Building Bridges

A Bold Vision for the DOE Fusion Energy Sciences

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U.S. DEPARTMENT OF ENERGY | Office of Science

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Department of Energy, Office of Science

- Joined as FES AD on July 1, 2023
- On leave from Penn State University
- Professor and Department Head, Nuclear Engineering, Penn State University
- Over 180 peer-reviewed and 300 publications in fusion materials, plasma technology, PMI, in-situ diagnostics
- Prior institutions: University of Illinois Urbana-Champaign, Purdue, ANL

Outline

- Mission and Vision for FES
- A Thriving FES Program
- Realizing the Bold Decadal Vision
- Summary and Outlook

FES Mission and Strategic Priorities

MISSION

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 foundations needed to develop a fusion energy source. This is accomplished by the study of the plasma state and its interactions with its surroundings.

The Energy Act of 2020 **expanded the scientific mission of FES** to support "**the development of a competitive fusion power industry in the U.S**."

FES PROGRAM PRIORITIES

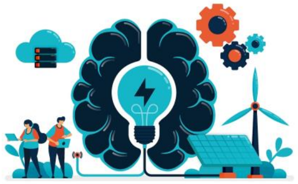
1. Accelerate fusion development as a carbon-free energy source via public-private partnerships ("bold decadal vision")
2. Support R&D Fusion Centers ("FIRE" centers) to establish S&T basis of a Fusion Pilot Plant (FPP)
3. U.S. participation in ITER to leverage engineering and study burning plasma science technology at power plant scale while expanding Inertial Fusion Energy (IFE) program
4. Support discovery plasma science and technology
5. Broaden participation in fusion and DEIA activities to enable the program

Vision for the DOE FES: Key Elements

- ***Workforce Development and Sustainment:*** ensuring we establish sustainable and resilient pathways for diverse and exceptional talent

- ***Bridging Gaps:*** Creating innovation engines with national laboratories, universities, and industry to resolve R&D gaps and support domestic supply chains for fusion energy

- ***Transformational Science:*** Nurturing plasma science and technology discovery translating to innovation impact



Foundational Science **will always** play a role in a vibrant ***private fusion industry***

Imperative for U.S. to remain a fusion energy world leader

- Global race to secure leadership in fusion energy
- Major investments** from UK, EU, Japan, Germany, and China

EU: $650M per year (EUROfusion ~ $270M/yr)

UK: $250M per year*

Japan: $237M per year

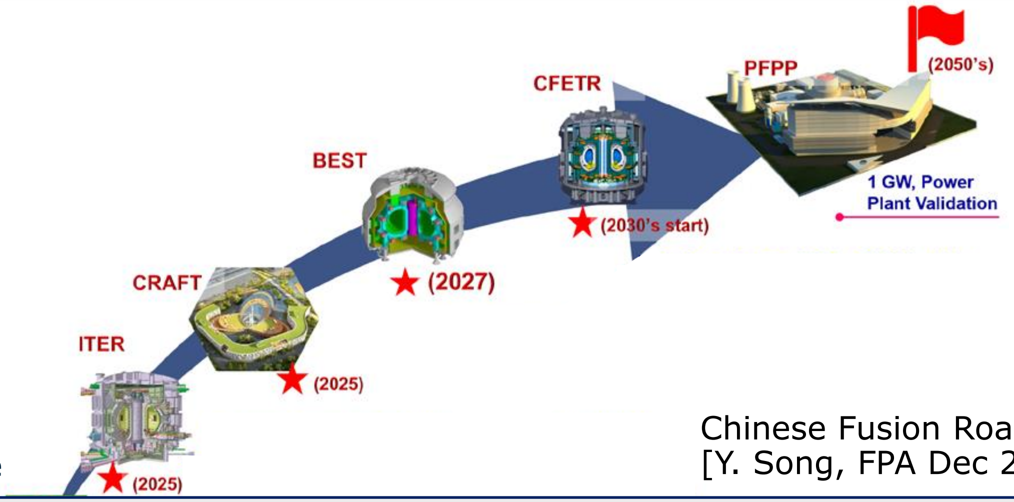
Germany: $220M/yr

- Where does the U.S. fit into this landscape?

*excludes ITER contrib.
**NOTE: $USD are estimates only with large variance

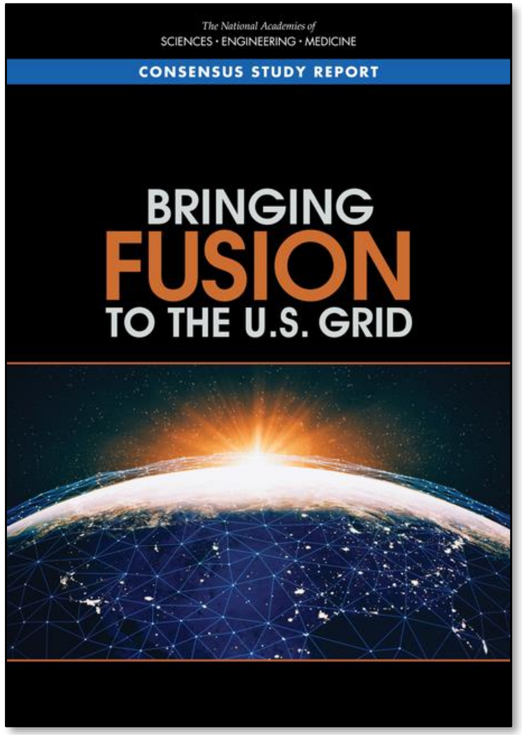
- In Feb 2023, it was reported that China has surpassed the U.S. in fusion technology patents [Astamuse, 2023]
- Chinese expenditures** in fusion energy **~1.5B/year**

**NOTE: $USD are estimates only with large variance

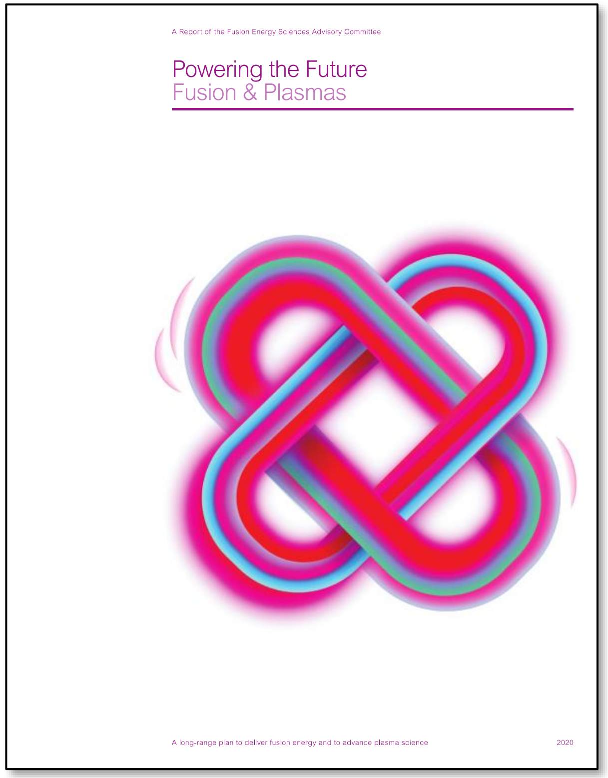


Chinese Fusion Roadmap
[Y. Song, FPA Dec 2022]

Guidance for the Coming Decade and Beyond



Challenges



- The political climate for big spending has waned
- For FPP we have order-of-magnitude technology gaps not found with other emerging energy sources
- Access to workforce is strained by competition from other energy sectors and non-energy industries

Opportunities

- Energy security will drive investment priorities
- Shared tech gaps with other industries can open the door for fusion to lead in partnerships

Aligning FES program to the FESAC LRP (Long Range Plan)

Context:

FESAC LRP provided the **"Why" and "What";** our blueprint for moving forward

Next Steps:

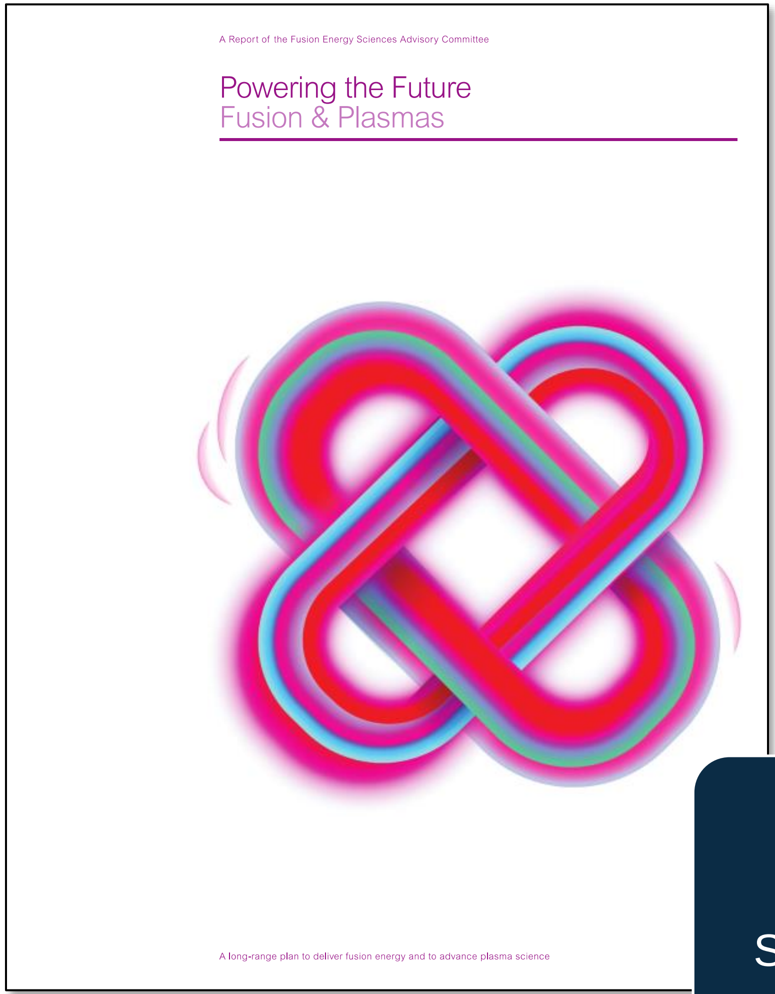
"How" and the "When" → **Fusion S&T Roadmap**

Key questions:

- How do we balance science and technology in FES as the US fusion industry pursues a fusion pilot plant?
- How to manage diverse priorities for US tokamak facilities and make progress on LRP Fusion Materials and Technology (FM&T) gaps?
- What are important synergies between fusion energy and the broader plasma science and technology portfolio?

