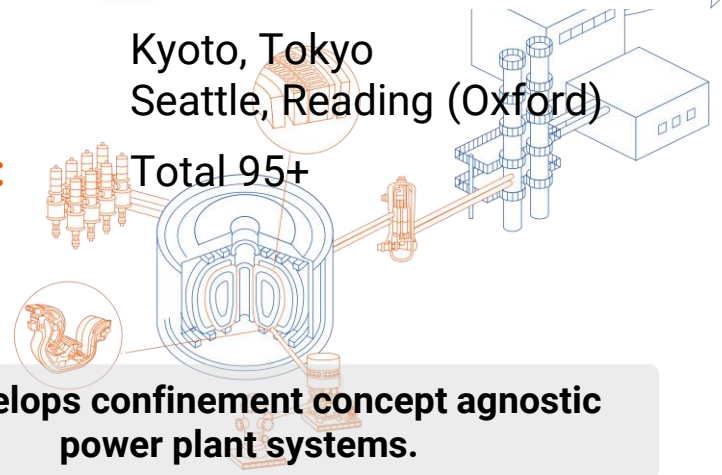
Founded: 0ct 2019

Funding: $90+ Million USD

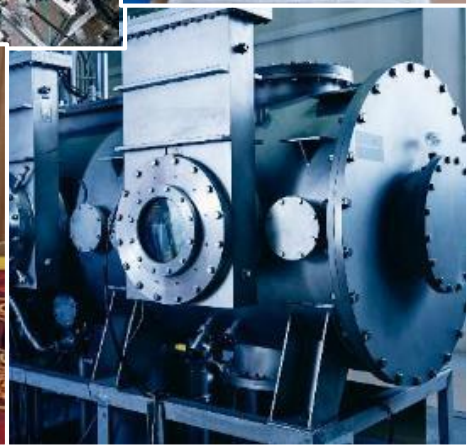
Shareholders:

Location: Kyoto, Tokyo
Seattle, Reading (Oxford)

Employees: Total 95+



KF develops confinement concept agnostic power plant systems.



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"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.

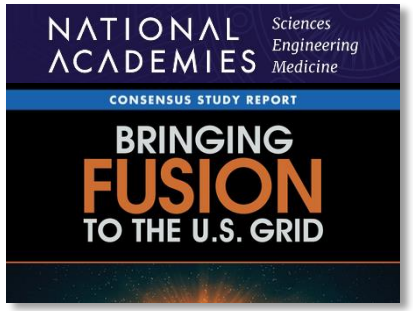
"Fusion energy holds transformative potential for global energy. Our partnership with CNL merges KF's fusion technology with CNL's tritium management expertise, positioning us to tackle some of commercial fusion power's most critical challenges."

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

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

The Need for this Partnership

Innovations Needed for Closing the Fuel Cycle



Recommendations

- Aim to have a viable design by 2028 and begin pilot plant operations between 2035-2040.
- Both extraction of fusion power and closing the fusion fuel cycle should be developed alongside fusion confinement concepts.

Innovations Needed for Closing the Fuel Cycle

- D-T fusion reactors need a closed tritium fuel cycle for functionality.
- Tritium is crucial for the fusion fuel cycle, but is challenging for control, accounting, and safety.
- Comprehensive understanding of processes involving tritium is essential for safe fusion operation and minimal environmental impacts.
- The tritium fuel cycle significantly impacts a fusion facility:
  - Tritium burn fraction in plasma.
  - Tritium processing time from plasma exhaust to fueling.
  - Extraction efficiencies from the breeder and coolant streams.
  - Tritium losses from and inventories in fusion core, near-core, and ex-core subsystems.
  - A series of other complexities in the fuel cycle system.

