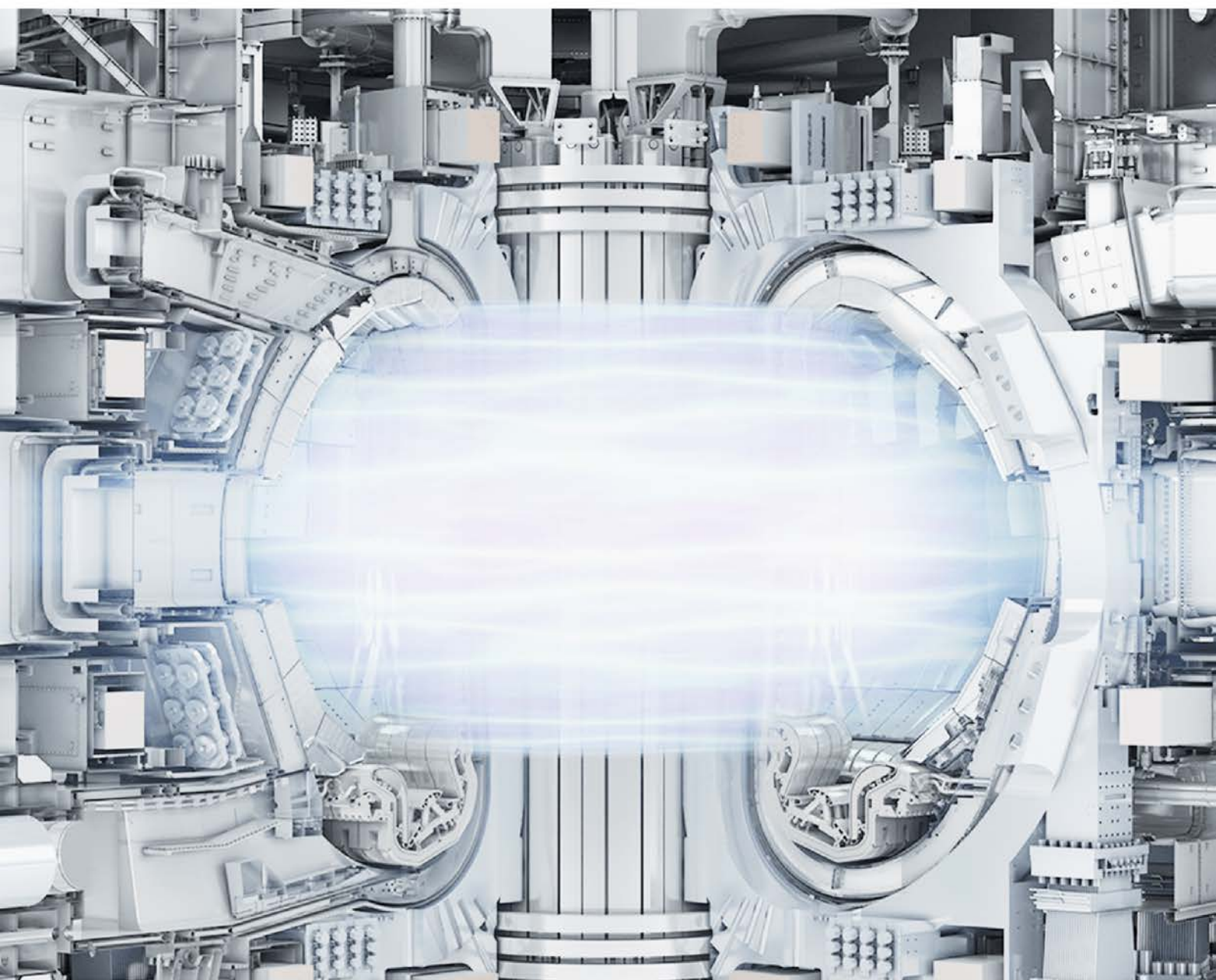
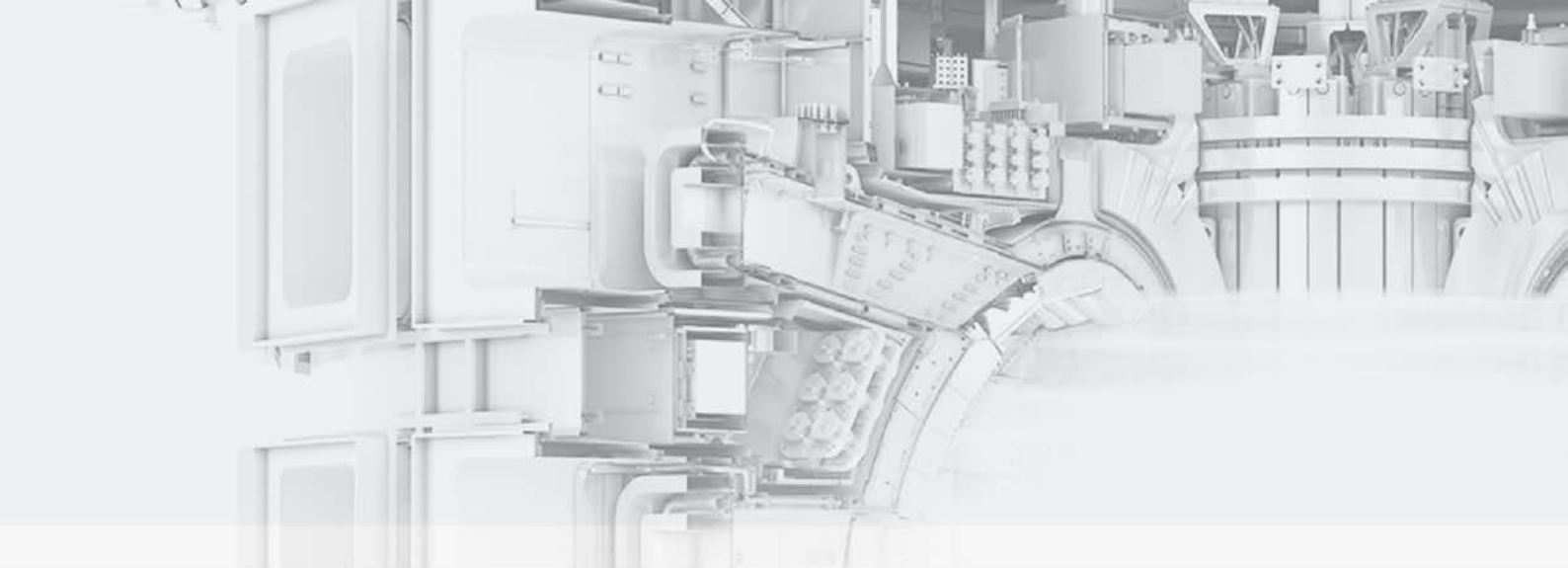


**2022**  
EDITION

# CANADIAN FUSION CAPABILITIES DIRECTORY

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# THE ITER PROJECT

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Originally called the International Thermonuclear Experimental Reactor, ITER is a project in southern France where 35 nations are collaborating to prove that fusion energy is a feasible option for the power plants of tomorrow. Scientists have long known the incredible efficiency achieved by generating electricity through fusion and have been collaborating internationally on this objective for more than forty years; this being one of the few topics that broke through the cold war between the US and the USSR.

As a Tier 1 nuclear country, Canada was involved in the initial ITER discussions and even proposed to host the ITER project at a site near OPG's Darlington Nuclear Generating Station. But the proposed CDN \$4.6B costs of membership towards the then anticipated \$17B projects was too much for the Canadian government to approve, even with the Ontario government agreeing to pay half the cost. With Canada stalling on joining the project, the site moved to a location in France proposed by the European Union and the project proceeded without Canada's participation.

