Fusion Energy Sciences

Overview

The mission of the Fusion Energy Sciences (FES) program is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. In addition, the FES mission includes advancing the basic research needed to solve fundamental science and technology gaps towards the development of fusion power as a clean energy source in the U.S using diverse set of tools and strategic approaches. This approach includes fulfilling the fusion energy mission by a shift in the balance of research toward the Long-Range Plan (LRP) Fusion Materials and Technology (FM&T) gaps, which connects the three science drivers: Sustain a Burning Plasma, Engineer for Extreme Conditions, and Harness Fusion Energy. SC supports U.S. participation in ITER to provide U.S. scientists access to a burning plasma experimental facility aligned with the goals of the LRP. The DIII-D National Fusion Facility and the National Spherical Torus Experiment-Upgrade (NSTX-U) facility are world-leading Office of Science (SC) user facilities for experimental research, used by scientists from national laboratories, universities, and industry research groups, to optimize magnetic confinement regimes. Complementing this effort are Inertial Fusion Energy (IFE) collaboration hubs to support strategic growth of inertial confinement approaches. Fusion Innovation Research Engine (FIRE) centers address critical scientific and technology gaps and bring together discovery science, innovation, and translational research in partnership through small group research collaboration with multiple public and private partners. Partnerships with the fusion private sector can accelerate viability of fusion energy by combining efforts to resolve common scientific and technological challenges via the Innovation Network for Fusion Energy (INFUSE) voucher program and the Fusion Development Milestone Program established by FES in support of the Administration's Bold Decadal Vision (BDV) for developing the foundation for commercializing fusion energy. FES supports significant efforts in fusion theory and simulation to predict and interpret the complex behavior of plasmas as self-organized systems that complement these experimental activities. FES also supports a Scientific Discovery through Advanced Computing (SciDAC) portfolio, in partnership with the Advanced Scientific Computing Research (ASCR) program. U.S. scientists use international partnerships to conduct research on overseas tokamaks and stellarators with unique capabilities. The development of novel materials and technologies that can withstand enormous heat and neutron exposure and breed the fuel that makes fusion a self-sustaining energy source is important for the design basis of a fusion pilot plant (FPP). The Material Plasma Exposure eXperiment (MPEX) facility will unravel knowledge gaps in plasma-material interactions.

The FES program supports discovery plasma science and technology in research areas such as plasma astrophysics, high-energy-density laboratory plasmas (HEDLP), and low-temperature plasmas. Practical applications of plasmas are found in plasma processing, nanomaterial synthesis, and plasma medicine. Some of this research is carried out through partnerships and/or coordination with the National Science Foundation (NSF) and the National Nuclear Security Administration (NNSA).

The FES program invests in several SC cross-cutting initiatives such as artificial intelligence and machine learning (AI/ML), quantum information science (QIS), microelectronics, and advanced computing. In addition, with continued funding for the Established Program to Stimulate Competitive Research (EPSCoR), the Reaching a New Energy Sciences Workforce (RENEW), and the Funding for Accelerated, Inclusive Research (FAIR) initiatives, FES will build strategic programs to enhance inclusion and advance belonging, accessibility, justice, equity, and diversity in SC-sponsored research at emerging research institutions and underserved communities, Historically Black Colleges and Universities (HBCU), and Minority Serving Institutions (MSI).

The 2020 Fusion Energy Sciences Advisory Committee (FESAC) LRP report entitled "Powering the Future: Fusion and Plasmas"[a] as well as reports from the National Academies of Sciences, Engineering, and Medicine (NASEM) and community workshops inform FES program directions and activities. Fusion energy is a critical clean energy and climate technology that can contribute to the global challenge of meeting the climate crisis and can help bolster the research and development (R&D) and industrial innovation that will build the Nation's future economic competitiveness as emphasized in the "Multi-Agency research and Development Priorities for the FY 2025 Budget" from the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP).[b]

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[a] https://science.osti.gov/-/media/fes/fesac/pdf/2020/202012/FESAC_Report_2020_Powering_the_Future.pdf

[b] https://www.whitehouse.gov/wp-content/uploads/2023/08/FY2025-OMB-OSTP-RD-Budget-Priorities-Memo.pdf

Restructure

The FES budget re-structuring identified here is the first step towards a re-alignment of the FES program to align with the Administration's Bold Decadal Vision and recommendations outlined in the FESAC LRP. Three overall goals are envisioned in this budget re-structure: flexibility, balance, and strategy. The budget re-structure provides flexibility that allows the fusion and plasma science and technology communities activities that map to the FESAC LRP three science drivers: Sustain a burning plasma, Engineer for extreme conditions, and Harness fusion power. The new budget re-structure also provides balance by organizing new activities that are consistent with the priorities identified in the FESAC LRP. Finally, the new FES budget re-structuring is strategic: it has several strategic cross-threads including Fusion Workforce Pathways, Public-Private Partnerships, and Facility Operations. Below is a brief description of each new activity, which are defined as the new FES fusion and plasma research pillars.

Theory and Simulation: This activity is not new; however, it complements a foundational understanding of how to sustain a burning plasma by leveraging AI/ML to address FESAC LRP and a physics basis for an FPP. In addition, this activity will support single-investigator research to coordinated, strategic activities under the new FIRE centers supporting topics such as advanced simulation for design and optimization, digital twin, and whole-facility modeling.

Fusion Materials and Internal Components: The FESAC LRP stated that to realize fusion energy, a shift towards addressing FM&T gaps was critical. This activity brings focus to areas such as plasma-facing components, structural fusion materials, blanket materials, actuators, functional, and enabling materials (e.g., plasma heating component materials, sensor materials, etc.)

Emergent Plasma Concepts: A key step of the new FES budget structure is the re-alignment of activities toward being more inclusive of diverse plasma confinement concepts that now include linear plasma systems such as field-reverse configuration, axisymmetric mirrors, and plasma pinches. The goal is that as tokamaks and other configurations reach more mature designs and are translated, FES will support new innovative concepts that emerge. This element includes the growing IFE activities and other innovative IFE approaches. The FESAC LRP stated that investments should be balanced over time towards emerging approaches as a mitigation strategy towards accelerated paths in realizing fusion energy. This activity also emphasizes the remaining key physics gaps in topics such as predicting the dynamic behavior of burning plasmas, alpha-particle heating, self-sustaining pathways, steady-state scenarios, enhanced performance, stability and control in burning plasma scenarios, predicting transient behavior, understanding turbulence and instabilities, and addressing core-edge coupling and its relationship with sustainable confinement conditions in a burning plasma environment.

Closing the Fusion Cycle: Understanding the behavior of the tritium radioisotope and interaction with its environment is one of the key challenges to realizing scalable fusion energy. This activity has breadth in fundamental technology questions focused on breeding tritium, harnessing fusion power, balance of plant, remote handling, and safety systems. Enabling technologies such as magnet systems, fueling and heating systems, neutronics for fusion systems, shielding, radiation hardened sensing, novel waste management and recycling, and fuel cycle promotes innovation from breeding to management.

Discovery Plasma Science and Technology: The FES program supports a broad spectrum of science and technology research in plasma discovery including HEDLP, industrial plasmas, foundational plasma physics, astrophysics, interfacial plasmas, thermal and non-thermal plasma technology, QIS, advanced microelectronics processing, and materials discovery with plasma-enhanced technologies and plasma medicine.

Other Subprograms and Activities: This activity supports items that cross-cut FES and threads the whole program including fusion workforce pathways, public-private partnerships, and facility operations.

Highlights of the FY 2025 Request

The FY 2025 Request of $844.5 million is an increase of $81.3 million over the FY 2023 Enacted with key elements listed below. The Request is aligned with recommendations in the recent FESAC LRP and the Administration's BDV. The FY 2025 Request includes:

Research
- DIII-D research: Characterize and exploit innovative heating and current drive sources relevant for power plants including development of high-confinement, steady-state operating scenarios.
- NSTX-U research: Support collaborative research including optimization for the aspect ratio for an FPP. Continue installation of remaining diagnostics and prioritize strategic FM&T initiatives.
- Partnerships with the private sector: For the Milestone development program, support the second phase of research activities of the teams that successfully met their initial milestones; continue to support the INFUSE program and initiate a pilot program to perform open research on private fusion and plasma science and technology facilities.
- Inertial Fusion Energy (IFE): Enhance research activities to implement the priority research opportunities that came out of the 2022 IFE Basic Research Needs (BRN) Workshop.
- FIRE Centers: Strengthen support for the multi-institutional, multi-disciplinary R&D centers to address critical science and technology gaps outlined in the LRP and supporting public & private FPP efforts. The FY 2025 Request updates programmatic planning for the R&D centers from the FY 2024 Request having multiple centers (instead of only four) in four technical areas including advanced simulation, fusion materials, blanket/fuel cycle and enabling technologies.
- International Collaborations: Continue to exploit international, long-pulse facilities by multi-institutional teams, and complete fabrication and installation of advanced diagnostic systems on new world-leading facilities.
- Discovery Plasma Science and Technology: Continue support for basic plasma science collaborative facilities, HEDLP research/facilities, QIS, microelectronics and expand plasma-based technology research.
- AI/ML: Support multi-disciplinary teams applying AI/ML for science discovery, data analysis, model extraction, plasma control, analysis of extreme-scale simulations, and data-enhanced prediction and control.
- EPSCoR, RENEW, and FAIR: Invest in a more diverse and inclusive workforce. Broaden participation and engagement with underserved communities as well as build capacity at emerging research institutions, HBCUs, and MSIs.

Facility Operations
- DIII-D operations: Support 16 weeks of facility operations, which is 90% of optimal operations, operate with a new divertor allowing higher plasma performance, and complete ongoing machine and infrastructure improvements.
- NSTX-U recovery and operations: Continue the recovery and repair activities including machine assembly and continue to support commissioning in preparation for plasma operations.

Projects
- U.S. hardware development and delivery to ITER: Support the continued design, fabrication, and delivery of U.S. in-kind hardware systems, including the continued fabrication, testing, and delivery of the Central Solenoid magnet modules, tokamak cooling water, tokamak exhaust processing, electron and ion heating transmission lines, diagnostics, tokamak fueling, disruption mitigation, vacuum auxiliary, and roughing pumps.
- Petawatt laser facility upgrade for HEDLP and IFE science: Support design activities for a world-leading upgrade to the Matter in Extreme Conditions (MEC) instrument on the Linac Coherent Light Source-II (LCLS-II) facility at SLAC National Accelerator Laboratory (SLAC).
- Major Item of Equipment (MIE) project for plasma-material interaction research: Continue to support the Material Plasma Exposure eXperiment (MPEX) MIE project, which includes the design, fabrication, installation, and commissioning of the MPEX linear plasma device, and associated facility modification and reconfiguration.

Other
- General Plant Projects/General Purpose Equipment (GPP/GPE): Support infrastructure improvements and repairs at the Princeton Plasma Physics Laboratory (PPPL) and other DOE laboratories.