Image Credit: Bryce Durbin, TechCrunch

Vision for a balanced and bold FES program



2020 FESAC
Long-Range Plan (LRP)

"Fulfilling the [fusion] energy mission demands a shift in the balance of research toward FM&T (Fusion Materials and Technology), which connects the three science drivers: Sustain a Burning Plasma, Engineer for Extreme Conditions, and Harness Fusion Energy." pg. 6 FESAC-LRP

- Fusion Science and Technology (S&T) Roadmap
- **Focus:** critical science and technology gaps
- Support public-private partnerships (PPPs)
- Leverage international collaborations

Sustain a Burning Plasma

Engineer for Extreme Conditions

Harness Fusion Energy

LRP Science Drivers

FPP

The Road to Fusion Energy is through *combined* private sector "pull" and public sector "push" - with extraordinary gaps to address

Build LRP FM&T Gap Facilities

A Fusion S&T Roadmap with metrics to track progress

- Our role in FES is to **focus** on the science and technology gaps as our "bridge" to realize a viable path towards fusion energy (an "interim stage")
- Transitions will be key to leverage resources
- Our workforce will be top priority and therefore we will develop a plan for designing, building, and operating facilities enabled by PPPs on the path to a fusion pilot plant

Building the Roadmap: a staged approach towards FPP

Stage I

Innovation Research & Development

- MPEX startup
- DIII-D, NSTX-U
  - Close physics gaps
- **FIRE Centers**
- **Milestone Program**
- Facility Studies
- IFE Foundations
- Diversify FES Portfolio

Mid 2020's

Support PPPs, seed supply chain, leverage International partners

Stage II

Integrated and Integration Facilities

- Sustain burning plasma
- Materials in extremes
  - FPNS, LMCE
- Advanced manufacturing
- Blanket and fuel cycle
- Neutron and plasma exhaust integration facility to address fusion S&T gaps

Late 2020's to mid 2030's

Expand FIRE Centers, Expand IFE, Translate to Public-Private Consortium Framework (PPCF)

Stage III

FPP to FOAK

- Diverse Energy Markets
- Diverse Plasma Tech Markets
- Expand emerging confinement concepts
- Expand innovation in fusion materials

Mid 2030's to 2040's

Expand bridges to supply chains, ITER burning plasma era, innovate new facilities

Managing FES transitions strategically and thoughtfully

Major goals of transition for FES to burning plasma era:

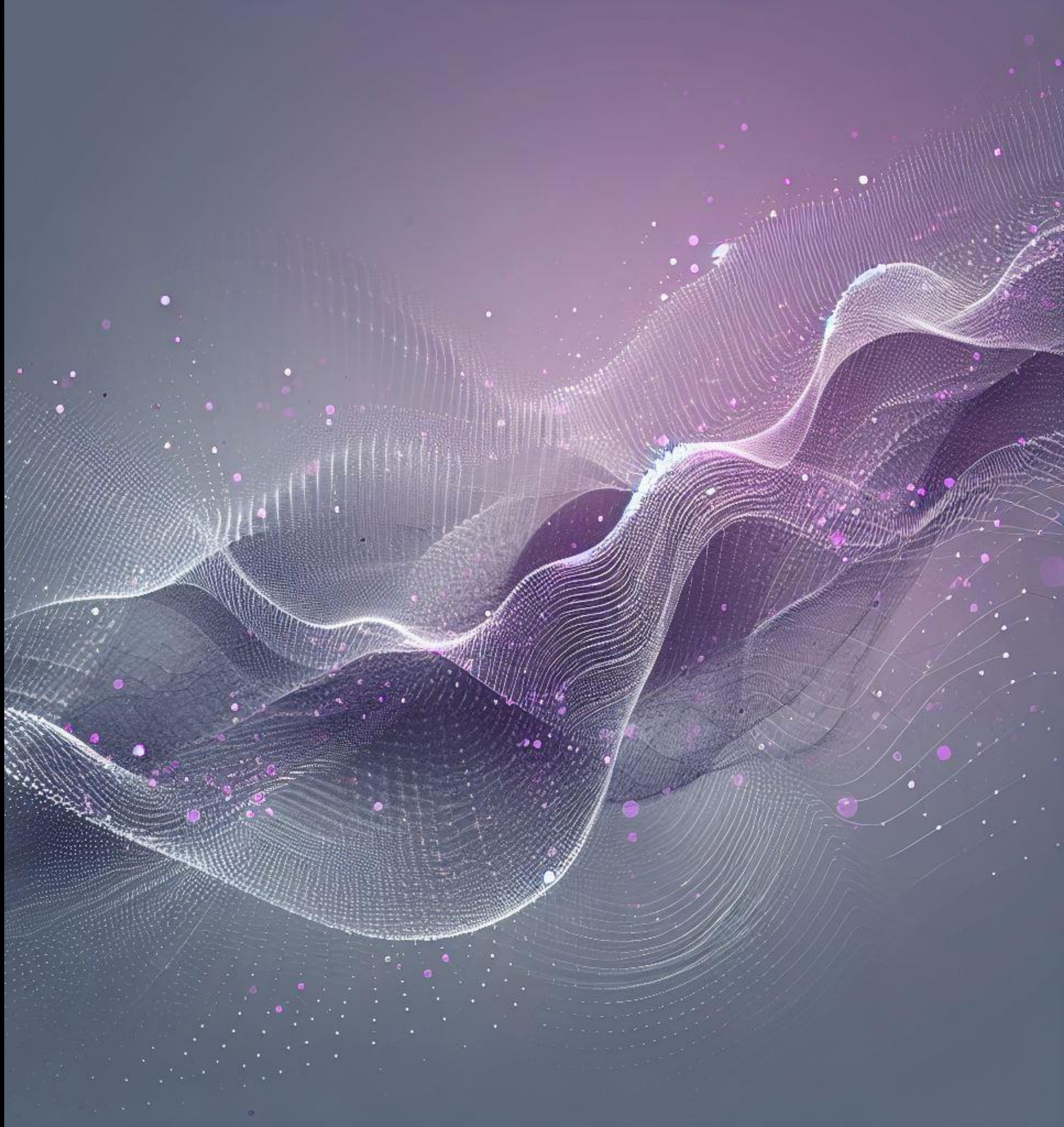
- Coordinated Collaborative Networks
- Scientific Excellence
- International Leveraging
- Enabling Technology Innovation
- Use-inspired Research (PPPs)

Highest priority:

Ensure our fusion scientific community is supported and provided opportunities to flourish and adapt successfully

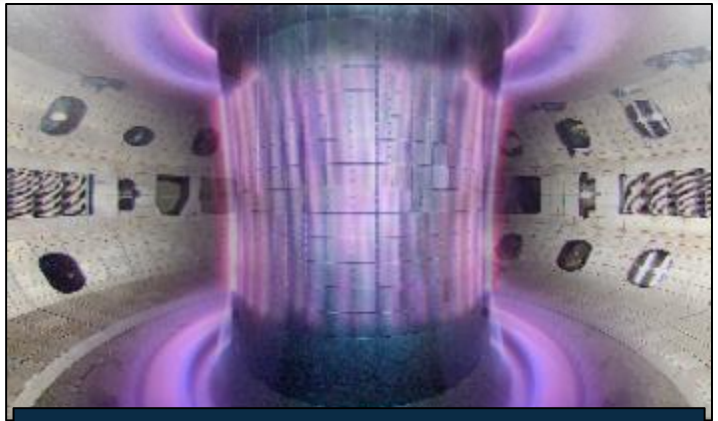
Image Credit: Ana Kova / U.S. Fusion Outreach, AIP