Today, ITER is on its way to producing the first plasma by December 2025. It aims to be the first to demonstrate a net-positive fusion reaction while Canadian companies remain on the outside looking in. But, the Canadian industry's interest in participating in ITER is growing, leading to a 2020 Nuclear Cooperation Agreement (NCA) between the Government of Canada and the ITER International Fusion Energy Organization for Cooperation in the Peaceful Uses of Fusion Energy. This agreement creates a path for cooperating and transferring Canadian-supplied nuclear material (tritium) and tritium-related equipment and technology.





# THE ITER PROJECT

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Building on the 2020 NCA, the first ITER-Canada Coordination Committee (ICCC) meeting was held on November 8, 2021, to lay the groundwork for future cooperation.

As members of the ICCC, the Fusion Energy Council of Canada (FECC) and the Organization of Canadian Nuclear Industries (OCNI) are committed to building on this momentum and creating, in particular, commercial opportunities for Canadian companies with ITER.

Whereas General Fusion in Vancouver, BC and the University of Saskatchewan are engaged in fusion activities, Canada is the only major developed country without a comprehensive fusion R&D program. Not participating in the development of this pathbreaking emission-free energy technology, with its immediate and long-term high-value innovation, job creation, and commercialization potential is a significant problem. However, a unique, time-limited opportunity exists now for Canada's re-entry into fusion energy development: build on the 2020 NCA and enable Canadian businesses to collaborate with ITER.







# FUSION: BEYOND ITER

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ITER member countries have secured most of the main scope through their membership agreements. However, 15% of the total ITER scope will be contracted directly from the ITER Organization and is potentially available to countries through 'associate memberships.' There is no doubt that a sizeable opportunity exists around specific Canadian expertise and our role as members of the Canadian nuclear community is to enable our participation.

There are many reasons to turn towards cleaner energy, and we're proud in Canada to be part of the emerging Small Modular Reactor market. Canada wouldn't be in such a position today if it weren't for the last 70 years of investment in Canadian nuclear fission. Beyond ITER, there will be even more significant opportunities, and those countries that invest today will be the leaders in the future fusion market.

Major fusion work is presently occurring worldwide at over 130 sites, with substantial investments focused on scientific and engineering research, commercialization, and supporting technologies such as magnets, lasers, and materials. The US Congress recently approved US\$713 million of new funding for fusion development, and US\$5 billion in private investments have accumulated in the past two years.



# CANADA'S FUSION OPPORTUNITY



Canadian companies are eager to participate in this CDN \$30B ITER project, including the ITER Hot Cell Facility (HCF) project. It will require advanced tritium handling processes and equipment that ITER recently acknowledged were well-within Canada's world-renowned expertise. Today, the ITER website proudly mentions the recent engagement with Canada and states: "(the agreement) will enable the ITER Project to associate one of the largest and most experienced technically-relevant tritium communities outside of the founding ITER Members."

The ITER member countries have secured most of the main scope through their membership agreements, but as much as 15% of the total ITER scope will be contracted directly from the ITER Organization and is potentially available to countries through 'associate memberships. There is no doubt that a sizeable opportunity exists around specific Canadian expertise and our role as members of the Canadian nuclear industry is to enable our participation.

Reliable, affordable energy for citizens, communities and industries is essential for Canada's present and future prosperity. Policies and ministerial mandate letters of the Government of Canada and other levels of government share the objective of meeting this need while ensuring environmental sustainability, reaching decarbonization goals, and enhancing economic wellbeing.

Fusion is an inherently low-risk technology, without risks of nuclear proliferation and explosions, and requiring only small quantities of raw materials, such as deuterium, tritium, and lithium. Fusion complements other forms of energy generation, such as solar, wind, and nuclear (including SMRs).

ITER Engagement: Contributing to the design, creation, and operation of the ITER facility (with a focus on tritium and remote handling) positions Canadian businesses as partners and suppliers in the rapidly growing fusion market, particularly in the USA, UK, EU, Australia, and Asian countries. It strengthens Canada's fusion competitiveness and contributes to Canada's post-COVID-19 recovery. Fusion work also complements activities related to nuclear plants, including small modular nuclear reactors.





# ABOUT OCNI

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The Organization of Canadian Nuclear Industries (OCNI) is a non-profit organization governed by a Board of Directors elected by association members. It was incorporated in 1979 by several privately-owned Canadian manufacturers and engineering consultants. Its purpose is to promote and strengthen the Canadian nuclear supply chain through innovation, leadership, and advocacy.

Today, the association consists of more than 250 companies that employ a highly skilled workforce of over 15,000 people who manufacture major equipment and components and provide critical services that support the Canadian nuclear industry. OCNI serves its members by delivering value through programs and initiatives that ensure their success in both domestic and international nuclear markets.

# ABOUT FECC

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The Fusion Energy Council of Canada (FECC), a registered, not-for-profit corporation, is dedicated to mobilizing human, financial, and other resources for the participation of Canadians and Canadian enterprises in first-generation fusion energy systems and uses. Its overarching objective is the creation of economic, environmental, and social benefits based on fusion energy generation and uses.

The FECC Board, Advisors, and Members have leading-edge expertise in fusion science and engineering, as well as fusion-support technologies, innovation, and business. Current strategic focus areas are: creating a fusion roadmap for Canada; applying and advancing tritium expertise; identifying and producing neutron and hydrogen isotope tolerant materials; conceptualizing a major Fusion Canada program.

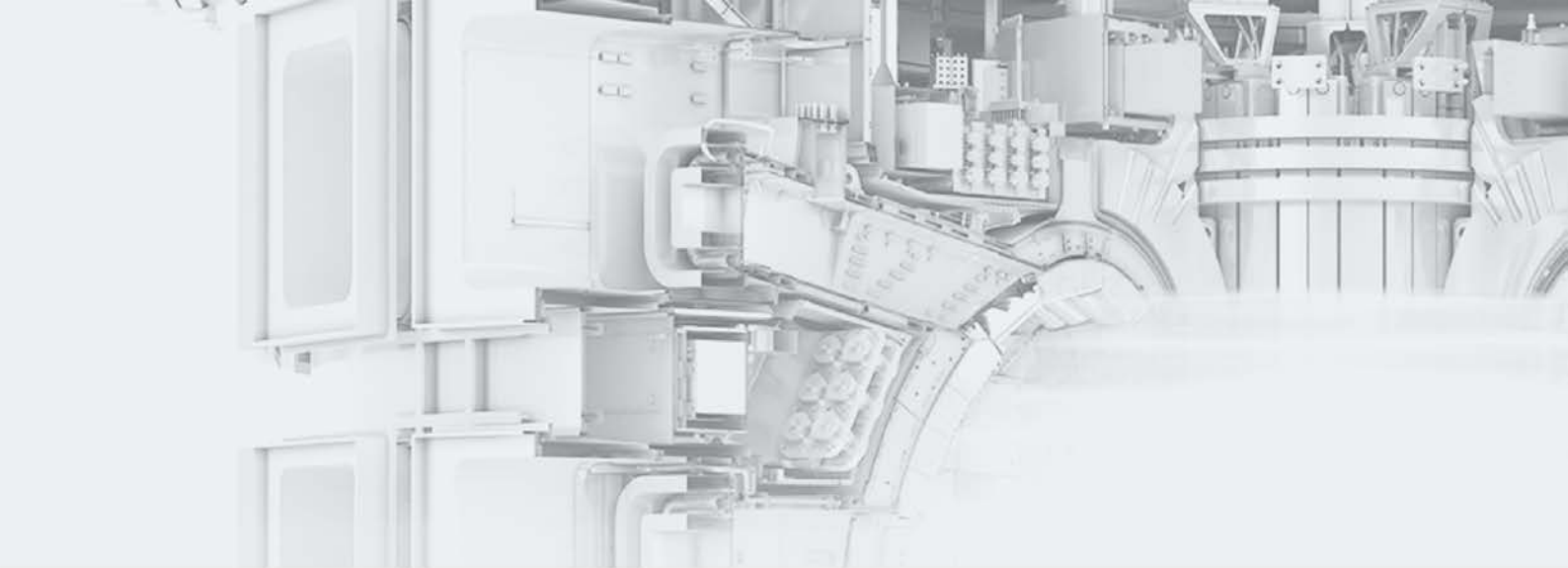
Given the importance of research, innovation, and human resources in all aspects of fusion development and deployment, FECC fosters collaboration and partnerships with research centres, universities, corporations, and government agencies in Canada and abroad.