Fusion Energy Sciences
Proposed FY 2025 Budget Structure

	(dollars in thousands)	
	Subprogram A1 (old) (25 PR)	**Subprogram A2 (new)**
FY 2025 Budget Structure		
Fusion Energy Sciences		
Subprogram A1 (old)		
Burning Plasma Science: Foundations		
Advanced Tokamak		
DIII-D		
Research	56,000	–
Operations	73,600	–
Enabling R&D	3,000	–
Fusion Energy R&D Centers: Enabling Technologies	10,000	–
Small-scale Experimental Research	3,000	–
Total, Advanced Tokamak	**145,600**	–
Spherical Tokamak		
NSTX-U		
Research	38,100	–
Operations	53,250	–
Small-scale Experimental Research	3,000	–
Total, Spherical Tokamak	**94,350**	–
Theory & Simulation		
Theory	21,000	–
SciDAC	23,143	–
Fusion Energy R&D Centers: Advanced Simulation for Design/Optimization	10,000	–
Advanced Computing FES	2,000	–
Total, Theory & Simulation	**56,143**	–
GPPGPE Infrastructure	**1,000**	–

	(dollars in thousands)	
	Subprogram A1 (old) (25 PR)	**Subprogram A2 (new)**
Public-Private Partnerships		
Fusion Development Milestone Program	30,000	–
Innovation Network for Fusion Energy INFUSE	5,000	–
Total, Public-Private Partnerships	**35,000**	–
Artificial Intelligence and Machine Learning	17,586	–
Inertial Fusion Energy (IFE)	**18,000**	–
Total, Burning Plasma Science: Foundations	**367,679**	–
Burning Plasma Science: Long Pulse		
Long Pulse: Tokamak	20,000	–
Long Pulse: Stellarators		
Superconducting Stellarator Research	6,000	–
Compact Stellarator Research	4,000	–
Total, Long Pulse: Stellarators	**10,000**	–
Materials & Fusion Nuclear Science		
Fusion Nuclear Science	20,000	–
Fusion energy R&D Centers: Structural/Plasma Facing Materials	20,000	–
Materials Research	20,000	–
Fusion Energy R&D Centers: Blanket/Fuel Cycle	20,000	–
Total, Materials & Fusion Nuclear Science	**80,000**	–
Projects		
Material Plasma Exposure Experiment MPEX MIE	25,000	–
Future Facility Studies	**3,797**	–
Total, Burning Plasma Science: Long Pulse	**138,797**	–
Burning Plasma Science: High Power		
ITER Research		
ITER Research	2,000	–
Total, Burning Plasma Science: High Power	**2,000**	–

(dollars in thousands)

	Subprogram A1 (old) (25 PR)	Subprogram A2 (new)
Discovery Plasma Science		
Plasma Science Frontiers		
General Plasma Science	22,168	–
High Energy Density Lab Plasmas	20,000	–
Total, Plasma Science Frontiers	**42,168**	–
Measurement Innovation	**3,000**	–
Quantum Information Science		
Quantum Information Science Research	7,500	–
Quantum Information Science Centers	2,500	–
Total, Quantum Information Science	**10,000**	–
Advanced Microelectronics FES		
Microelectronics Centers FES	15,000	–
Advanced Microelectronics FES	5,000	–
Total, Advanced Microelectronics FES	**20,000**	–
Other FES Research		
FES Other	5,852	–
Total, Other FES Research	**5,852**	–
FES - Reaching a New Energy Sciences Workforce (RENEW)	**12,000**	–
FES - Funding for Accelerated, Inclusive Research (FAIR)	**6,000**	–
FES - Established Program to Stimulate Competitive Research (EPSCoR)	**2,000**	–
Total, Discovery Plasma Science	**101,020**	–
Subtotal, Fusion Energy Sciences	**609,496**	–

	(dollars in thousands)	
	Subprogram A1 (old) (25 PR)	**Subprogram A2 (new)**
Construction		
20-SC-61 Matter in Extreme Conditions (MEC) Petawatt Upgrade, SLAC	**10,000**	–
14-SC-60 U.S. Contributions to ITER		
ITER In-Kind Hardware	160,000	–
ITER Cash Contributions	65,000	–
Total, 14-SC-60 U.S. Contributions to ITER	**225,000**	–
Subtotal, Construction	**235,000**	–
Total, Fusion Energy Sciences	**844,496**	–
Subprogram A2 (new)		
Fusion and Plasma Research		
Theory and Simulation		
Theory	–	21,000
Scientific Discovery through Advanced Computing (SciDAC)	–	23,143
FIRE Centers: Advanced Simulation for Design and Optimization	–	10,000
Advanced Computing	–	2,000
Artificial Intelligence & Machine Learning (AI/ML)	–	17,586
Total, Theory and Simulation	–	**73,729**
Fusion Materials and Internal Components		
Materials Research	–	20,000
FIRE Centers: Structural and Plasma Facing Materials	–	20,000
Fusion Materials Projects		
Materials Plasma Exposure eXperiment (MPEX)	–	25,000
Total, Fusion Materials and Internal Components	–	**65,000**

	(dollars in thousands)	
	Subprogram A1 (old) (25 PR)	**Subprogram A2 (new)**
Emergent Plasma Concepts		
DIII-D Research	–	56,000
National Spherical Torus Experiment-Upgrade (NSTX-U) Research	–	38,100
Small-Scale Experimental Research		
Advanced Tokamak Small Scale Experimental Research	–	3,000
Spherical Tokamak Small Scale Experimental Research	–	3,000
Total, Small-Scale Experimental Research	–	**6,000**
Long Pulse: Tokamak	–	20,000
Inertial Fusion Energy (IFE)	–	18,000
Superconducting Stellarator Research	–	6,000
Compact Stellarator Research	–	4,000
Measurement Innovation	–	3,000
Future Facilities Studies	–	3,797
ITER Research	–	2,000
Total, Emergent Plasma Concepts	–	**156,897**
Closing the Fusion Cycle		
Fusion Nuclear Science	–	20,000
FIRE Centers: Blanket and Fuel Cycle	–	20,000
Enabling R&D	–	3,000
FIRE Centers: Enabling Technologies	–	10,000
Total, Closing the Fusion Cycle	–	**53,000**
Discovery Plasma Science and Technology		
High Energy Density Lab Plasmas (HEDLP)	–	20,000
General Plasma Science and Technology		
General Plasma Science Research	–	22,168
Total, General Plasma Science and Technology	**–**	**42,168**

(dollars in thousands)

	Subprogram A1 (old) (25 PR)	Subprogram A2 (new)
Advanced Microelectronics		
Microelectronics Research	–	5,000
Microelectronics Centers	–	15,000
Total, Advanced Microelectronics	–	**20,000**
Quantum Information Science (QIS)		
Quantum Information Science Research	–	7,500
Quantum Information Science Centers	–	2,500
Total, Quantum Information Science (QIS)	–	**10,000**
Discovery Plasma Science Projects		
Matter in Extreme Conditions (MEC) OPC		
Total, Discovery Plasma Science and Technology	–	**30,000**
Public Private Partnerships		
Innovation Network for Fusion Energy (INFUSE) Program	–	5,000
Fusion Development Milestone Program	–	30,000
Total, Public Private Partnerships	–	**35,000**
Fusion Workforce Pathways		
Reaching a New Energy Sciences Workforce (RENEW)	–	12,000
Funding for Accelerated, Inclusive Research (FAIR)	–	6,000
Established Program to Stimulate Competitive Research (EPSCoR)	–	2,000
Total, Fusion Workforce Pathways	–	**20,000**
Other Research		
Other Research		
Other	–	5,852
Fusion Infrastructure	–	1,000
Total, Other Research	–	**6,852**
Total, FES Research	–	**482,646**

	(dollars in thousands)	
	Subprogram A1 (old) (25 PR)	**Subprogram A2 (new)**
Fusion Facility Operations		
DIII-D Operations	–	73,600
National Spherical Torus Experiment-Upgrade (NSTX-U) Operations	–	53,250
Total, Fusion Facility Operations	–	**126,850**
Construction		
Matter in Extreme Conditions (MEC) Petawatt Upgrade	–	**10,000**
U.S. Contributions to ITER Project		
ITER In-Kind Hardware Contributions	–	160,000
ITER Cash Contribution	–	65,000
Total, ITER	–	**225,000**
Total, Projects	–	**235,000**
TOTAL, Fusion Energy Sciences	**–**	**844,496**
Total, Program A	**844,496**	**844,496**

SBIR/STTR funding:

- FY 2023 Enacted: SBIR $10,921,000 and STTR $1,536,000
- FY 2024 Annualized CR: SBIR $12,357,000 and STTR $1,741,000
- FY 2025 Request: SBIR $14,254,000 and STTR $2,005,000

Fusion Energy Sciences
Explanation of Major Changes

	(dollars in thousands) FY 2025 Request vs FY 2023 Enacted
Fusion and Plasma Research	**+$482,646**

Funding for DIII-D Research will continue to focus efforts on developing the scientific foundation and operating scenarios for a burning plasma. Funding for NSTX-U Research will maintain collaborative research at other facilities and establish new strategic FM&T initiatives. The Request continues support for the Fusion Development Milestone Program. The Request enhances funding for the FIRE R&D centers on Structural/Plasma Facing Materials, Blanket/Fuel Cycle, Enabling Technologies, and Advanced Simulation for Design and Optimization to address the FESAC LRP gaps. In addition, the Request updates programmatic planning for the R&D centers from FY 2024 by having multiple centers (instead of only four) in the four technical areas identified above. The Request continues support for IFE science and technology in IFE-Science and Technology Accelerated Research (STAR) hubs and increases support for AI/ML research in areas such as control theory, materials design, and disruption mitigation research. The Request expands high-priority international collaboration activities and establish new ones, for both tokamaks and stellarators that support burning plasma studies for U.S. scientists. The Request supports continuation of the MPEX MIE project. The Request also supports Future Facilities Studies program focusing on new strategic experimental facilities addressing scientific and technological gaps identified in the FESAC LRP.

For General Plasma Science, the Request emphasizes user research on collaborative research facilities at universities and national laboratories including the Facility for Laboratory Reconnection Experiments (FLARE) at PPPL and expands work in emerging plasma technology topics. For HEDLP, the Request continues MEC instrument support and research on the ten LaserNetUS networked facilities. Support for SC-wide Microelectronics Science Research Centers will emphasize convergence of plasma technology and advanced microelectronic materials. For QIS, the Request supports the core research portfolio stewarded by FES and the National QIS Research Centers. The RENEW initiative expands targeting efforts to increase participation and retention of individuals from underrepresented groups. Support continues for FAIR and the EPSCoR program. The Request initiates a new pilot program for fusion community to perform research on private fusion and plasma science facilities.

Fusion Facility Operations	**+$126,850**

The Request continues to support the recovery activities for the NSTX-U program, including the installation of remaining diagnostics and commissioning in preparation for plasma operations. Funding for DIII-D operations will support 16 weeks of facility operations, operate with a new divertor allowing higher plasma performance, and complete ongoing machine and infrastructure improvements.

Construction	**-18,000**

FES will continue to support design activities for the MEC-U. The U.S. Contributions to ITER project will continue design, fabrication, and delivery of hardware, including continued fabrication and delivery of the central solenoid superconducting magnet modules. The Request supports funding for construction financial contributions to the ITER Organization (IO).

Total, Fusion Energy Sciences	**+$81,274**

Basic and Applied R&D Coordination
FES participates in coordinated intra- and inter-agency initiatives within DOE and with other federal agencies on science and technology issues related to fusion and plasma science. Within SC, FES operates the MEC instrument at the SLAC LCLS user facility operated by the Basic Energy Sciences (BES) program, supports high-performance computing research with ASCR, uses the BES-supported High Flux Isotope Reactor (HFIR) facility at Oak Ridge National Laboratory (ORNL) for fusion materials irradiation research, and supports the construction of a high field magnet vertical test facility at the Fermi National Accelerator Laboratory with the High Energy Physics (HEP) program. Within DOE, FES manages a joint program with NNSA in HEDLP science and continues to coordinate research activities with the Advanced Research Projects Agency-Energy (ARPA-E). FES also supports the fusion crosscutting team focusing on the BDV. Outside DOE, FES coordinates basic plasma science research with NSF. The joint programs with NNSA and NSF involve coordination of solicitations, peer reviews, and workshops.

Program Accomplishments
Integrated Core-Pedestal Simulation Identifies Attractive Regimes for Sustained Operation of a High Gain Tokamak.
Achieving a fusion gain factor (Q) of greater than unity is a key feat necessary for a working reactor. Researchers at ORNL have combined and optimized multiple heating and current drive methods to achieve broad equilibrium profiles capable of achieving a sustained, high gain operation while avoiding deleterious plasma instabilities. The developed scenarios are high-performance, optimized for core transport and plasma stability using a multitude of high-performance computing codes coupled together within a single framework. This state-of-the-art, modular, integrated simulation workflow is applicable to future FPP designs, guiding the engineering and development of such a device towards reactor-relevance.

Milestone Program: Public-private partnerships to advance fusion energy.
The Milestone-Based Fusion Development Program was announced in 2022, and in May 2023 the eight teams selected for award negotiations were announced. The award mechanism for this first-of-a-kind Milestone program will be Technology Investment Agreements (TIAs), which offer flexible intellectual property and other terms that are more amenable to private industry participation. The eight teams selected under this program include a variety of approaches, including tokamaks, stellarators, inertial fusion energy, and alternates.

First definitive demonstration of magnetorotational instability in the laboratory.
Magnetorotational instability (MRI) is thought to be the mechanism in the accretion disk around a black hole or a young star. For the accretion or accumulation of plasma particles to occur to form a new star, angular momentum must be transferred from the inner parts of the accretion disk to the outer parts. In the last thirty years, a large body of evidence suggested that MRI-driven turbulence is likely to play a role in accretion. However, all that evidence has been theoretical or computational. Recently, Princeton University and PPPL researchers have demonstrated in a laboratory experiment that MRI does exist in nature, with properties consistent with theoretical and computational predictions.

