Fusion and Fission Energy and Science

Fusion Energy

Fusion Energy Division experts are developing the understanding required for the deployment of practical fusion energy systems. This includes realizing next-generation fusion materials, achieving a sustainable fuel cycle, ensuring adequate power exhaust in high-confinement systems, and maintaining long-term control of the plasma.

Burning Plasma Foundations
Provide the technical basis and resolve key challenges in achieving and sustaining high performance burning plasmas in fusion devices.

1. *Plasma Theory and Modeling* — Deliver the theoretical foundation and state-of-the-art simulation/modeling capabilities to resolve critical issues and inform design/operation of ITER and future fusion devices.

2. *Diagnostics and Control* — Develop and validate innovative measurement and control capabilities needed to understand and control important physics phenomena in present devices and maintain robust control in the fusion nuclear environment of future fusion devices.

3. *Advanced Tokamak Physics* — Establish high confidence, embodied in a validated modeling suite, in achieving high performance, steady-state tokamak regimes in ITER and future fusion devices.

4. *Power Exhaust and Particle Control* — Deliver power exhaust/particle control solutions and accompanying physics basis required for compact fusion devices.

Fusion Nuclear Science, Technology, and Engineering
Establish the technical basis and provide cost-attractive solutions for fusion subsystems needed to turn a burning plasma into a viable commercial power plant

1. *Blanket and Fuel Cycle* — Provide the technical basis and solutions for closing the tritium fuel cycle and efficient power extraction in future fusion systems.

2. *Fusion Technology* — Develop innovative technology approaches for heating, fueling, and controlling plasmas required for efficient operation of future fusion systems.

3. *Fusion Engineering* — Develop advanced designs and engineering solutions for both individual components and integrated systems for future US and international fusion systems.

4. *Remote Systems* — Provide creative solutions for remote monitoring and manipulation in extreme environments.

Nuclear Energy and Fuel Cycle

ORNL is a world-leader in innovation for nuclear energy and is working to accelerate the deployment of economical technologies from concept through industry and regulatory adoption. The Nuclear Energy and Fuel Cycle Division provides science and technology breakthroughs to extend the lives of current nuclear plants, to accelerate the deployment of new, advanced nuclear-power technologies, to further the state-of-the-art in modeling and simulation capabilities for nuclear application, to deliver new insights into nuclear fuel performance at all stages of the fuel cycle, and provide new innovations for nuclear fuel systems.

Advanced Reactor Engineering and Development
World-class capabilities for design and performance analysis of advanced reactor concepts and development of advanced technologies for cost-competitive nuclear energy.

1. *Advanced Reactor Systems* — System analysis for advanced reactor concepts: Provides assessment of reactor performance and impact of modern technologies on cost-competitiveness for nuclear energy.

2. *Energy Systems Development* — Component testing and integration: Provides technology development and testing for molten-salt components and advanced energy conversion systems.

3. *Advanced Nuclear System Safety and Licensing* — Siting, safety, and systems analysis for advanced reactor systems: Provides support for deployment of advanced reactors, microreactors, and space reactor systems. Provides reactor expertise for safeguard and security activities.

4. *Thermal Hydraulics* — Computational fluid-dynamics and experimental testing: Provides performance analysis of thermal hydraulics in advanced reactor concepts, detailed computational and experimental analysis of components.

5. *Nuclear Structures and Construction* — Expertise in civil engineering and concrete performance for nuclear structures: Provides characterization and predictive analysis of concrete performance under time, stress, and irradiation. Development of new construction architectures.

6. *Modern Nuclear I&C* — Development of instrumentation and control systems for nuclear applications: Provides development of new measurement approaches, analytics of data for nuclear components, and artificial intelligence for automated control systems.

Nuclear Modeling & Simulation Development and Deployment
Leads application-driven development of innovative and validated computational tools and analysis methods to efficiently model fission energy systems, nuclide transmutation, and nuclear fuel cycles.

1. *Power Reactor Modeling* — Power reactor R&D focuses on commercial nuclear power systems including tool development and analysis expertise to support nuclear industry and NRC customers.

2. *Depletion Modeling* — Depletion modeling R&D at ORNL focuses on method development and analysis applied for nuclear fuel cycle assessments, radionuclide inventories, source terms, and decay heat.

3. *Research and Test Reactor Modeling* — Research reactor R&D focuses on non-commercial nuclear power systems including tool development and analysis expertise to support key national user facilities such as HFIR and VTR as well as first-of-a-kind systems such as TCR.

4. *Nuclear Code Integration* — Support for code development, revision, and upgrades: Provides an essential capability in deployment of modeling and simulation packages by providing technical support for code quality, debugging, as well as customer support.

