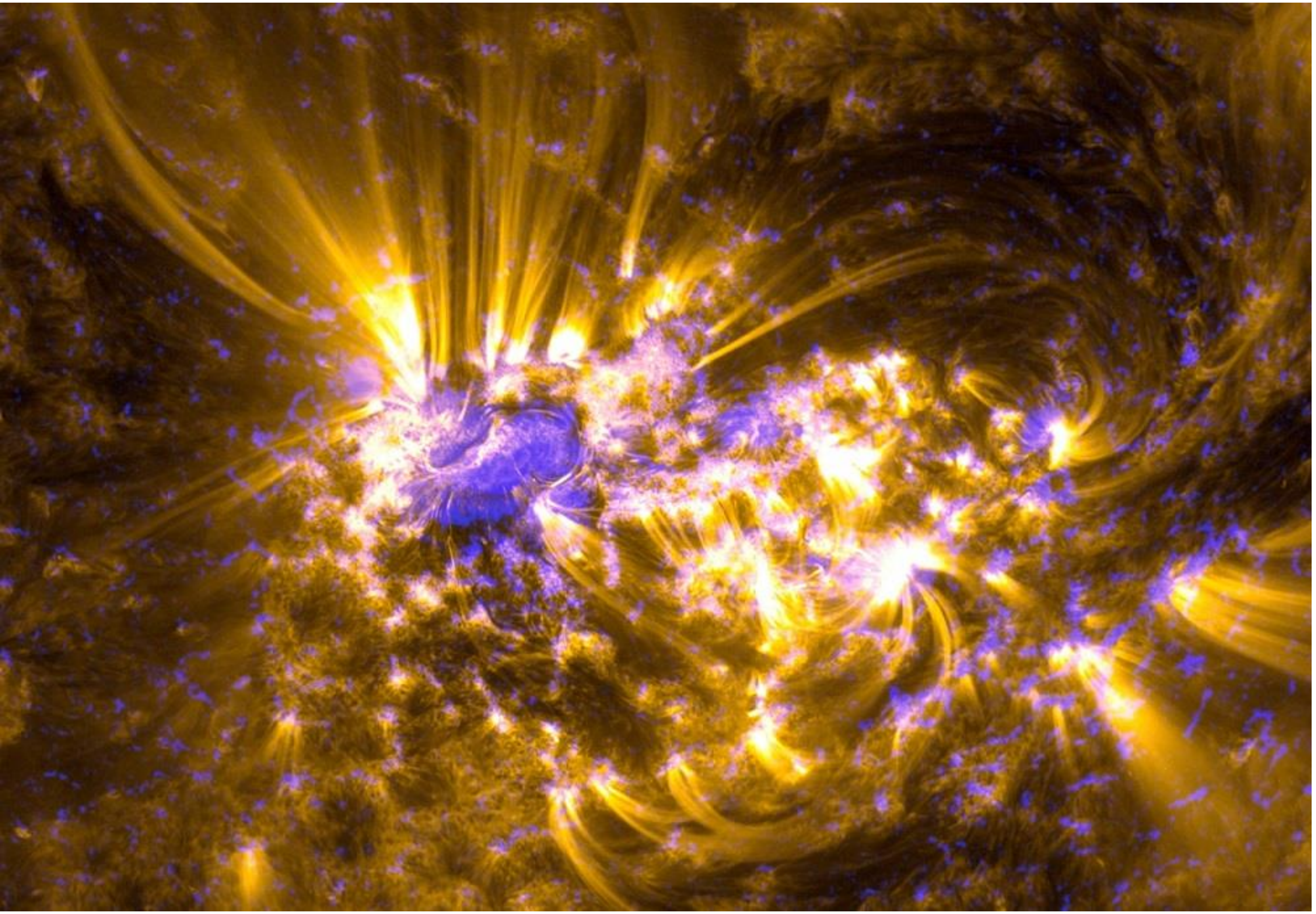
Public-Private Partnerships



Innovation Network for Fusion Energy: Past Performance, Future Plans and Lessons Learned

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FESAC Meeting
August 31, 2021