Challenges & Requirements

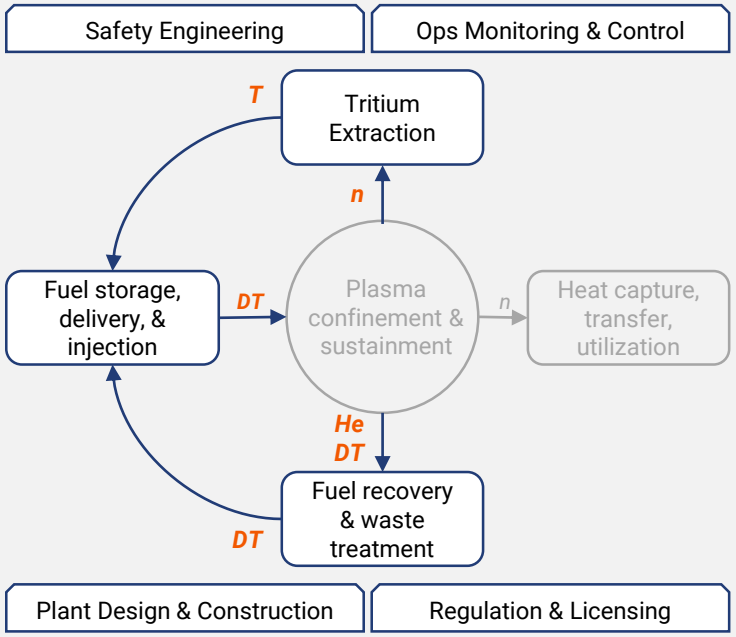
- Closing the fuel cycle safely and efficiently is a significant challenge.
- For deuterium-tritium fusion designs, processes to fuel, exhaust, confine, extract, and separate tritium in large quantities are required.
- To achieve economical fusion energy in the coming decades, rapid escalation in R&D of essential materials, components, and fusion nuclear technologies is crucial.

4 Innovations and Research Needed to Address Key Fusion Pilot Plant Goals | Bringing Fusion to the U.S. Grid | The National Academies Press

What We Will Offer

Your Holistic Fuel Cycle Support Team

Collaboration Scope: Fusion Fuel Cycle



Enabling fusion vendors to focus on their key differentiators. Rely on our decades of experience to meet your fuel cycle needs. KF and CNL will:

Innovate Tritium Fuel Cycle Technologies and Systems: Advancing the readiness level of the complete tritium fuel cycle with a focus on safety, public protection, and system economics.

Support Fusion Developers in Design and Development of Pilot Plants: Proving comprehensive design, consulting, engineering, testing and technology to meet the needs of public and private fusion energy development programs globally.

Support Tritium Handling and Management: Offering insights and solutions for efficient tritium behavior control and extraction in Fusion Pilot Plant devices.

Central to this collaboration is UNITY-2 (slide 8-9). Designed to emulate fusion power plant conditions, it will be a global first, integrating a **full deuterium-tritium fuel cycle** with the highest safety and tritium handling standards.

Partnership Capabilities

A Full Suite of Supporting Capabilities and Facilities

Turnkey Fuel Cycle System Solutions:

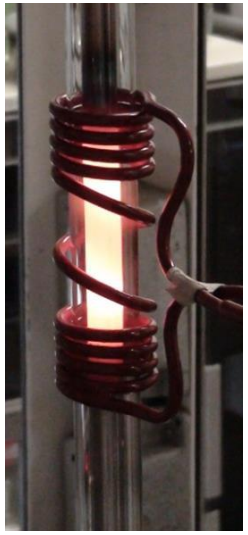
- Design and engineering
- Fabrication and procurement
- Testing and performance validation
- Commissioning and operations support
- Waste management consultation and technical support
- Licensing and safety case support

Materials Testing and Selection:

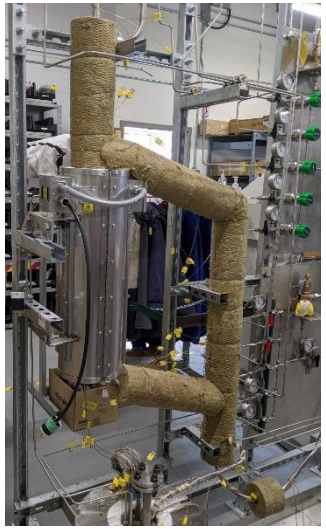
- World-class library of material performance data
- Custom material test rig design and operation
- Experimental design up to the highest QA standards
- Irradiated and non-irradiated materials
- Irradiation planning and consultation
- Deep corrosion and chemistry expertise
- All supported by comprehensive modelling capabilities

Tritium Separation Processes:

- Decades of practical experience in tritium separation from laboratory scale to full commercial industrial scale
- Water, air, and breeder material tritium separation expertise
- Modelling and design for complete tritium separation systems



