Innovation Network for Fusion Energy (INFUSE) Program for Public-Private Partnership with the Fusion EnterprisePast *Performance, Future Plans, and Lessons Learned*

Ahmed Diallo & Dennis Youchison
INFUSE Leadership 2019 - 2022

2nd IAEA Workshop on Fusion Enterprises
Jul 11, 2022 - Jul 12, 2022

Program Overview

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

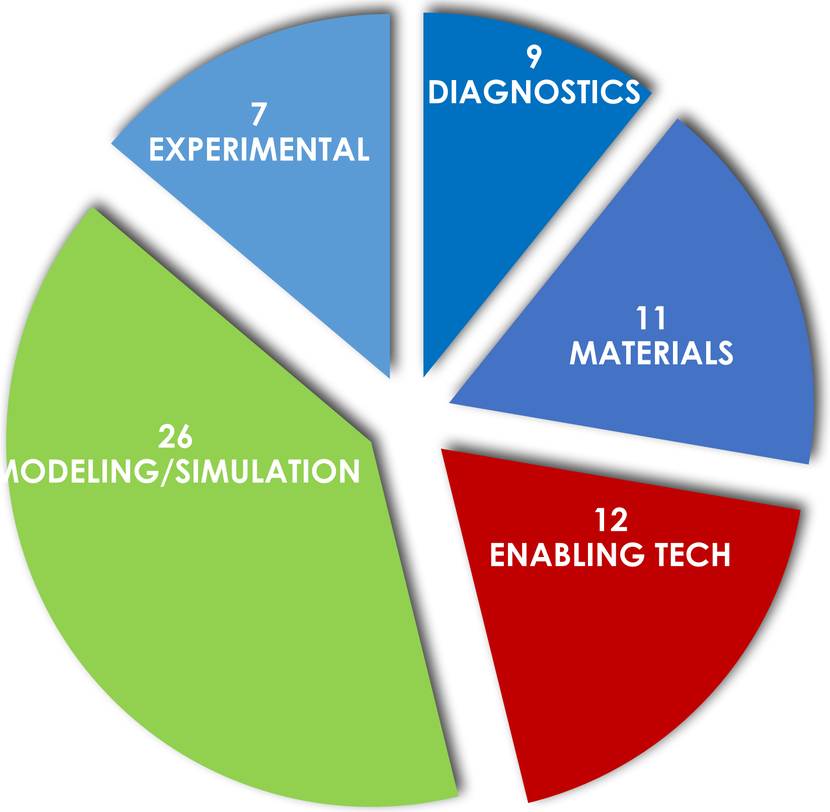
- **Initiated due to the recent surge in private sector investment in fusion energy - Leverages the many unique and important capabilities are located at DOE National Laboratories**
  - *In 2022 - US Universities with known capabilities were included*

- **Focused on providing a quick, streamlined approach for companies to access DOE Laboratory Capabilities and US Universities (since 2022).**
  - *"Time is of the essence"*

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

INFUSE Projects

Awarded Topical Areas



US-DoE National Laboratories

- **65 awards (2 rescinded) went to 20 U.S. companies in 11 states involving 9 national labs and 8 universities**

  total value of $17 M ($13 M DOE)

Program Organization

INFUSE is implemented by the "Point-of-Contacts" POC panel whose members come from each of the participating laboratories.

- **Duty of POCs is to interface with:**
  - Fusion Energy Science
  - Lab Strategic Partnership Program office
  - DOE site office
  - Company PIs and CEOs
  - Lab capabilities and PIs

Laboratory	Point of Contact	Email
Brookhaven National Laboratory (BNL)	Kathleen Amm	ammk@bnl.gov
Idaho National Laboratory (INL)	Masashi Shimada	masashi.shimada@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*~~ **Arnold Lumsdaine**	~~youchisondl@ornl.gov~~
Pacific Northwest National Laboratory (PNNL)	Wahyu Setyawan	wahyu.setyawan@pnnl.gov
Princeton Plasma Physics Laboratory (PPPL)	~~Ahmed Diallo**~~ **Walter Guttenfelder**	~~adiallo@pppl.gov~~
Sandia National Laboratories (SNL)	Rob Kolasinski	rkolasi@sandia.gov
Savannah River National Laboratory (SRNL)	Jim Klein	james.klein@srnl.doe.gov

Congratulations to Arnold and Walter as incoming Director and Deputy Director of INFUSE!