A Thriving FES Program

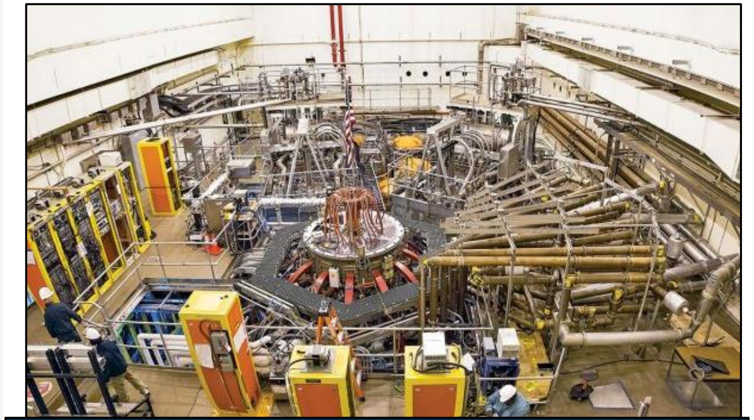


Foundational and Enabling Technology Research in FES

SC User Facilities

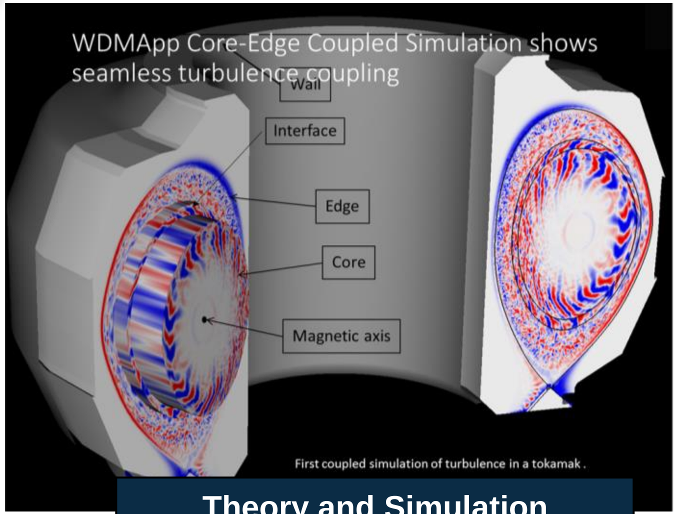


DIII-D National Fusion Facility

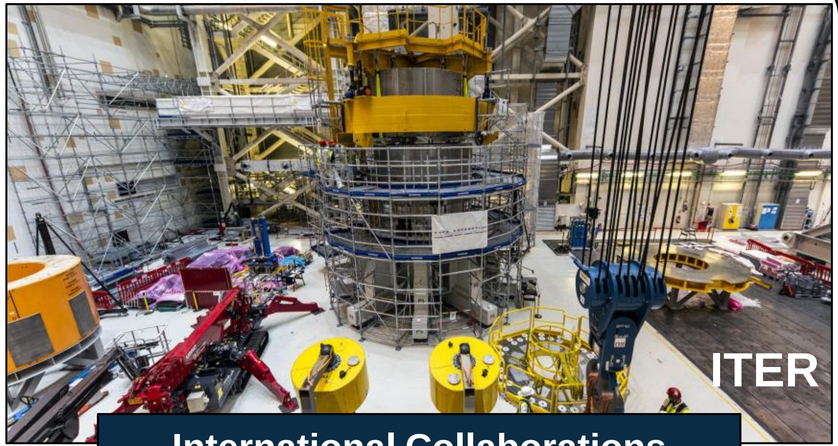


National Spherical Torus Experiment-Upgrade

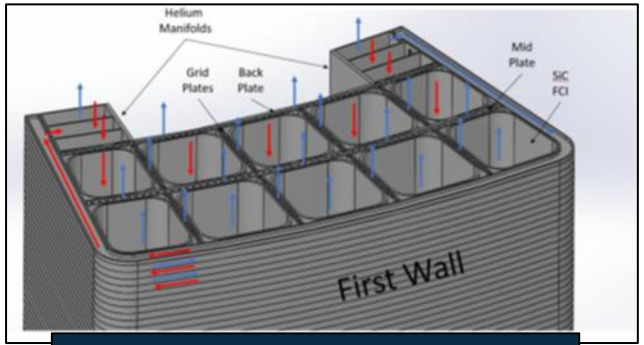
Burning Plasma Science



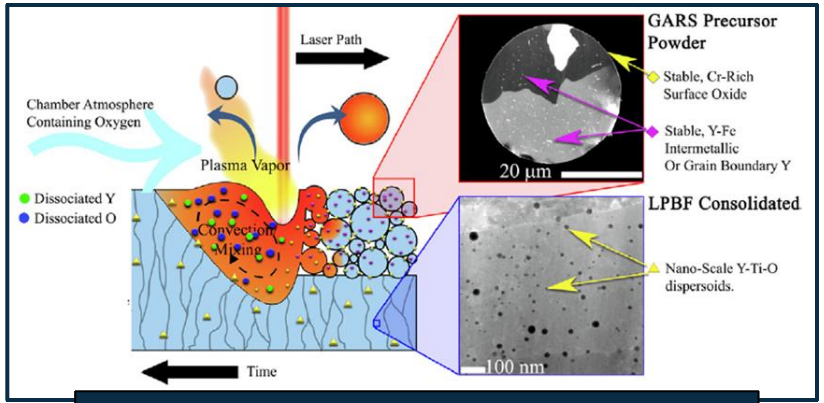
Theory and Simulation



International Collaborations



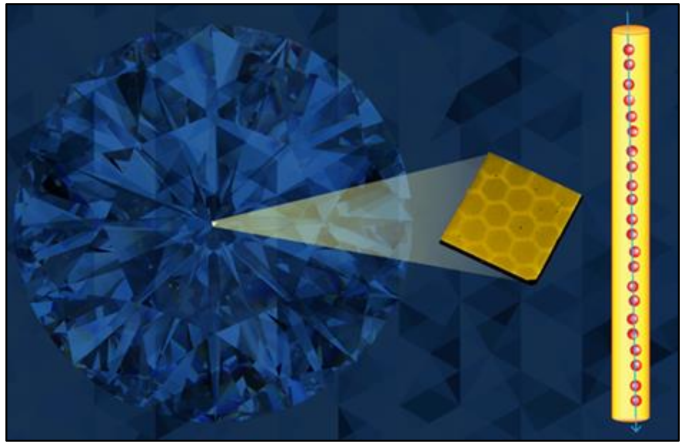
Fusion Nuclear Science



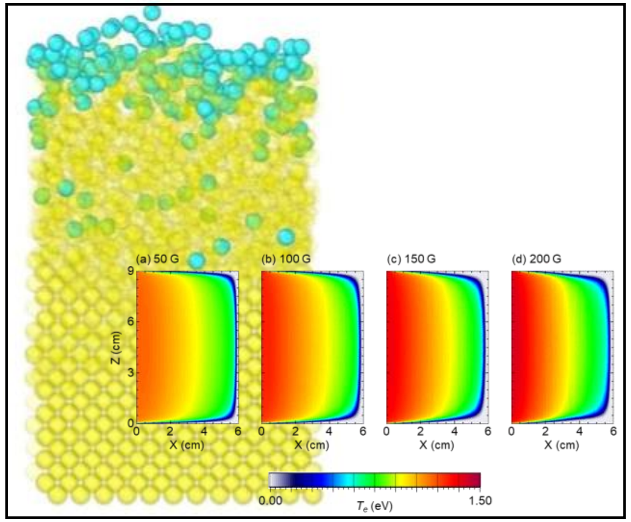
Materials Science / AM

Funding at 61 universities, 14 national laboratories, and 23 private companies
> 1,500 FTEs, >300 grad students, >120 postdocs

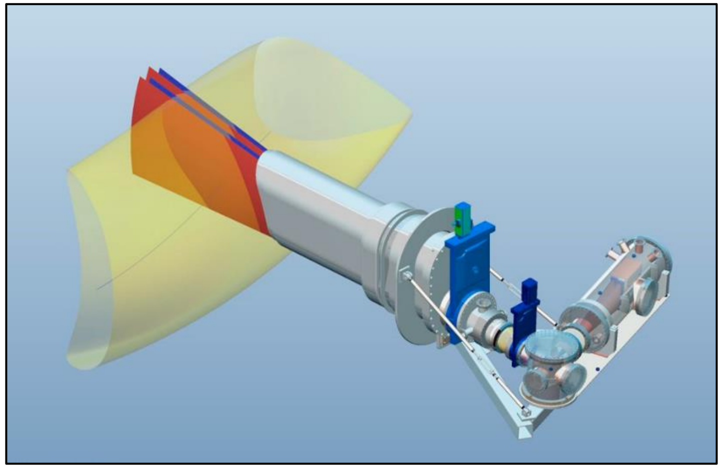
Excellence in Plasma Science Discovery and Technology



Quantum Information Science



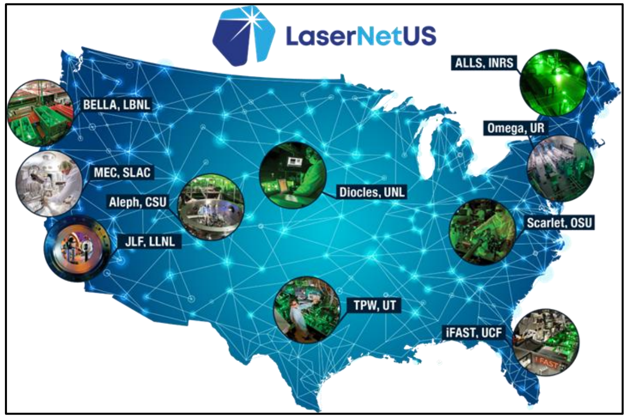
Low Temperature Plasmas



Plasma Diagnostics

AI/ML

General Plasma Science

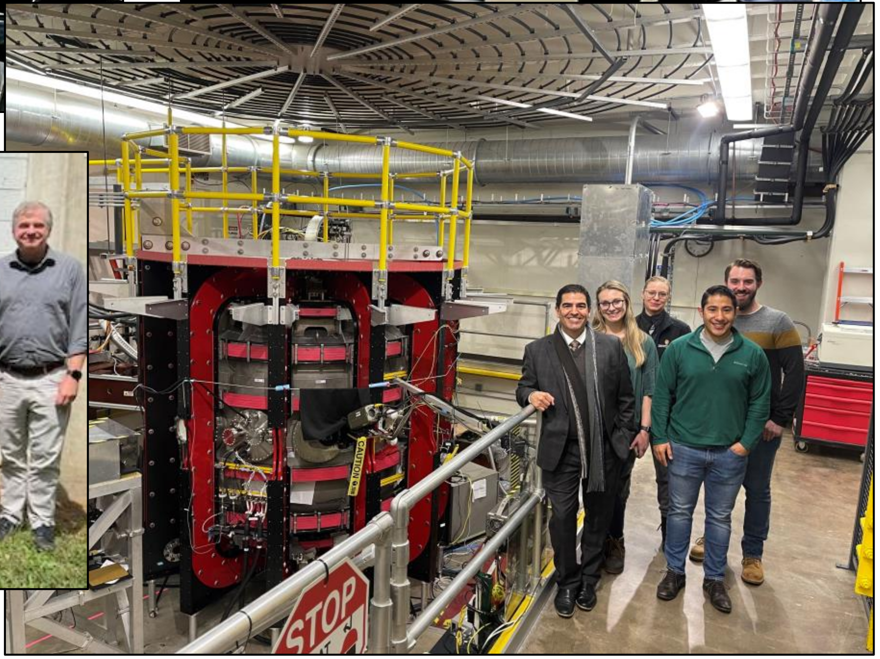


LaserNetUS / HEDLP

Our FES Program is all about people and excellence in science

- Decades of investment has resulted in the expertise the fusion industry seeks daily
- Lots of visits!

  ORNL, U.Tenn, PPPL, Princeton U., General Atomics, UCSD, LLNL, INL, MIT, UW Madison, CFS, CEA IFRM, ITER, QST JT60-SA, Tokamak Energy, and many more coming…

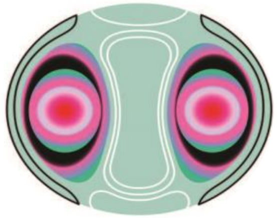


Recent funding in strategic areas*

- *AI/ML and Data Resources:* ***$29M****,*
- *Discovery through Advanced Computing-FES partnership:* ***$120M***
- *Quantum Information Science:* ***$11.4M***
- *IFE-STAR:* ***$42M***

* Partial list

New *Emergent Plasma Concepts* program in FES

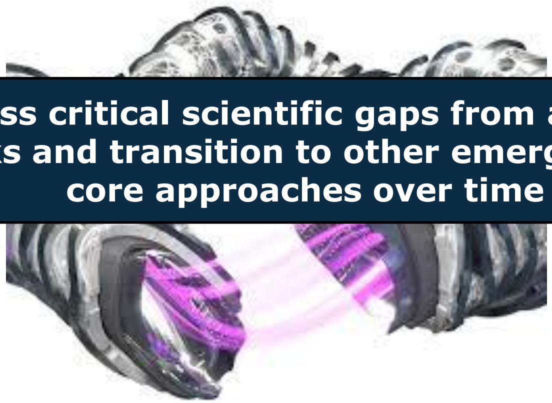


FESAC LRP, pp 6-7

"The tokamak approach for the plasma core is the most technically advanced and mature confinement concept."