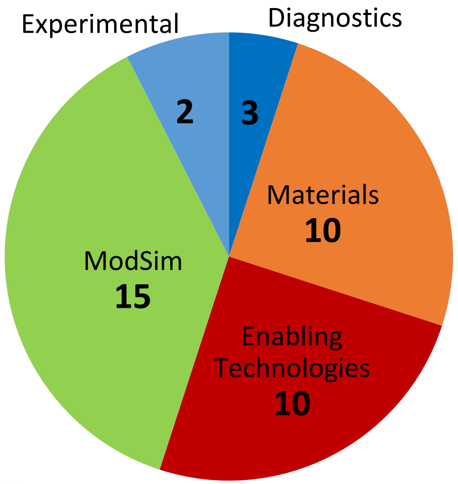
https://infuse.ornl.gov/

INFUSE Innovation Network for Fusion Energy

AWARDS

- 40 projects funded to date with a total value of $9.93 M ($7.77 M DOE)
- The 40 awards went to 17 U.S. companies in 9 states involving 8 national labs
- Detailed list: https://infuse.ornl.gov/wp-content/uploads/2021/01/Cumulative_AwardList.pdf

Awarded Topical Areas



10 Participating laboratories:

Topical areas:

1) Enabling Technologies including magnets
2) Materials Science
3) Plasma Diagnostics
4) Theory and Simulation
5) Magnetic Fusion Experimental Capabilities

Program Overview

- **INFUSE program is a Public-Private Partnership (P3) Program started by FES with a Pilot Program in FY 2019**
  - ***This is first of a kind P3 program within the Office of Science***

- **Initiated due to the recent surge in private sector investment in fusion energy - Leverages the many unique and important capabilities are located at DOE National Laboratories**

- **Focused on providing a quick, streamlined approach for companies to access DOE Laboratory Capabilities.**

- **The INFUSE Program is modeled after other successful DOE P3 programs, most notably the Gateway for Accelerated Innovation in Nuclear (GAIN) Nuclear Energy Voucher program established by the DOE Office of Nuclear Energy (NE), which has been very successful in providing the nuclear fission industrial community with access to the resources available across the DOE complex.**

- **The Request for Assistance (RFA) Calls are managed by a consortium of FES funded laboratories, led by ORNL and PPPL.**

Program Organization

INFUSE is implemented by the "Point-of-Contacts" POC panel whose members come from each of the participating laboratories. They provide program oversight and facilitate the P# program at their laboratory.

Laboratory	Point of Contact	Email
Brookhaven National Laboratory (BNL)	Ramesh Gupta	gupta@bnl.gov
Idaho National Laboratory (INL)	Paul Humrickhouse	paul.humrickhouse@inl.gov
Lawrence Berkeley National Laboratory (LBNL)	Steve Gourlay	sagourlay@lbl.gov
Lawrence Livermore National Laboratory (LLNL)	Andris Dimits	dimits1@llnl.gov
Los Alamos National Laboratory (LANL)	John Kline	jkline@lanl.gov
Oak Ridge National Laboratory (ORNL)	Dennis Youchison*	youchisondl@ornl.gov
Pacific Northwest National Laboratory (PNNL)	Wahyu Setyawan	wahyu.setyawan@pnnl.gov
Princeton Plasma Physics Laboratory (PPPL)	Ahmed Diallo**	adiallo@pppl.gov
Sandia National Laboratories (SNL)	Rob Kolasinski	rkolasi@sandia.gov
Savannah River National Laboratory (SRNL)	Jim Klein	james.klein@srnl.doe.gov

Interfaces:

- SC FES
- Lab SPP office
- DOE site office
- Company PIs and CEOs
- Lab capabilities and PIs

*INFUSE Director

**INFUSE Deputy Director

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Request for Assistance (RFA) Details

Scope

- Work is performed in support of the requesting company using expertise of DoE national lab focused on research necessary for the company's fusion goals, not commercialization
- Focused on unique capabilities at DOE laboratories, not items readily available elsewhere
- A single institution may submit up to five RFA's to a single RFA call

Budget and Schedule

- Majority of requests are for single year awards with a value of between $50k - $250k
- In special cases, applicants may request up to $500k in total value with a duration of up to two years 20 percent cost share is required, which can be cash, equipment, or in-kind contributions

Company Certification

- Requestors must certify that they will accept one of the two standardized Cooperative Research and Development Agreements (CRADAs)
- Requestors must certify that they will provide the required 20 percent upon selection for a partnership award

Request for Assistance (RFA) Details

Eligible Requester

- U.S. based private entity with U.S. ownership
- U.S. based private entity with foreign ownership so long as that entity's participation is in the economic interest of the U.S.

RFA Execution Requirements

- Most* work under an INFUSE award must be performed in the U.S.
- Products embodying intellectual property developed under the assistance must be substantially manufactured in the U.S.
- The transfer of technology and data resulting from INFUSE awards are subject to U.S. export control laws.