Fusion Energy  
Council of Canada



Conseil canadien  
de l'énergie de fusion





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ATS Automation provides bespoke robotics, remote tooling, automated delivery systems and Hot Cells to the nuclear sector. Our integrated system design approach has successfully delivered effective tooling solutions for our customers on time and on budget and reducing critical outage time. Over 23,000 projects completed worldwide, ATS has developed the industry's most comprehensive automation engineering and assembly resource team – 6,000 staff – 75 facilities globally. Nuclear customers trust in our automation expertise to provide them with an unparalleled mix of proven technology, experience, and scale.

#### Key highlights of fusion support capabilities:

- MetalRobotics and Remote systems for high radiation
- Maintenance and inspection tooling
- Hot Cells and Hot Cell automation
- Waste handling & waste volume reduction
- Decommissioning tooling
- Engineering & field services
- Fuel handling, assembly and inspection
- Medical isotope technology,
- Small modular reactor tooling.



#### ATS Industrial Automation

ATS Industrial Automation is an end-to-end automated assembly and test solutions provider. Our single-source solutions can span the full project life cycle, from pre-automation to post-automation through automation and integration. ATS Industrial Automation brings your ideas for innovation and automation to life. Intelligently, efficiently, effectively. We provide a global footprint of assembly, manufacturing and service locations and more than 40 years of proven experience. ATS Industrial Automation delivers smarter solutions with superior returns and faster results for multi-national customers in industries like Mobility, Nuclear, Energy, Warehousing & Distribution, Electronics, and Consumer Products.

- Nuclear
- Energy Storage
- Warehousing & Distribution
- Mobility

[Learn More](#)

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Brotech is a metal component manufacturing company, specializing in high precision industries – Nuclear, Aerospace, Defense and Medical in particular. Working in these industries for over 25 years, Brotech has quality systems to match these industries' requirements. From ISO 9001:2015 to AS9100, and CSA N299.3, our quality systems ensure all the process and documentation requirements are met.

**Key highlights of fusion support capabilities:**

- Metal component manufacturing - Ultra high precision components of most materials including exotics, for use in any nuclear environment. Using advanced technology CNC machines for repeatability and reliability.
- Assembly - Engineering and execution of complex assemblies using extreme temperature modifications where needed to achieve the most demanding fit requirements.
- Quality systems built to exceed CSA N299.3 standards
- Special processes utilizing a network of qualified suppliers who are experienced in the nuclear industry
- Higher volume production utilizing multiple machines, shifts and automation
- Low volume production



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# Bucephalus Consulting

Bucephalus Consulting which undertakes studies for and provides independent expert advice to organizations interested in any aspect of the nuclear industry including: The Canadian nuclear supply chain, nuclear communications and engagement, small modular reactors, advanced reactors, decommissioning and waste management, medical Isotopes , international markets and fusion.

Neil Alexander, the principal consultant of the firm initiated the Fusion 2030 Plan and was one of the signatories to this plan to reinstate a fusion research program in Canada.

## Key highlights of fusion support capabilities:

- Technology and economic assessments.
- Conduct studies for potential investors interested in fusion technologies.
- Advise on the regulatory readiness for fusion technologies.



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Calian Nuclear is a centre of excellence for the development of technological safety and risk-based solutions. With professionals who are recognized as experts in their respective fields, Calian Nuclear provides its clients with a wide range of nuclear safety services.

Calian Nuclear provides a full-cycle approach to safety critical domains which is demonstrated by its involvement in research and development, nuclear safety analysis, regulatory compliance and licensing, operations, environmental protection, emergency planning and preparedness, and training and exercises. This approach has resulted in the full participation of hundreds of projects serving the nuclear industry and all levels of government, both in Canada and internationally.

## Key highlights of fusion support capabilities:

### Radiation Protection

- Supports clients in the development, implementation and certification of radiation protection and dosimetry programs and supporting clients to achieve CSA standards compliance. Our team has extensive experience in designing radiation shielding and evaluating its effectiveness for high-energy applications. Our team has supported clients with on-site radiation surveys and evaluations and preparing Radiation Protection plans including field work for high dose rate field activities.

### Nuclear Safety & Licensing

- Extensive knowledge of nuclear regulatory requirements and standards, as well as comprehensive experience in supporting regulatory activities both in Canada and internationally. This includes the interpretation of regulatory requirements, development of a licensing strategy and providing support throughout its execution, as well as documenting a licensing basis in a safety case or a safety report.

### Decommissioning and Waste Management

- Covers a full range of decommissioning and waste management capabilities from characterization to packaging to transportation and storage; building a logical process for our clients from beginning to end. Calian Nuclear has experience planning, performing, and evaluating the results of characterization and final status surveys in accordance with industry best practices like MARSSIM, CSA, and EPRI.

### Regulatory Affairs and Licensing

- Provides experienced interpretation of regulatory requirements which includes developing a licensing strategy and support throughout execution, documenting a licensing basis in a safety report, liaising with the regulatory authority on behalf of the licensee or applicant, and performing regulatory compliance audits and inspections of nuclear safety and support programs.

## Key highlights of fusion support capabilities:

### Emergency Preparedness and Training

- Calian is a leader in providing Nuclear Emergency Response (NER) training and exercises. This includes planning, executing, and reporting on full-scale emergency response exercises, workshops and drills and developing emergency response plans and procedures. Our team also provides simulation and training for emergency operations centres providing courses designed specifically for nuclear operations and response activities.

### Probabilistic Safety Assessments

- Calian is a world leader in Level III probabilistic safety assessment services (PSA). Our team performs probabilistic consequence assessments of the entire spectrum of postulated accidents which includes planning basis for emergency preparedness and risk-based cost evaluation of accidents.



### Environment & Nuclear

#### Technological Safety and Risk-Based Solutions

For over 20 years, the Calian team of experts have helped ensure the safety and security of Canada's nuclear infrastructure. This approach has resulted in full participation in hundreds of projects serving the nuclear industry and all levels of government, both in Canada and internationally. Our team brings together a diverse set of capabilities and provides value-add to all our products, systems and services. Calian Nuclear is an ISO 9001 certified division of Calian. Our processes are rigorously audited by our clients, thus ensuring the highest level of quality control and customer satisfaction.



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Canadian Nuclear Laboratories is Canada's premier nuclear science and technology organization offering unique facilities and over 60 years of nuclear industry experience. CNL's Chalk River Laboratories represent the largest single complex within Canada's science and technology infrastructure and contains several licensed nuclear facilities and more than 50 other unique facilities and laboratories.

CNL has unique capabilities and specialized facilities that support key nuclear science and technology priorities: innovation for industry, safety, security, health, environmental, and clean energy technologies. It is supported by Canada's most highly skilled nuclear workforce, delivering a range of nuclear services to domestic as well as international government and industry stakeholders. Services range from R&D, design, engineering, to specialized technology development.

#### Key highlights of fusion capabilities:

- State-of-the-art Tritium Facility equipped with scientific and technical staff executing research and developing programs and commercial activities associated with tritium technology.
- Tritium Facility consists of three main laboratory spaces containing a tritium handling apparatus inside an inert atmosphere glove box (secondary enclosure) for tritium dispensing and loading operations, two additional inert atmosphere glove boxes for handling tritium in liquid or gaseous forms, several fume hoods and air-purged enclosures for experimental work as well as for maintenance activities, plus liquid scintillation counters, and several pieces of specialized experimental equipment.
- Expertise in hydrogen isotopes (hydrogen, deuterium and tritium), including production, storage and handling. Of particular importance is the expertise on Water Detritiation using Combined Electrolysis and Catalyst Exchange Processes (CECE), Water Distillation (WD) and several other process combinations.
- Development and testing of tritium-compatible proton-ex-change-membrane (PEM) materials for use in PEM-based electrolytic cells for tritium applications.
- Commercial work in the Tritium Facility includes assay and dispensing of high-purity tritium using the tritium handling apparatus in the inert atmosphere glove box as well as preparation of gas standards with customer-specified tritium content, carrier gas, cylinder size and pressure. Past commercial work has involved tritium immobilization and absorption in solids for targets for neutron generation.