5. *HPC Methods for Nuclear Applications* — Extends modeling and simulation tools for nuclear to high performance computing: Most mod-sim tools for nuclear applications are not compatible with modern computational tools. This requires a multi-disciplined approach, bridging both exascale computing and nuclear engineering.

Nuclear Criticality, Radiation Transport and Safety

Provide integrated nuclear data, modeling & simulation, nuclear criticality safety and radiation transport analysis capabilities to enable innovative technical solutions for nuclear technology applications.

1. *Nuclear Criticality* — Modeling and simulation and nuclear criticality safety analysis: Possesses a broad range of physics and nuclear engineering expertise that is used to provide technical support to nuclear criticality safety licensing submittals and other issues associated with storage and handling of nuclear fuel at power plants and in storage and transportation systems.

2. *Nuclear Data* — Improved measurement of nuclear data and new measurement techniques: Provides high-quality nuclear data with covariances, which are required for the design and analysis of nuclear systems. The group develops new methods for measurement in partnership with leading facilities around the world.

3. *Radiation Transport* —Leading analysis of radiation transport and shielding: Develops, applies and deploys state-of-the-art modeling and simulation capabilities along with extensive expertise to solve challenging radiation transport problems across a wide range of applications, including shielding for ITER and other facilities, as well as spent nuclear fuel.

Fuel Development

World-leading expertise in the fundamental science and characterization of fuel cladding and fuel performance, the development of advanced fuel systems, and unique experience in design and implementation of in-reactor testing.

1. *Advanced Fuel Forms Development* —Innovation in development of new, high-performance fuel forms: Applies modern materials science to design, develop, optimize, and test prototypical advanced nuclear fuels that will accelerate the deployment of higher performance nuclear energy systems.

2. *Nuclear Cladding Development and Characterization* — Characterization and development of nuclear fuel cladding for existing and advanced reactors: Provides advanced materials characterization and modeling of cladding materials. The use of advanced and additive manufacturing technologies provides innovative performance solutions to cladding systems.

3. *Particle Fuel Forms* — International leadership in development of coated particle fuel forms (TRISO): Delivers new fuel particle innovations and designs, supports industry partners in production and processing, leading capability in post-irradiation examination and long-term performance of fuel particles.

4. *Irradiation Testing Design and Fabrication* — Experimental design and analysis for complex experiments and testing for reactor service: Combines leading edge thermal, fluid, and structural analysis methods with sophisticated experimental techniques to develop effective solutions for testing.

5. *Nuclear Experiments* — Fabrication and qualification of experiments for reactor components and systems: Group expertise is applied to solve the most challenging thermal hydraulic problems and complex experimental designs such as coolant loops and instrumentation.

Integrated Fuel Cycle

World-leading fission fuel cycle capabilities that underpin reactor deployment and operation.

1. *Fuel Cycle Chemistry Research* — Performs applied research on chemical reactions (conversions) and separations chemistry associated with the production of nuclear materials. Activities are of a more fundamental nature that will be incorporated into technologies developed and assessed by the FRT group.

2. *Fuel Reprocessing Technology* — Performs applied R&D with emphasis on technology and process development for nuclear materials, processing irradiated materials, and immobilizing wastes. This also includes systems analysis and experimentation for determination and characterization of facility source terms.

3. *Uranium Process Chemistry* — Research on the handling, behavior, environmental fate, and detection of materials associated with gas phase U enrichment processes. This includes development of methods and devices for determining U assay and processing history.

4. *Extended Burn-Up and Increased Enrichment Fuel* — Characterization and performance of extended burnup fuel and cladding: Delivers fuel characterization of used fuel using advanced modeling and simulation capabilities, and insights from characterization supporting industry and regulator decisions. Analysis of increased enrichment forms and performance is a priority.

5. *Packaging Systems and Logistics* — Characterization of packaging containers and logistics: Supports implementation and planning for storage and maintaining a database of the nation's used fuel inventory, as well as safeguarding of spent nuclear fuel and high-level waste. Spent fuel package testing, development of standards and transportation methods, and logistics are key capabilities.

6. *Used Fuel Disposition* — Implementation of disposition of used fuel: Leads activities associated with disposal of spent fuel, development of standards and transportation methods, and analysis of disposition scenarios.

US ITER Project

The mission of the international ITER project is to demonstrate the scientific and technological feasibility of fusion energy. Now under construction, ITER will allow scientists to study reactor-scale burning plasmas and explore technical challenges related to the development of a power-producing fusion reactor.

As an ITER member, the United States receives full access to all ITER-developed technology and scientific data but bears less than 10 percent of the total construction cost. The US contribution consists of R&D, hardware design and manufacturing for 12 different ITER systems, plus assignment of personnel and funding for the US share of common expenses.

US ITER is managed by Oak Ridge National Laboratory with partner labs Princeton Plasma Physics Laboratory and Savannah River National Laboratory.

For more information, see www.usiter.org.