Steady-state operation demonstrated in an optimized stellarator.
The first demonstration of high-power, steady-state stellarator operation was achieved at the Wendelstein 7-X (W7-X) experiment with a total discharge length of 500 seconds and a total injected energy of 1.3 GigaJoules. This is a key step in validating the physics and engineering needed to manage the steady-state flows of energy in future power plants. As expected, the water cooled divertors reached steady-state temperatures well below design limits, which paves the way for future 30-minute pulses with even higher input power. U.S. contributions to W7-X were critical to this successful result, including delivery of magnetic field coils to control the heat loads, diagnostics, and the associated personnel to monitor plasma parameters, theory, and computational codes to develop the plasma scenario, and core leadership in developing the scientific plan leading to this substantial advancement.

Further progress in U.S. Contributions to ITER project.
The U.S. contributions to ITER project is the largest capital investment in the FES portfolio and is an essential contribution to the international effort to demonstration of the first burning plasma tokamak device at power plant scale. The U.S. contributions to ITER project successfully delivered Central Solenoid Magnet Modules 4 and 5 to the ITER Organization (IO), continued work on Tritium Exhaust Processing system prototypes, and further advanced the Vacuum Auxiliary system design.

Fusion Energy Sciences
Fusion and Plasma Research

Description

This subprogram advances our scientific understanding, utilizing both modeling/computation and experimental results from domestic and international devices, of how to control and sustain a burning plasma. It supports the development of the required materials and technology that can withstand the harsh fusion environment to make fusion a future energy source as well as building a foundation of a competitive fusion power industry in the U.S. through partnerships with the private sector that can take advantage of this research activity. In addition, it supports research that explores the fundamental properties and complex behavior of matter in the plasma state to understand the plasma universe and to learn how to control and manipulate plasmas for a broad range of applications. A key capability that helps to address the scientific gaps in the program will be the FIRE centers which are expected to be collaborative activities involving a number of institutions.

Theory and Simulation

The Theory and Simulation activity supports research on foundational theory to advance the scientific understanding of the behavior of fusion plasmas, and multi-institutional interdisciplinary efforts under the SciDAC program, in partnership with ASCR, to accelerate scientific discovery in fusion plasma science and technology by capitalizing on SC investments in leadership-class computing systems. This activity also includes research and investments in enhanced data infrastructure capabilities under Advanced Computing and the FIRE centers for advanced simulations, which addresses critical scientific gaps within the design of FPP concepts in coordination with the other FIRE centers.

This program supports the application of AI/ML techniques encompassing multiple FES areas in partnership with data and computational scientists through the establishment of multi-institutional, interdisciplinary collaborations.

Fusion Materials and Internal Components

The selection of materials for any future fusion device is foundational. Every component, from the innermost chamber walls to the outer framework, requires a variety of materials that can withstand a range of conditions, including heat, particle exposure, and neutron fluxes. The Fusion Materials and Internal Components program aims to build a scientific understanding of how materials' properties change while also focusing on predicting how materials will behave in these advanced devices, ensuring their durability and effectiveness in the challenging fusion environment. To address some of the larger and more difficult challenges, FIRE centers have been initiated under this program.

The MPEX MIE project, which is a new U.S. materials experimental capability initiated in FY 2019, will enable solutions for new plasma-facing materials, including exposing irradiated samples, for understanding materials degradation in the fusion nuclear environment.

Emergent Plasma Concepts

The Emergent Plasma Concepts (EPC) activity supports a diversity of approaches to confinement of plasmas in fusion energy systems. EPC addresses the FESAC LRP Sustain a Burning Plasma FT&S driver with an inclusive and broad approach. This element will include traditional confinement approaches including toroidal systems such as tokamaks (advanced, spherical) and stellarators. As these approaches address physics and technology gaps outlined by the FESAC LRP and CPP reports and are translated to development programs, novel approaches, such as linear plasma concepts (field-reverse configuration, axisymmetric mirrors, and plasma pinches), will be nurtured and expanded. This element also includes the growing IFE activities and other innovative IFE approaches. EPC also addresses the FESAC LRP recommendation that the program be balanced over time toward emerging approaches to accelerate the path in realizing fusion energy. This activity also emphasizes the remaining key physics gaps for toroidal confinement approaches in topics such as predicting the dynamic behavior of burning plasmas, alpha-particle heating, self-sustaining pathways, steady-state scenarios, enhanced performance, stability, and control in burning plasma scenarios, predicting transient behavior, understanding turbulence and instabilities, and addressing core-edge coupling and its relationship with sustainable confinement conditions in a burning plasma environment.

The DIII-D user facility at General Atomics is the largest magnetic fusion research experiment in the U.S. Its flexibility to explore various operating regimes makes it a world-leading tokamak research facility. Its focus will continue to be building the scientific foundation and operating regimes to sustain a burning plasma in a fusion device. The NSTX-U user facility at PPPL, when all recovery activities are completed, will be the highest performing ST in the world. For now, this activity will continue to focus its attention on conducting collaborative research on other machines but also begin preparation for full operation soon of NSTX-U.

The Advanced Tokamak (AT) Small-Scale Experimental Research activity supports a broad range of activities focused on closing gaps in the scientific and technical basis for the tokamak approach to fusion energy. An AT is an integrated fusion energy system that achieves a stationary plasma state by maximizing plasma performance within stability limits by a comprehensive optimization of plasma parameters.

The Spherical Tokamak (ST) Small-Scale Experimental Research activity supports experimental studies and physics model validation efforts involving both domestic and international facilities. Additionally, small-scale ST plasma research involving high-risk, high-reward experimental efforts are supported that may either greatly simplify or significantly enhance the ST concept.

The Long-Pulse Tokamak activity supports interdisciplinary teams from multiple U.S. institutions for collaborative research aimed at advancing the scientific and technology basis for sustained long-pulse burning plasma operation in tokamaks. Collaborative research on international facilities with capabilities not available in the U.S. aims at building the science and technology required to control, sustain, and predict a burning plasma, as described in the FESAC LRP. Multidisciplinary teams work together to close the underlying S&T gaps that underpin the design of future FPPs, especially in the areas of plasma-material interactions, transients' control, and current drive for steady-state operation. The team approach provides unique training experiences for the next generation of fusion scientists, as well as the opportunity to establish international collaborations in new areas.

The Inertial Fusion Energy (IFE) activity supports the development of the scientific foundations and technologies for IFE. Key areas of research informed by the 2022 IFE BRN workshop include increasing laser efficiency and the damage threshold of optics and crystals, reducing laser-plasma Instabilities, improving target robustness with respect to ignition and evaluating implosion sensitivities, demonstrating high-volume techniques for spherical capsule fabrication, using simulation and modeling tools to predict the gain in IFE-relevant target designs, and developing advanced radiation-hardened diagnostics at high repetition rates. The IFE Science & Technology Accelerated Research (IFE-STAR) innovation hubs and single investigators grants will advance these research activities. The IFE program will also leverage the FIRE centers.

The Superconducting Stellarator Research activity supports research on stellarators, which offer the potential of steady-state confinement regimes without transient events such as disruptions. The participation of U.S. researchers on Wendelstein 7-X (W7-X) in Germany provides an opportunity to develop and assess divertor configurations for long-pulse, high-performance stellarators, including a U.S. supplied pellet fueling injector for quasi-steady-state plasma experiments. U.S. researchers will play key roles in developing the operational scenarios and hardware configuration for high-power, steady-state operation. Domestic compact stellarator research is focused on improvement of the stellarator magnetic confinement concept through quasi-symmetric shaping of the toroidal magnetic field.

The Measurement Innovation activity supports the development of world-leading transformative and innovative diagnostic techniques and their application to new, unexplored, or unfamiliar plasma regimes or scenarios.

The Future Facilities Studies activity supports studies and research for required facilities that are critical to the development of fusion energy and address needs of both the public and private sectors.

The ITER Research activity supports the organization of a U.S. ITER research team so that the fusion community can be ready on day one to benefit from the scientific and technological opportunities offered by ITER. Building such a team was also among the highest recommendations in the recent FESAC LRP. A Basic Research Needs workshop was held in FY 2022 to identify the highest-priority research and engagement opportunities for the U.S. to maximize the benefit of its participation in ITER. In addition, this activity supports the efficient dissemination of ITER data in support of FPP activities.

Closing the Fusion Cycle

Within a fusion power system, essential engineering systems are vital for energy production, including power capture, fueling, waste management, and reliable operation. The Closing the Fusion Cycle activity aims to build the scientific understanding necessary to engineer these systems. Simultaneously, the program addresses the challenges of integrating these systems effectively, with the overarching goal of realizing practical fusion power. To address some of the larger and more difficult challenges, FIRE centers, virtual small group research collaborations, have been initiated under this part of the program.

To harness power from fusion, specific plasma conditions must be achieved, which is supported by engineering systems that enable plasma formation, ignition, and sustainment. The Enabling Technologies activity seeks to advance systems that currently support FES research facilities, develop the next generation systems, and develop new systems. The focus is on supporting more optimized plasma conditions, a critical step toward unlocking the potential of fusion energy. To address some of the larger and more difficult challenges, FIRE centers which are virtual small group research collaborations have also been initiated under this part of the program.

Discovery Plasma Science and Technology

Discovery Plasma Science and Technology (DPST) research supports activities in high energy density laboratory plasmas (HEDLP), foundational plasma science research, transformational plasma science technology, innovation in advanced microelectronics, and efforts in the convergence of plasmas and quantum information science.

Research in HEDLP is directed at exploring the behavior of plasmas at extreme conditions of temperature, density, and pressure including relativistic high energy density (HED) plasmas and intense beam physics, magnetized HED plasma physics, ionized HED atomic physics, HED hydrodynamics, warm dense matter, nonlinear optics of plasmas and laser-plasma interactions, laboratory astrophysics, and diagnostics for HEDLP. This activity also includes LaserNetUS, a geographically distributed network of ten high-intensity laser facilities that provides students and scientists with broad access to unique facilities and enabling technologies and advances the frontiers of high energy density and laser science research.

General Plasma Science and Technology (GPST) focuses on the frontiers of basic and low-temperature plasma science, including dynamical processes in laboratory, space, and astrophysical plasmas, such as magnetic reconnection, dynamo, shocks, turbulence cascade, structures, waves, flows and their interactions; behavior of dusty plasmas, non-neutral, single component matter or antimatter plasmas, and ultra-cold neutral plasmas. Whereas basic and low-temperature plasma science seeks to perform experiments into new regimes and develop accurate theoretical descriptions of the complex emergent behavior of the plasma state through validation, plasma astrophysics translates these fundamental discoveries to a better understanding of space and the cosmos, while low temperature plasma science translates discoveries into societal benefits.

DPST research stewards' world-class plasma science experiments and collaborative research facilities at small and intermediate scales. This effort maintains collaborations with NNSA and NSF.

Transformational plasma science technology includes frontier research in interfacial plasmas, plasma medicine, thermal and non-thermal plasma applications, atmospheric plasmas, plasmas for agriculture and enhanced energy systems, and the interaction of emerging plasmas and their environments.

The Advanced Microelectronics activity supports discovery plasma research in a multi-disciplinary, co-design framework to accelerate plasma-based microelectronics fabrication and advance the development of microelectronic technologies. The direction of the Advanced Microelectronics efforts is informed by the FESAC LRP, the NASEM Plasma 2020 decadal survey report, a FY 2022 workshop on plasma science for microelectronics nanofabrication, and the Creating Helpful Incentives to Produce Semiconductors for America (CHIPS) and Science Act of 2022.

The Quantum Information Science (QIS) activity supports basic research in QIS that can have a transformative impact on FES mission areas, including fusion and discovery plasma science, as well as research that takes advantage of unique FES-enabled capabilities to advance QIS development.

Public-Private Partnerships

Resilient public-private partnerships (PPPs) will foster bridges between the public and private sectors to address foundational gaps and accelerate fusion toward viability. Within this PPP framework, the Innovation Network for Fusion Energy (INFUSE) provides private-sector fusion companies with access to world-class expertise and capabilities at DOE's national laboratories and U.S. universities to overcome critical scientific and technological hurdles. The Fusion Development Milestone Program aims to accelerate progress toward the development of commercial fusion energy through PPPs, with near-term goals of delivering preconceptual designs and technology roadmaps for a FPP and enabling significant performance improvements of FPP concepts. A new activity initiated in FY 2025 will support a Private Facility Research Program which offers the opportunity for fusion community researchers to conduct open scientific studies on privately constructed facilities for the mutual benefit of all parties. Uniquely, this program aims to advance fusion and plasma science and technology through the open dissemination of S&T results and datasets acquired from world-leading private experimental facilities.

