GAMOW—**G**alvanizing **A**dvances in **M**arket-Aligned Fusion for an **O**verabundance of **W**atts

PROJECT DESCRIPTIONS

Oak Ridge National Laboratory – Oak Ridge, TN

Fusion Energy Reactor Models Integrator (FERMI) - $3,100,000

ORNL and its partners will develop an integrated simulation environment, the Fusion Energy Reactor Models Integrator (FERMI), to assess and accelerate the design cycle of integrated fusion-energy systems. FERMI will substantially shorten the overall design cycle and reduce costs, while significantly improving accuracy. The project team will integrate FERMI's capabilities and demonstrate utility by simulating and assessing the innovative and potentially transformative liquid-immersion blanket concept that could enable a compact, high-field path to commercial fusion energy.

University of California, San Diego – La Jolla, CA

Renewable Low-Z Wall for Fusion Reactors with Built-In Tritium Recovery - $1,750,000

The simultaneous handling of high expected wall heat loads and erosion while allowing for tritium recovery remains an unsolved challenge that could impede the successful development of commercial fusion energy. The University of California, San Diego, seeks to address this issue by developing a low-atomic-number renewable wall for fusion devices that contains a slurry composed of carbon, ceramics, and a volatile binder. The slurry will be continuously pumped and extruded through first-wall openings, where it dries partially into a pebble conglomerate upon exposure to the plasma. Gravity drives the conglomerate down the vessel walls, carrying heat and byproducts such as tritium. Tritium recovery is achieved by outgassing the recovered carbon pebbles. This project will determine and demonstrate the required slurry composition and thermo-mechanical properties with simulated heat flux.

Savannah River National Laboratory – Aiken, SC

Process Intensification Scale-Up of Direct LiT Electrolysis - $1,500,000

Direct lithium tritide (LiT) electrolysis uses advanced solid lithium-conducting electrolytes to reduce the complexity and footprint of tritium extraction from blanket breeding materials, such as lead-lithium, in fusion-energy systems. The new process eliminates the need for expensive equipment like centrifugal systems and molten salts used in similar proposed technologies. The process improvements allow the reaction to be performed in existing process vessels such as the blanket material buffer tank and reduces the entire tritium-extraction system's footprint. This project will scale up the process from the presently demonstrated proof-of-concept scale to an intermediate scale, thus demonstrating viability for further fusion-relevant scaleup.

Colorado School of Mines – Golden, CO

Interfacial-Engineered Membranes for Efficient Tritium Extraction - $1,397,973

Tritium, an isotope of hydrogen with a short half-life, is a fusion fuel and must be continuously generated, recovered, and recycled in any tritium-fueled fusion power plant. Currently, scalable tritium extraction and pumping technologies do not exist. Colorado School of Mines will develop and demonstrate engineered composite membranes for efficient tritium extraction for fusion applications. This technology enables a lower-cost and safer fusion energy system by eliminating major fuel cycle components and reducing tritium inventory, release, and required breeding ratios.

Savannah River National Laboratory – Aiken, SC

EM-Enhanced HyPOR Loop for Fast Fusion Fuel Cycles - $2,300,000

Fusion power cannot be realized without vacuum pumps. The vacuum technology needed to operate a commercial fusion power plant does not currently exist, however. Although existing vacuum technology could be adapted to meet the challenges posed by fusion energy, a radically new pump oil treatment and recycling system may be necessary to handle tritium removal and radiation damage. Savannah River National Laboratory will identify an optimal pump-oil molecular composition and a tunable and selective catalytic process that can meet the pump-oil processing requirements for a fusion power plant. The project's successful execution would potentially enable fusion pumping solutions capable of reducing pump operational costs >100X, pump electric-power consumption by 10X, and tritium inventory by more than 4X.

University of Houston – Houston, TX

Advanced HTS Conductors Customized for Fusion - $1,500,000

RE-Ba-Cu-O (REBCO, RE = rare earth) tapes enable >20-T magnets in compact, high-field magnetic-fusion devices. However, commercial REBCO tapes are expensive and use substrates that limit their yield strength at the operating condition of high-temperature superconductor (HTS) magnets for compact fusion energy systems. The University of Houston proposes to address these challenges by developing HTS conductors with increased critical current at >20 T and lower raw-materials cost for use in commercial fusion systems. The team will employ an advanced metal organic chemical vapor deposition process to reduce costs while achieving high critical-current thresholds, and use high-strength alloys to increase the yield strength of REBCO tapes. These innovations could reduce the cost of HTS conductors by a factor of 30.

Princeton Fusion Systems – Plainsboro, NJ

Wide-Bandgap Semiconductor Amplifiers for Plasma Heating and Control - $1,100,000

Fusion power plants will need various efficient, high-power electrical drivers for plasma heating, compression, and control. Wide-bandgap (WBG) semiconductor devices and innovative amplifiers may speed up the development of fusion systems and reduce their eventual cost of electricity. Princeton Fusion Systems will develop prototype, high-efficiency switching amplifiers using WBG SiC devices and amplifier boards that employ advanced cooling and digital control. The project will design, test, and qualify individual circuit boards as the building blocks for various short-pulse, long-pulse, and continuous-wave electrical-driver power supplies for fusion-energy systems.

University of California, Los Angeles – Los Angeles, CA

AMPERE - Advanced Materials for Plasma-Exposed Robust Electrodes - $1,250,000

Many lower-cost fusion concepts require high-performance, long-life electrodes for plasma generation, maintenance, and refueling. Due to the plasma and high-current-density environments needed for fusion, electrodes can erode quickly, which contaminates and cools the plasma leading to increased maintenance costs. The University of California, Los Angeles (UCLA) has recently explored a new class of plasma-robust materials with the potential to significantly reduce electrode erosion, allowing for five times greater electrode life and reduced plasma contamination. In the AMPERE project, UCLA will identify materials composition with “plasma-favorable” characteristics and test/characterize materials samples in a plasma environment, with the objective of identifying a promising electrode material to be used and tested in future fusion experiments.