## Key highlights of fusion capabilities:

- Experimental research in tritium-compatible materials for isotope separation, tritium concentration and recovery. Research is also conducted on tritium permeation barriers to prevent tritium diffusion through materials. Includes range of methods for safe storage.
- Helium-3 extraction (removal) and purification.
- Offers education in Tritium Safe Handling Course which combines in-class and laboratory training for the safe handling of tritium in the industry community of users.
- Licensed nuclear fuel fabrication and testing facilities that could be adapted for research on fusion blanket materials and components.
- Expertise and facilities for carrying out computational and experimental thermal-hydraulic studies for components that are used on the primary or secondary side of a fusion power plant.
- Expertise in high-temperature loop operations.
- Expertise in computational neutronics and radiation transport modelling, which is relevant for modelling the neutron activation of system components, and blankets for breeding tritium or breeding fissile fuel in hybrid fusion-fission reactor concepts.
- Performs materials testing and analysis for high-temperature advanced reactors
- Comprehensive hot cells and active labs suitable to support a wide array of irradiated material examination and characterization.



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Welding / Solid State Fusion (not Friction). FuseRing is a solid state fusion and welding company that has been operational since X. It uses proprietary FuseRing technology as an intermediary that enables your pipeline construction project to reduce costs and time by reducing handling points. The result—a truly mechanized fusion product with zero defects.

**Key highlights of fusion support capabilities:**

- Joining similar or dissimilar materials with no flaws, no fusion lines, and no stress risers.

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Fusion power is complex, with multiple interdependencies and the need to develop, adapt, and deploy new and novel technologies. You need a partner who understands the industry, with experience in supporting the development and commercialization of first-of-a-kind technologies.

We have the experience, and the bench strength, to provide you with the very best in fusion power-and-energy engineering, planning, and management consulting services. Big. Small. Whatever your plans, whatever your scope.

We can help.

Active in the energy industry for over 100 years, Hatch is a global firm with Canadian and International experience in supporting fusion power development, advanced and small modular reactor development, and power plant engineering. Together with our vast process engineering experience in industrial design and our corporate resume in commercializing new technologies, we provide full project lifecycle support for R&D, demonstration, through to commercial operations.

**Key highlights of fusion support capabilities:**

**Tritium extraction, purification, and handling:**

- Leveraging our experience gained in the support of CANDU decommissioning plans, as well as experience with molten metal process plants, Hatch has experience in extraction technologies, radiological safety and design, and molten metal technologies to support requirements for tritium extraction, purification, and handling to help close the fusion fuel cycle.

**Lithium processing, handling, and purification:**

- From our work in primary lithium metal production, our process engineers design and develop proven industrial processes to support your needs.

**Lead-Lithium processing, handling, purification:**

- Combining our experience with lead smelting and lithium production, our pyrometallurgical and furnace design engineers can create custom processes to address the challenging material considerations associated with fusion power.

**First-of-a-Kind:**

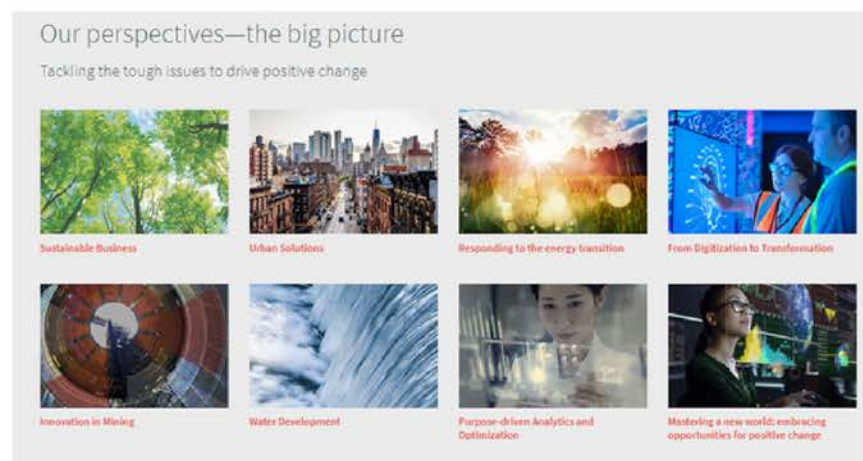
- Through our history Hatch has been involved in numerous first-of-a-kind projects in the energy, mining and metals, and infrastructure spaces. We pride ourselves on tackling the world's toughest challenges and have a mature project lifecycle process leveraging our corporate history to support the design process, deployment, and commissioning of new technologies.

**Key capabilities:****Commercialization support:**

- As an OEM, Hatch supplies equipment to metals processing facilities around the world. Leveraging this experience, we support our clients and our internal product teams in designing, testing, and deploying first-of-a-kind technologies for critical assets around the world.

**Integration:**

- As a technology integrator, we apply best practices and a rigorous project management framework that allows us to execute over \$50 billion USD in capital projects at any given time. Hatch plans and executes tasks to ensure risks are mitigated early, to ensure value, and maintain cost and schedule certainty.

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Company website: [www.hatch.com](http://www.hatch.com)



# The Ian Martin Group

For more than 50 years, The Ian Martin Group has been trusted to deliver the best technical staff to the Power Generation industry in Canada. A dedicated "Nuclear Hub" of experienced industry-specific Recruiters based in Pickering, Toronto and Tiverton ON and Saint John NB draw from our extensive network of Nuclear professionals and we handle the details to make your project a success – from recruitment and contract administration, to payroll, compliance and contractor care. Skilled staff when and where you need them to help ensure your project is realized – on time and under budget.

## Key highlights of fusion support capabilities:

- Business Development and Consulting,
- Contracting and Project Management,
- Electrical Equipment,
- Engineering Services,
- Information Tech

### Power & Nuclear

- Engineering Managers
- Project Managers
- Commissioning Engineers
- Health & Safety Specialists
- Planners & Schedulers
- Risk Analysts
- Trainers
- Electrical / I&C Engineers

### Information Technology

- Infrastructure Management
- Developers
- Data Analysts & BI Analysts
- Desktop & Technical Support Leads
- Applications & Solutions Architects
- ERP Systems Specialists
- Documentation & Technical Writers
- QA Analysts

### Automotive

- Application / Design Engineers
- CAE Engineers
- Control Systems Engineers
- Design Release Engineers
- Environmental Engineering
- Industrial Engineers
- PFMEA Technicians
- Requirements Analysts

### Aerospace

- Quality Engineers
- Interiors Systems Engineers
- Avionics Specialists
- Aircraft Designers
- Electrical & Wiring Designers
- Technical Writers
- Structures Engineers

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Kinectrics is a global engineering firm providing life cycle management services for the electricity industry. With operations and facilities worldwide, we create innovative and sustainable solutions that connect our people, facilities, and customers. Our expertise in engineering, testing, inspection, and certification is backed by our licensed laboratory and renowned testing facilities, a diverse fleet of field inspection equipment and an award-winning team of over 1,100 engineers and technical experts.

We collaborate closely with our clients to ensure that assets perform safely, reliably, and efficiently throughout their entire life cycle. Headquartered in Toronto, Canada, with origins tracing back to 1912, Kinectrics is widely recognized as an innovative company that employs some of the best and brightest minds in the industry.