Fusion Workforce Pathways

This activity supports the RENEW, FAIR, and EPSCoR initiatives to provide research and student training opportunities with academic institutions underserved in the U.S. Science and Technology ecosystem and aligns with a recommendation in the FESAC LRP. In addition, these initiatives expand efforts to build capacity in emerging research institutions and HBCUs and MSIs, as well as invest in underserved communities for a more diverse and inclusive workforce.

Other Research

This activity supports the Postdoctoral Research Program, FESAC, multiple fusion and plasma science outreach programs, the U.S. Burning Plasma Organization, critical general infrastructure and environmental monitoring at PPPL and other DOE laboratories, and other programmatic activities.

Fusion Energy Sciences
Fusion and Plasma Research

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Burning Plasma Science: Foundations	**$345,122**	**$ —**	**$ —**
Advanced Tokamak	$134,122	$ —	$ —
Funding supports 20 weeks of operations at the DIII-D facility, which is 90 percent of optimal. Research continues to exploit innovative current drive systems to assess their potential as actuators for a fusion pilot plant and to optimize plasma performance. Upgrades include increasing electron cyclotron power, completing the installation of the high-field-side lower hybrid current drive system and commencing experiments, and increasing the power of the neutral beam injection system. Funding continues to support research in high-temperature superconducting magnet technology, plasma heating and current drive, plasma fueling, and other enabling technologies for fusion. Funding continues support for small-scale AT experiments.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Spherical Tokamak	$107,000	$ —	$ —
Funding for operations supports the remaining NSTX-U Recovery fabrication and machine reassembly activities and begins supporting the commissioning of auxiliary heating systems in preparation for plasma operations. Research efforts focus on studies utilizing a variety of domestic and international spherical tokamak facilities; these studies are aligned with the mission of the NSTX-U program, which contributes to the development of the design basis for a next-step FPP. Funding continues supporting small-scale ST studies dedicated to simplifying and reducing the capital cost of future fusion facilities.			
Theory & Simulation	$50,500	$ —	$ —
Funding supports efforts at universities, national laboratories, and private industry focused on the fundamental theory of magnetically confined plasmas and the development of a predictive capability for magnetic fusion. Funding supports the SciDAC portfolio with emphasis on whole-facility modeling, in alignment with the LRP recommendations. It also provides a consistent set of high-fidelity tools for design and performance assessment of FPP concepts. Funding also supports Advanced Computing, including investments in enhanced data infrastructure capabilities to address the growing data needs of fusion research.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
GPP-GPE Infrastructure	$1,500	$ —	$ —
Funding supports infrastructure improvements, repair, maintenance, and environmental monitoring at PPPL and other DOE laboratories.			
Public-Private Partnerships	$31,000	$ —	$ —
Funding continues to support the INFUSE program, providing the private sector with access to DOE developed capabilities at both national laboratories and universities. Funding also continues support for a milestone-based fusion development program through partnerships with the private sector.			
Artificial Intelligence and Machine Learning (AI/ML)	$11,000	$ —	$ —
Funding supports a competitive solicitation to identify multi-institutional collaborations focused on deploying AI/ML applications across FES program elements.			
Inertial Fusion Energy (IFE)	$10,000	$ —	$ —
Funding supports the new IFE program focused on the priority research opportunities in scientific foundations and technologies that were identified in the FY 2022 Basic Research Needs Workshop for IFE.			
Burning Plasma Science: Long Pulse	**$81,000**	**$ —**	**$ —**
Long Pulse: Tokamak (old)	$15,000	$ —	$ —
Funding supports the second budget period for U.S. teams conducting research on international facilities, which helps close key gaps in the design basis for an FPP.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Long Pulse: Stellarators	$7,500	$ —	$ —
In the next W7-X experimental campaign, funding supports research on turbulent transport, stability and edge physics, and boundary and scrape-off-layer physics. Funding also supports experiments on domestic stellarators in regimes relevant to the mainline stellarator magnetic confinement efforts.			
Materials & Fusion Nuclear Science	$56,500	$ —	$ —
Funding supports research activities in these areas, consistent with the recommendations of the FESAC Long-Range Plan. This includes continued development of critical technologies for an FPP, such as plasma-facing components, structural and functional materials. Funding also continues to support research into advanced manufacturing technologies consistent with the SC initiative in this area. Finally, funding supports the MPEX MIE project, with efforts focused on construction following the combined baselining and start of construction that was received on August 22, 2022.			
Future Facilities Studies	$2,000	$ —	$ —
Funding supports the Future Facilities Studies activity to conduct design studies for an integrated fusion plant, e.g., an FPP, consistent with the FESAC Long-Range Plan recommendation.			
Burning Plasma Science: High Power	**$2,000**	**$ —**	**$ —**
ITER Research	$2,000	$ —	$ —
Funding supports the highest-priority research and engagement opportunities identified in the Basic Research Needs workshop that was held in FY 2022.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Discovery Plasma Science	**$82,100**	**$ —**	**$ —**
Plasma Science and Technology	$46,000	$ —	$ —
General Plasma Science	*$19,000*	*$ —*	*$ —*
Funding supports core research at the frontiers of basic and low temperature plasma science, as well as operations of and user-led experiments on collaborative research facilities.			
High Energy Density Laboratory Plasmas	*$27,000*	*$ —*	*$ —*
Funding supports basic and translational science, MEC and LaserNetUS operations and user support, and the SC-NNSA joint program.			
Measurement Innovation	$2,915	$ —	$ —
Funding supports the development of innovative and transformative diagnostics.			
Quantum Information Science	$10,000	$ —	$ —
Funding supports priority research opportunities identified in the 2018 Roundtable Workshop Report. It also continues to support the SC QIS Research Centers.			
Advanced Microelectronics	$5,000	$ —	$ —
Funding supports high priority research and the continuation of laboratory awards made through a competitive lab call and review in FY 2021.			
Other FES Research	$4,185	$ —	$ —
Funding supports programmatic activities such as the FES Postdoctoral Research Program, the FES Fusion and Plasma Science Outreach programs, USBPO, peer reviews for FES solicitations and project activities, and FESAC.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Reaching a New Energy Sciences Workforce (RENEW)	$6,000	$ —	$ —
Funding supports the RENEW initiative to provide undergraduate and graduate training opportunities for students and academic institutions under-represented in the U.S. S&T ecosystem and aligns with a recommendation in the FESAC LRP.			
Funding for Accelerated, Inclusive Research (FAIR)	$2,000	$ —	$ —
Funding supports the Funding for Accelerated, Inclusive Research (FAIR) initiative, which provides focused investment on enhancing research on clean energy, climate, and related topics at minority serving institutions, including attention to underserved and environmental justice communities.			
Accelerate Innovations in Emerging Technologies	$4,000	$ —	$ —
Funding supports the Accelerate initiative, which supports scientific research to accelerate the transition of science advances to energy technologies.			
Established Program to Stimulate Competitive Research (EPSCoR)	$2,000	$ —	$ —
FY 2023 EPSCoR funding emphasizes Implementation Awards to larger multiple investigator teams. Investment continues in early career research faculty from EPSCoR-designated jurisdictions and in co-investment with other programs for awards to eligible institutions.			

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Fusion and Plasma Research	**$ —**	**$482,646**	**+$482,646**
Theory and Simulation	$ —	$73,729	+$73,729
Funding supports efforts at universities, national laboratories, and private industry focused on the fundamental theory of magnetically confined plasmas and the development of a predictive capability for magnetic fusion.		The Request will continue to support efforts at universities, national laboratories, and private industry focused on the fundamental theory of fusion plasmas.	
Funding supports the SciDAC portfolio with emphasis on whole-facility modeling, in alignment with the LRP recommendations. It also provides a consistent set of high-fidelity tools for design and performance assessment of FPP concepts.		The Request will continue to support the SciDAC portfolio selected in FY 2023. The FIRE centers for advanced simulations will continue to develop and apply predictive simulation tools to enable commercially relevant FPP designs.	Research efforts in theory and SciDAC will focus on the highest-priority activities, including continuing support of the SciDAC portfolio. The funding increase will strengthen the FIRE centers for advanced simulations.
Funding also supports Advanced Computing, including investments in enhanced data infrastructure capabilities to address the growing data needs of fusion research.		The Request will continue to support Advanced Computing, including investments in enhanced data infrastructure capabilities.	No change.
Funding supports a competitive solicitation to identify multi-institutional collaborations focused on deploying AI/ML applications across FES program elements.		The Request will continue to support research in cross-cutting interdisciplinary fusion energy and plasma science research.	Funding increase will support additional team awards to advance FPP design efforts, exploit SC's Integrated Research Infrastructure, and plan for fusion and plasma "spokes" for SC's High Performance Data Facility.
Fusion Materials and Internal Components	$ —	$65,000	+$65,000
Funding supports research activities in these areas, consistent with the recommendations of the FESAC Long-Range Plan. This includes continued development of critical technologies for an FPP, such as plasma-facing components, structural and functional materials, and breeding-blanket and tritium-handling systems. Funding also continues to support research into advanced manufacturing technologies consistent with the SC initiative in this area. Finally, funding supports the MPEX		The Request will enable growth in the key area of materials which is critical in developing the scientific foundation for fusion energy. The Request will continue to support the FIRE centers for structural and plasma facing materials which will focus their efforts on addressing the scientific and technical gaps identified in the FESAC LRP as well as in recent community workshops. The Request will also continue to support the MPEX MIE project,	Funding increase will support the FIRE centers for structural and plasma facing materials, which are vital in establishing U.S. R&D capabilities to address the scientific/technical gaps in these programs. Funding for the MPEX project will support the project's approved cost/schedule baseline.

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
MIE project, with efforts focused on construction following the combined baselining and start of construction that was received on August 22, 2022.	consistent with the approved baseline for the project.	
Emergent Plasma Concepts $ —	$156,897	+$156,897
Research continues at DIII-D to exploit innovative current drive systems to assess their potential as actuators for a fusion pilot plant and to optimize plasma performance. Upgrades include increasing electron cyclotron power, completing the installation of the high-field-side lower hybrid current drive system and commencing experiments, and increasing the power of the neutral beam injection system.	The Request will support research at DIII-D needed for ITER and a future FPP, and training opportunities for the next generation of fusion researchers.	Funding will support research aligned with the FESAC LRP including DIII-D enhancements.
Funding for operations supports the remaining NSTX-U Recovery fabrication and machine reassembly activities and begins supporting the commissioning of auxiliary heating systems in preparation for plasma operations. Research efforts focus on studies utilizing a variety of domestic and international spherical tokamak facilities; these studies are aligned with the mission of the NSTX-U program, which contributes to the development of the design basis for a next-step FPP.	The Request will support research efforts that strengthen the scientific foundation of the ST concept including laying the ground work for the initiation of NSTX-U research activities.	Research funding will focus on the highest-priority scientific objectives.
Funding continues support for small-scale experimental research.	The Request continues to support the small-scale AT and ST experiments.	The funding increase will support AT small-scale experimental operations and enhancements.
Funding supports the second budget period for U.S. teams conducting research on international facilities, which helps close key gaps in the design basis for an FPP.	The Request will support U.S. consortia conducting research on international facilities with capabilities not available in the U.S. The activity will target extensions of U.S. expertise in strategic areas of burning plasmas, plasma technology, and model validation.	The funding increase will support expansion of research elements on superconducting facilities.

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Funding supports the new IFE program focused on the priority research opportunities in scientific foundations and technologies that were identified in the FY 2022 Basic Research Needs Workshop for IFE.	The Request will support the priority research opportunities identified in the FY 2022 Basic Research Needs Workshop (BRN) for IFE.	The funding increase will enhance support for the existing IFE-STAR hubs.
In the next W7-X experimental campaign, funding supports research on turbulent transport, stability and edge physics, and boundary and scrape-off-layer physics. Funding also supports experiments on domestic stellarators in regimes relevant to the mainline stellarator magnetic confinement efforts.	The Request will support W7-X pellet fueling experiments with a goal of sustaining plasmas for extended duration. Data from various W7-X diagnostic systems will be analyzed to support optimizing future operations. Support for the domestic stellarator devices will continue.	The funding increase will support control of plasma turbulence using a W7-X pellet fueling injector, and reduction of plasma turbulence in quasi-helically symmetric experiments. State-of-the-art diagnostic systems will be enhanced to pursue key physics questions. Funding for domestic stellarator research will also be increased.
Funding supports the development of innovative and transformative diagnostics.	The Request will continue to support the development of innovative and transformative diagnostics.	Funding will support highest-priority activities.
Funding supports the Future Facilities Studies activity to conduct design studies for an integrated fusion plant, e.g., an FPP, consistent with the FESAC Long-Range Plan recommendation.	The Request will support conducting scoping studies and research to help define requirements for future fusion facilities.	The funding increase will support R&D and scoping studies activities for future fusion facilities.
Funding supports the highest-priority research and engagement opportunities identified in the ITER Research Basic Research Needs workshop that was held in FY 2022.	The Request will continue supporting the highest-priority research and engagement opportunities identified in the ITER Research BRN workshop that was held in FY 2022, as well as supporting the dissemination of ITER data in support of FPP activities.	No change.
Closing the Fusion Cycle $ —	$53,000	+$53,000
Funding supports research activities in these areas, consistent with the recommendations of the FESAC Long-Range Plan. This includes continued development of critical technologies for an FPP, such as breeding-blanket and tritium-handling systems.	The Request will enable growth in the key areas of fusion nuclear science and enabling R&D which are critical in developing the scientific foundation for fusion energy. The Request will continue to support the FIRE centers for blanket/fuel cycle and enabling technologies which will focus their efforts on	The funding increase will support the FIRE centers for blanket/fuel cycle and enabling technologies.