Merit Review

- The Review Process is organized by the INFUSE POC panel, with input provided to FES for final selection
- RFA applications are evaluated and competitively selected in accordance with the Office of Science Review Criteria
- Reviewers are asked to comment on the value of the work and impact to fusion overall

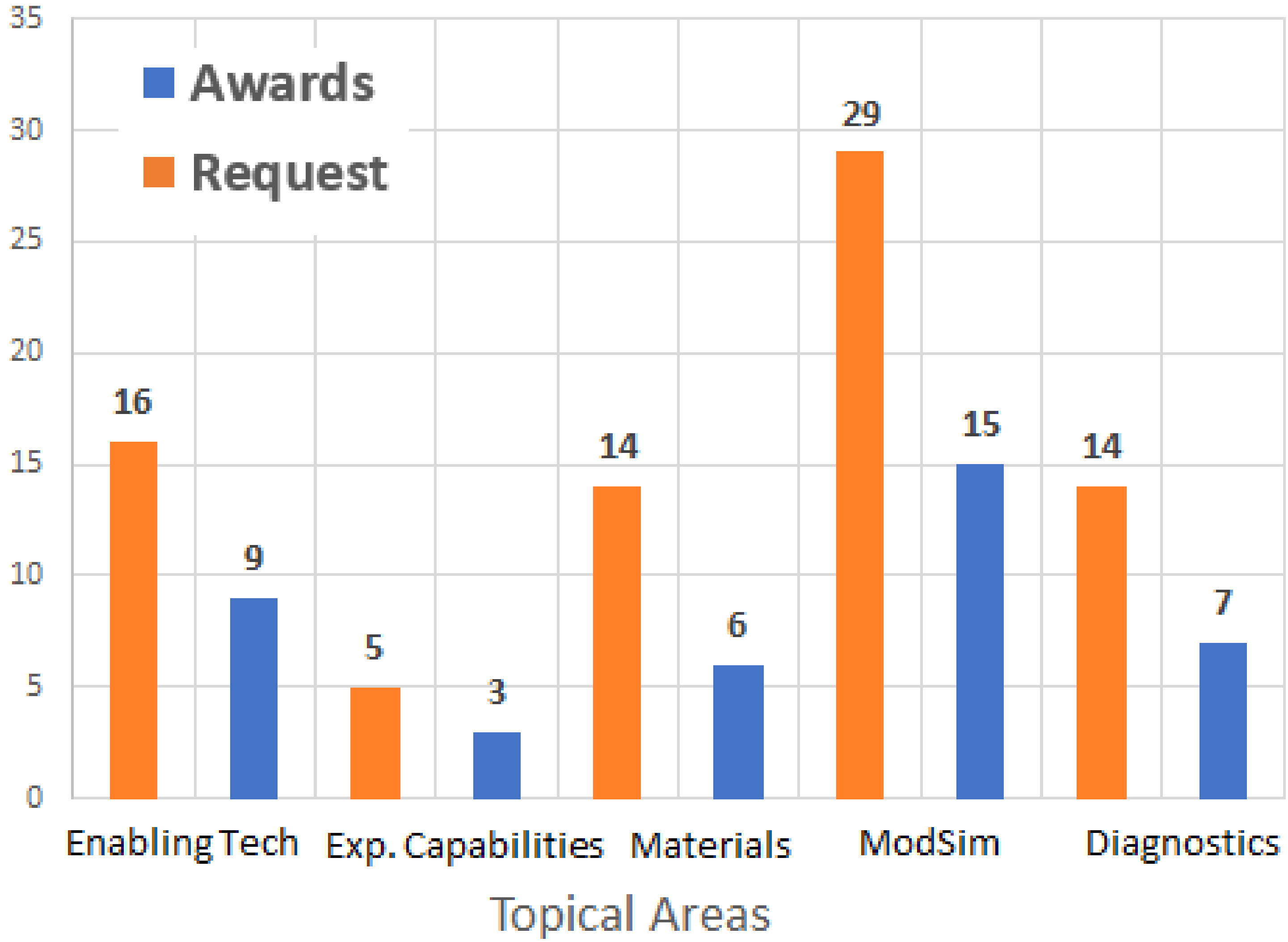
More details available: https://infuse.ornl.gov/rfa-announcement-and-submission/

Award Abstracts: https://infuse.ornl.gov/wp-content/uploads/2021/07/Cumulative_AwardList.pdf

Request Details (Continued)

	Requests	Awards	Rate
All RFA's	78	40	51%
FY19	21	11	52%
FY20-A	25	10	40%
FY20-B	16	10	63%
FY21-A	16	9	56%
FY21-B	11		