### **Key highlights of fusion capabilities include:**

#### **Licensing and Regulatory Affairs**

- Lead provider of nuclear safety and licensing services in Canada and international jurisdictions with a long history of working with nuclear licensees and regulatory bodies on new reactor types and fusion technologies.

#### **Safety Analysis**

- Performs gamma dose rate, radiation, and neutron field calculations for plasma generators to support the development of fusion technologies. These capabilities include neutron and photon radiation shielding, activation analysis, radiation damage, structural and heat transfer, and thermal-hydraulic analysis.

#### **Design Engineering/Owners engineer role**

- Offers a full range of engineering design and drafting capability covering all disciplines required to support any plant modification, such as mechanical, electrical, civil, and structural. Core engineering skills include human factors engineering, finite element analysis and computational fluid dynamics analysis, probabilistic risk assessment, seismic engineering, fuel performance, and nuclear design. Supports the full life cycle of design engineering modifications as well as the Owner's engineer role to support complex projects.

#### **Tritium Fuel Management**

- Provides technical expertise in tritium handling, storage, and monitoring. Kinectrics offers accredited laboratories that provide Analytical Chemistry, Nuclear Waste Management, Decontamination, and Environmental Services. Specialized capabilities include isotope separation, tritium systems design, and contamination control.

#### **Solutions for Tritium Abatement and Management of Tritiated Wastes**

- Manages complex tritiated waste, analysis of tritium in a wide range of matrices, Tritium monitoring, and emissions control, and developing innovative technologies for Tritium abatement. Kinectrics' innovative solutions include a Universal Separation Process (USEO) removal of Tritium from mixed organic wastes and an immobilization process for Tritiated wastes resulting in minimal volume increases.

## Advanced and Additive manufacturing nuclear components:

- Optimization of design and manufacturing of a range of components and replacement used within nuclear power generation processes. Implementing additive manufacturing methods for safety-critical components.

## Material and Major Components:

- Testing, examining, analyzing, and demonstrating fitness-for-service of significant reactor components and structures. Covers a wide range of materials, e.g. polymers, metals, composites, non-metallics, and concrete. Facilities include Non-Active and Active Laboratories for Microstructural and Mechanical properties testing and evaluation, several dedicated facilities eg for Burst Tests and Isotope production and separation processes.

## Nuclear Equipment Qualification:

- Performs accelerated thermal aging of components and determine component or system activation energies. Provides equipment qualification testing services such as Thermal and Radiation Aging, Seismic and Vibration Simulations, Electromagnetic Interference testing, and Steam Event Simulations (Loss of Coolant Accident). Seismic testing equipment consists of a tri-axial seismic testing table and a single axis random input motion (RIM) table capable of performing a full range of seismic testing.

## Skid/Modular Design, Fabrication, and Testing:

- Kinectrics has the full capability to design, manufacture, assemble and test assemblies. Kinectrics is highly qualified and has significant experience in skid/modular design, fabrication, and testing.

## Transmission and Distribution Technologies:

- Kinectrics offers a range of electrical and mechanical testing for transmission and distribution components, such as conductors, insulators, and aged components. Kinectrics work with many of the world's leading manufacturers on a wide range of Cables, including Superconductors participates in, standards development, HV and HC testing, product certification, failure analysis, and new internal innovation developments such as nanotechnology materials for self-healing and high-performance insulators.

## Cross Platform Collaboration

- Extensive experience in a number of specialist areas and often brings teams together for clients or internal major projects to deliver a complete integrated solution and service.

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Laurentis Energy Partners, a commercial subsidiary of Ontario Power Generation, is an innovator and leader in the clean-energy industry. Based in Canada and with operations in Europe, Laurentis serves customers in energy markets and health care around the world.

Laurentis specializes in small modular reactor licencing and development, inspection and engineering services, refurbishment, nuclear materials and decommissioning, and the production of medical isotopes and heavy water.

**Key highlights of fusion support capabilities::**

- Radiation Protection
- Licencing and Owner's Engineer services for large capital projects. ☺
- Over 30 years of experience in hydrogen isotopes management and safe storage.
- Laurentis has experience in extracting Helium-3, a non-renewable isotope that occurs during the decay of tritium.

**Highlights:**

- Fusion Energy Council of Canada member

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Founded in 1972, Marmen is a family-owned Canadian company based in Trois-Rivières (QC, Canada). With international expertise in high-precision machining, fabrication and mechanical assembly, Marmen is a leading manufacturing partner for major OEMs. The company's success has been reflected in its numerous expansions, Marmen has a large and growing team of 1400 employees in 7 facilities in Canada and USA. In addition of manufacturing services, Marmen offers a highly professional project management service, with skilled and experienced team of mechanical and manufacturing engineers and technicians able to provide a vast range of services from initial concept through to full detail design.

Marmen's mission is to provide the best innovative manufacturing services and expertise; be a driving force in ambitious and challenging projects; and build the world's industrial future.

**Key highlights of fusion support capabilities:**

- Design for manufacturing of vacuum vessel for fusion.
- Manufacturing of magnets (welding, NDT inspection, machining) for fusion.
- Diversified knowledge for manufacturing hard-metal complex components and assemblies.
- 55,000 square meters / 600,000 sq.ft. of manufacturing capabilities, including welding (manual to robotic), stress-relief, NDT, machining (70+ CNC machine tools with the capacity to machine from 30 cm to 20 meters), surface treatment and mechanical and electrical assembly. More than 200T of lifting capacity



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MDA is best known in Canada for the iconic Canadarm, Canadarm2 and Dextre space robots used on the Space Shuttle and the International Space Station. These are examples of projects that have made MDA one of the world's most experienced and trusted sources of design, development, field implementation, and operations support for a wide variety of sophisticated mission-critical systems.

For over thirty years, MDA's nuclear automation systems and engineering services have been safely and successfully used in Canada and the United States for inspection, maintenance, and remediation activities. MDA has previous experience with the ITER program and its predecessor programs, and has provided expertise and systems for remote handling.

#### **Key highlights of fusion support capabilities:**

- **Remote handling systems:** MDA develops and supports end-to-end remote handling systems for customers in challenging environments with major deployments in the space, nuclear and medical industries. MDA has an extensive inventory of robotic technology developed for our space programs that allow us to provide unique and effective solutions to tasks in challenging, regulated environments. This technology has been successfully delivered for applications in neurosurgery, cancer diagnosis, and nuclear reactor inspection and maintenance. This capability is available and relevant for fusion's remote handling applications.
- **Systems engineering/Owner's engineering:** MDA provides systems engineering and owner's engineering services to our clients for the engineering development and oversight of remote handling tooling systems. We offer a systems engineering methodology derived from our aerospace background that ensures a structured and disciplined approach to the development and integration of technology into new systems. Key benefits of our approach include operations-based design, early risk mitigation, disciplined integration and test, and contingency planning.
- **Radiation Hardened Electronics:** MDA has extensive experience in the electronics design and development capability for components, subsystems and systems to be used in harsh radiation environments. This capability is a routine part of our space programs and is also applied in the nuclear sector. MDA has previously developed radiation-hardened electronics for the ITER and its predecessor programs and would be interested to provide this service to fusion programs again.
- **Quality system:** MDA performs all of its work under stringent quality management systems in highly regulated industries including manned space flight standards (AS9100) and nuclear standards (N299.1)

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Promation Nuclear is a leading designer and manufacturer of high-quality custom tooling, automation, and robotic systems – offering nimble and effective project management, engineering, and manufacturing expertise. We have been supporting nuclear clients since 2009 and provide our customers with the highest quality, on-time, on-schedule, and on-budget performance while catering to the unique requirements of the nuclear industry.



Promation Nuclear was built upon our years of successful development of leading-edge nuclear technology for CANDU customers. Promation Nuclear's engineering and advanced technologies are designed to support plant life management, extend plant design life, reduce maintenance costs, and develop cost-effective solutions to existing challenges.