Tritium Permeation Test Rig

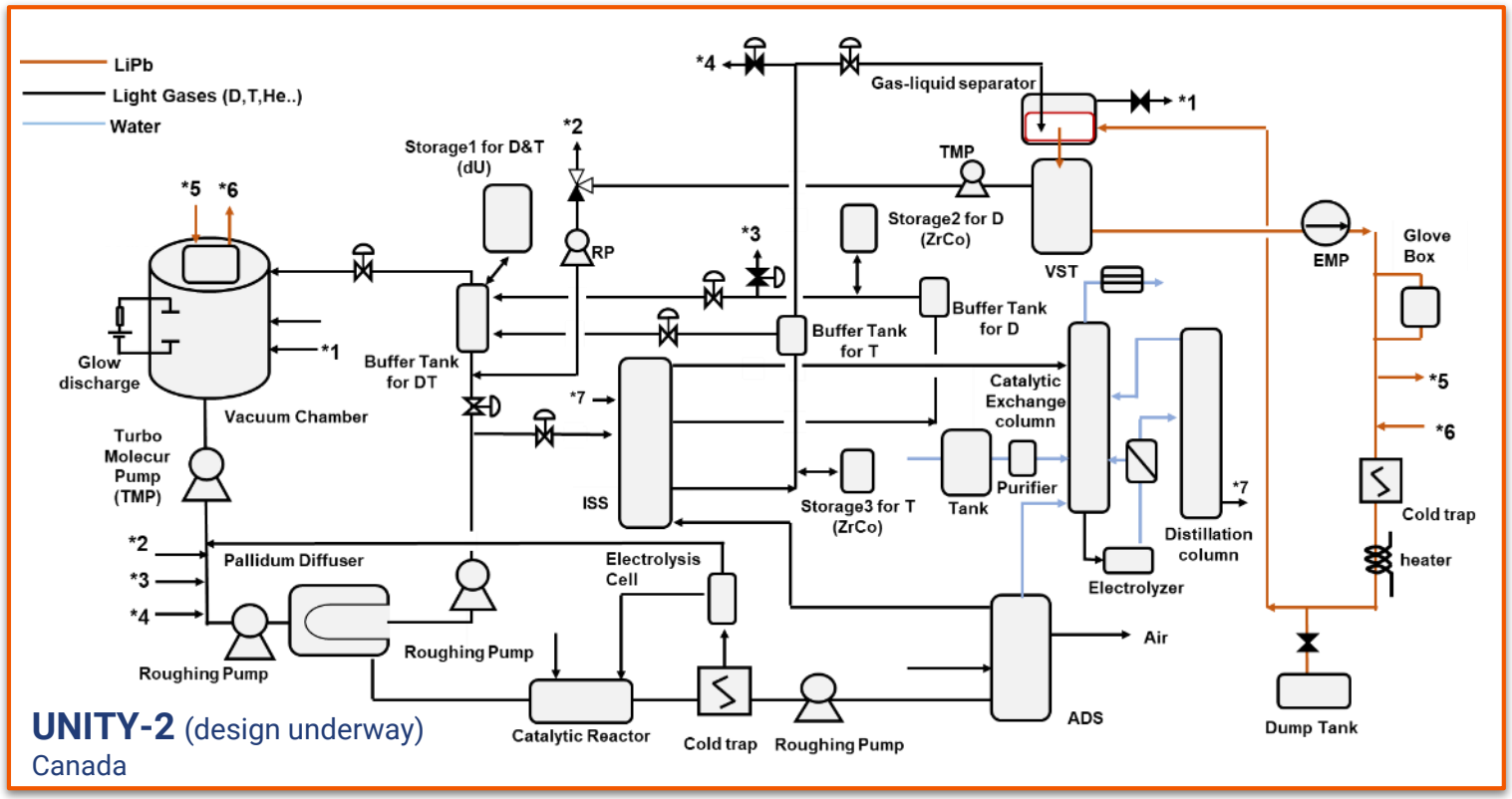


FLiBe Corrosion Loop

High-Performance Catalyst

Industrial Scale Water Detritiation Facility

Central to this collaboration is UNITY-2, a proposed full deuterium-tritium fuel cycle test loop



