DIII-D National Fusion Facility Upgrade

The ability of the facility to contribute to world-leading science in the next decade (2014-2024)
Grade: (b) - important

The mission of the U.S. research program on DIII-D is to establish the scientific basis for the optimization of the tokamak approach to fusion energy production. The DIII-D National Fusion Facility is the U.S.'s largest magnetic fusion research experiment, with a proven record of scientific excellence. Enhancements to the facility will provide access to new operational regimes and a broader range of parameters relevant to burning plasmas. These upgrades will enable researchers from the U.S. and abroad to utilize DIII-D's world-leading diagnostic capability to test emerging theoretical concepts and validate state-of-the-art physics models with high fidelity in fusion-relevant conditions. These capabilities, together with a broad international team and close cooperation with theory and simulation, also provide an excellent platform for educating and training the next generation of fusion scientists.

Research at the facility in this time frame will contribute to world-leading science by 1) providing solutions to physics and operational issues critical to the success of ITER; 2) developing the physics basis for steady-state operation required for efficient power production; 3) contributing substantially to the technical basis for a Fusion Nuclear Science Facility (FNSF); and 4) advancing the fundamental understanding and predictive capability of fusion science. The upgrades will provide capability to:

- **Explore the physics of the burning plasma state** through an increase in electron cyclotron heating power to 15megawatts (MW) for dominant electron heating at low injected torque (variable co/counter neutral beam injection), and upgrades to diagnostics.
- **Investigate and understand the conditions required for steady-state operation** through broadened current distributions using increased off axis neutral beam power (10MW) with increased beam energy and pulse length (24MW for 6 seconds), and 15MW electron cyclotron current drive.
- **Develop the three-dimensional (3D) optimization of the tokamak concept** to improve edge stability, rotation and core mode control, through the implementation of additional perturbation coils with higher toroidal range (to n=6), poloidal flexibility and power supplies.
- **Provide the basis for solutions that resolve the divertor challenge for FNSF and a future demonstration power plant (DEMO)** through installation of a new advanced divertor concept and reactor-relevant materials.
- **Resolve the disruption problem for the tokamak** through advanced stability control (3D and electron cyclotron heating upgrades), new plasma quench mitigation systems, and innovative diagnostic measurements.

The readiness of the facility for construction
Grade: (a) – ready to initiate construction

Conceptual designs of each of the aforementioned upgrades have been developed, with no technical barriers to realizable implementation identified. In addition, significant experience already exists in the construction and implementation of all of these upgrades, although some do represent a significant step from previous work (e.g., helicon wave current drive, advanced divertor geometry). The DIII-D facility is well suited for these upgrades, with available space and sufficient infrastructure to accommodate them, as well as a knowledgeable staff for installation, commissioning, and operation. In addition, previous facility improvements of the scope envisioned with these upgrades have been implemented successfully.

Scientific community considerations

The need to advance tokamak fusion science within the U.S. fusion program, support the ITER project, and establish the technical basis for a future fusion nuclear science facility or demonstration power plant has been described in the Fusion Energy Sciences Advisory Committee (FESAC) reports *Scientific*

Challenges, Opportunities, and Priorities for the US Fusion Energy Sciences Program (April 2005) and *Priorities, Gaps, and Opportunities: Towards A Long-Range Strategic Plan for Magnetic Fusion Energy* (October 2007). It was further described in the report *Research Needs for Magnetic Fusion Energy* (2010), which resulted from a community exercise that culminated in a research needs workshop (June 2009). The role of the DIII-D facility was mentioned extensively in these documents and addressed specifically in the FESAC report *Characteristics and Contributions of the Three Major United States Toroidal Magnetic Fusion Facilities* (August 2005).