**2023 Fusion Energy Sciences Advisory Committee Facilities Charge**

In response to Dr. Berhe's December 2023 Facilities Charge, Fusion Energy Sciences is providing the following list of projects for consideration by the subcommittee.

**ITER**
*Total Project Cost (TPC) = $6.5B, FY38 is final funding year*

ITER is an international collaboration among seven members as defined in the ITER Joint Implementation Agreement (JIA), namely the European Union, India, Japan, Korea, China, Russia, and the United States. ITER will be a burning plasma fusion device, designed and built to address the principal remaining scientific uncertainty in fusion energy research: the understanding, control, and predictability of a steady-state burning plasma at power plant scale, as well as addressing the associated technologies required to sustain such a device. The U.S. Contributions to ITER consist of approximately 9.09% of the overall project costs, made up of in-kind hardware contributions as well as cash contributions to fund the ITER Organization to support design, assembly, and management of the project. U.S. ITER Project Office (IPO) is located at Oak Ridge National Laboratory, ITER is sited in Saint Paul les Durance, France. ITER is post CD-2/3 for first plasma scope and is pursuing CD-2/3 (ESAAB held December 2023) for remaining scope, Line-item funded.

**Matter in Extreme Conditions Petawatt Laser Upgrade (MEC-U)**
*Total Project Cost (TPC) range of $264M to $461M*

MEC-U will provide an internationally preeminent combination of high-energy lasers and high repetition rate, high peak- and average-power lasers with the LCLS XFEL. The MEC-U will have the ability to simultaneously prepare and probe a wide range of targets at extreme field strengths, plasma densities, pressures, and temperatures at a repetition rate that will enable very high productivity scientific output of relevance to High Energy Density Science and inertial fusion energy. The facility will have the ability to study the dynamics of relativistic plasmas and precision material properties and create and study powerful high-flux secondary particle sources. MEC-U will be located at SLAC to allow for coupling with the LCLS XFEL. MEC-U received CD-1 on October 4, 2021.

**Fusion Prototypic Neutron Source (FPNS)**
*Total Project Cost (TPC) range of $200M-$2.5B*

The scientific and engineering demonstration of fusion energy will require mastering materials science and performance issues, particularly those associated with materials degradation due to bombardment by the energetic (14.1 MeV) deuterium-tritium (D-T) fusion neutrons. This performance degradation provides the basis for and is one of the largest inherent limiting factors for the economic, safety, and environmental attractiveness of fusion energy. The FPNS device will be designed and built to provide a high-throughput (greater than 5 dpa/year in 50 $cm^3$) fusion irradiation capability consistent with community specified requirements and will provide critical scientific and engineering data for both Fusion Pilot Plant (FPP) and commercial fusion energy systems. This facility could be located at a national laboratory (or lab-class facility at a R1 university) or hosted by a private company as a Public/Private partnership. FPNS is pre-CD-0.

**D-IIID Upgrade (eXcite)**
*Total Project Cost (TPC) range of $75M-$300M*

Addressing the core/exhaust integration challenge requires a new tokamak facility, the EXhaust and Confinement Integration Tokamak Experiment (eXcite). High-magnetic field approaches to a tokamak-based FPP raise specific scientific and engineering challenges. High-divertor-power exhaust solutions need to be integrated with sustainment of high-power-density plasma cores, which are needed for generation of significant fusion power. Both the NASEM Burning Plasma Report and the Community Planning Process (CPP) report identify the need to address these challenges in an integrated fashion, rather than at separate facilities. This requirement motivates the need for construction of a new domestic tokamak, previously referred to as NTUF (New Tokamak User Facility) in the CPP report. This project will be located at General Atomics to take advantage of existing D-IIID infrastructure. eXcite is pre CD-0.

**Blanket Component Test Facility (BCTF)**
*Total Project Cost (TPC) range of $130M-$520M*

Blanket research and the associated BCTF will provide the scientific understanding and basis to qualify fusion power system blankets for an FPP. The CPP report outlines an R&D program on blanket materials and transport phenomena that culminates in the design and fabrication of blanket-section prototypes, which undergo staged testing in a BCTF. The CPP report describes a BCTF that integrates all non-nuclear features of a fusion blanket and its ancillary systems (prototypic, at-scale complex structures and coolants) under prototypic conditions of temperature, pressure, magnetic field, and mechanical stress, with surrogate surface and volumetric heating and injected hydrogen or deuterium in place of tritium. Concepts successfully vetted in the BCTF, and fission and/or fusion irradiations, could potentially proceed to full nuclear testing and tritium production. This project could be hosted at a university, national laboratory or a private company as part of a Public/Private partnership. BCTF is pre-CD-0.