Process: Request for Assistance (RFA)

- **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 of 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 (*3 reviewers are requested to comment on the value of the RFA and impact to fusion overall)*

More details available

Current Lab Participation Structure

Preparation Phase

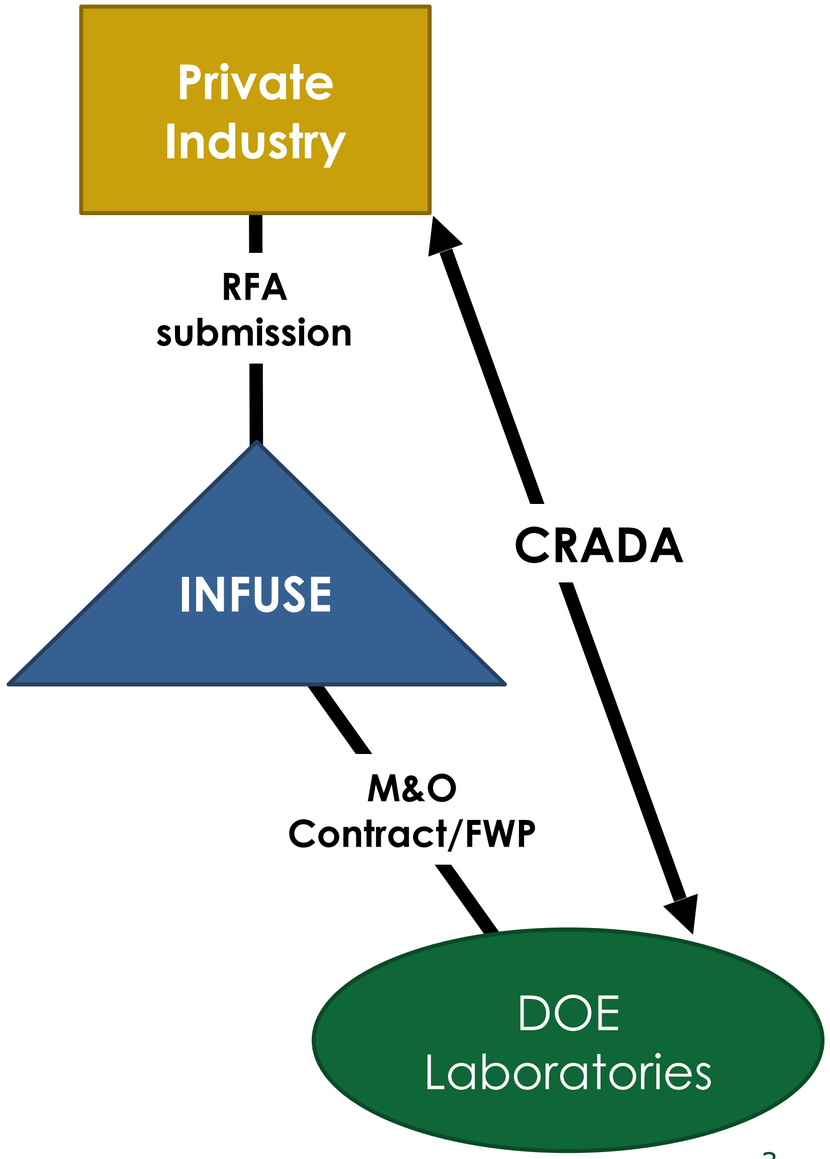
- Identify priority R&D
- Identify partner institution
- Agree upon work scope (Record of Discussion)

Application Phase

- Technical narrative
- Budget and cost-share
- Supporting documents
- CRADA Certification

Award Phase

- Award notification
- Lab submits Field Work Proposal (FWP) and receives funding
- Establish standardized CRADA
- Begin work