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Funding continues to support research in high temperature superconducting magnet technology, plasma heating and current drive, plasma fueling, and other enabling technologies for fusion.	addressing the scientific and technical gaps identified in the FESAC LRP as well as in recent community workshops.	
Discovery Plasma Science and Technology $ —	$72,168	+$72,168
Funding supports basic and translational science, MEC and LaserNetUS operations and user support, and the SC-NNSA joint program.	The Request will continue to support basic and translational science, MEC and LaserNetUS operations and user support, and the SC-NNSA joint program.	Funding will support highest-priority activities.
Funding supports core research at the frontiers of basic and low temperature plasma science, as well as operations of and user-led experiments on collaborative research facilities.	The Request will continue to support core research at the frontiers of basic and low-temperature plasma science, as well as operations of midscale collaborative research facilities and external collaborations on these facilities.	The funding will broaden the research and operations of midscale collaborative research facilities in General Plasma Science and Technology.
Funding supports high priority research and the continuation of laboratory awards made through a competitive lab call and review in FY 2021.	The Request will support priority research opportunities identified in the recent workshop on plasma science for microelectronics nanofabrication.	The funding will enhance support for the plasma science needed for advanced microelectronics R&D.
Funding supports priority research opportunities identified in the 2018 Roundtable Workshop Report. It also continues to support the SC QIS Research Centers.	The Request will continue to support core research awards selected in FY 2024 in QIS as well as support for the recompetition/renewal of the National QIS Research Centers.	No change.
Public-Private Partnerships $ —	$35,000	+$35,000
Funding continues to support the INFUSE program, providing the private sector with access to DOE developed capabilities at both national laboratories and universities. Funding also continues support for a milestone-based fusion development program through partnerships with the private sector.	The Request will support public-private partnerships through the Fusion Development Milestone Program and the INFUSE program, both of which connect the private sector to DOE developed capabilities at national laboratories and universities. A new Private Facility Research pilot program will be initiated which will offer the opportunity for publicly	The funding increase will support the second phase of the Fusion Development Milestone Program, enabling enhanced experiments to continue de-risking an array of approaches to fusion. Funding will continue to support the INFUSE program. It will also support the new Private Facility Research pilot program.

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
	funded researchers to conduct open scientific studies on privately constructed facilities for the mutual benefit of all parties.	
Fusion Workforce Pathways $ —	$20,000	+$20,000
Funding supports the RENEW initiative to provide undergraduate and graduate training opportunities for students and academic institutions under-represented in the U.S. S&T ecosystem and aligns with a recommendation in the FESAC LRP.	The Request will continue to support targeted efforts to increase participation and retention of individuals from underrepresented groups in FES research activities, including a RENEW graduate fellowship.	The funding increase will broaden RENEW activities within the FES research portfolio.
Funding supports the Funding for Accelerated, Inclusive Research (FAIR) initiative, which provides focused investment on enhancing research on clean energy, climate, and related topics at minority serving institutions, including attention to underserved and environmental justice communities.	The Request will continue to support the FAIR initiative efforts to increase participation and retention of individuals from underrepresented institutions in FES research activities.	The funding will enhance support of the FAIR initiative within the FES research portfolio.
Funding supports the Accelerate initiative, which supports scientific research to accelerate the transition of science advances to energy technologies.	The Request includes no funding for this activity.	Support for highest-priority activities will be continued through other parts of the FES portfolio.
FY 2023 EPSCoR funding emphasizes Implementation Awards to larger multiple investigator teams. Investment continues in early career research faculty from EPSCoR-designated jurisdictions and in co-investment with other programs for awards to eligible institutions.	The Request will support EPSCoR State-National Laboratory Partnership awards and early career awards.	No change.
Other Research $ —	$6,852	+$6,852
Funding supports programmatic activities such as the FES Postdoctoral Research Program, the FES Fusion and Plasma Science Outreach programs, USBPO, peer reviews for FES solicitations and project activities, and FESAC.	The Request will continue to support programmatic activities such as the FES Postdoctoral Research Program, the FES Fusion and Plasma Science Outreach programs, the U.S. Burning Plasma Organization, peer reviews and project activities, and FESAC.	The funding increase will support the highest priority programmatic activities

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Funding supports infrastructure improvements, repair, maintenance, and environmental monitoring at PPPL and other DOE laboratories.	The Request will continue to support infrastructure improvements, repair, maintenance, and environmental monitoring at PPPL and other DOE laboratories.	Funding will support highest-priority activities.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*
- *FY 2023 funding amounts are populated in the current structure, only FY 2025 is populated in the proposed restructure.*

Fusion Energy Sciences
Fusion Facility Operations

Description

The DIII-D National Fusion Facility and the National Spherical Torus Experiment-Upgrade (NSTX-U) facility are world-leading Office of Science (SC) user facilities for experimental research, used by scientists from national laboratories, universities, and industry research groups, to optimize magnetic confinement regimes. The operation of these facilities addresses the FESAC Long-Range Plan Fusion Science & Technology recommendation to "utilize research operations on DIII-D and NSTX-U, and collaborate with other world-leading facilities, to ensure that Fusion Pilot Plant (FPP) design gaps are addressed in a timely manner." Gaps that can be addressed by the operation of the FES user facilities include low aspect ratio physics, disruption avoidance and mitigation, plasma control, core-edge integration, steady state burning plasma scenario development, and plasma facing component integration, including assessment of liquid metal approaches. These facilities also represent a valuable resource for the private fusion energy sector to resolve science and technology challenges associated with their confinement concepts. In addition, they play a significant role in training the next generation of diverse and inclusive fusion scientists and preparing the U.S. research community to take full advantage of ITER operations.

<u>DIII-D Operations</u>
The DIII-D scientific user facility at General Atomics is the largest, most adaptable, magnetic confinement facility in the U.S. DIII-D has been in operation since 1986 and investments in the facility include regular refurbishments, upgrades, and enhancements have maintained its status as a world-leading fusion research facility. DIII-D is a normal aspect ratio tokamak and focuses on the Advanced Tokamak (AT) path to fusion energy. The AT is an integrated fusion energy system that simultaneously achieves a stationary plasma state characterized by high plasma pressure, high fractions of self-generated plasma current, adequate heat and particle confinement, and levels of heat and particle exhaust compatible with plasma-facing surfaces. DIII-D can sustain plasmas at temperatures relevant to burning plasma conditions. Its extensive set of advanced diagnostic systems and extraordinary flexibility to explore various operating regimes make it a world-leading tokamak research facility with an important role in closing science and technology gaps. In FY 2023, it supported 700 onsite and remote users from 95 institutions and 18 countries. It also engaged 30 faculty members and 139 students, including 35 undergraduate students. FY 2025 Request will support 16 weeks of operations, operation with a new divertor allowing higher plasma performance, the completion of ongoing facility and infrastructure enhancements, research needed for ITER and a future FPP, and training opportunities for the next generation of fusion researchers. Longer-term, the facility will focus on integrated core-edge solutions for the FPP, burning plasma transport and performance optimizations, plasma stability control solutions, validation of simulation predictions, assessment of compatibility of viable FPP scenarios with relevant first wall materials, and the viability of negative triangularity shaped plasmas for FPPs.

<u>National Spherical Torus Experiment-Upgrade (NSTX-U) Operations</u>
The National Spherical Torus Experimental Upgrade (NSTX-U) scientific user facility at Princeton Plasma Physics Laboratory (PPPL) is used to explore the unique advantageous properties of a magnetically confined plasma configuration called a Spherical Tokamak (ST). Specifically, a ST is shaped like a cored apple. NSTX-U will operate with toroidal magnetic fields as high as one Tesla and confine superheated plasmas with internal currents as high as two megaamperes. NSTX-U is the world's most powerful ST, with external heating of approximately 19 megawatts. Previous experiments and high-fidelity simulations have shown that STs may offer higher energy confinement than other fusion devices at fusion relevant conditions. In NSTX-U, if existing NSTX results can be extended experimentally to near fusion conditions, then the ST may serve as the optimal configuration for building a next step FPP, which is the primary goal of the FES Bold Decadal Vision. Additionally, NSTX-U aims to test if higher normalized plasma pressure limits observed in STs can be sustained in higher performance plasmas. If so, it would enable higher fusion power in a given volume (reduced device size) and higher achievable bootstrap current, which reduces the need for external current drive, and hence, reduces the recirculated power in a future energy source (improved economics). Combining an upgraded neutral beam heating system with unique ST plasma properties, NSTX-U is also an ideal test bed for studying interactions between plasma waves and fast fuel ions in ways that are relevant to burning plasma science. To effectively measure and control these ST plasmas, NSTX-U is outfitted with roughly three dozen unique plasma diagnostic systems that are operated by PPPL as well as many collaborators from other National Laboratories, Universities, and Industry partners. In FY 2025, support will continue the recovery and repair activities including machine assembly as well as preparation for plasma operations.

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Burning Plasma Science: Foundations	**$345,122**	**$ —**	**$ —**
Advanced Tokamak	$134,122	$ —	$ —
Funding supports 20 weeks of operations at the DIII-D facility, which is 90 percent of optimal. Research continues to exploit innovative current drive systems to assess their potential as actuators for a fusion pilot plant and to optimize plasma performance. Upgrades include increasing electron cyclotron power, completing the installation of the high-field-side lower hybrid current drive system and commencing experiments, and increasing the power of the neutral beam injection system. Funding continues to support research in high-temperature superconducting magnet technology, plasma heating and current drive, plasma fueling, and other enabling technologies for fusion. Funding continues support for small-scale AT experiments.			

FY 2023 Enacted		FY 2025 Request		Explanation of Changes FY 2025 Request vs FY 2023 Enacted
Spherical Tokamak	$107,000		$ —	$ —
Funding for operations supports the remaining NSTX-U Recovery fabrication and machine reassembly activities and begins supporting the commissioning of auxiliary heating systems in preparation for plasma operations. Research efforts focus on studies utilizing a variety of domestic and international spherical tokamak facilities; these studies are aligned with the mission of the NSTX-U program, which contributes to the development of the design basis for a next-step FPP. Funding continues supporting small-scale ST studies dedicated to simplifying and reducing the capital cost of future fusion facilities.				
Fusion Facility Operations	**$ —**		**$126,850**	**+$126,850**
DIII-D Operations	$ —		$73,600	+$73,600
Funding supports 20 weeks of operations at the DIII-D facility, which is 90 percent of optimal. Research continues to exploit innovative current drive systems to assess their potential as actuators for a fusion pilot plant and to optimize plasma performance. Upgrades include increasing electron cyclotron power, completing the installation of the high-field-side lower hybrid current drive system and commencing experiments, and increasing the power of the neutral beam injection system.		The Request will support 16 weeks of operations in FY 2025 at the DIII-D facility. The program will also support facility and infrastructure enhancements.		The funding increase will support DIII-D enhancements.

FY 2023 Enacted	FY 2025 Request	Explanation of Changes FY 2025 Request vs FY 2023 Enacted
National Spherical Torus Experiment-Upgrade (NSTX-U) Operations $ —	$53,250	+$53,250
Funding for operations supports the remaining NSTX-U Recovery fabrication and machine reassembly activities and begins supporting the commissioning of auxiliary heating systems in preparation for plasma operations.	The Request for operations funding will support NSTX-U Recovery fabrication and machine reassembly activities and continue to support commissioning in preparation for plasma operations.	Operations funding, consistent with the baseline, will support the continuation of the NSTX-U Recovery activities.