"A tokamak FPP will require completing critical research on existing domestic facilities and participation in ITER."

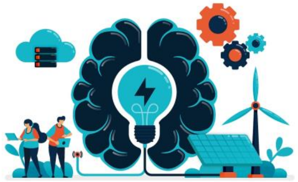
"Investment in alternate (plasma core) approaches is important both as a risk mitigation strategy for the tokamak approach and to support innovations… towards accelerated paths in commercial fusion energy."



Address critical scientific gaps from advanced tokamaks and transition to other emergent plasma core approaches over time

Beyond Fusion: Plasma Science and Technology Ecosystem

Expanding public-private partnerships in all aspects of plasma science and engineering



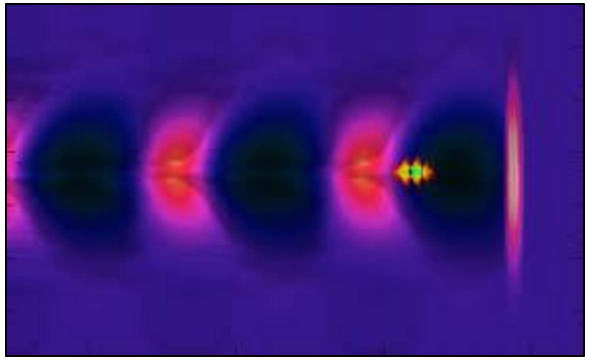
- Establish Plasma Frontier Research Centers (PFRCs)
- Interface with private industry (e.g., leverage FLARE facility at PPPL)
- Advanced plasma X-ray lithography

International Partnerships and Strategic Directions

- *Korea-US (KFE and DOE SC FES on plasma industry for medicine, agriculture and microelectronics)*
- *Strategic Directions: SC FES and NIH on plasma medicine, AFSOR/SFRO/NRL/FES: plasma thrusters*

J.L. Lopez, Seton Hall 2019

Drexel U. 2016



The Wire 2016

Futuristic 2018

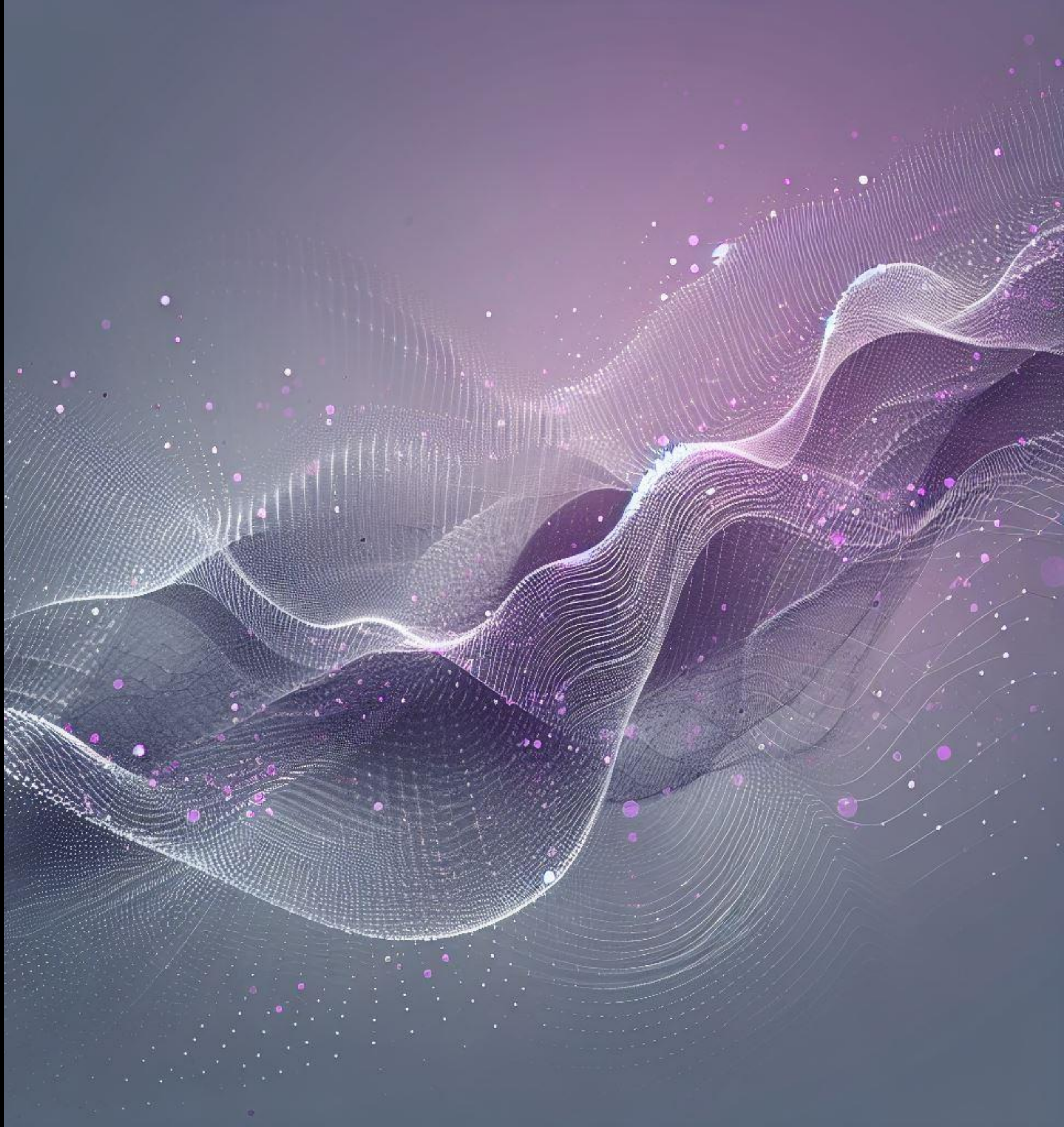
Reshaping the FES

- A re-structure of FES funding elements to reflect our Long-Range Plan strategy
- We will leverage opportunities in strategic directions (e.g., PPPs, international partnerships, specialized facilities) and link them to FES best practices

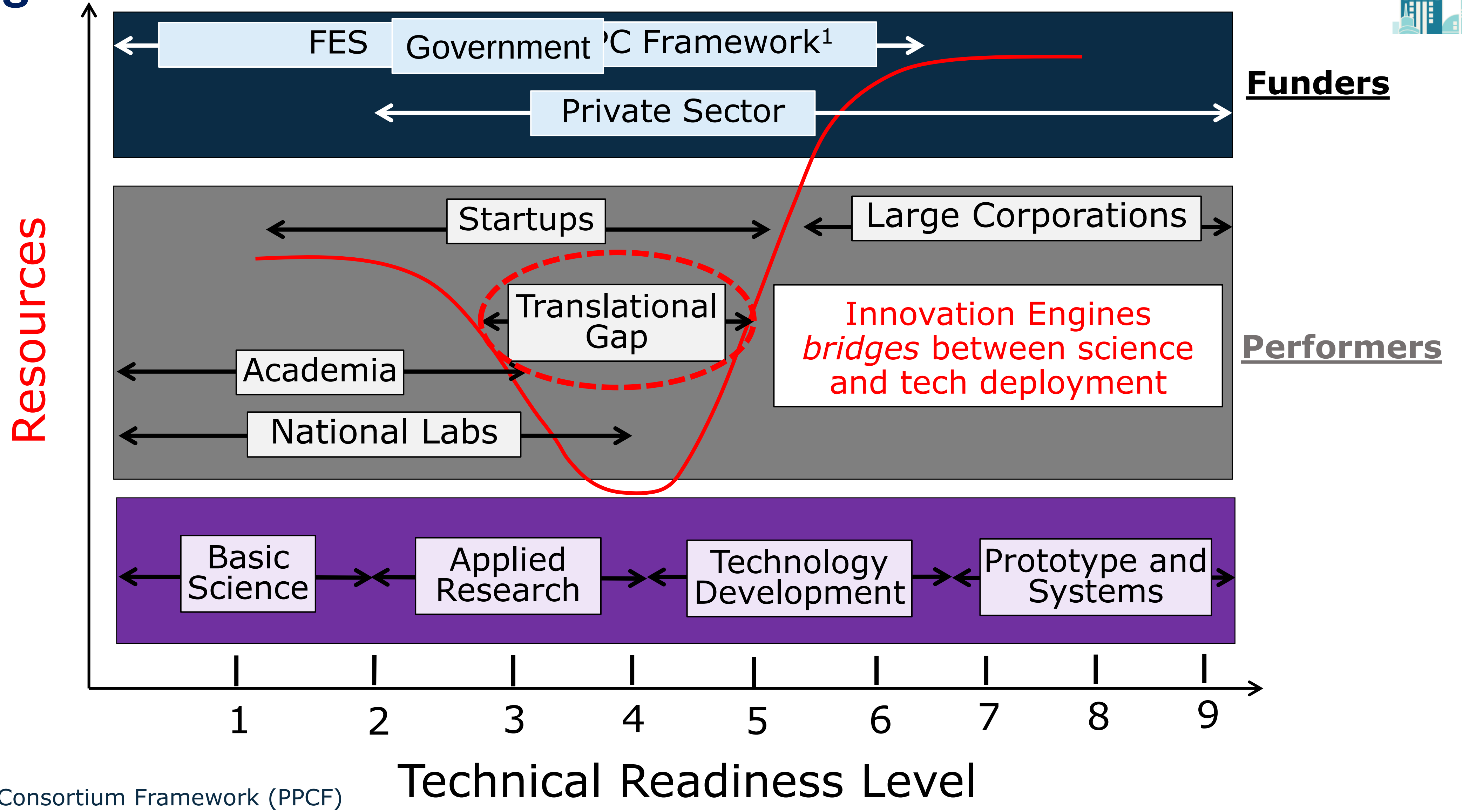
Theory and Simulation	Fusion Materials and Internal Components	Emergent Plasma Concepts	Closing the Fusion Cycle	Discovery Plasma Science and Technology
• Multi-scale modeling • Advanced Computing • FM&T multi-scale computation • AIML in control systems	• Fusion Nuclear Materials • PFCs • Actuators • LMs • Adv. Manufacturing • MPEX	• Advanced and Spherical Tokamak • Stellarators • IFE, MIF • FRC, Mirror, Pinch • Enabling Technologies	• Nuclear Science • Blanket innovation • T, D, Li-6 management • Balance-of-Plant • RAMI • Waste streams	• Foundational Plasmas and Astrophyiscs • Industrial Plasmas • HEDLP • MEC-U • QIS

Cross-threads: DIII-D, NSTX-U, PPPs, new strategic facilities, & ITER

Realizing the Bold Decadal Vision



Building the fusion ecosystem: *Identifying where to establish bridges*



[1]Pubic Private Consortium Framework (PPCF)

We will have a bold plan towards de-risking FM&T gaps

US leadership and innovation to establish a PPP platform focused on FM&T gaps in an extreme burning plasma environment

Fusion is very challenging!