**High Heat Flux Test Facility (HHF)**
*Total Project Cost (TPC) range of $90M-$360M*

Testing capabilities to explore properties of materials and plasma-facing components, both solid and liquid, under high heat fluxes addresses a key gap toward FPP material definitions. Experimental capabilities to conduct fundamental testing on coupon levels (centimeter scale) are a necessary testbed for model validation of material properties. The coupon level testing is a prerequisite for component-level testing (tens of centimeters to meters scale) to qualify components for an FPP. Accordingly, testing facilities for both levels of high-heat-flux materials research are required. This project could be hosted at a university, national laboratory or a private company as part of a Public/Private partnership. HHTF is pre- CD-0.

**Midscale Stellarator**
*Total Project Cost (TPC) range of $180M-$720M*

A proof-of-concept stellarator experimental facility is needed to demonstrate improved steady-state plasma confinement in combination with a novel non-resonant divertor. Development of this stellarator research line could provide risk mitigation for the mainline tokamak approach and could lead to a commercially more attractive fusion system. The mid-scale stellarator facility would be a discoveryoriented research facility that could stimulate a great deal of innovation.  This facility could be located at a university or national lab. This project is pre-CD-0.

**NSTX-U Liquid Metal/Core Edge Facility (LMCE)**
*Total Project Cost (TPC) range of $75M-$300M*

Liquid-metal plasma-facing components have the potential to ameliorate some of the extreme challenges of the plasma-solid interface and may reveal new plasma operating regimes.  Liquid metal plasma-facing components potentially expand the reactor-wall power limits and alleviate lifetime constraints due to material erosion. Low-recycling, liquid lithium walls may open pathways to high plasma confinement and compact FPP designs. Development of liquid metal plasma-facing-component concepts in non-plasma test stands and existing magnetic confinement facilities should be targeted and should build on PFC concepts developed in the existing domestic program. Core-edge innovation coupled to LM PFC concepts in an integrated high aspect ratio spherical tokamak configuration is a unique opportunity for U.S. to take leadership and as a test hub for industry stakeholders.  This facility would be located at Princeton Plasma Physics Laboratory (PPPL) to take advantage of existing infrastructure. LMCE is pre-CD-0.

**Fuel Cycle Test Facility (FCTF)**
*Total Project Cost (TPC) range of $125M-$500M*

Creating/developing a continuously operational deuterium-tritium (D-T) fuel cycle that can efficiently breed, extract, process, and inject tritium back into the plasma, with an eye toward minimizing inventory of this limited resource, is critical for fusion to achieve its environmental/safety potential as a future energy resource. The FCTF will need to have the testing/experimental capabilities to test all aspects of the fuel cycle systems/technology including separating all the different types of impurities from the hydrogen isotopes that will come from the plasma exhaust and the various blanket concepts, isotopically separating the hydrogen isotopes, and then providing the D-T fuel back into the fusion device to keep it operating. The FCTF will also be a test bed to enhance the scientific foundation of tritium exposure to all the various materials/components that will encounter it.  This facility is best located at a National Laboratory due to tritium handling considerations. FCTF is pre-CD-0.

**Fusion Integration Research and Science Test Facility (FIRST)**
*Total Project Cost (TPC) range of $800M-$3.2B*

The FIRST project is envisioned as an integrated test facility which encompasses the key research capabilities provided by many single purpose test facilities.  Economies of scale can be leveraged by operating a singled facility to address the materials science and performance issues, particularly those associated with materials degradation due to bombardment by the energetic (14.1 MeV) deuterium-tritium (D-T) fusion neutrons; the nuclear features of a fusion blanket and its ancillary systems (prototypic, at-scale complex structures and coolants) under prototypic conditions of temperature, pressure, magnetic field, and mechanical stress, with surrogate surface and volumetric heating and injected hydrogen, deuterium as well as tritium. FIRST will also allow for the testing of all aspects of the fuel cycle systems/technology including separating all the different types of impurities from the hydrogen isotopes that will come from the plasma exhaust and the various blanket concepts, isotopically separating the hydrogen isotopes, and then providing the D-T fuel back into the fusion device to keep it operating. In addition, the facility would generate neutrons from a plasma core that could be a torus-based fusion configuration (e.g. tokamak or spherical tokamak) or non-torus (mirror, FRC, inertial fusion-based). With a nominal plasma core, additional gaps on plasma sustainment and core-edge could be used in an integrated design for accelerating development of fusion energy.   This facility could be hosted at a National Laboratory or at a private site as part of a Public/Private partnership. FIRST is pre-CD-0.