Note:

- *Funding for the subprogram above, includes 3.65 percent of research and development (R&D) funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, excluding facility operations.*
- *FY 2023 funding amounts are populated in the current structure, only FY 2025 is populated in the proposed restructure.*

Fusion Energy Sciences
Construction

Description

This subprogram supports all line-item construction projects for the FES program. All Total Estimated Costs (TEC) are funded in this subprogram.

20-SC-61 Matter in Extreme Conditions (MEC) Petawatt Upgrade, SLAC

The MEC Petawatt Upgrade project will provide a collaborative user facility that utilizes the LCLS-II light source and is focused on High-Energy-Density Science that will maintain U.S. leadership in the field of high intensity lasers. The project received Critical Decision-1 (CD-1), "Approve Alternative Selection and Cost Range," on October 4, 2021. The FY 2025 Request of $10,000,000 will support preliminary design activities. The estimated total project cost range is $264,000,000 to $461,000,000. CD-2, Approve Performance Baseline, is expected in 1Q FY 2026.

14-SC-60 U.S. Contributions to ITER

The ITER facility, currently under construction in Saint Paul-lez-Durance, France. is more than 75 percent complete to First Plasma. ITER is designed to provide fusion power output approaching reactor levels of hundreds of megawatts, sustained as a burning plasma for hundreds of seconds. ITER is a necessary step toward developing a carbon-free fusion energy pilot plant and will help keep the U.S. competitive internationally. Construction of ITER is a collaboration among the U.S., European Union, Russia, Japan, India, Korea, and China, governed under an international agreement (the "ITER Joint Implementing Agreement"). As a co-owner of ITER, the U.S. contributes in-kind hardware components and financial contributions for the ITER Organization (IO) management and overhead (e.g., design integration, nuclear licensing, quality control, safety, overall project management, and installation and assembly of the components provided by the U.S. and other Members). The U.S. also has over 50 nationals employed by the IO and working at the site.

An independent review of CD-2, "Approve Performance Baseline," for the U.S. Contributions to ITER—First Plasma subproject (SP-1) was completed in November 2016 and then subsequently approved by the Project Management Executive on January 13, 2017, with a total project cost of $2,500,000,000. Responding to Congressional direction in the FY 2021 Appropriations Act, the project was baselined in December 2023 and achieved CD-2/3B, which includes a rebaseline of SP-1 scope, baseline of Post-First Plasma (SP-2) scope, and financial contributions for the project to CD-4, "Approve Project Completion". SP-1 scope is currently over 75 percent complete and will include the delivery of the completed Central Solenoid Magnet System, Steady-state Electrical Network, and Disruption Mitigations System. SP-1 also contains a portion of design and fabrication for the remaining nine systems scope associated with SP-2 and will deliver the balance of completed work to include the Tritium Exhaust Processing System, Ion Cyclotron Heating and Electron Cyclotron Heating Systems, diagnostics, and roughing pumps.

The FY 2025 Request of $225,000,000 will support the continued systems design, fabrication, and delivery of in-kind hardware, and financial contributions for IO construction operations. The revised baseline is $6,500,000,000, which includes all U.S. in-kind hardware and financial construction contributions through the completion of the ITER project. Upon baselining in December 2023, the TPC range will no longer exist, and reporting will be to the approved TPC of $6,500,000,000. ITER Organization will be providing an updated baseline to the ITER council in the FY 2024 timeframe. U.S. Contributions to ITER are estimated to remain within the TPC of $6,500,000.

The U.S. in-kind contribution represents 9.09 percent (1/11th) of the overall ITER project but will provide access to 100 percent of the science and engineering associated with what will be the largest magnetically confined burning plasma experiment ever created. The U.S. involvement in ITER will help to advance the promise of carbon-free, inherently safe, and abundant fusion energy

Activities and Explanation of Changes

(dollars in thousands)

FY 2023 Enacted		FY 2025 Request	Explanation of Major Changes FY 2025 Request vs FY 2023 Enacted
Construction	**$253,000**	**$235,000**	**-$18,000**
20-SC-61, Matter in Extreme Conditions (MEC) Petawatt Upgrade, SLAC	$11,000	$10,000	-$1,000
Funding supports design activities and preparation for developing a project performance baseline.		The Request will continue to support design activities and preparation for developing a project performance baseline.	Funding will support critical preparation activities for developing the performance baseline.
14-SC-60, U.S. Contributions to ITER (Historical)	$242,000	$225,000	-$17,000
Funding supports continued design and fabrication of in-kind hardware systems and requested construction financial contributions.		The Request will support continued design and fabrication of in-kind hardware systems and requested construction financial contributions.	Funding will support design and fabrication of in-kind hardware and fulfill the U.S. obligations for financial contributions to the ITER Organization.

Fusion Energy Sciences
Capital Summary

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Capital Operating Expenses						
Capital Equipment	N/A	N/A	22,443	41,500	38,700	+16,257
Minor Construction Activities						
General Plant Projects	N/A	N/A	1,500	1,000	1,000	-500
Total, Capital Operating Expenses	**N/A**	**N/A**	**23,943**	**42,500**	**39,700**	**+15,757**

Capital Equipment

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Capital Equipment						
Major Items of Equipment						
Fusion and Plasma Research						
Material Plasma Exposure eXperiment (MPEX)	188,179	103,456	14,000	25,000	22,200	+8,200
Total, MIEs	N/A	N/A	14,000	25,000	22,200	+8,200
Total, Non-MIE Capital Equipment	N/A	N/A	8,443	16,500	16,500	+8,057
Total, Capital Equipment	**N/A**	**N/A**	**22,443**	**41,500**	**38,700**	**+16,257**

Note:

- The Capital Equipment table includes MIEs located at a DOE facility with a Total Estimated Cost (TEC) > $10M and MIEs not located at a DOE facility with a TEC >$2M.

Fusion Energy Sciences
Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
General Plant Projects (GPP)						
Total GPPs $5M or less	N/A	N/A	1,500	1,000	1,000	-500
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**1,500**	**1,000**	**1,000**	**-500**
Total, Minor Construction Activities	**N/A**	**N/A**	**1,500**	**1,000**	**1,000**	**-500**

Note:

- *GPP activities $5M and less include design and construction for additions and/or improvements to land, buildings, replacements or addition to roads, and general area improvements. AIP activities $5M and less include minor construction at an existing accelerator facility.*

Fusion Energy Sciences
Major Items of Equipment Description(s)

Burning Plasma Science: Long Pulse MIEs:

Material Plasma Exposure eXperiment (MPEX)

FES is developing a first-of-a-kind, world-leading experimental capability to explore solutions to the plasma-materials interactions challenge. This device, known as MPEX, will be located at ORNL and will enable dedicated studies of reactor-relevant plasma-material interactions at a scale not previously accessible to the fusion program. The overall goal of this project is to create a new class of fusion materials science enabling the study of the combined effects of fusion-relevant heat, particle, and neutron fluxes for the first time anywhere in the world. The project received CD-2/3 "Approve Performance Baseline/Start of Construction" on August 22, 2022, with a TPC of $201,000,000. The FY 2025 Request includes $22,200,000 in TEC funding and $2,800,000 in Other Project Costs (OPC) funding and allow the project to execute the approved performance baseline. MPEX scope includes the design, fabrication, installation, and commissioning of the MPEX linear plasma device, as well as associated facility and infrastructure modifications and reconfiguration.

Fusion Energy Sciences
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
20-SC-61, Matter in Extreme Conditions (MEC) Petawatt Upgrade, SLAC						
Total Estimated Cost (TEC)	448,700	44,487	11,000	10,000	10,000	-1,000
Other Project Cost (OPC)	12,300	6,900	-	-	-	-
Total Project Cost (TPC)	**461,000**	**51,387**	**11,000**	**10,000**	**10,000**	**-1,000**
14-SC-60, U.S. Contributions to ITER						
Total Estimated Cost (TEC)	6,429,698	2,353,617	242,000	240,000	225,000	-17,000
Other Project Cost (OPC)	70,302	70,302	-	-	-	-
Total Project Cost (TPC)	**6,500,000**	**2,423,919**	**242,000**	**240,000**	**225,000**	**-17,000**
Total, Construction						
Total Estimated Cost (TEC)	**N/A**	**N/A**	**253,000**	**250,000**	**235,000**	**-18,000**
Other Project Cost (OPC)	**N/A**	**N/A**	**-**	**-**	**-**	**-**
Total Project Cost (TPC)	**N/A**	**N/A**	**253,000**	**250,000**	**235,000**	**-18,000**

Fusion Energy Sciences
Scientific User Facility Operations

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

(dollars in thousands)

	FY 2023 Enacted	FY 2023 Current	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Scientific User Facilities - Type A					
DIII-D National Fusion Facility	**130,000**	**124,001**	**128,600**	**129,600**	**-400**
Number of Users	700	714	700	625	-75
Achieved Operating Hours	–	788	–	–	–
Planned Operating Hours	800	788	560	640	-160
Unscheduled Down Time Hours	–	256	–	–	–
National Spherical Torus Experiment-Upgrade	**104,000**	**99,498**	**85,007**	**91,350**	**-12,650**
Number of Users	300	336	373	339	+39
Total, Facilities	**234,000**	**223,499**	**213,607**	**220,950**	**-13,050**
Number of Users	1,000	1,050	1,073	964	-36
Achieved Operating Hours	–	788	–	–	–
Planned Operating Hours	800	788	560	640	-160
Unscheduled Down Time Hours	–	256	–	–	–

Notes:

- *Achieved Operating Hours and Unscheduled Downtime Hours will only be reflected in the Congressional budget cycle which provides actuals.*
- *Percent optimal operations defines what is achieved at this funding level. This includes staffing, up-to-date equipment and software, operations and maintenance, and appropriate investments to maintain world leadership.*

Fusion Energy Sciences
Scientific Employment

	FY 2023 Enacted	FY 2024 Annualized CR	FY 2025 Request	FY 2025 Request vs FY 2023 Enacted
Number of Permanent Ph.Ds (FTEs)	1,025	1,055	1,141	+116
Number of Postdoctoral Associates (FTEs)	126	122	141	+15
Number of Graduate Students (FTEs)	341	356	380	+39
Number of Other Scientific Employment (FTEs)	1,530	1,576	1,703	+173
Total Scientific Employment (FTEs)	**3,022**	**3,109**	**3,365**	**+343**

Note:

- *Other Scientific Employment (FTEs) includes technicians, engineers, computer professionals and other support staff.*

20-SC-61 Matter in Extreme Conditions (MEC) Petawatt Upgrade, SLAC
SLAC National Accelerator Laboratory, SLAC
Project is for Design and Construction

1. Summary, Significant Changes, and Schedule and Cost History

Summary

The FY 2025 Request for the Matter in Extreme Conditions (MEC) Petawatt Upgrade project is $10,000,000 of Total Estimated Cost (TEC) funding. The project has a preliminary estimated Total Project Cost (TPC) range of $264,000,000 to $461,000,000. Currently, this cost range encompasses the most feasible preliminary alternatives.

The future MEC Petawatt user facility will be a premier research facility to conduct experiments in the field of High Energy Density Plasmas. It will utilize the Linac Coherent Light Source II (LCLS-II) X-Ray Free-Electron Laser (XFEL) beam at SLAC to probe and characterize plasmas and extreme states of matter.

Significant Changes

The MEC Petawatt Upgrade project was initiated in FY 2019. The project achieved CD-1, "Approve Alternative Selection and Cost Range," on October 4, 2021, and initiated the TEC-funded preliminary design phase.

FY 2023 funding allowed the project to advance design of the civil construction required to support the new facility including tunneling. The FY 2024 Request will advance the design of the test chamber that interfaces with the LCSL-II XFEL. FY 2025 Request will advance the design of the Petawatt and Kilojoule (KJ) lasers and their support systems. The Project will also develop the cost and schedule basis to support baselining efforts planned for the first quarter of FY 2026.

A Level III Federal Project Director has been assigned to the MEC Petawatt Upgrade project.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-4
FY 2025	1/4/19	3/9/21	10/4/21	1Q FY 2026	Q1 FY 2026	1Q FY 2026	1Q FY 2033

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range; **Conceptual Design Complete** – Actual date the conceptual design was completed (if applicable); **CD-1** – Approve Alternative Selection and Cost Range; **CD-2** – Approve Performance Baseline; **Final Design Complete** – Estimated/Actual date the project design will be/was complete(d); **CD-3** – Approve Start of Construction; **D&D Complete** – Completion of D&D work; **CD-4** – Approve Start of Operations or Project Closeout.