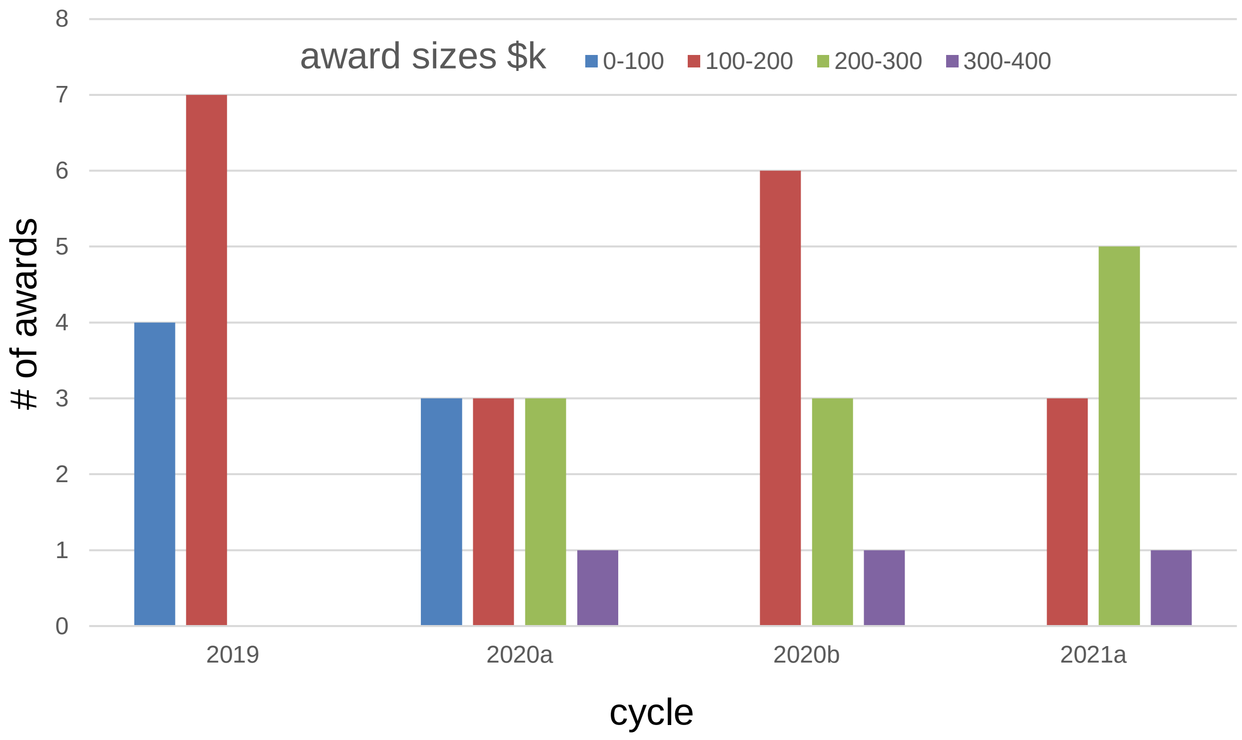
- FY19 RFA Call included restriction of one request per topical area



Funding Statistics

Lab funds	Total Requested	Total Awarded	Average Size
All RFA's	$14,601 k	$7,773 k	$177 k
FY19	$2,870 k	$1,543 k	$137 k
FY20-A	$4,481 k	$1,949 k	$179 k
FY20-B	$3,426 k	$2,150 k	$214 k
FY21-A	$3,824 k	$2,131 k	$237 k
FY21-B	$2,522 k		