- Innovate in technology
- Innovate in cost, schedule, construction
- Build versatile platforms

Global Race to Fusion

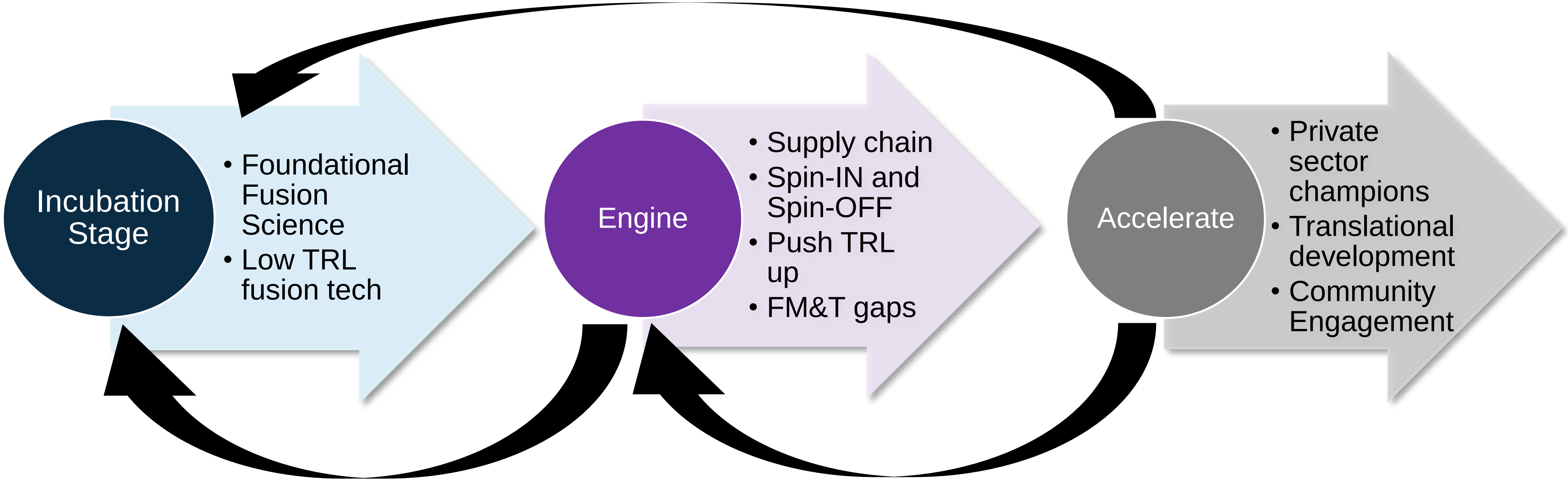
We need to be first! Build key FM&T infrastructure by end of this decade

Our Fusion community has been very active! Thank You for your engagement!

- **IFE BRN June 2022**
- **Fusion Prototypical Neutron Source Workshop Sept 2022 Hosted by EPRI**
- **Fusion Non-proliferation Hosted by PPPL in Jan**
- **Fusion Neutronics Hosted by ORNL in Jan**
  - Follow-on: Report summary and workshop
- **Fusion Magnet R&D Hosted by PPPL in Mar**
  - Follow-on: [Fusion Magnet Workshop]
- **Fusion Blanket and Fuel Cycle Hosted by EPRI in May**
  - Follow-on: [Blanket and Fuel Cycle Page] and a workshop roadmap report
- **Fusion Materials Hosted by EPRI Nov 14-15**

Fusion Innovation Research Engine (FIRE) Centers

FIRE Centers address critical scientific and technology gaps and bring together discovery science, innovation, and translational research in partnership with multiple public and private partners.
Science Drivers and themes: multi-scale computing and simulation, fusion materials, closing fuel cycle, plasma confinement innovation, blanket technology, and more.

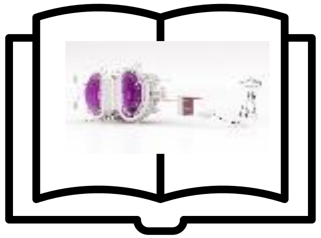


Milestone-Based Fusion Development Program and beyond

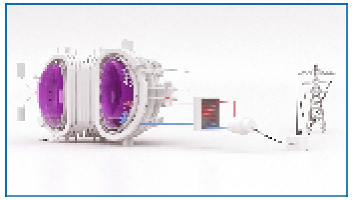
- Building resilient public-private partnerships that are equitable and provides a bridge to our public expertise and know-how in FES
- FES PPP portfolio: Milestone, INFUSE, other PPP elements are "seeds" for further development that must be translated to a framework for collaborative participation on fusion FM&T gaps and accelerated development

Milestone Work Scopes

- Enabling materials/technology
- Foundational (concept maturity)
- Manufacturing Readiness
- Community Benefits Plans
- Remote Maintenance
- Physics & Hardware demos
- Fuel Cycle
- Site & Cost Evaluation

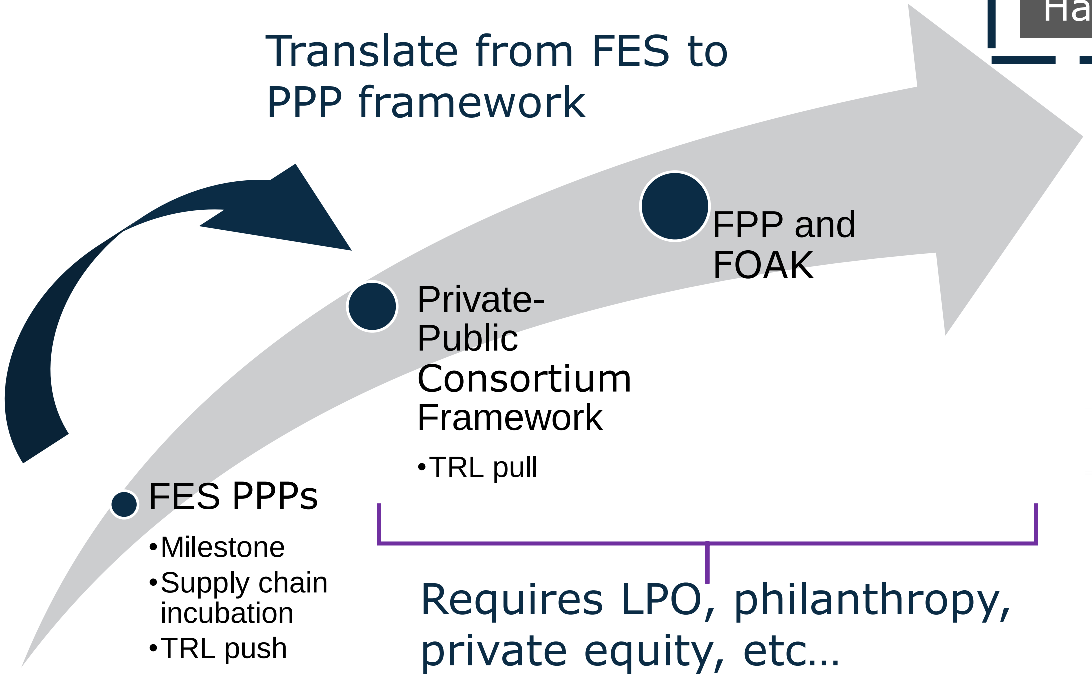


The Milestone Program *will* produce designs & data



The Milestone Program will *not* build fusion plants.

Translate from FES to PPP framework



Requires LPO, philanthropy, private equity, etc…

Commercial Fusion Industry

Realta Fusion, Commonwealth Fusion Systems, Thea Energy, Tokamak Energy, Xcimer Energy Corporation, Focused Energy, Zap Energy, Type One Energy

FES Public Private Partnership Elements

- INFUSE (Innovation Network for Fusion Energy)
  - Leverage National Laboratory and university infrastructure/capabilities for industry use
- Milestone-Based Fusion Development Program
  - Fusion companies partner with national labs and universities to provide viable FPP designs and technology roadmaps
- New PPP funding and financing program
  - Create a new bridge between the public and private sectors in fusion science and technology
  - Innovative PPP program to design and/or build facilities to de-risk low-TRL fusion technologies
  - To provide the public sector an opportunity to leverage strategic private sector infrastructure
  - CPP, FESAC LRP, FESAC IB, FESAC FCP, NASEM reports and US S&T Roadmap will all inform this program

International Partnerships in a New Era of Fusion Energy Development: *Public International Engagement Strategy for Fusion Energy*

- *Identify and pursue opportunities for international cooperation or partnerships on fusion R&D, and enable access to or shared development of key infrastructure*
- *Grow the future global marketplace*
- *Coordinate on regulatory frameworks that create a secure environment for fusion energy*
- *Foster and strengthen a diverse and global workforce pipeline*
- *Improve public education and engagement in fusion energy*

Special Presidential Envoy for Climate John Kerry at COP-28

International Partnerships

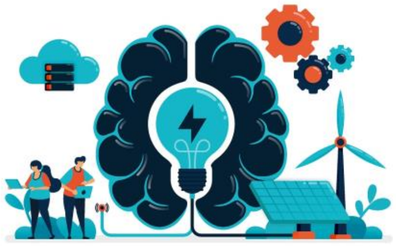
- FES will strengthen existing partnerships and establish new ones focused on three primary themes:
  - *Access or shared development of key infrastructure addressing fusion FM&T gaps (FESAC LRP, FESAC International Benchmark)*
  - *Support of fusion technology supply chains by driving innovation*
  - *Support global workforce development, public engagement and fusion education*
- *New opportunities to engage our international partners will be forthcoming*

Coming in 2024

- FES Virtual Town Hall Series: hosted by performers, focused on emergent topics in fusion science and technology

- New FES opportunities (join us!)
  - **IPAs:** Engage with our leadership and program managers to help establish U.S. National Fusion S&T Roadmap
  - **Early-Career Scientists**: New program for early-career scientists that want experience in policy and program management

- An Evolving FES
  - Re-structure FES budget to reflect the FESAC LRP fusion science drivers and plasma discovery priorities.
  - Establish a Fusion Science & Technology Roadmap
  - Begin facility CD-0 studies and begin linking to Roadmap
  - Build new public-private partnership bridges and activities



Key Takeaways

- Foundational Science is engine to innovate. We need a prolific and thriving Fusion Science office to help realize fusion energy.
- New FES vision will build a **metric-driven roadmap towards** fusion energy by having a clear **focus on remaining science and technology** gaps supported by FESAC LRP.
- New FESAC charges will help guide roadmap (with community input from our workshops) in 2024 to align and prioritize FES program elements.
- A Fusion Science and Technology Roadmap will be bold and aggressive to build facility(ies) to de-risk S&T gaps and provide the U.S. options to help drive fusion energy development with creative international and public-private partnerships.