Project Cost History

(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	55,487	393,213	448,700	12,300	12,300	461,000
FY 2025	85,487	363,213	448,700	12,300	12,300	461,000

Note:

- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

2. Project Scope and Justification

Scope

The scope of the MEC Petawatt Upgrade project includes the development of a user facility that couples long-pulse (1 KJ or higher) and short-pulse (1 petawatt or higher) drive lasers to an X-ray source, as well as a second target chamber that will accommodate laser-only fusion and material science experiments. The lasers will be placed in a dedicated MEC experimental hall (located at the end of the LCLS-II Far Experimental Hall), composed of an access tunnel, experimental hall, control room, and associated safety systems and infrastructure.

Justification

The FES mission is to build the scientific foundations needed to develop a fusion energy source and to expand the fundamental understanding of matter at very high temperatures and densities. To meet this mission, there is a scientific need for a petawatt or greater laser facility, which is currently not available in the U.S. The National Academies of Sciences, Engineering, and Medicine (NASEM) 2017 report titled "Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light"[c] found that about 80 percent to 90 percent of the high-intensity laser systems are overseas, and all the highest-power lasers currently under construction or already built are overseas as well. The report made five recommendations that would improve the nation's position in the field, including a recommendation for DOE to plan for at least one large-scale, open-access, high-intensity laser facility that leverages other major science infrastructures in the DOE complex.

The NASEM report focuses on high-intensity, pulsed petawatt-class lasers (1 petawatt is 10^{15} watts). Laser beams of this intensity can drive nuclear reactions, heat matter to mimic conditions found in stars, and create electron-positron plasmas. In addition to discovery-driven science, petawatt-class lasers can generate particle beams with potential applications in medicine, intense neutron and gamma ray beams for homeland security applications, directed energy for defense applications, and radiation for extreme ultraviolet lithography.

Co-location of high-intensity lasers with existing infrastructure such as particle accelerators has been recognized as a key advantage of the U.S. laboratories over the Extreme Light Infrastructure concept in Europe. A laser facility with high-power, high-intensity beam parameters that is co-located with hard X-ray laser probing capabilities (i.e., with an X-ray wavelength that allows atomic resolution) will provide the required diagnostic capabilities for fusion discovery science and related fields. Recent research on ultrafast pump-probe experiments using the LCLS at the SLAC National Accelerator Laboratory has demonstrated exquisite ultrafast measurements of the material structural response to radiation. The upgrade includes the petawatt laser beam and the long-pulse laser beam. The latter is required to compress matter to densities relevant to planetary science and fusion plasmas. The MEC Petawatt Upgrade will have the potential to address some Inertial Fusion Energy (IFE) questions including spherical capsule ablator materials and high-repetition rate IFE targets tracking and engagement.

FES is pursuing development of a new world-class petawatt laser capability to meet the FES mission and address the recommendations from the NASEM report.

The project will be conducted utilizing the project management principles described in DOE Order 413.3B*, Program and Project Management for the Acquisition of Capital Assets*.

Key Performance Parameters (KPPs)

The KPPs are preliminary and may change during design phase as the project continues towards CD-2. At CD-2 approval, the KPPs will be baselined. The Threshold KPPs represent the minimum acceptable performance that the project must achieve. The Objective KPPs represent the desired project performance. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. The project is in the conceptual design phase, and the KPPs reflect the types of parameters being considered and are notional at this stage.

[c] https://www.nap.edu/catalog/24939/opportunities-in-intense-ultrafast-lasers-reaching-for-the-brightest-light

Performance Measure	Threshold	Objective
Optical Laser Systems		
▪ High repetition rate short pulse laser	▪ 30 Joules of energy ▪ 300 fs pulse length ▪ 1 Hz frequency	▪ 150 Joules of energy ▪ 150 fs pulse length ▪ 10 Hz frequency
▪ High energy long pulse laser	▪ 200 Joules of energy on target ▪ 10 ns pulse length 1 shot per 60 minutes	▪ 1000 Joules of energy on target ▪ 10 ns pulse length 1 shot per 30 minutes
X-ray Beam Delivery		
▪ Photon energy	▪ 5-25 keV energy delivered to target center	▪ 5-45 keV of energy delivered to target center

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	34,487	34,487	23,487	—
Prior Years - IRA Supp.	10,000	10,000	—	—
FY 2023	11,000	11,000	8,539	10,000
FY 2024	10,000	10,000	10,000	—
FY 2025	10,000	10,000	10,000	—
Outyears	10,000	10,000	23,461	—
Total, Design (TEC)	**85,487**	**85,487**	**75,487**	**10,000**
Construction (TEC)				
Outyears	363,213	363,213	363,213	—
Total, Construction (TEC)	**363,213**	**363,213**	**363,213**	**—**
Total Estimated Cost (TEC)				
Prior Years	34,487	34,487	23,487	—
Prior Years - IRA Supp.	10,000	10,000	—	—
FY 2023	11,000	11,000	8,539	10,000
FY 2024	10,000	10,000	10,000	—
FY 2025	10,000	10,000	10,000	—
Outyears	373,213	373,213	386,674	—
Total, Total Estimated Cost (TEC)	**448,700**	**448,700**	**438,700**	**10,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	6,900	6,900	6,900	–
Outyears	5,400	5,400	5,400	–
Total, Other Project Cost (OPC)	**12,300**	**12,300**	**12,300**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	41,387	41,387	30,387	–
Prior Years - IRA Supp.	10,000	10,000	–	–
FY 2023	11,000	11,000	8,539	10,000
FY 2024	10,000	10,000	10,000	–
FY 2025	10,000	10,000	10,000	–
Outyears	378,613	378,613	392,074	–
Total, TPC	**461,000**	**461,000**	**451,000**	**10,000**

Note:
- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

4. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	62,587	42,587	**N/A**
Design - Contingency	22,900	22,900	**N/A**
Total, Design (TEC)	**85,487**	**65,487**	**N/A**
Construction	129,093	129,093	**N/A**
Equipment	118,076	138,076	**N/A**
Construction - Contingency	116,044	116,044	**N/A**
Total, Construction (TEC)	**363,213**	**383,213**	**N/A**
Total, TEC	**448,700**	**448,700**	**N/A**
Contingency, TEC	*138,944*	*138,944*	***N/A***
Other Project Cost (OPC)			
R&D	350	350	**N/A**

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Conceptual Planning	4,650	4,650	**N/A**
Conceptual Design	1,900	1,900	**N/A**
Other OPC Costs	3,800	3,800	**N/A**
OPC - Contingency	1,600	1,600	**N/A**
Total, Except D&D (OPC)	**12,300**	**12,300**	**N/A**
Total, OPC	**12,300**	**12,300**	**N/A**
Contingency, OPC	*1,600*	*1,600*	***N/A***
Total, TPC	**461,000**	**461,000**	**N/A**
Total, Contingency (TEC+OPC)	***140,544***	***140,544***	***N/A***

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	—	11,000	10,000	—	438,700	459,700
	OPC	—	—	—	—	12,300	12,300
	TPC	—	11,000	10,000	—	451,000	472,000
FY 2025	TEC	—	11,000	10,000	10,000	438,700	469,700
	OPC	—	—	—	—	12,300	12,300
	TPC	—	11,000	10,000	10,000	451,000	482,000

Note:

- *This project has not received CD-2 approval; therefore, funding estimates are preliminary.*

6. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	1Q FY 2033
Expected Useful Life	30 years
Expected Future Start of D&D of this capital asset	1Q FY 2063

Related Funding Requirements
(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Previous Total Estimate	**Current Total Estimate**	**Previous Total Estimate**	**Current Total Estimate**
Operations, Maintenance and Repair	TBD	21,200	TBD	636,000

7. D&D Information

The new area being constructed for this project is under analysis at this time.

	Square Feet
New area being constructed by this project at SLAC..	TBD
Area of D&D in this project at SLAC..	TBD
Area at SLAC to be transferred, sold, and/or D&D outside the project, including area previously "banked"	TBD
Area of D&D in this project at other sites	TBD
Area at other sites to be transferred, sold, and/or D&D outside the project, including area previously "banked"	TBD
Total area eliminated	TBD

8. Acquisition Approach

FES is proposing that the MEC-U project be acquired by Stanford University under the SLAC Management and Operations (M&O) Contract (DE-AC02-76-SF00515) for DOE. The acquisition of large research facilities is within the scope of the DOE contract for the management and operations of SLAC and consistent with the general expectation of the responsibilities of DOE M&O contractors.

SLAC does not currently possess all the necessary core competencies to design, procure and build the laser systems. To address this, SLAC will collaborate with Lawrence Livermore National Laboratory (LLNL) and University of Rochester—Laboratory for Laser Energetics (LLE) as partners through signed Memorandum of Agreements to perform significant portions of the MEC-U laser systems scope of work. Memorandum Purchase Orders will be used to define work scopes and budgets with LLNL as funds become available. Any work accomplished through LLE will be completed using the standard DOE format university agreements. Procurements authorized by the partner institutions will utilize the approved DOE purchasing systems.

14-SC-60 U.S. Contributions to ITER
Project is for Design and Construction

1. Summary, Significant Changes, and Schedule and Cost History

Summary

The FY 2025 Request for the U.S. ITER project is $225,000,000 of Total Estimated Cost (TEC) funding. The Total Project Cost (TPC) for the U.S. Contributions to ITER (U.S. ITER) project is $6,500,000,000. In FY 2023, the entire U.S. ITER project was baselined, with a top-end cost range of $6,500,000,000, and includes SP-1 and SP-2 scope, as well as the total construction cash contribution. Sections of this Construction Project Data Sheet (CPDS) have been tailored accordingly to reflect the unique nature of the U.S. ITER project. Fusion energy is expected to provide a carbon-free, inherently safe energy source that will significantly contribute to the development of a commercial fusion energy pilot plant.

Significant Changes

The U.S. ITER project was initiated in FY 2006. On January 13, 2017, U.S. ITER SP-1 achieved both Critical Decision (CD)-2, “Approve Performance Baseline,” and CD-3, “Approve Start of Construction.” CD-4, “Project Completion,” for SP-1 is currently planned for December 2028.

In response to Congressional direction articulated in the Consolidated Appropriations Act 2021 to baseline the entire project, the full requirement to complete the U.S. Contributions to ITER project was baselined in December 2023.
The U.S. baselined the entire U.S. Contributions to ITER project, including re-baselining SP-1 and the baselining of SP-2 as a result of the IO rebaselining for the overall project due to COVID and first-of-a-kind component delivery delays, material specification and fabrication issues as well as quality challenges.

The Inflation Reduction Act provided $256,000,000 to the U.S. ITER project. $66,000,000 was utilized to provide for Cash Contributions to fulfill U.S. agreements to the ITER Organization (IO). The remaining $190,000,000 will be used to significantly enhance the design and fabrication performance of project scope in FY 2023–2024 to include the full funding of the Central Solenoid agent and the Tokomak Cooling Water System (within SP-1).
In FY 2023, two Central Solenoid Modules (CSM) were delivered and accepted by the IO. In addition, progress continued on the Tokomak Cooling Water System with all major fabrication contracts being awarded. The U.S. ITER project obligated more than $1,700,000,000 through the end of FY 2023, of which more than 80 percent is to U.S. industry, universities, and DOE laboratories.

In FY 2024, two more CSMs will be delivered bringing the total to five of seven that make up the Central Solenoid Magnet (including one spare). Additionally in FY 2024, the first fabrication contracts will be awarded for the Electron Cyclotron Heating system.

The FY 2025 Request of $225,000,000 will support the continued design and fabrication of multiple in-kind hardware systems including the Ion Cyclotron Heating system and diagnostic systems. Additionally, the FY 2025 Request will fund Construction Cash contributions to the IO.

A Federal Project Director with level I certification has been assigned to this Project and is currently pursuing higher-level certification.

Critical Milestone History

Fiscal Year	CD-0	Conceptual Design Complete	CD-1	CD-2	CD-3	CD-4
FY 2025	7/5/05	–	1/25/08	12/12/2023	12/12/2023	1Q FY 2040

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range; **Conceptual Design Complete** – Actual date the conceptual design was completed (if applicable); **CD-1** – Approve Alternative Selection and Cost Range; **CD-2** – Approve Performance Baseline; **Final Design Complete** – Estimated/Actual date the project design will be/was complete(d); **CD-3** – Approve Start of Construction; **D&D Complete** – Completion of D&D work; **CD-4** – Approve Start of Operations or Project Closeout.