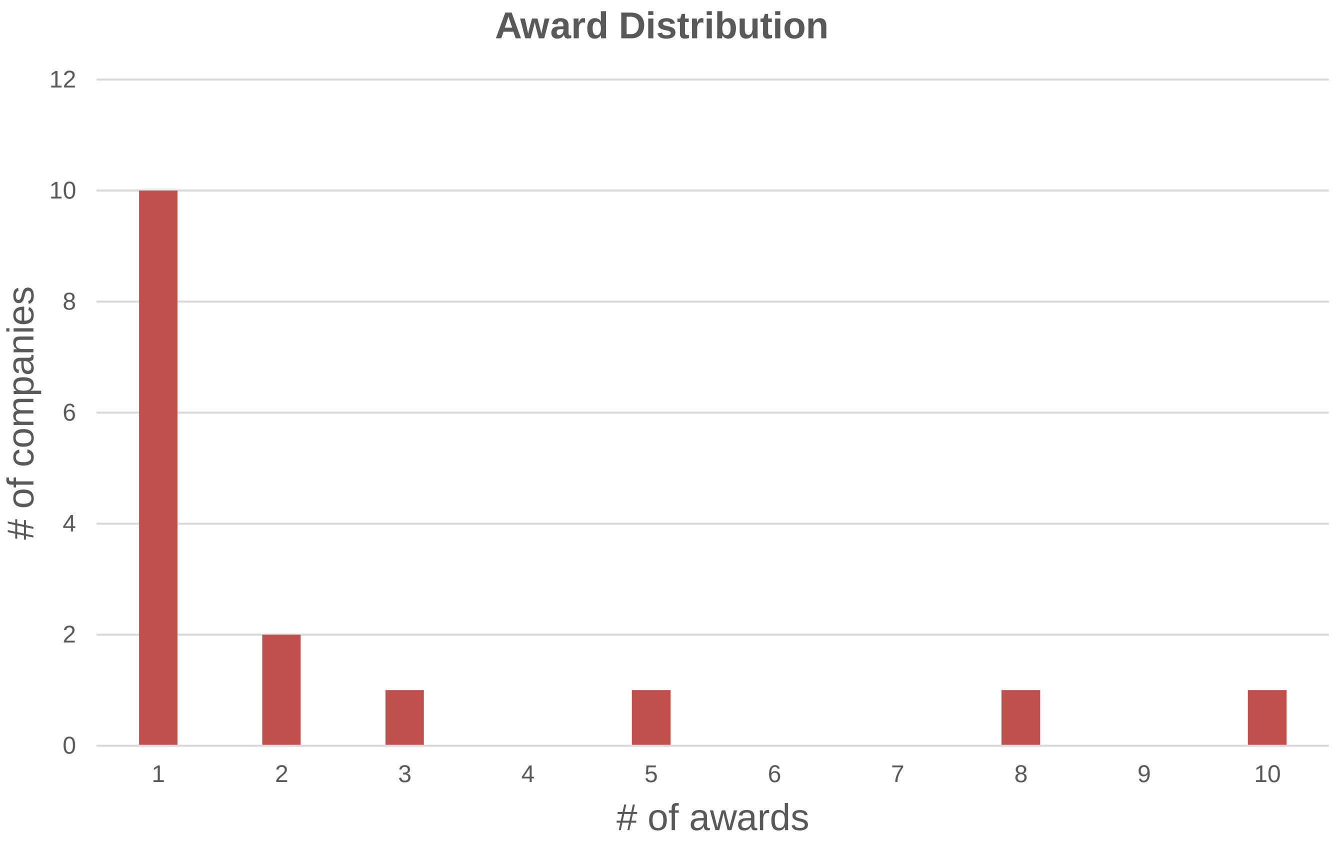
- **DOE share only – does not include cost share**
- **FY20 RFA Calls increased the funding level to $500k total**



