Powering the Future

Fusion & Plasmas

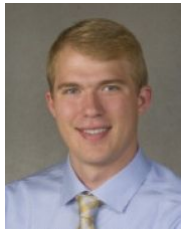
A long-range plan to deliver fusion energy and to advance plasma science

FPA Meeting, December 2020

2018 FESAC Charge

- Charge covers entire FES portfolio: "…should identify and prioritize the research required to advance both the scientific foundation needed to develop a fusion energy source, as well as the broader FES mission to steward plasma science."
- Two part process, community driven phase (Community Planning Process) and FESAC-led phase
- "Optimized FES program over the next ten years" (FY22-FY31). Consider three budget scenarios: constant level of effort, modest growth (2% above inflation), and unconstrained but prioritized
- "...assume that the US Contributions to ITER project will continue throughout this entire period": focus on the non-ITER-project portion of the budget.

FESAC Long Range Planning Subcommittee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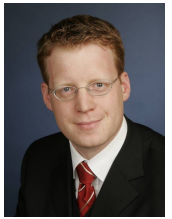
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Subcommittee Process

- Subcommittee work began February, ramped up with delivery of the “Phase 1” Community Planning Process report in March
- Entire process conducted virtually (many subcommittee members have never met before in person). Uncountable number hours spent on Zoom (countable number on MS Teams)
- Many guest speakers: from other federal agencies, on related reports, on private-public partnership models
- Community engagement through focus groups, virtual workshop
- Scenarios developed using extensive budget analysis: utilizing data from FES, range of inputs on facilities costs including costing experts with extensive DOE project experience (Jeff Hoy, Carl Strawbridge)
- Worked by consensus process to produce the final report

Executive summary: Now is the time for fusion & plasmas

- **Now is the time** to move aggressively toward the development of fusion energy. Recent advances point the way toward a unique US vision for fusion development, targeting a fusion pilot plant by the 2040s. Growth of a fusion energy industry is important for this vision and that industry is already seeded.
- **Plasmas transform society.** Far-reaching impact spans: advances key to enabling fusion energy; deeper understanding of our universe; creating exotic states of matter with the most intense lasers in the world; transformative applications that impact our everyday lives and have the potential to enable a more sustainable society
- **Fusion and plasmas are inextricably linked,** have strong connections and important shared history

Executive summary: Partnerships and Leadership

- **Partnerships accelerate progress.** International partnership, especially ITER, is critical. Public private partnerships have the potential to reduce time to commercially viable fusion and support the growth of a fusion energy industry. Interagency partnerships can maximize progress in research and development.
- **Fusion and plasma research in the US are world-leading; continued scientific leadership requires nurturing and agility.** US is poised to create world-leading fusion industry, should be supported. Leadership in key areas is threatened by the absence of investment in major new facilities to address critical R&D needs.

Executive summary: First time process

- **For the first time, scientists have created a long-range plan to accelerate the development of fusion energy AND advance plasma science.** The community-driven CPP process is the foundation of this long-range planning process. Not only identified important new opportunities, but developed guidance for prioritization through a consensus process. The resulting CPP report forms the basis for this strategy.

THANK YOU!

New directions for the FES program

- The Fusion Science and Technology (FST) area should focus on establishing the scientific and technical basis for a fusion pilot plant by the 2040s
- The Plasma Science and Technology (PST) area should focus on new opportunities to advance fundamental understanding, and in turn translate these advances into technologies that benefit society
- These new directions are embodied in six technology and science drivers

Technology and Science Drivers: FST

- **Sustain a burning plasma**
  Build the science and technology required to confine and sustain a burning plasma
- **Engineer for extreme conditions**
  Develop the materials required to withstand the extreme environment of a fusion reactor
- **Harness fusion power**
  Engineer the technologies required to breed fusion fuel and to generate electricity in a fusion pilot plant

Technology and Science Drivers: PST

- **Understand the plasma universe**
  Plasmas permeate the universe and are the heart of the most energetic events we observe
- **Strengthen the foundations**
  Explore and discover new regimes and exotic states of matter, enabled by new experimental capabilities
- **Create transformative technologies**
  Unlock the potential of plasmas to transform society