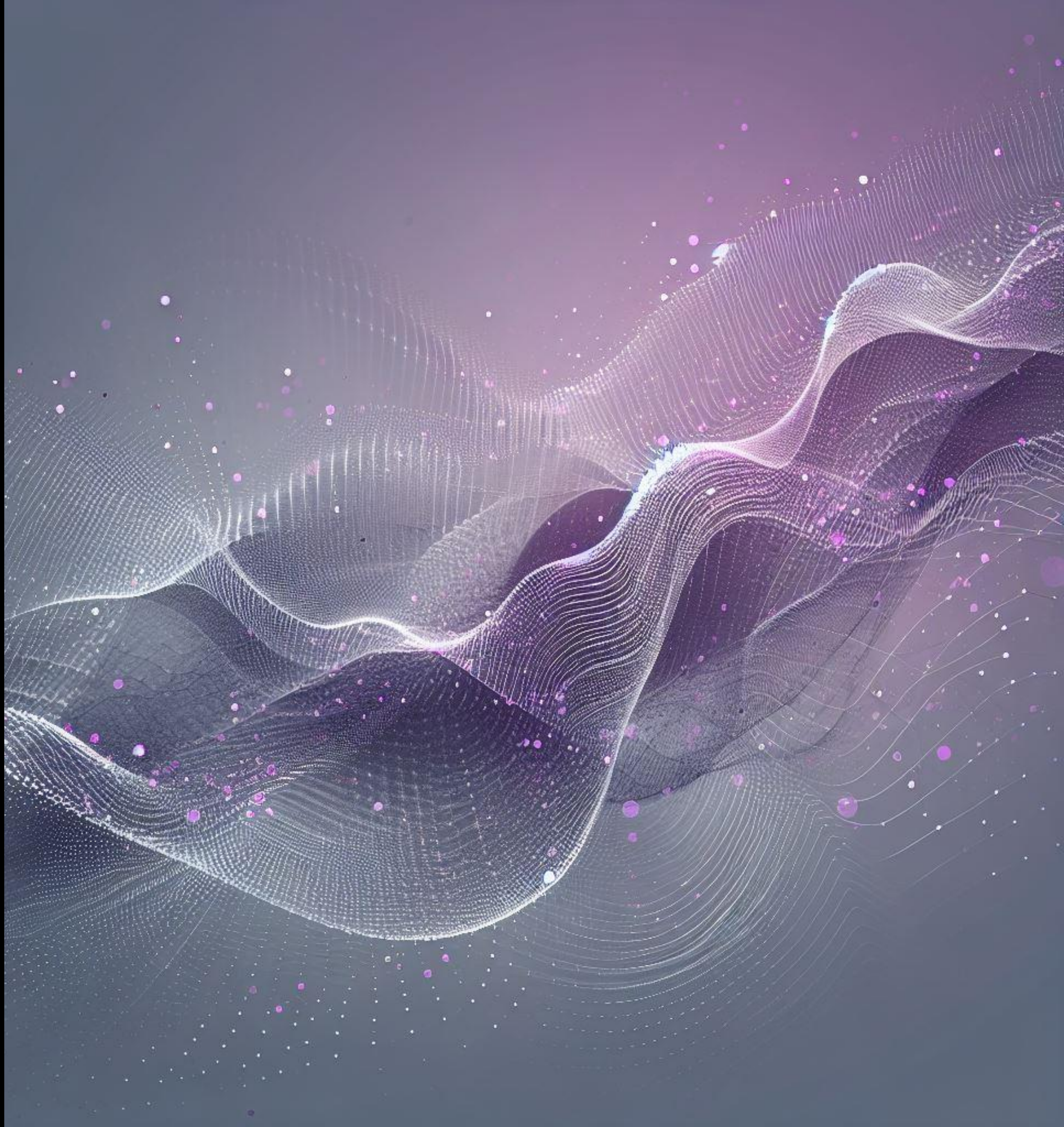
Fusion energy is in an unprecedented era due to an increase in global public and private funding and a culmination of decades of scientific research and development.

Fusion Energy is a critical element for multiple strategies aimed at overcoming our net-zero carbon challenges.

FES will continue to be a responsible steward of taxpayer funding – maximizing the impact of available resources.

Silos have no place in the vibrant U.S. fusion ecosystem. It is imperative that we collaboratively leverage our strengths, uniting to address the science and technology gaps outlined by CPP/LRP initiatives.

Extra Slides



Milestone Program: 8 Teams selected for funded awards

Tokamaks

Commonwealth Fusion Systems

Tokamak Energy

Inertial Fusion Energy

XCIMER ENERGY CORPORATION

FOCUSED ENERGY

Stellarators

TYPE ONE ENERGY

THEA ENERGY

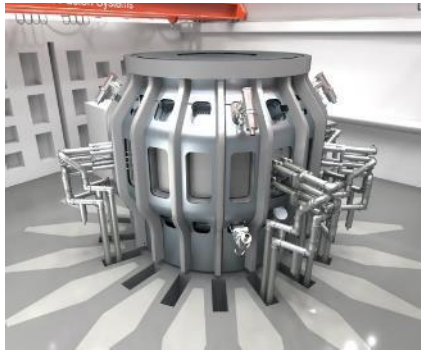
Alternates

ZAP ENERGY

REALTA FUSION

Tokamaks

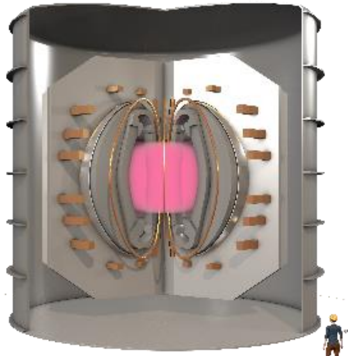
Commonwealth Fusion Systems



Innovation: Modern, high field superconducting magnets to enable compact, high gain tokamaks

https://cfs.energy/technology/sparc

Tokamak Energy

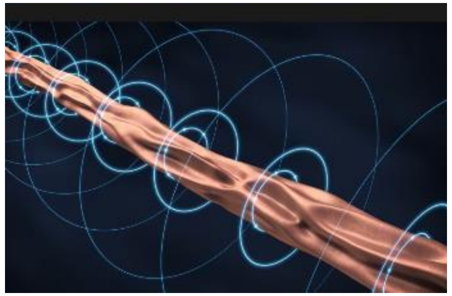


Innovation: ST40, the world's highest field spherical tokamak (UK) has shown fusion-relevant ion temperatures in a compact spherical tokamak for the first time

https://www.tokamakenergy.co.uk/technology/

Alternates

ZAP ENERGY



Innovation: The sheared flow-stabilized (SFS) Z-pinch may offer favorable scaling, simplicity & stability vs. traditional z-pinches.

https://www.zapenergy.com/how-it-works

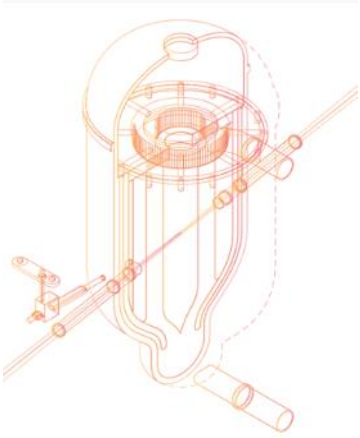
REALTA FUSION

Innovation: HTS may help make the physics of a magnetic mirror viable. Team is also considering industrial heat applications, which should help make the mirror economically viable.

https://realtafusion.com/

Inertial Fusion Energy

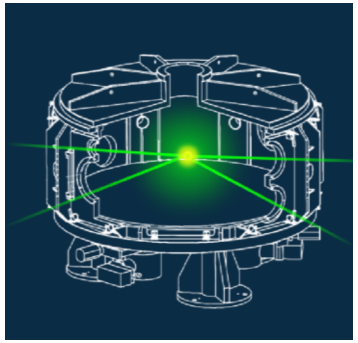
XCIMER ENERGY CORPORATION



Innovation: Excimer lasers to heat & compress a fuel pellet, which should offer greater efficiency, lower cost, and simpler operation than existing laser facilities.

https://xcimer.energy/index.html

FOCUSED ENERGY

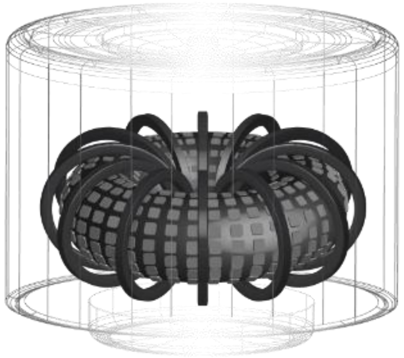


Innovation: Proton fast ignition (PFI), separates the two stages of fuel compression & heating, with targets that are robust against laser/target imperfections.

https://focused-energy.world/

Stellarators

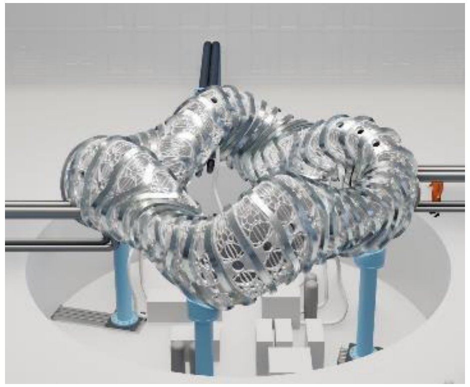
THEA ENERGY



Innovation: Arrays of planar magnets on the surface which should offer a cheaper, lower maintenance pathway to fusion.