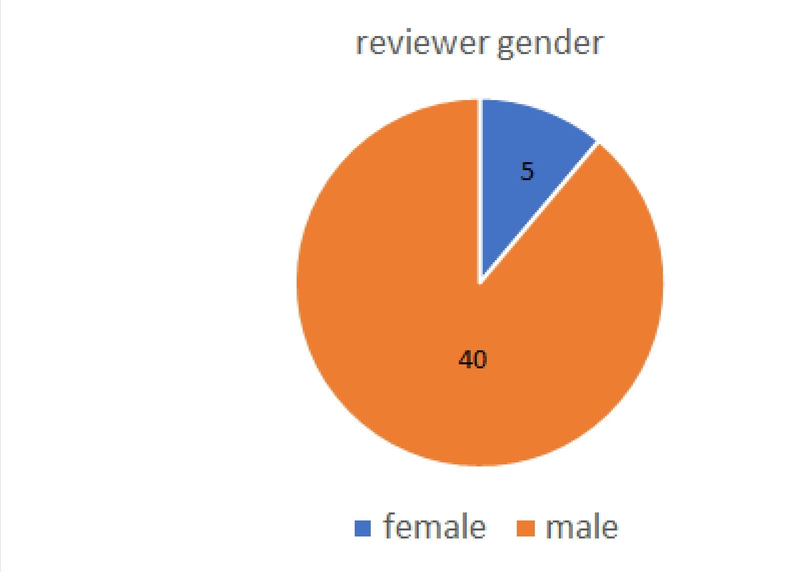
Company Diversity

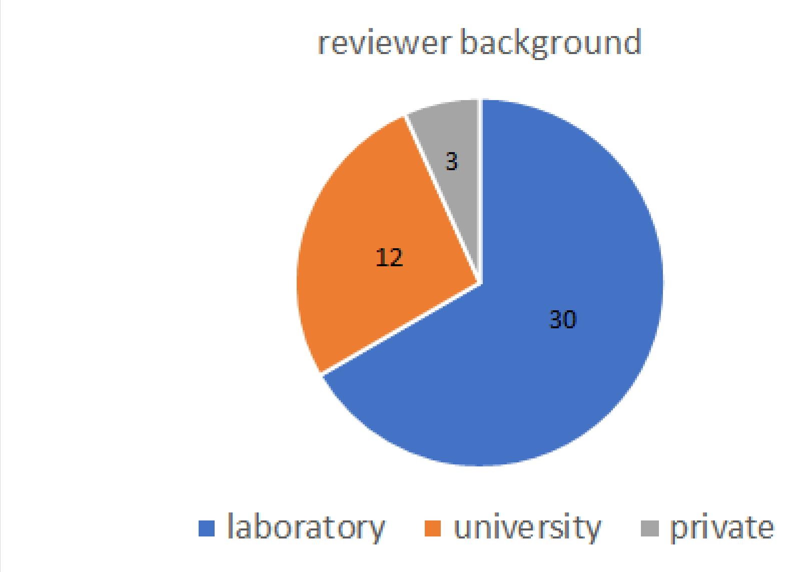
	Total Requests	Unique Requesters	Unique Awardees
All RFA's	78	19	12
FY19	21	11	5
FY20-A	25	13	6
FY20-B	16	10	8
FY21-A	16	9	7
FY21-B	11	8	

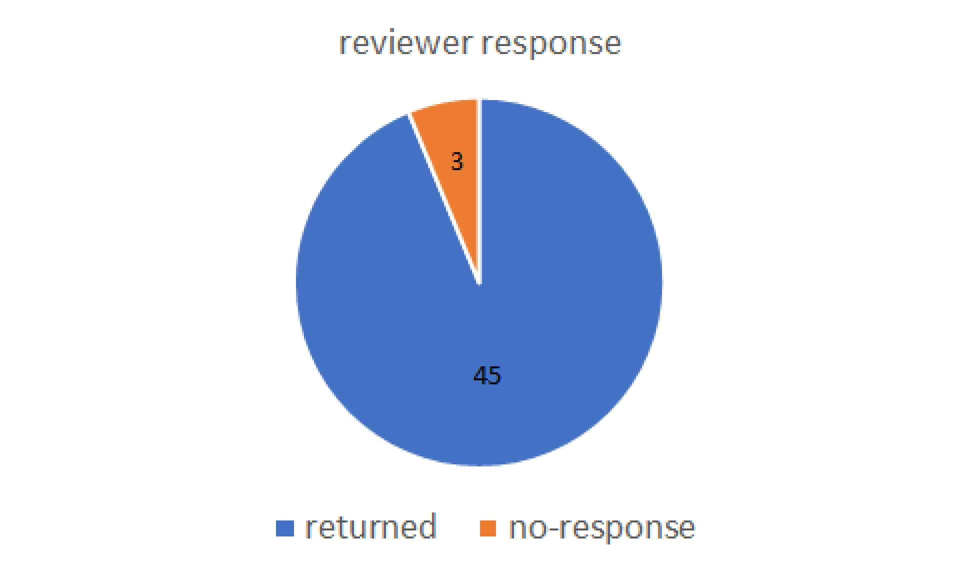
- One company selected in FY19 was dropped due to insolvency
- Of the 7 other companies who were unawarded, 5 only submitted once



Reviewer Demographics 2021a – 16 RFAs







Future Outlook

FES and the INFUSE Team are continuing to evaluate the INFUSE Program moving forward to ensure success

- 2019 pilot projects ended or are near completion - Awardees will submit final reports, including highlight, publications, and other metrics of success
- Two INFUSE Workshops have been held to help bring the labs and private industry together as well as to provide feedback on room for improvement
  - FY21 Workshop was cohosted by FES, the Electric Power Research Institute (EPRI), and the Fusion Industry Association (FIA)
  - Included over 195 Participates from private companies, DOE laboratories, universities, international organizations and utilities
  - FY22 Workshop will again be virtual in December
- FES is considering additional modifications to INFUSE to address company recommendations
- FES is actively exploring other P3 programs for engaging private industry directly

Metrics (2019)

CFS: Alpha Particle Diagnostics Simulation

“This INFUSE program informed the maximum allowable Toroidal Field ripple for SPARC, which in turn affects decisions regarding the number, size and fabrication tolerances of the TF coils. These decisions directly impact the total system cost. The program also compared and improved the ASCOT and SPIRAL codes for fusion alpha particle distribution, directly benefiting the fusion community as a whole. The work led to a publication in the *Journal of Plasma Physics*.”