**Key highlights of fusion support capabilities:**

- Robust Quality Assurance Program
- Custom Reactor Tooling
- Contaminated and Active Waste Handling Equipment
- Process Systems and Automation
- Rapid Prototyping and Development, AMM
- Isotope Production and Transport Tooling
- Reactor inspection control systems
- Remote control of autonomous access platforms

**Design, Manufacturing, and testing of:**

- Robotic manipulators and end effectors for high dose, highly contaminated nuclear work areas
- Specialized robotic handling of ultra-high source activation products (hot particles)
- Reactor component robotic inspection systems
- Shielded transfer flasks, cabinets and assemblies

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Shawcor is a trusted Canadian based manufacturer of ShawFlex wire and cable as well as DSG-Canusa electrical accessories with over five decades of experience. The ShawFlex product line includes nuclear grade cables for instrumentation, thermocouple, control, power, and custom composite cable designs that have been used for over 30 years in CANDU facilities in Canada and worldwide.

Our commitment to our customers and applications is backed by comprehensive services including in-house research, product development, and pre-qualification testing. The ShawFlex brand of electrical wire and cable is manufactured in our world-class Toronto, Canada facility that maintains the highest quality management standards through accreditation to CSA N299.2 and ISO 9001.

Choosing a ShawFlex cable means more than selecting products from a catalogue. It means:

- Working with you and responding to technical problems with innovative solutions
- Meeting your needs for dependable products, manufactured and tested to your specifications
- Meeting deadlines and showing leadership and responsiveness that result in dependable service



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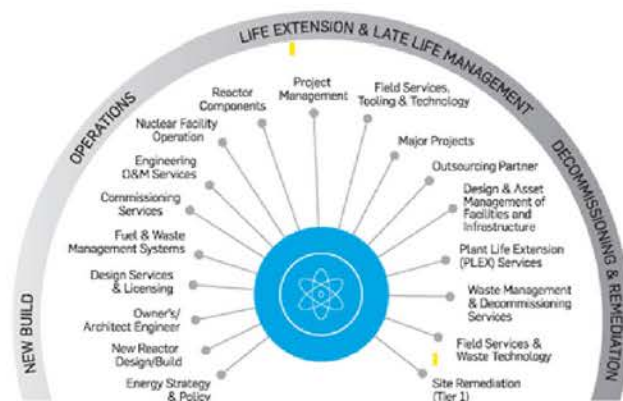


SNC-Lavalin is a trusted end-to-end solutions provider across the project lifecycle for all reactor types including CANDU, AGR/BWR/PWR, and SMRs. Our services range from New Builds, Operations, Life Extension, Late-life Management, Decommissioning and Tooling. As the steward of CANDU® technology, we've developed and licensed Nuclear technology for over 60 years. With our knowledge of global policy and regulatory frameworks across the four CANDU continents, we've been able to expand to new geographies across a wide range of reactor technologies.

We are a safety leader amongst our largest peers. We have End-to-end capabilities across all reactor types, projects and services with a global presence and local execution. Our culture of collaboration makes us agile and responsive with the ability to form strong partnerships. We provide differentiated solutions that deliver more efficiency, productivity and insights through our team of 3000+ nuclear experts.

**Key highlights of fusion support capabilities:**

- CANDU, AGR/BWR/PWR, and SMRs.
- New Builds,
- Operations,
- Life Extension,
- Late-life Management,
- Decommissioning and Tooling.



**Local expertise on a global scale**

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# Sunlit Strategic Inc.

Sunlit Strategic is a consulting company specializing in providing strategic advice to clients, with an integration of technical and commercial concepts and inputs.

Sunlit Strategic primarily focuses in clean energy solutions and nuclear medicine. We are a forward-thinking organization with a passion for transforming ideas into reality through imagination, creativity, outside-of-the-box thinking, and collaboration.

## **Key highlights of fusion support capabilities:**

- Demonstrated ability for bridging technical concepts with corporate strategy.
- Formulates comprehensive frameworks that articulate the value of business opportunities to clients.
- Supports clients in the journey from the conceptual stages of fusion technology towards the final steps of building the business case that leads to commercialization.



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TYNE ENGINEERING is a turn-key supplier of equipment for the nuclear and FUSION industries. Tyne has a Nuclear Quality Assurance program and 30 YEARS EXPERIENCE in TRITIUM HANDLING and makes systems to capture, purify, assay or SEPARATE tritium.

Tyne's WATER DETRITIATION system uses our own TRITIUM-RESISTANT ELECTROLYZER. We make our own High-Sensitivity portable and room TRITIUM MONITORS, in-line ion chambers, and complete Radiation Monitoring Systems. We manufacture Passive Autocatalytic Recombiners for Hydrogen mitigation.

Tyne models dryers and Wet SCRUBBERS for air detritiation. Our double-containment GETTER BEDS include our own license-pending TRITIUM TRANSPORTATION CONTAINER. We provide ISOTOPIC SEPARATION SYSTEMS using Cryogenic Distillation or Thermal Cycling Absorption technologies. Our hydrogen-oxygen recombiners are of gas-phase and trickle bed types.

Tyne has a nuclear-audited Commercial Grade Dedication program that can be applied for fusion and research reactor applications to save costs.

**Key highlights of fusion support capabilities:**

- Tritium-resistant electrolyzer
- Tritium monitors
- In-line ion chambers
- Radiation Monitoring Systems
- Passive Autocatalytic Recombiners for Hydrogen mitigation.



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Westinghouse Electric Canada is a growing provider of technology and end-to-end services in the Canadian nuclear industry. With 250 employees in Canada backed by 9,000 global nuclear experts, we are a leading global supplier of safe and innovative energy solutions.

We provide customers with reliable nuclear power plants (AP1000, eVinci Micro Reactor), nuclear fuel, plant automation, operating plant products and services (CANDU, PWR, BWR, VVER), and decommissioning and waste management solutions.

From parts and components through to digital engineering, fire protection and customized tooling solutions, our client-focused team is committed to delivering cost-effective and efficient solutions that meet our customer requirements. Westinghouse is proud to bring an inclusive and respectful environment to all our interactions with partners, suppliers and clients.

**Key highlights of fusion support capabilities:**

- Long history and extensive experience in the supply of leak-tight vessels to contain tritium for storage and transportation. In-house facilities for the production of titanium sponge getter materials.
- Experienced and qualified helium leak test personnel.
- Specific prior experience in the design and supply of Uranium Scavenger beds for the Princeton tokamak fusion test reactor.
- Custom remote handling and transportation systems including prior design & supply of equipment for ITER diverter plate removal and replacement.
- Skid-mounted process systems design, supply and testing, including electrical, mechanical, plus full instrumentation, controls and programming.
- Full nuclear Quality Assurance pedigree.

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# Wild Matriarch Inc.

Reputation and trust go hand in hand. For clients investing in a social license, Wild Matriarch can help you authentically connect with diverse publics.

Wild Matriarch is a boutique consultancy focused on governance, culture, and reputation. We pair diversity and innovation with deep understanding of the safety and regulatory imperatives of nuclear and high-reliability industries, where social license is crucial to success. We use the creative talents of our team of collaborators to give clients confidence to take bold actions and find new ways to connect with their diverse publics through dialogue, engagement and shared experience.

We look forward to helping you tell your story and build lasting relationships! Wild Matriarch is a woman-owned business committed to diversity and inclusion.

**Key highlights of fusion support capabilities:**

- Expertise in engagement, strategic communications and reputation management.
- Team capabilities to connect authentically with youth, Indigenous people, and diverse voices.
- Including translating technical topics into plain language.
- Expertise in safety culture assessment and improvement.

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Worldwide Security Ltd. (WWS) is an ISO9001 certified security technology and communications integrator with over three decades of experience in supplying equipment and manufactured solutions in commercial, heavy-industrial, nuclear, and government sectors. We specialize in custom, turnkey voice and vision solutions, inspection cameras and equipment, custom manufacturing, and advanced voice and vision systems integration. WWS has been active in the CANDU nuclear environment since 2006, in reactor refurbishment, as well as ongoing operations and inspection applications. Our OPEX in the nuclear power industry is extensive and ensures that our solutions come with a proven track record of performance in this demanding environment. Our deployments have proven to reduce delays during outages, optimize worker communication, and increase safety.