https://thea.energy/history/

TYPE ONE ENERGY



Innovation: Advanced manufacturing and improved computational design tools + HTS magnets to reduce cost of the stellarator platform

https://typeoneenergy.com/envisioning-a-fusion-future/

FY 2023 Early Career Research Awards

FES has made four university and four lab awards in 2023

Prof. Elizabeth Paul, Columbia University
Modeling Fast Ion-mode Interactions Toward a Stellarator Fusion Power Plant

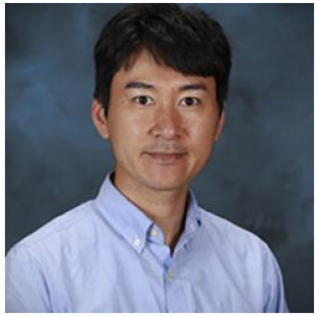
Prof. Derek Schaeffer, UCLA
Ion Acceleration by Quasi-Parallel Magnetized Collisionless Shocks

Prof. Chuanfei Dong, Boston University
Reconnection-Driven Turbulent Cascade in Magnetized Collisional and Collisionless Plasmas

Prof. Lane Carasik, Virginia Commonwealth University
Viability of a Molten Salt Liquid Immersion Breeder Blanket System for Heat Removal and Power Extraction in Fusion Devices

Dr. Holly Flynn, SRNL
The Development of a Real-Time Accountancy Open Framework for Fusion Energy

Dr. Vinicius Duarte, PPPL
Phase-Space Engineering of Supra-thermal Particle Distribution for Optimizing Burning Plasma Scenarios



Dr. Takaaki Koyanagi, ORNL
Advanced Additive Manufacturing of Silicon Carbide for Fusion Applications

Dr. Daniel Casey, LLNL
Understanding Implosion Physics Degradations to Advance IFE-Relevant Targets

$14M invested in tremendous talent from our national labs and universities!

FY 2023 FES Postdoctoral Fellows

Dr. Todd Elder
Research Title: Exploring novel methods to simplify stellarator design
Institutions: University of Maryland - Institute for Research in Electronics & Applied Physics and Max-Planck Institute for Plasma Physics – Greifswald, Germany

Dr. Felipe Novais
Research Title: Detailed Neutronics Analysis and Optimization of Fusion Nuclear Devices
Institution: Plasma Science and Fusion Center - Massachusetts Institute of Technology

Dr. Alvin Garcia
Research Title: Machine-learning based fast-ion profile prediction using FIDA diagnostic data on DIII-D
Institution- Princeton Plasma Physics Laboratory

Dr. Rebecca Masline
Research Title: Physics of helium transport and exhaust in compact tokamak fusion pilot plant divertors
Institution: Massachusetts Institute of Technology Plasma Science and Fusion Center

FY 2022 FES Funding Opportunity Announcements

FOA Title	Results
Collaborative Research in Magnetic Fusion Energy Sciences on International Tokamaks	10 awards at $30M for three years
Collaborative Research on International and Domestic Spherical Tokamaks	12 awards at $20M for three years
High-Energy-Density Laboratory Plasma Science (joint program with NNSA)	9 FES awards at $3.4M & 11 NNSA awards at $4.9M for three years (Total: $8.3M)
Opportunities in Frontier Plasma Science	20 awards at $3.2M for one to two years
SC Early Career Research Program	9 FES five-year awards (5 to universities and 4 to Labs), $14M total, $6M in FY 2022
FES-Reaching a New Energy Sciences Workforce (RENEW)	6 awards at $4M for two years (4 to universities and 2 to Labs)
Milestone-Based Fusion Development Program	8 awards at $46M for five years (initial funding for 18 months)

Additional awards in other parts of the program (e.g., Theory & Simulation, Materials Science, DIII-D collaborations, etc.) were made through the SC Annual FOA

FY 2023 FES Funding Opportunity Announcements

FOA Title	Results
Scientific Discovery through Advanced Computing (SciDAC) – FES Partnerships	12 multi-institutional awards at $120M for four years
Machine Learning, Artificial Intelligence, and Data Resources for Fusion Energy Sciences	20 awards at $29M for three years
Innovative Fusion Technology and Collaborative Fusion Energy Research in the DIII-D National Program	9 awards at $18M for three years
High-Energy-Density Laboratory Plasma Science (joint program with NNSA)	10 FES awards at $4.65M$ & 1 NNSA award at $0.6M for three years (Total: $5.25M)
SC Early Career Research Program	8 FES five-year awards (4 to universities and 4 to Labs), $13.5M total, $5.5M in FY 2023
Research in Basic Plasma Science and Engineering	13 awards at $8.5M for three years
Research on General Plasma Science Collaborative Research Facilities	17 awards at $1.5M for one to two years
Quantum Information Science Research for Fusion Energy Sciences	6 awards at $11.4 for three years

FY 2023 FES Funding Opportunity Announcements – cont.

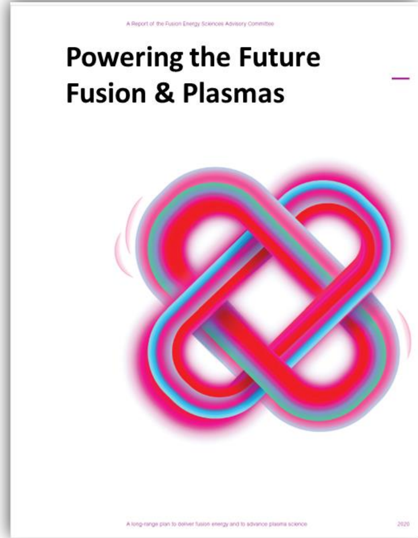
FOA Title	Results
LaserNetUS for Discovery Science and IFE	10 awards at $28.5M for three years
Inertial Fusion Energy Science & Technology Accelerated Research (IFE-STAR).	3 multi-institutional awards at $42M for four years
FES-Reaching a New Energy Sciences Workforce (RENEW)	5 awards at $6.3M for three years
Funding Accelerated Inclusive Research (FAIR)	3 awards at $2.2M for three years
Accelerate Innovations in Emerging Technologies	1 award at $8M.

Additional awards in other parts of the program (e.g., Theory & Simulation, Materials Science, etc.) were made through the SC Annual FOA

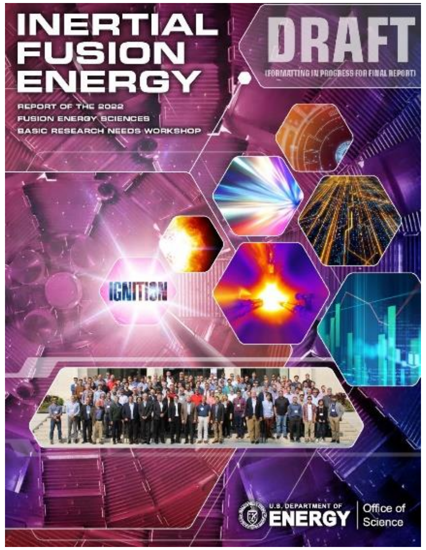
For more information, check:

- Funding Opportunity Announcements: https://science.osti.gov/fes/Funding-Opportunities
- Award information:
  - https://science.osti.gov/Funding-Opportunities/Award, and
  - https://pamspublic.science.energy.gov/WebPAMSExternal/interface/awards/AwardSearchExternal.aspx

Inertial Fusion Energy (IFE) in FES



LRP:
"An IFE program that leverages US leadership and current investments should be targeted."



IFE Basic Research Needs Workshop Report:
"The recent demonstration of thermonuclear ignition on the National Ignition Facility constitutes a pivotal point in the development of inertial fusion energy."

Background

– In December 2022, the National Ignition Facility achieved ignition and scientific (target) gain of 1.5 and repeated this feat with a gain of 2.0 in July 2023!

IFE Research Activities

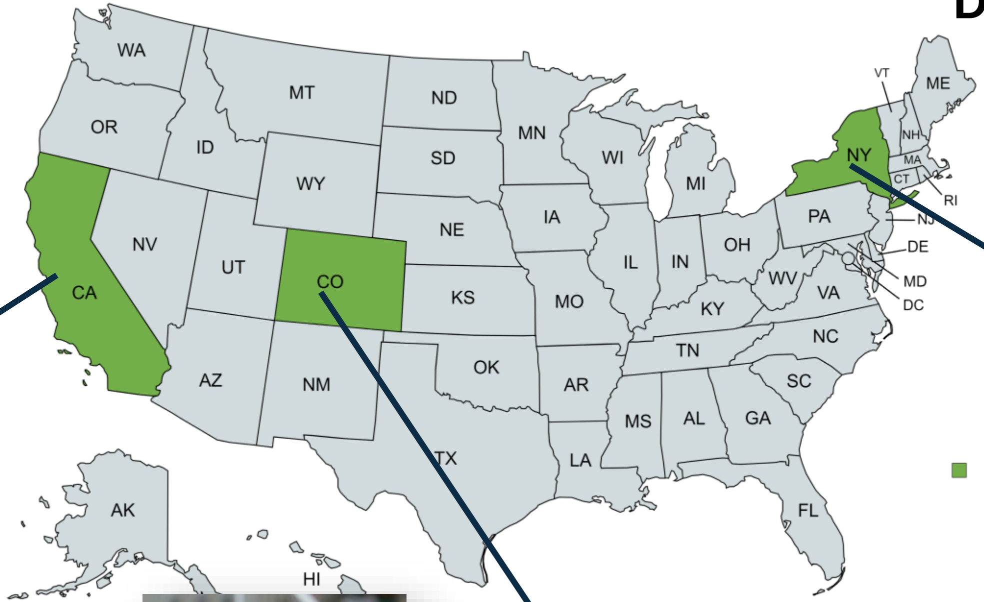
– A FOA was issued in FY 2023 to address the Priority Research Opportunities (PROs) outlined in the IFE BRN with announcement pending.

– The PROs include S&T in Target Physics & Ignition, Driver & Target Technologies, IFE Workforce Development, and Public-Private Partnerships.