~Shiyun Ruan

CFS: Divertor Component Testing

“Travis and Dennis,
I'd like to personally thank you for helping us get to the 30% milestone on time. We held the review all last week and it was a success. SPARC is now ready to construct.
The INFUSE PFC testing is an important part of the SPARC program.
Special thanks in addition to Dennis for his work on the INFUSE program.
Onwards to 60%!”

~Dan Brunner

TAE: Simulations of Global Stability in the C-2W Device

In collaboration with TAE researchers, Elena Belova (PPPL) performed global stability simulations of FRC plasmas and found a new fast-ion driven compressible mode which, as it saturates at small amplitude, may explain some of the stable low-order fluctuations which have been observed in the C-2W experiment.

~Sean Dettrick

Simulation of Equilibrium, Stability, and Transport in Advanced FRCs

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Dettrick, S. A. ; Barnes, D. C. ; Belova, E. V. ; Ceccherini, F. ; Galeotti, L. ; Galkin, S. A. ; Gupta, S. ; Hubbard, K. ; Koshkarov, O. ; Lau, C. K. ; Lin, Z. ; Mok, Y. ; Necas, A. ; Nicks, B. S. ; Onofri, M. ; Park, J. ; Putvinski, S. V. ; Steinhauer, L. S. ; Tajima, T. ; Wang, W. ; ...

The Advanced FRC is a Field Reversed Configuration maintained by neutral beam injection and electrode biasing, with scrape-off-layer (SOL) pumping and electron heat confinement provided by expander divertors. This alternate magnetic confinement system has been developed at TAE Technologies, Inc in the C-2, C-2U and C-2W (aka NORMAN) devices. To study this configuration, hybrid fluid/kinetic equilibrium models have been developed which include the effects of fast ion pressure anisotropy. The 3D hybrid PIC codes FPIC and HYM are being used to understand the interplay of beams and biasing in global stability. The 2D hybrid kinetic/MHD/neutral code, Q2D, is being used to study global transport including coupled perpendicular/parallel FRC/SOL transport, neutral gas effects, and field line expansion and electrostatic potential formation in the expander. The 3D electrostatic PIC codes ANC and GTC-X add wave-particle kinetic ion and electron effects to the global transport studies, including shear flows and sheath effects related to biasing. Parallel electron heat transport in the SOL is studied using the KSOL 1d2v continuum code.

Publication: APS Division of Plasma Physics Meeting 2020, abstract id.VP13.016
Pub Date: 2020
Bibcode: 2020APS..DPPV13016D

J. Plasma Phys. (2020), *vol.* 86, 865860508 1
Published by Cambridge University Press

doi:10.1017/S0022377820001087

Fast-ion physics in SPARC

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(Received 27 May 2020; revised 19 August 2020; accepted 20 August 2020)

Potential loss of energetic ions including alphas and radio-frequency tail ions due to classical orbit effects and magnetohydrodynamic instabilities (MHD) are central physics issues in the design and experimental physics programme of the SPARC tokamak. The expected loss of fusion alpha power due to ripple-induced transport is computed for the SPARC tokamak design by the ASCOT and SPIRAL orbit-simulation codes, to assess the expected surface heating of plasma-facing components. We find good agreement between the ASCOT and SPIRAL simulation results not only in integrated quantities (fraction of alpha power loss) but also in the spatial, temporal and pitch-angle dependence of the losses. If the toroidal field (TF) coils are well-aligned, the SPARC edge ripple is small (0.15–0.30 %), the computed ripple-induced alpha power loss is small (~0.25 %) and the corresponding peak surface power density is acceptable (244 kW m^{-2}). However, the ripple and ripple-induced losses increase strongly if the TF coils are assumed to suffer increasing magnitudes of misalignment. Surface heat loads may become problematic if the TF coil misalignment approaches the centimetre level. Ripple-induced losses of the energetic ion tail driven by ion cyclotron range of frequency (ICRF) heating are not expected to generate significant wall or limiter heating in the nominal SPARC plasma scenario. Because the expected classical fast-ion losses are small, SPARC will be able to observe and study fast-ion redistribution due to MHD including sawteeth and Alfvén eigenmodes (AEs). SPARC's parameter space for AE physics even at moderate Q is shown to reasonably overlap that of the demonstration power plant ARC (Sorbom *et al.*, *Fusion Engng Des.*, vol. 100, 2015, p. 378), and thus measurements of AE mode amplitude, spectrum and associated fast-ion transport in SPARC would provide relevant guidance about AE behaviour expected in ARC.