## Key highlights of fusion support capabilities:

### Wireless communications

- Offers wireless communications tailored for nuclear environments with years of OPEX in delivering trusted solutions for general operations, refurbishments, and outages. Creates rapid solutions with the lowest amount of disruption to normal operations. With fusion technology advancing, WWS remains poised to support the industry in deploying effective wireless communications.

### Inspection cameras

- Offers a wide variety of custom inspection cameras suitable for all highly secure environments. With solutions ranging from medical isotope processing, waste remediation, in-vault inspections, and other applications, WWS has the capabilities to develop custom solutions to meet the needs of the fusion environment.

### Vision systems

- Deploys full end-to-end turn-key vision systems. Including small inspection/camera systems to large enterprise systems requiring hundreds of devices, IP imaging, or no-latency analog and real-time performance, WWS has deployed our custom systems into practically every sector of the nuclear industry. Our proven OPEX and performance allow us to be ready to develop whatever solutions are required for specific fusion applications.

### Radiation tolerant vision systems

- Alongside conventional imaging, WWS also supports and integrates many types of OEM radiation tolerant cameras and assemblies within our vision systems.

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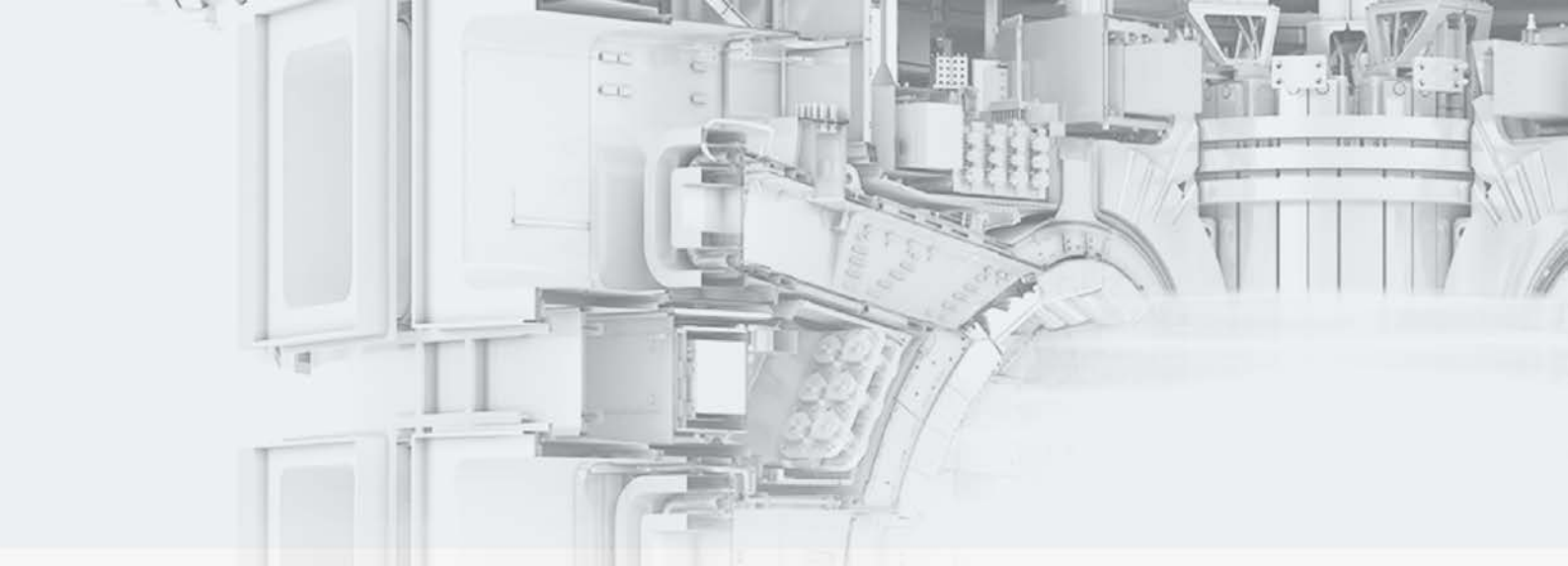
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# Canadian Research Institutes

University Network of Excellence in Nuclear Engineering	35-38
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UNENE is a not-for-profit partnership based in Canada, bringing together 14 nuclear universities along with the major Canadian nuclear industry organizations. UNENE sponsors, oversees and disseminates nuclear research in a wide variety of fields, through our member universities, along with education programs and outreach initiatives. While UNENE's activities and programs have been largely focused on nuclear fission, the capabilities and interests of member universities closely align with fusion science and technologies. Overall, the UNENE membership and organization have taken a strong interest in the potential of nuclear fusion technologies and have prepared for more active involvement, recognizing the rapid progress and momentum in the field. UNENE universities work in close collaboration with other organizations in Canada and internationally, and have been part of Canada's significant history of nuclear fusion engagement over many decades. This includes the development and use of Tokamak experimental facilities, deep knowledge in tritium handling and management, and the recent increasing international cooperation with projects such as ITER.

## Outline of Capabilities

The UNENE university community is listed in Table 1 below. The community includes a wide range of capabilities, facilities and expertise, with particular relevance to fusion development. The following is not an exhaustive listing but provides an indication of this range, to help prepare for a more detailed review.

## Major Facilities:

UNENE and partner universities have established a very broad range of world-class facilities used in nuclear research, including many facilities specific to, already in use for or applicable to fusion research, including:

- Experimental Tokamak facility and lab at the University of Saskatchewan
- 5MW research reactor at McMaster, coupled with an extensive hot cell array and world-class national microscopy facility
- Reactor Materials Test Laboratory Accelerator at Queen's University, capable to provide fusion-level irradiations including ongoing projects
- Facilities to study tritium properties, handling, and separation at several universities
- Extensive corrosion test facilities including applications to irradiated materials at several universities
- Plasma test facilities at McMaster and Ontario Tech universities, that provide fusion neutron sources for an array of experiments



## Research Activities and Capabilities :

A range of fusion-related research activities are underway at the universities, and there is a strong and active interest in applying fusion-related capabilities as the momentum grows in this field. In addition to the regular use of the major facilities above, current fusion related research includes:

- Study of the adaptation and use of dense plasma focus device including fusion neutron beams
- Joint study to evaluate radiation damage and determining mechanical property changes in structural and process materials.
- Studies of the synergy between fission and fusion systems, e.g. regarding tritium production
- Experimental studies of the first wall and divertor heat transfer experience
- Use of Laser-Induced Breakdown Spectroscopy (LIBS) systems for nuclear material interrogation and hydrogen isotope measurement in metals
- Modelling of plasma material interactions and divertor damage processes using advanced computational tools
- Nano-fluids application in fusion.
- Safety studies including experimental guided simulation of ITER coolant leak accident.
- Design and optimization of fusion control, protection, and monitoring systems for plasma generation
- Liquid metal thermal-hydraulics experiments.

In addition to these specific research initiatives, the university community has a very deep level of activity, expertise and capability applicable to fusion topics, that can be tapped into as part of a fusion research program. Topics include:

- Outstanding experience in remote handling and robotics, including UNENE-funded research
- Energy transfer research and overall energy delivery
- Instrumentation and control in high-radiation environments
- Radwaste handling and disposal
- Environmental and radiation multi-field monitoring, environmental risk assessment

## Collaborations

UNENE universities have a strong record of collaborations in nuclear technologies, both together and through international cooperation. UNENE universities have a long history of close cooperation with Canada's national nuclear laboratory, CNL at Chalk River. Universities have been engaged in collaborative activities and with the international fusion community, e.g. through experience in Canada with General Fusion; internationally, e.g. through the UK National Fusion Centre CCFE. The UNENE university group has an outstanding research record and reputation which enables collaboration with similar academic institutions worldwide.