UNITY-2 (design underway)
Canada

Tentative Timeline

2023

Initiation:
Design and individual component testing

2024

Procurement:
Key systems and components

2025

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

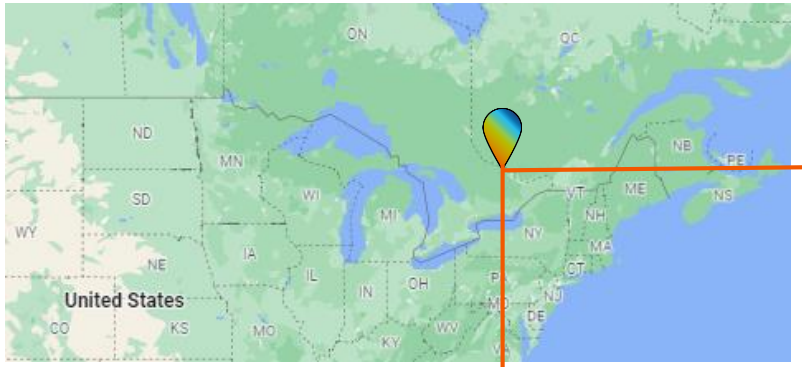
Tritium:

- 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 will be housed in CNL's existing Tritium Facility in Chalk River, Ontario

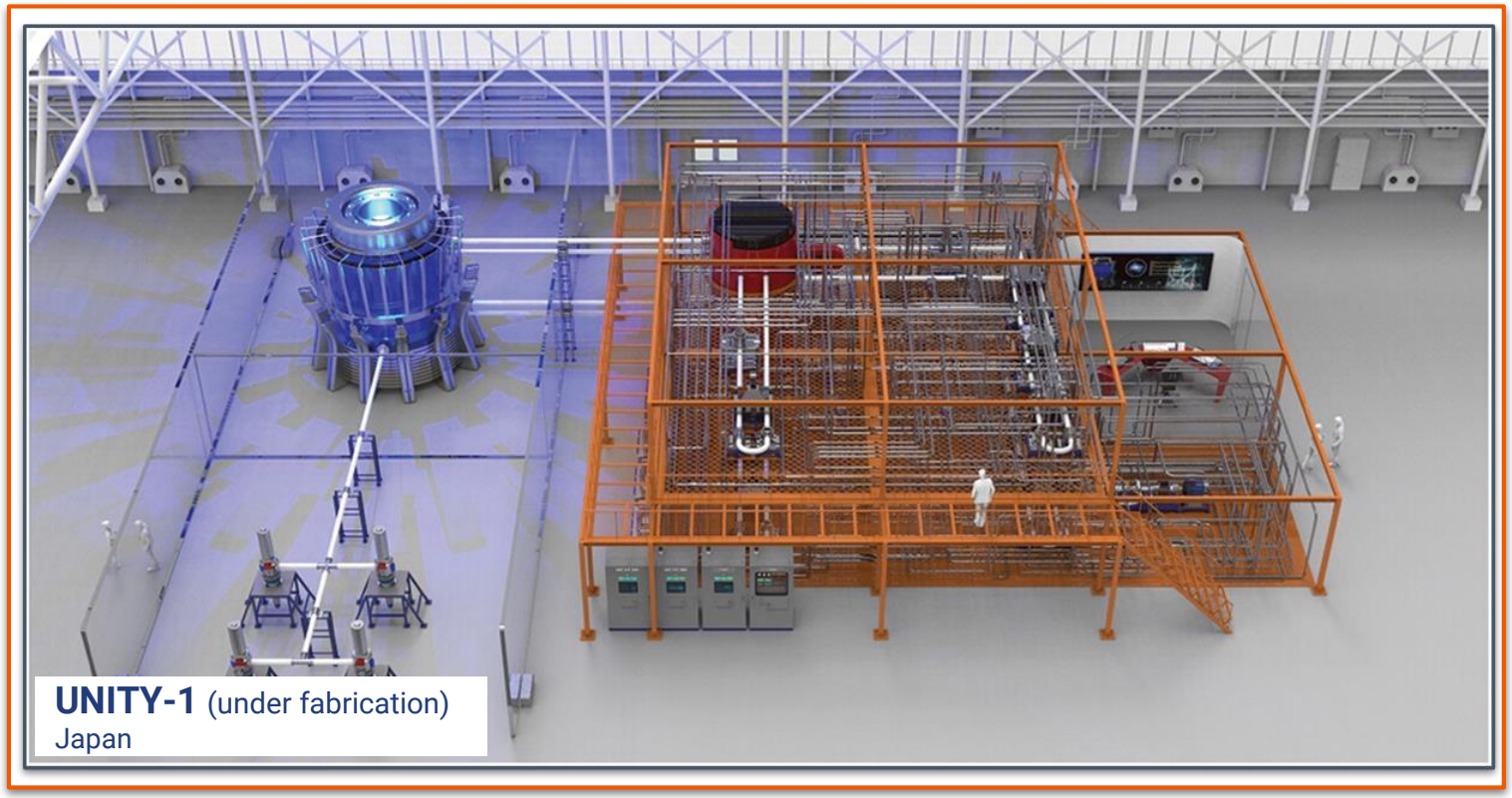


Location of UNITY-2

- 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 of tritium

Complementary to UNITY-1 in Japan

While UNITY-2 focuses on the development of the fuel cycle system, UNITY-1 largely focuses on the blanket and thermal cycle systems.