Fiscal Year	Performance Baseline Validation	CD-1 Cost Range Update	CD-1R	CD-3A	CD-3B	CD-4A
FY 2025	1/13/17	1/13/17	1/13/17	1/13/17	12/12/23	1Q FY 2040

CD-1R – Approve Alternative Selection and Cost Range, Revised
CD-3A – Approval of the project starting construction of original 2017 approved baseline.
CD-3B - Approval of the project starting construction under the 2023 approved baseline.
CD-4A - Completion of In-kind Hardware Scope.

Project Cost History

At the time of CD-1 approval in January 2008, the preliminary cost range was $1,450,000,000 to $2,200,000,000. Until 2016, however, it was not possible to confidently baseline the project due to delays early in the international ITER construction schedule. Various factors (e.g., schedule delays, design and scope changes, funding constraints, regulatory requirements, risk mitigation, and inadequate project management and leadership issues in the IO at that time) affected the project cost and schedule. Shortly after the arrival of the new Director General in March 2015, the overall ITER Project was baselined for cost and schedule.

In response to a 2013 Congressional request, a DOE SC Independent Project Review (IPR) Committee assessed the project and determined that the existing cost range estimate of $4,000,000,000 to $6,500,000,000 would likely encompass the final TPC (includes SP-1, SP-2, and Cash Contributions). In preparation for baselining SP-1, based on the results of an Independent Project Review, the acting Director for the Office of Science updated the lower end of this range to reflect updated cost estimates, resulting in the current approved CD-1 Revised (CD-1R) range of $4,700,000,000 to $6,500,000,000.

FY 2023 reflects only SP-1 and associated cash contributions. Beginning in FY 2024, the entire U.S. ITER Project was baselined per Congressional direction in the Consolidated Appropriations Act, 2021. The TPC for the entire project is projected to be $6,500,000,000.

In December 2023, per Congressional direction, the project was baselined and achieved CD-2/3B for the entire scope with a Total Project Cost of $6,500,000,000. The FY 2025 Request of $225,000,000 will support the continued systems design, fabrication, and delivery of in-kind hardware, and financial contributions for IO construction operations.

U.S. Contributions to ITER In-kind Hardware and Construction Cash Contributions
(dollars in thousands)

Fiscal Year	TEC, Design	TEC, Construction	TEC, Cash Contributions	TEC, Total	OPC, Except D&D	OPC, Total	TPC
FY 2024	439,243	4,663,877	1,326,578	6,429,698	70,302	70,302	6,500,000
FY 2025	439,243	4,677,455	1,313,000	6,429,698	70,302	70,302	6,500,000

2. Project Scope and Justification

ITER, currently one of the largest science experiments in the world, is a major fusion research facility under construction in St. Paul-lez-Durance, France by an international partnership of seven Members or domestic agencies, specifically, the U.S., China, the European Union, India, Korea, Japan, and the Russian Federation. ITER is co-owned and co-governed by the seven Members. For the U.S. The Energy Policy Act of 2005 (EPAct 2005), Section 972(c)(5)(C) authorized U.S. participation in ITER. The Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project (Joint Implementation Agreement or JIA), signed on November 21, 2006, provides the legal framework for the four phases of the program: construction, operation, deactivation, and decommissioning. The JIA is a Congressional-Executive Hybrid Agreement. The other six Members entered the project by treaty. The IO is a designated international legal entity located in France.

Scope

U.S. Contributions to ITER – Construction Project Scope

The overall U.S. ITER project includes three major elements:

- In-kind Hardware systems (13 in total), built under the responsibility of the U.S., and then shipped to the ITER site for IO assembly, installation, and operation. Included in this element is cash provided in-lieu of U.S. In-kind component contributions to adjust for certain reallocations of hardware contributions between the U.S. and the IO.
- Funding to the IO to support common expenses, including ITER research and development (R&D), design and construction integration, overall project management, nuclear licensing, IO staff and infrastructure, IO-provided hardware, on-site assembly/installation/testing of all ITER components, installation, safety, quality control, and operation.
- Other project costs, including R&D (other than mentioned above) and conceptual design-related activities.

Justification

The purpose of ITER is to investigate and conduct research in the “burning plasma” regime—a performance region that exists beyond the current experimental state of the art. Creating a self-sustaining burning plasma will provide essential scientific knowledge necessary for practical fusion power. There are two planned experimental outcomes expected from ITER. The first is to investigate the fusion process in the form of a "burning plasma," in which the heat generated by the fusion process exceeds that supplied from external sources (i.e., self-heating). The second is to sustain the burning plasma for a long duration (e.g., several hundred to a few thousand seconds), during which time equilibrium conditions can be achieved within the plasma and adjacent structures. ITER will provide a sustained burning plasma for long-term experimentation which is a necessary step toward developing a fusion pilot plant.

Although not classified as a Capital Asset, the U.S. ITER project is being conducted following project management principles of DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets,* to the greatest extent possible.

Key Performance Parameters (KPPs)

The U.S. Contributions to the ITER Project will not deliver an integrated operating facility, but rather in-kind hardware contributions, which represent a portion of the international ITER facility. The U.S. ITER project defines project completion as delivery and IO acceptance of the U.S. in-kind hardware.

3. Financial Schedule

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Estimated Cost (TEC)				
Design (TEC)				
Prior Years	439,243	439,243	439,243	—
Total, Design (TEC)	**439,243**	**439,243**	**439,243**	**—**
Construction (TEC)				
Prior Years	1,277,877	1,277,877	1,045,072	—
Prior Years - IRA Supp.	190,000	190,000	—	—
FY 2023	172,000	172,000	81,387	43,449
FY 2024	170,000	170,000	170,000	—
FY 2025	160,000	160,000	160,000	—
Outyears	2,707,578	2,707,578	3,030,996	146,551
Total, Construction (TEC)	**4,677,455**	**4,677,455**	**4,487,455**	**190,000**
Cash Contributions (TEC)				
Prior Years	380,497	380,497	380,497	—
Prior Years - IRA Supp.	66,000	66,000	—	—
FY 2023	70,000	70,000	70,000	63,086
FY 2024	70,000	70,000	70,000	—
FY 2025	65,000	65,000	65,000	—
Outyears	661,503	661,503	661,503	2,914
Total, Cash Contributions (TEC)	**1,313,000**	**1,313,000**	**1,247,000**	**66,000**
Total Estimated Cost (TEC)				
Prior Years	2,097,617	2,097,617	1,864,812	—
Prior Years - IRA Supp.	256,000	256,000	—	—
FY 2023	242,000	242,000	151,387	106,535
FY 2024	240,000	240,000	240,000	—
FY 2025	225,000	225,000	225,000	—
Outyears	3,369,081	3,369,081	3,692,499	149,465
Total, Total Estimated Cost (TEC)	**6,429,698**	**6,429,698**	**6,173,698**	**256,000**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Other Project Cost (OPC)				
Prior Years	70,302	70,302	70,302	–
Total, Other Project Cost (OPC)	**70,302**	**70,302**	**70,302**	**–**

(dollars in thousands)

	Budget Authority (Appropriations)	Obligations	Costs	IRA Supp. Costs
Total Project Cost (TPC)				
Prior Years	2,167,919	2,167,919	1,935,114	–
Prior Years - IRA Supp.	256,000	256,000	–	–
FY 2023	242,000	242,000	151,387	106,535
FY 2024	240,000	240,000	240,000	–
FY 2025	225,000	225,000	225,000	–
Outyears	3,369,081	3,369,081	3,692,499	149,465
Total, TPC	**6,500,000**	**6,500,000**	**6,244,000**	**256,000**

Notes:

- *The entire project was baselined in December 2023 with a TPC of $6,500,000,000.*
- *All Appropriations to date for the U.S. Contributions to ITER project include both funding for SP-1 and funding for Cash Contributions, as well as for work associated with the new overall In-kind Hardware baseline.*
- *Obligations and costs through FY 2023 reflect actuals; obligations and costs for FY 2024 and the outyears are estimates.*

4. Details of Project Cost Estimate

The overall U.S. Contributions to ITER project has an approved revised CD-1R. Cost Range (CD-1R). In 2016, DOE chose to divide the project hardware scope into two distinct subprojects (First Plasma SP-1, and Post-First Plasma or SP-2) so that an initial portion of the project that was mature enough to baseline could be accomplished. The baseline for SP-1 In-kind Hardware ($2,500,000,000) was approved in January 2017. In December 2023, per Congressional direction, the project was baselined and achieved CD-2/3B.

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design	439,243	439,243	573,660
Design - Contingency	N/A	N/A	122,365
Total, Design (TEC)	**439,243**	**439,243**	**696,025**
Construction	3,317,455	3,720,360	**N/A**
Equipment	N/A	N/A	1,362,521

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction - Contingency	1,360,000	943,517	371,152
Total, Construction (TEC)	**4,677,455**	**4,663,877**	**1,733,673**
Cash Contributions	1,313,000	1,017,000	**N/A**
Cash Contributions Contingency	N/A	309,578	**N/A**
Total, Cash Contributions (TEC)	**1,313,000**	**1,326,578**	**N/A**
Total, TEC	**6,429,698**	**6,429,698**	**2,429,698**
Contingency, TEC	*1,360,000*	*1,253,095*	*493,517*
Other Project Cost (OPC)			
OPC, Except D&D	70,302	70,302	70,302
Total, Except D&D (OPC)	**70,302**	**70,302**	**70,302**
Total, OPC	**70,302**	**70,302**	**70,302**
Contingency, OPC	***N/A***	*N/A*	***N/A***
Total, TPC	**6,500,000**	**6,500,000**	**2,500,000**
Total, Contingency (TEC+OPC)	***1,360,000***	***1,253,095***	***493,517***

Notes:
- *In the table above, the previous total estimate includes cash contributions estimate to align with the TPC budget request. The "Original Validated Baseline" reflects SP-1 only.*
- *Current total estimated design reflects work done prior to CD-2/3. SP-2 design work is accounted for in TEC Construction as part of SP-1 scope approved at CD-2/3.*

5. Schedule of Appropriations Requests

(dollars in thousands)

Fiscal Year	Type	Prior Years	FY 2023	FY 2024	FY 2025	Outyears	Total
FY 2024	TEC	—	242,000	240,000	—	6,157,832	6,639,832
	OPC	—	—	—	—	66,853	66,853
	TPC	—	242,000	240,000	—	6,224,685	6,706,685
FY 2025	TEC	—	242,000	240,000	225,000	6,113,832	6,820,832
	OPC	—	—	—	—	50,853	50,853
	TPC	—	242,000	240,000	225,000	6,164,685	6,871,685

6. Related Operations and Maintenance Funding Requirements

The U.S. Contributions to ITER operations phase is to begin with initial integrated commissioning activities with an assumed useful life of 30 to 35 years. The fiscal year in which commissioning activities begin depends on the international ITER project schedule, which currently indicates 2025. As a result of COVID-19 and other known delays, the overall ITER project is being re-baselined to update cost and schedule estimates.

Start of Operation or Beneficial Occupancy	1Q FY 2040
Expected Useful Life	35 years
Expected Future Start of D&D of this capital asset	1Q FY 2075

7. D&D Information

Since ITER is being constructed in France by a coalition of countries and will not be a DOE asset, the “one-for-one” requirement is not applicable to this project.

The U.S. Contributions to ITER decommissioning phase is assumed to begin no earlier than 30 years after the start of operations. The deactivation phase is also assumed to begin no earlier than 30 years after operations begin and will continue for a period of five years. The U.S. is responsible for 13 percent of the total decommissioning and deactivation cost; this requirement will be collected and escrowed out of research Operations funding.

8. Acquisition Approach

The U.S. ITER Project Office (USIPO) at Oak Ridge National Laboratory, with its two partner laboratories (Princeton Plasma Physics Laboratory and Savannah River National Laboratory), will procure and deliver in-kind hardware in accordance with the Procurement Arrangements established with the IO. The USIPO will subcontract with a variety of research and industry sources for design and fabrication of its ITER components, ensuring that designs are developed that permit fabrication, to the maximum extent possible, to use fixed-price subcontracts (or fixed-price arrangement documents with the IO) based on performance specifications, or more rarely, on build-to-print designs. USIPO will use cost-reimbursement type subcontracts only when the work scope precludes accurate and reasonable cost contingencies being gauged and established beforehand. USIPO will use best value, competitive source-selection procedures to the maximum extent possible, including foreign firms on the tender/bid list when necessary. Such procedures shall allow for cost and technical trade-offs during source selection. For the large-dollar-value subcontracts (and critical path subcontracts as appropriate), USIPO will utilize unique subcontract provisions to incentivize cost control and schedule performance. In addition, where it is cost effective and it reduces risk, the USIPO will participate in common procurements led by the IO or request the IO to perform activities that are the responsibility of the U.S.