Fusion Nuclear Science Facility (FNSF)

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

The U.S. Fusion Energy Sciences Advisory Committee has identified the mission of a FNSF as a vital research gap worldwide that must be filled for fusion's advance and as a valuable leadership opportunity for the U.S.

Four topical themes describe the scientific and technical issues that must be resolved to achieve practical fusion energy: (1) controlling high-performance burning plasmas, (2) taming the plasma-materials interface, (3) conquering nuclear degradation of materials and structures, and (4) harnessing fusion power (tritium science, chamber technology and power extraction). The scientific and technical challenges associated with these themes are extraordinary and will require exceptional, world-leading experiments to address them. ITER will address the issues associated with the first theme and will contribute substantially to resolving issues associated with the second theme. However, addressing fully the issues associated with themes (2)-(4) will require an integrated facility that can investigate these three themes simultaneously, operating in parallel with ITER. This is because the materials directly in contact with the fusion plasma will experience extreme fluxes of heat and particles, while simultaneously suffering neutron radiation damage, which involves coupled physical phenomena over a wide range of time and length scales. Finally, FNSF will investigate the breeding of tritium fuel, which is a necessity for practical fusion energy. This integrated nuclear science mission can only be carried out on the FNSF. It will operate at fusion-power-plant heat flux and neutron flux levels for up to two weeks at a time. This will enable world-leading research on first-wall materials, structural materials, and components, as well as on the development of blanket modules that can breed tritium fuel and extract the power produced by fusion reactions.

The readiness of the facility for construction
Grade: (b) – significant scientific/engineering challenges to resolve before initiating construction

Research on existing fusion experiments over the next several years will provide the physics and engineering data required to optimize the design of the FNSF. Collaborative efforts, taking advantage of new superconducting devices overseas, will demonstrate and validate operating scenarios at the extended pulse lengths that will be required. Ongoing efforts supporting the ITER program, such as the development of techniques for control and mitigation of disruptions, will also contribute to the successful design of the FNSF. Work on all of these experiments will continue to advance the development of the control tools and actuators that will be required to operate the FNSF at maximum performance levels. Refinement and optimization of the detailed engineering parameters (such as aspect ratio, field strength, and plasma current magnitude) and of the auxiliary heating and current drive requirements will benefit from a continuing strong program to develop theoretical understanding and predictive models. Supporting materials research and development in dedicated test facilities will be conducted to examine and qualify plasma-facing component choices.

Scientific community considerations

The need to advance fusion nuclear science within the U.S. fusion program and to establish the technical basis for a fusion nuclear science facility was 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). A subsequent community-based study resulted in a

report *Fusion Nuclear Science Pathways Assessment* (February 2012). Also, a DOE-sponsored review committee issued a report on the technical plan and cost estimate for the U.S. ITER test blanket module program (August 2006). A community-inspired international workshop hosted at Princeton Plasma Physics Laboratory in 2011 led to a summary report on *Magnetic Fusion Energy Roadmapping in the ITER Era* (published in Nuclear Fusion journal, March 2012). Mostly recently, FESAC issued a report *Opportunities for Fusion Materials Science and Technology Research Now and During the ITER Era* (February 2012).