UNITY-1 (under fabrication)
Japan

Location: Japan (under construction)

Thermal Cycle and Blanket System:

- 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
- 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

The Strategic Alliance allows CNL and KF to Serve Critical Needs

Now

1. Pilot Plant & Test Facility Design

- FPP fuel cycle conceptual & preliminary design
- UNITY-like facility design for blanket and fuel cycle testing (including UNITY-2 adaptations)
- Tritium safety and management consulting

2. Component Supply and R&D Services

- Select Tritium-compatible component supply
- Material tritium-related testing & analysis
- Fuel cycle R&D, modelling support and tech. roadmap development

2025
Planned UNITY-2 commissioning

1. Testing Services at UNITY-2:

- Integrated component testing under fusion-relevant conditions
- Blanket module testing & integration with fuel cycle\

2. UNITY-like facility construction & operation

- Fuel cycle system supply, testing, & commissioning
- Facility operation and data gathering

3. Pilot Plant EPC

- Detailed design of fuel cycle system
- Siting, licensing and operation support

NOTE

The collaboration covers:

- Fuel exhaust and pumping
- Direct internal recycling
- Fuel clean-up and isotope separation
- Tritium management and storage
- Tritium extraction from liquid metal
- Air and water detritiation
- Reactor fueling

For more information, please contact KF at biz@kyotofusioneering.com or CNL at commercial@cnl.ca

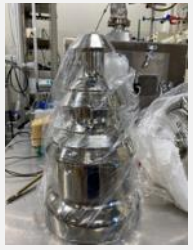
More than the Fuel Cycle

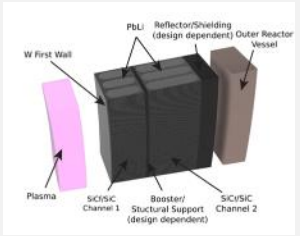
KF and CNL Serve Critical Needs Beyond the Fuel Cycle

Independent KF Scope

Design, development and demonstration in these domains:

- **Thermal breeding blanket** system
- **Heat injection**: Gyrotron, Waveguide
- **Material Development**: SiC/SiC, Mo HX
- 1000°C **heat exchanger**
- **Power generation** system
- **Divertor** system
- Metal **diffusion pumps**
- **Plant safety** engineering / monitoring
- **Lithium isotope separation**
- **FLiBe** refining





Collaborative Scope:

Functions:

- Fuel exhaust and pumping
- Direct internal recycling
- Fuel clean-up and isotope separation
- Tritium management and storage
- Tritium extraction from liquid metal
- Air and water detritiation
- Reactor fueling

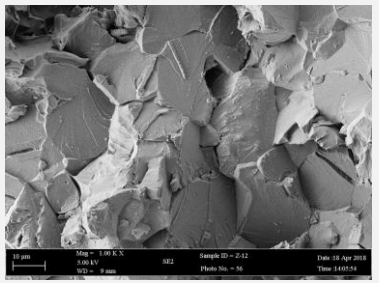
Operations:

- Tritium system safety
- Tritium accountancy and monitoring
- Fuel cycle system operations and maintenance
- Fuel cycle control system

Independent CNL Scope

Specialized services including:

- **Materials testing** in representative conditions
- **Thermalhydraulic** modelling and testing (**FLiBe** and other fluids)
- Irradiation planning and **irradiated materials** examination
- **Waste management** consultation for radioactive materials
- **Safety and licensing** for nuclear facilities
- System **chemistry** consultation
- **Corrosion** testing for fusion system environments
- Specialized **tooling** design



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Joint Team

Executive Leadership

Satoshi Konishi

Co-Founder & Chief Fusioneer
Kyoto Fusioneering Ltd.

Prof. Satoshi Konishi, a distinguished figure in fusion engineering, co-established Kyoto Fusioneering in 2019. Serving as the Chief Fusioneer, he directs technology innovation and shapes its strategic future. Educated with a Ph.D. in Engineering from the University of Tokyo, his expertise stretches over 40 years, delving deep into fusion technology, advanced nuclear design, and tritium engineering, with a particular emphasis on the ITER project.