Inertial Fusion Energy Accelerated Research (IFE-STAR) Awardees

Director
Tammy Ma
LLNL

THE NATIONAL IFE “**STARFIRE**” HUB: SCIENCE & TECHNOLOGY ACCELERATED RESEARCH FOR FUSION INNOVATION & REACTOR ENGINEERING

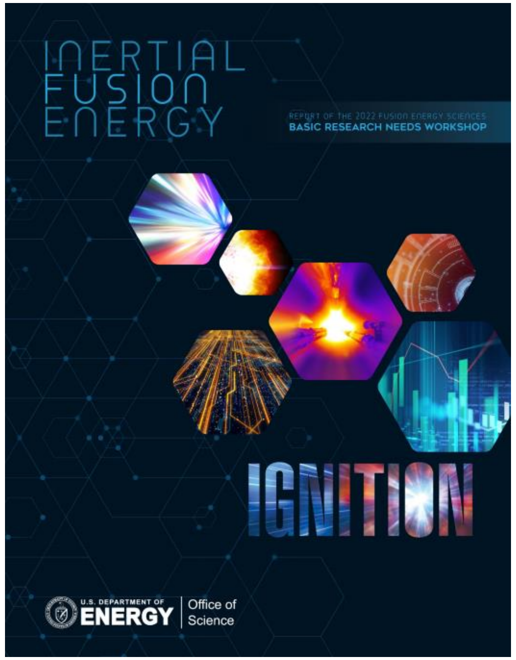


Director
Dustin Froula
UR/LLE

A Hub for **Broadband** Laser-Plasma Science Focused on Inertial Fusion Energy

Director
Carmen Menoni
CSU

THE INERTIAL FUSION SCIENCE AND TECHNOLOGY (**RISE**) HUB



Charges to the FESAC

J.P. Allain

U.S. DEPARTMENT OF ENERGY | Office of Science

FES Decadal Plan charge to the FESAC

The 2020 report of the Fusion Energy Sciences Advisory Committee (FESAC) Long-Range Plan (LRP) “Powering the Future: Fusion & Plasmas” states in its Executive Summary that “*Now is the time to move aggressively toward the deployment of fusion energy which could substantially power modern society while mitigating climate change*.” In addition, the same report states, “*Fulfilling the [fusion] energy mission demands a shift in the balance of research toward FM&T (Fusion Materials and Technology), which connects the three science drivers: Sustain a Burning Plasma, Engineer for Extreme Conditions, and Harness Fusion Energy*.” Furthermore, a key recommendation in the 2021 Consensus Study Report of the National Academies of Sciences, Engineering, and Medicine (NASEM) “Bringing Fusion to the U.S. Grid” was that “*For the United States to be a leader in fusion and to make an impact on the transition to a low-carbon emission electrical system by 2050, the Department of Energy and the private sector should produce net electricity in a fusion pilot plant in the United States in the 2035-2040 timeframe*.” The recommendations in these reports, which reflected the tremendous progress in fusion science and technology over the last decades as well as the rapid growth and significant investments of the private sector in fusion, contributed to the Administration’s recognition of the potential of fusion energy to advance the goal to get to net-zero emissions by 2050.

In March 2022, the White House Office of Science and Technology Policy and the Department of Energy co-hosted a summit on *Developing a Bold Decadal Vision for Commercial Fusion Energy*, which called for accelerating the viability of commercial fusion energy in partnership with the private sector. As a first major step in achieving the Bold Decadal Vision (BDV), the Fusion Energy Sciences (FES) program issued a Funding Opportunity Announcement (FOA), "Milestone-Based Fusion Development Program", to accelerate the development of a fusion pilot plant (FPP) by working with private industry. This initiative is also consistent with the Energy Act of 2020, which expanded the scientific mission of FES with supporting "*the development of a competitive fusion power industry in the U.S*."

The private sector responded enthusiastically to this FOA, and in May 2023, FES announced $46 million in awards to eight fusion startup companies. The Office of Fusion Energy Sciences (FES) budget request for fiscal year (FY) 2024 includes additional support for the BDV, specifically enhanced support for the Milestone Program, the establishment of fusion research and development (R&D) centers to resolve critical science and technology gaps, and support for future facilities studies including a fusion prototypic neutron source.

The BDV builds upon the FESAC LRP and the NASEM report and accelerates the timeline to an FPP. The FESAC LRP and the American Physical Society/Division of Plasma Physics (APS/DPP) Community Planning Process provided important community input on prioritization among various FES program elements. Given recent developments, it is necessary to re-assess the alignment of the FES program with the FESAC LRP and the expanded mission of the FES program in addressing the BDV in a decadal timeframe. Namely, what new opportunities exist for accelerating fusion energy development and what are some unique synergistic opportunities with discovery plasma science and technology.

We are therefore asking FESAC to form a subcommittee to re-assess the program elements and their alignment with the FESAC LRP science drivers and the BDV, within the four major categories of the FES budget structure: Burning Plasma Science: Foundations (which includes Advanced Tokamak, Spherical Tokamak, Theory & Simulation, Public-Private Partnerships, and Inertial Fusion Energy); Burning Plasma Science: Long Pulse (which includes the FES international collaborations under Long Pulse: Tokamak, international collaborations and domestic efforts under Long Pulse: Stellarators, and Materials & Fusion Nuclear Science); Burning Plasma Science: High Power (which includes ITER Research); and Discovery Plasma Science (which includes General Plasma Science, High-Energy Density Laboratory Plasmas, and Measurement Innovation). The subcommittee should represent diversity in experiences and perspectives, especially as relates to the private sector engagement requirements to achieve the goals of the BDV.

The following program elements will not be part of the requested assessment: United States (U.S) Contributions to ITER project, Artificial Intelligence/Machine Learning, Material Plasma Exposure eXperiment project, Matter in Extreme Conditions – Upgrade project, Quantum Information Science, Advanced Microelectronics, Advanced Manufacturing, Reaching a New Energy Science Workforce, Funding for Accelerated Inclusive Research, Accelerate Innovations in Emerging Technologies (Accelerate), Established Program to Stimulate Competitive Research, General Plant Projects/General Purpose Equipment/Infrastructure, and Other Research.

For each program element in each category, identify opportunities or current plans to contribute to the FESAC LRP FM&T and fusion plasma science gaps establishing the basis of an FPP in the context of the BDV, taking into consideration the diversity in FPP concepts represented in the Milestone Program awardees. In particular, identify a scope that will address near-term scientific and technological gaps impacting the design and construction of an FPP on the pathway to commercialization within the timeframe of the BDV.

For the scope within a program element that is not identified as critical to support the LRP Science Drivers or the BDV, identify specific elements that can be deferred with minimal or modest impact on the FES Program to enable redirection in support of the LRP FM&T gaps and the BDV. Identify the program elements that need to be increased to meet the goals of the LRP FM&T gaps establishing the basis of an FPP in the context of the BDV and those that can be decreased. In addition, the subcommittee should identify the role of the public sector and the FES user facilities (National Spherical Torus Experiment - Upgrade and Doublet III) in addressing the FM&T gaps and advancing commercial fusion applications going forward. Throughout the process, please take the full FESAC LRP into account and consider sustainable support for foundational research as synergies between discovery plasma science and fusion energy development (e.g., spin-off plasma technology applications from fusion) are valued.

In your deliberations, you should consider the impact of your recommendations on workforce continuity, diversity of the workforce, and continuing U.S. leadership in fusion and plasma science. Your assessment should be informed by the APS/DPP Community Planning Process report, FESAC LRP, NASEM report, objectives of the Administration’s BDV, and recent workshop reports and community reports. We would appreciate receiving a final written report from FESAC by Fall 2024.

Facilities Construction Projects Charge to FESAC

The Department of Energy's Office of Science (SC) has envisioned, designed, constructed, and operated many of the premiere scientific research facilities in the world. More than 38,000 researchers from universities, other government agencies, and private industry use SC User Facilities each year—and this number continues to grow.

Stewarding these facilities for the benefit of science is at the core of our mission and is part of our unique contribution to our Nation's scientific strength. It is important that we continue to do what we do best: build facilities that create institutional capacity for strengthening multidisciplinary science, provide world class research tools that attract the best minds, create new capabilities for exploring the frontiers of the natural and physical sciences, and stimulate scientific discovery through computer simulation of complex systems.

To this end, I am asking the SC advisory committees to look toward the scientific horizon and identify what new or upgraded facilities will best serve our needs in the next ten years (2024-2034). More specifically, I am charging each advisory committee to establish a subcommittee to:

1. Consider what new or upgraded facilities in your disciplines will be necessary to position the Office of Science at the forefront of scientific discovery. The Office of Science Associate Directors have prepared a list of proposed projects that could contribute to world leading science in their respective programs in the next ten years. The Designated Federal Officer (DFO) will transmit this material to their respective advisory committee chairs. The subcommittee may revise the list in consultation with their DFO and Committee Chair. If you wish to add projects, please consider only those that require a minimum investment of $100 million. In its deliberations, the subcommittee should reference relevant strategic planning documents and decadal studies.

2. Deliver a short letter report that discusses each of these facilities in terms of thetwo criteria below and provide a short justification for the categorization, but do not rank order them:

a. **The potential to contribute to world-leading science in the next decade.** For each proposed facility/upgrade consider, for example, the extent to which it would answer the most important scientific questions; whether there are other ways or other facilities that would be able to answer these questions; whether the facility would contribute to many or few areas of research and especially whether the facility will address needs of the broad community of users including those whose research is
supported by other Federal agencies; whether construction of the facility will create new synergies within a field or among fields of research; and what level of demand exists within the (sometimes many) scientific communities that use the facility. **Please place each facility or upgrade in one of four categories: (a) absolutely central; (b) important; (c) lower priority; or (d) don't know enough yet.**

b. **The readiness for construction**. For proposed facilities and major upgrades, please consider, for example, whether the concept of the facility has been formally studied; the level of confidence that the technical challenges involved in building the facility can be met; the sufficiency of R&D performed to date to assure technical feasibility of the facility; the extent to which the cost to build and operate the facility is understood; and site infrastructure readiness. **Please place each facility in one of three categories: (a) ready to initiate construction; (b) significant scientific/engineering challenges to resolve before initiating construction; or (c) mission and technical requirements not yet fully defined.**

Many additional criteria, such as expected funding levels, are important when considering a possible portfolio of future facilities, however, for this assessment I ask that you focus your report on the two criteria discussed above.

I look forward to hearing your findings and thank you for your help with this important task. I appreciate receiving your **final report by May 2024.**