## Benefits

UNENE universities offer a very wide range of world-class research facilities, experts and program capabilities. The long history of nuclear technology study in Canada demonstrates the commitment and dedication within the Canadian academic environment. In addition, given support from private industry, UNENE researchers can leverage project funding via partnership grants from Canada's Natural Science and Engineering Research Council, and similar provincial research foundations, to provide 2:1 or greater government funding support. UNENE can provide essential facilitation and mobilize and guide university response through its role as a collaboration hub. Finally, working with the UNENE universities also enables a window to collaboration with companion universities in Canada, and with national laboratories, through their close association.

## Logistics

In addition to these specific research initiatives, the university community has a very deep level of activity, expertise and capability applicable to fusion topics, that can be tapped into as part of a fusion research program. Topics include:

- Engagement and discussion with the client to understand research priorities and opportunities, and to discuss the overall framework for UNENE support to research
- Identify potential research project scope that meets client needs and also qualifies for government funding
- UNENE work with universities to develop joint proposals that are aligned with client needs
- Move to gain agreement, government funding support as appropriate and project(s) kick-off

Table 1: UNENE Members: Universities and Industrial Members

- |   |   |
|---|---|
| • McMaster University   | • Canadian Nuclear Labs (CNL) (formerly AECL-CRL) |
| • Queen's University  | • Bruce Power                                     |
| • Ontario Tech (formerly University of Ontario Institute of Technology) | • Ontario Power Generation (OPG)                  |
| • University of Saskatchewan  | • Canadian Nuclear Safety Commission (CNSC)       |
| • University of Toronto   | • CANDU Owners Group (COG)                        |
| • University of Waterloo  | • NWMO  |
| • University of Western Ontario   | • Kinectrics                                      |
| • Ecole Polytechnique   | • SNC-Lavalin-Nuclear (formerly Candu Energy Inc) |
| • University of New Brunswick   |   |
| • Royal Military College  |   |
| • University of Guelph  |   |
| • University of Windsor   |   |
| • University of Regina  |   |

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The University of Alberta is a top academic and research institution in Canada. The university is a leader in energy-related research in Canada, which is our priority area, as evidenced by declaring Energy Systems our first signature area of teaching and research and by the establishment of the Future Energy Systems initiative supported by the Canada First Research Fund (CFREF). A long history of discoveries at the University have enabled Canada's energy industry to prosper, contributing numerous innovative technologies, business practices, social studies and public policies. The University has a commitment to educate students and conduct research that will answer the challenges of today and tomorrow, while addressing long term impacts.

The UofA is home to some of the best and most advanced nanotechnology facilities and equipment in Canada. The UofA researchers are also leaders in the political, economic, environmental and safety aspects of energy systems.

Examples of areas of research interests related to fusion energy and their researchers including information about their departments are listed below:

#### A) Inertial Confinement Fusion Energy Technology

(i) Laser-Plasma Interaction Science: Jason Myatt (ECE), Amina Hussein (ECE), Wojciech Rozmus (Phys), Robert Fedosejevs (ECE), Ying Tsui (ECE), Richard Sydora (Phys), John Bowman (MSS).

(ii) Implosion and Fusion Energy Science: Robert Fedosejevs (ECE), Jason Myatt (ECE), Ying Tsui (ECE), Amina Hussein (ECE), Richard Sydora (Phys) and John Bowman (MSS).

(iii) Laser Technology: Gil Porat (ECE), Robert Fedosejevs (ECE), Behrad Gholipour (ECE).

(iv) Target Technology: Xuehua Zhang (CME), Manisha Gupta (ECE), Ying Tsui (ECE), Hao Zhang (CME).

ASB - Alberta School of Business

CME - Chemical & Materials Engineering

ECE - Department of Electrical & Computer Engineering

ME - Mechanical Engineering

MSS - Department of Mathematics & Statistical Sciences

Phys - Department of Physics

PS - Department of Political Science

MSS - Department of Mathematics & Statistical Sciences

REES - Department of Resource Economics and Environmental Sociology

B) Materials for Fusion Reactors: Leijun Li (CME), James Hogan (ME), Weixing Chen (CME), Andre MacDonald (ME), Hao Zhang (CME), Robert Fedosejevs (ECE), Ying Tsui (ECE).

C). Political, Economic, Environmental and Safety Aspect of Energy Systems: Andrew Leach (ASB), Lori Thorlakson (PS), Amit Kumar (ME), Lianna Lefsrud (CME), John Parkins (REES), Wiktor Adamowicz (REES).

ASB - Alberta School of Business

CME - Chemical & Materials Engineering

ECE - Department of Electrical & Computer Engineering

ME - Mechanical Engineering

MSS - Department of Mathematics & Statistical Sciences

Phys - Department of Physics

PS - Department of Political Science

MSS - Department of Mathematics & Statistical Sciences

REES - Department of Resource Economics and Environmental Sociology

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The University of New Brunswick is Canada's oldest English-language university. Founded in 1785, the multi-campus institution has a rich history and a dynamic focus on innovation, experiential learning and entrepreneurship. UNB has more than 10,500 students from over 100 countries enrolled in degree-credit courses on its campuses, online and at partner institutions around the world, as well as thousands of continuing education learners. As a comprehensive university, UNB is home to substantial research expertise in many disciplines. Its faculty and staff have collaborated extensively with public and private sector leaders to advance research and foster innovation.

## Key fusion areas of research and focus include:

- **Metal Additive Manufacturing:** UNB MAMCE is developing the technological requirements for 3D printing of fusion reactor critical components from copper-based alloys.
- **Nanocomposites and Mechanics Lab:** Nanostructured feedstock cold spray advanced manufacturing.
- **Canadian Institute for Cybersecurity:** cybersecurity solutions for critical infrastructure and digital grids.



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Ontario Tech is a young institution focused on discovery and application of knowledge to accelerate economic growth, regional development and social innovation. Ontario tech inspires and equips the students to make a positive impact in a tech-focused world. The ethical application of technology is a key component of Ontario Tech teaching, learning practices and innovative research projects.

**Key fusion areas of research and focus include:**

- Plasma material interactions using advanced computational tools, erosion and divertor damage during plasma instabilities, nanofluids application of fusion.
- Materials under fusion environments, tritium removal experiments and experimental guided simulation of ITER coolant leak accident. . Design and optimization of control, protection, and monitoring systems for plasma generation and fusion reactors with AI and data analytics.



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The Plasma Physics Laboratory at the University of Saskatchewan has a long history for research on plasma physics and engineering related to fusion energy development. The laboratory operates the STOR-M tokamak and the University of Saskatchewan Compact Torus device and trains graduate students and researchers.

**Key fusion areas of research and focus include:**

- Study of anomalous transport in the STOR-M tokamak plasma
- Feasibility study of innovative and efficient fuelling technologies for fusion reactors based on compact torus injection.
- Theoretical study and numerical simulations



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# Acknowledgements

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A note of gratitude is extended to each listed point of contact whose input has made up the entries found within the 2022 Edition Canadian Fusion Capabilities Directory.

## Fusion Support Organizations

- ATS Automation
- Brotech
- Bucephalus Consulting
- Calian Ltd
- Canadian Nuclear Laboratories
- Fuse Ring
- Hatch
- The Ian Martin Group
- Kinectrics
- Laurentis Energy Partner
- Mermen Inc
- MacDonald. Dettwilder and Associated (MDA)
- Promotion Nuclear
- Shawcor Ltd.
- SNC-Lavalin
- Sunlit Strategic Inc
- Tyne Engineering Inc
- Westinghouse Canada Inc
- Wild Matriach Inc
- Worldwide Security Ltd.

## Academic Institutions

- University Network of Excellence in Nuclear Engineering
- University of Alberta
- The University of New Brunswick
- Ontario Tech University
- University of Saskatchewan