Holding a tenured professorship at Kyoto University, Prof. Konishi has chaired the Test Blanket Program for ITER since 2009 and stood as the Japanese face on the ITER committee in 2012. As the helm of The Institute of Sustainable Science at Kyoto University, he passionately seeks the equilibrium between humanity and the environment.

His affiliations are vast: a board member of Japan's Atomic Energy Society, Plasma and Fusion Society, the Fusion Technology Division of the American Nuclear Society, and an editorial role at Elsevier's Fusion Engineering and Design magazine.

A beacon in sustainable science and fusion technology, Prof. Konishi's extensive knowledge and innovative approach anchor Kyoto Fusioneering's pioneering mission.

Jeff Griffin

Vice-President, Science & Technology
Canadian Nuclear Laboratories

In this role, Dr. Griffin manages a diverse portfolio of science and technology spanning fundamental research in physics, biology and chemistry through nuclear energy generation, health effect, environmental impacts, nuclear medicine and high impact global security programs.

Prior to joining CNL, Dr. Griffin led field operations for the U.S. Department of Energy's Office of Environmental Management (DOE-EM), he also served as Associate Laboratory Director at the Savannah River National Laboratory (SRNL), the U.S. DOE's premier environmental cleanup laboratory.

Among his career accomplishments, Dr. Griffin led the implementation of a risk reduction campaign to accelerate the closure of DOE-EM sites, resulting in multi-billion dollar cost savings; developed new business opportunities for the SRNL environmental management program to grow the program by 50%; and led U.S. national laboratory engagement with Tokyo Electric Power Company and other Japanese agencies in support of remediation efforts at the Fukushima Daiichi Power Station.

He holds a Ph.D. in Nuclear Chemistry from Georgia Institute of Technology.

Joint Team

Business Team

Kiyoshi Seko

Director, Business Operations

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.

Ian Castillo

Head of the Hydrogen and Tritium Technologies Directorate

Dr. Castillo directs the R&D activities of CNL's Hydrogen and Tritium Directorate, aligning with government stakeholder needs, market trends, and leveraging CNL's extensive hydrogen isotopes expertise both nationally and internationally. With over 17 years in the nuclear industry, he is an expert in hydrogen production, recombination, heavy water and tritium management, chemistry, and process engineering. Dr. Castillo earned his Ph.D. in Chemical Engineering from McGill University.

Bibake Uppal

Senior Manager, Business Development

Bibake leads KF's North American expansion, building partnerships and commercial ties to accelerate the development and commercialization of KF's technology. He has a wealth of experience in M&A and strategy consulting in the ERI industry, and corporate communications and government relations in the Canadian public sector. An MBA and MSc. graduate from IE Business School, Bibake is a decisive, outcome-focused leader in the evolving energy landscape.

Denys Elliot

Director, Business Development, Advanced Reactors

Denys Elliot is the Director of Business Development for Advanced Reactors (AR) at CNL. He is the primary liaison between CNL and AR vendors for contract establishment and advancing AR technologies. Additionally, Denys oversees CNL's Canadian Nuclear Research Initiative, supporting collaborative AR research in Canada. His expertise lies in contract formation with AR developers throughout the commercialization process.

Andrew Ballard

Manager, Business Development

Dr. Andrew Ballard, a nuclear engineering PhD graduate from the University of Tokyo, has a distinguished career spanning multiple reactor projects. He worked at Mitsubishi Heavy Industries in Tokyo and Tractebel-ENGIE in the UK. Later, as Project Director at Moltex Energy Canada, he penned a successful $50m CAD Strategic Innovation Fund submission and led two DOE ARPA-E Projects. Andrew also headed the R&D department, pioneering Canada's first molten salt-based spent fuel extraction experiment.

Sam Suppiah

Technical Director, Hydrogen and Tritium Technologies Directorate

Dr. Suppiah, with over 35 years' expertise, drives hydrogen and tritium technology advancements at CNL. Formerly with the British Gas Corporation, he's an expert in Tritium Technologies, Catalysis, and Energy Storage. He's Canada's delegate for the GEN IV VHTR Hydrogen Production Board and a CHFCA board member. A regular at IAEA presentations, he holds a Ph.D. in Chemical Engineering from the University of Birmingham, UK.

Thank you

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