Overarching Recommendations

- **Resources for ongoing design and construction of major new experimental facilities should be established in the DOE Fusion Energy Sciences budget**
- **Opportunities should be provided for developing new experimental capabilities at a range of scales, as appropriate to address the goals of this strategic plan**
- **Maturation of pre-conceptual designs, scope, and costing for proposed new experimental facilities should be part of regular program activities**
- **This long-range planning process, including a strong community-led component, should be repeated no later than every five years in order to update the strategic plan**

Overarching Recommendations, cont'd

- **Expand existing and establish new public-private partnership (PPP) programs to leverage capabilities, reduce cost, and accelerate the commercialization of fusion power and plasma technologies**
- **Explore and implement mechanisms for formal coordination between funding agencies that support fusion and plasma science research**
- **DOE and FES should develop and implement plans to increase diversity, equity and inclusion in our community. This should be done in consultation with DEI experts and in collaboration with other institutions; involving study of workplace climate, policies, and practices, via assessment metrics and standard practices.**
- **Restore DOE's ability to execute discipline-specific workforce development programs that can help recruit diverse new talent to FES-supported fields of research**

FST Recommendations

- **Initiate a design effort that engages all stakeholders to establish the technical basis for closing critical gaps for a fusion pilot plant, utilizing and strengthening the US's world-leading theory and computation capabilities and engineering design tools.**
- **Rapidly expand the research and development effort in fusion materials and technology**
- **Immediately establish the mission need for an FPNS facility to support development of new materials suitable for use in the fusion nuclear environment, and pursue design and construction as soon as possible**
- **Develop the scientific infrastructure necessary for the study of plasma-materials interactions needed to develop plasma facing components for a fusion pilot plant by completing the MPEX and additional high-heat flux testing facilities**
- **Significantly expand blanket and tritium R&D programs**

FST Recommendations, cont'd

- **Utilize research operations on DIII-D and NSTX-U, and collaborate with other world-leading facilities, to ensure timely closure of FPP design gaps.**
- **Ensure full engagement of the US fusion community in ITER by forming an ITER research team that capitalizes on our investment to access a high gain burning plasma**
- **Immediately establish the mission need for an EXCITE facility to close the integrated tokamak exhaust and performance gap and pursue design and construction as soon as possible**
- **Strengthen the innovative and transformative research that offers promising opportunities for fusion energy commercialization: stellarators, liquid metal plasma facing components, inertial fusion energy and alternate concepts**

PST Recommendations

- **Steady support for fundamental plasma science is needed to enable a stream of innovative ideas and talent; laying the scientific foundation upon which the next generation of plasma-based technologies can be built**
- **Complete the design and construction of MEC-Upgrade**
- **Establish a plasma-based technology research program focused on translating fundamental scientific findings into societally beneficial applications**
- **Coordinate a High Intensity Laser Research Initiative in collaboration with relevant DOE offices and other federal agencies**
- **Pursue the development of a multi-petawatt laser facility and a high-repetition-rate high-intensity laser facility in the US, in partnership with other federal agencies where possible.**

PST & Cross Cutting Recommendations

- **Support networks to coordinate research and broaden access to state-of-the-art facilities, diagnostics, and computational tools**
- **Strengthen support of laboratory-based research relevant to astrophysical and space plasmas through increased programmatic and facility funding as well as expansion of partnership opportunities**

Cross cutting:

- **Ensure robust support for foundational research activities that underpin all aspects of plasma and fusion science and technology**
- **Support research that supplies the fundamental data required to advance fusion energy and plasma science and engineering**

Scenarios: Significant return on increased investment

- Constant level of effort: redirection can occur and important scientific and technical progress will continue, but major lost opportunities, significant risk to FPP goal and US leadership position
- Significant return on the investment for the increment from the constant to the modest growth scenario. However, risks and missed opportunities remain, including threat to the goal of an FPP by 2040s.
- Unconstrained scenario: the complete strategy can be implemented. Additional investment beyond the modest growth scenario will have substantial return. Important scientific advances would be enabled and progress toward realizing practical fusion energy would be accelerated.
  - With staging, program pivoting, and utilization of partnerships, we believe these additional activities can be accomplished in a timely manner and under realizable budgets