Bridge 12 Technologies, Inc. – Framingham, MA

High Efficiency, Megawatt-Class Gyrotrons for Instability Control of Burning-Plasma Machines - $2,300,000

Prototype burning-plasma fusion devices must operate at long pulse lengths to support power generation, making them susceptible to catastrophic disruption from plasma instabilities. Electron cyclotron heating and current drive powered by gyrotrons (vacuum electron devices capable of generating high-power, high-frequency radiation) are the most effective ways to heat and stabilize plasmas. Bridge 12 Technologies aims to develop and build a 1-MW, 250-GHz gyrotron demonstrator with a total efficiency >65 % that can be used in cost-effective, breakeven-class magnetic-fusion devices at operating parameters relevant for a commercial fusion power plant. The team will build some of the high-power handling components using additive manufacturing, with advanced copper alloys allowing for higher performance, robustness, and cost-effectiveness.

Phoenix, LLC – Madison, WI

Application of Plasma-Window Technology to Enable an Ultra-High-Flux DT Neutron Source - $2,500,000

Phoenix will seek to increase the neutron flux by a factor of 100 over that of state-of-the-art beam-target fusion neutron sources by developing and testing a plasma window (PW) to enable an increase in the pressure of the gas target. By project end, the PW should be ready for integration with a commercial steady-state gas-target neutron generator. This combination may ultimately enable a cost-effective, groundbreaking, “fusion-prototypic” source of neutrons representative of the environment that fusion-power-plant materials/subsystems will endure in operation. It will enable tests to accelerate fusion materials and small-component development, offering the potential to help reduce the technical, financial, and regulatory risks of fusion-energy technologies.

Oak Ridge National Laboratory – Oak Ridge, TN

Advance Castable Nanostructured Alloys for First-Wall/Blanket Applications - $3,300,000

Reduced-activation ferritic-martensitic (RAFM) steels are critical materials for fusion-energy subsystems such as integrated first-wall and blanket technology. Present RAFM steels are incapable of operating at above ~550° C (1020° F). However, castable nanostructured alloys (CNAs), recently developed at the laboratory scale, have the potential to achieve significantly higher temperatures. ORNL will establish a new class of RAFM steels based on carbide-strengthened CNAs to demonstrate the viability of industry-scale CNA production. High-strength CNA with superior microstructure and optimal chemistry is expected to improve reliability and expand the performance envelope at a reduced cost. State-of-the-art simulations will be employed to assist scaled-up heats production and experimental designs, as well as provide physics-based support for results interpretation and credible extrapolation beyond the experimental results. This approach can potentially reduce the required mass and costs of RAFM materials in future fusion power plants by a factor of two while allowing for improved levelized cost of energy via higher-temperature blanket operation.

Stony Brook University – Stony Brook, NY

ENHANCED Shield: A Critical Materials Technology Enabling Compact Superconducting Tokamaks - $2,400,000

Stony Brook University seeks to improve the effectiveness and longevity of shield materials for high-temperature-superconducting fusion magnets. The team will leverage innovative manufacturing methods to fabricate novel two-phase composites that simultaneously moderate and absorb neutrons while attenuating gamma radiation. This new class of shield is comprised of highly absorbing metal hydrides entrained within an irradiation-stable ceramic matrix. These composites, which can operate at high temperature, possess hydrogen density approaching that of water with a high and adjustable absorption amount. The proposed shield materials’ advantages over present technology include enhanced neutron-absorbing capabilities allowing for thinner shields, engineered radiation tolerance, high-temperature stability, and long component lifetimes, eliminating the need for shield component replacement. This new shield material could potentially reduce the radial-build size of fusion power plants by a factor of two and increase magnet lifetimes, both of which provide compounding reductions on the levelized cost of energy.

Pacific Northwest National Laboratory – Richland, Washington

Microstructure Optimization and Novel Processing Development of ODS Steels for Fusion Environments - $2,250,000

This project's objective is scalable, cost-effective fabrication of high-performance, oxide-dispersion-strengthened (ODS) steel with advanced-manufacturing methods for fusion blanket-breeding applications. Gas atomization reaction synthesis (GARS) enables the synthesis of precursor ODS steel powders without prolonged mechanical alloying. This process creates a chromium (Cr)-enriched surface oxide with yttrium/titanium (Y/Ti)-enriched intermetallics in powder interiors. Pacific Northwest National Laboratory will consolidate and extrude GARS powder in one step using first-of-a-kind shear assisted processing and extrusion (ShAPE) and laser-based AM processes. Such scalable, cost-effective fabrication of ODS steels may enable efficient power conversion cycles (≥40%) at operating temperatures beyond 900 K in future fusion power plants.

Oak Ridge National Laboratory – Oak Ridge, TN

Plasma-Facing Component Innovations by Advanced Manufacturing and Design - $2,250,000

Development of plasma-facing components (PFCs) is one of the most critical challenges standing in the way of commercial fusion energy. PFCs must maintain the capability to handle the extreme heat, high-density plasma, high-energy neutrons, and fuel cycling in safe and economical operation. The ORNL-led team aims to establish the materials and manufacturing-technology basis for fusion PFCs by developing additive manufacturing for the plasma-facing "armor" material (tungsten), along with a seamless graded transition to the underlying reduced-activation steel structure. A high-quality integrated structure will promote designs of PFCs, for a range of fusion-energy concepts, with unprecedented flexibility for performance and reliability.