Key words: fusion plasma, plasma simulation, plasma confinement

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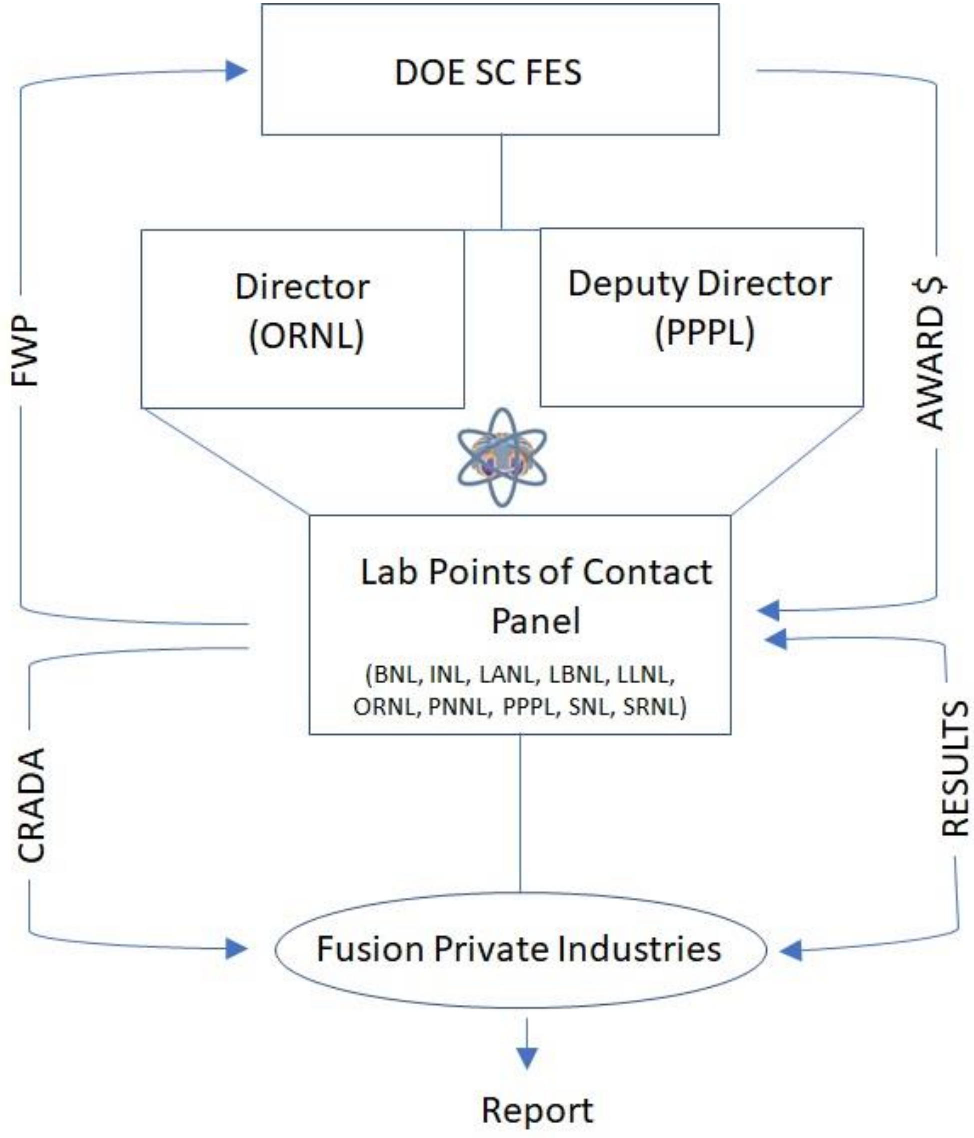
Lessons Learned

- Structure of the US Government
- Eligibility issues and cost share
- Participating labs and sr. bandwidth
- COI mitigations and the INFUSE POCs
- FWP cycle
- CRADA processing (NDAs, IP and ECI)
- CRADA amendments
- INFUSE supplementals
- University involvements
- INFUSE workshops – Dec. 2021 (virtual)



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Feedback, please

- What can we improve about INFUSE?
- What is the proper balance between public and private research or investment in fusion energy?
- How is the broader fusion community outside the labs engaged?
- General Q&A