New University Participation Structure

Preparation Phase

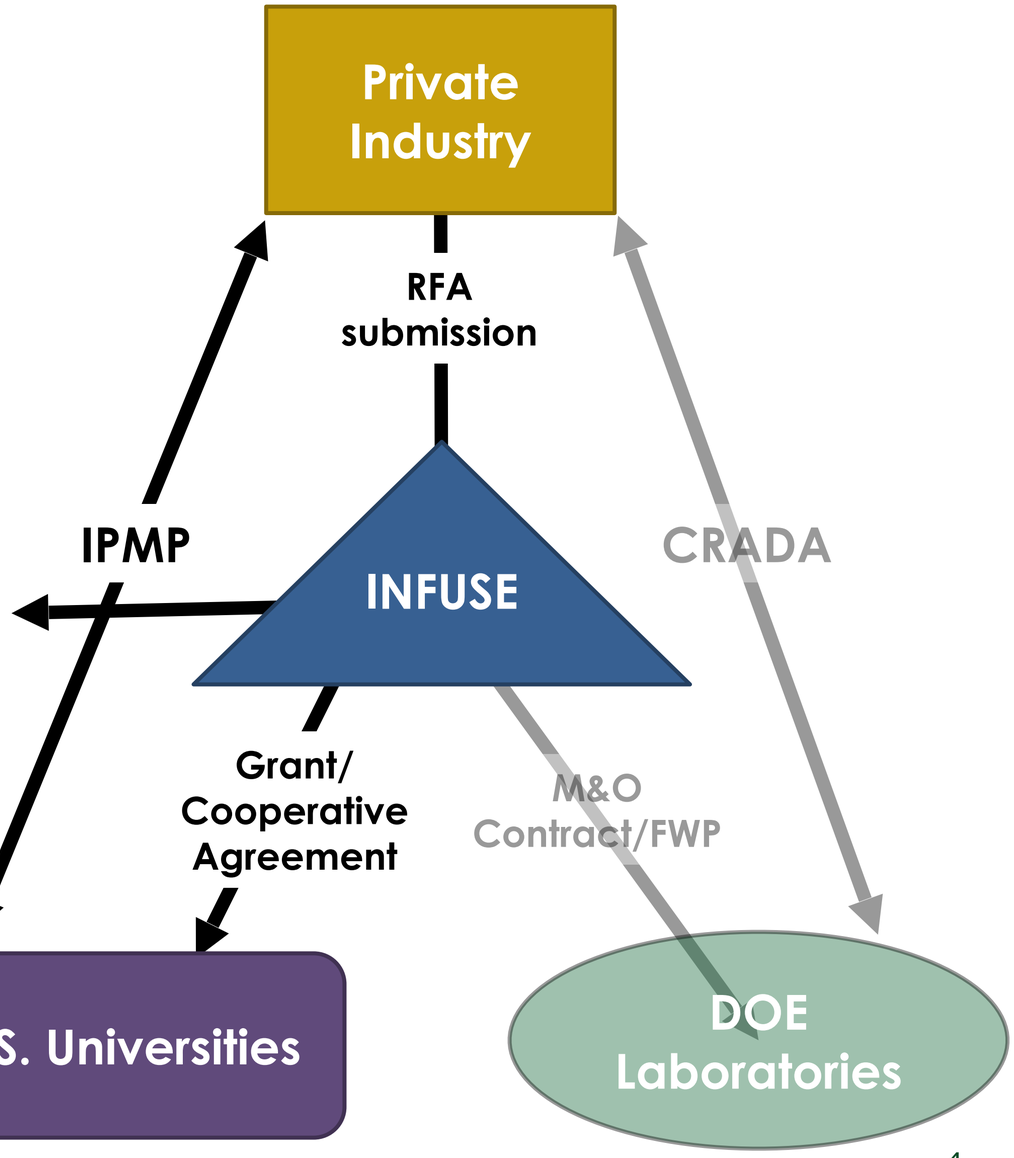
- Identify priority R&D
- Identify partner institution
- Agree upon work scope (Record of Discussion)

Application Phase

- Technical narrative
- Budget and cost-share
- Supporting Documents
- ~~CRADA certification~~
- Establish Intellectual Property Management Plan (IPMP) and IPMP certification

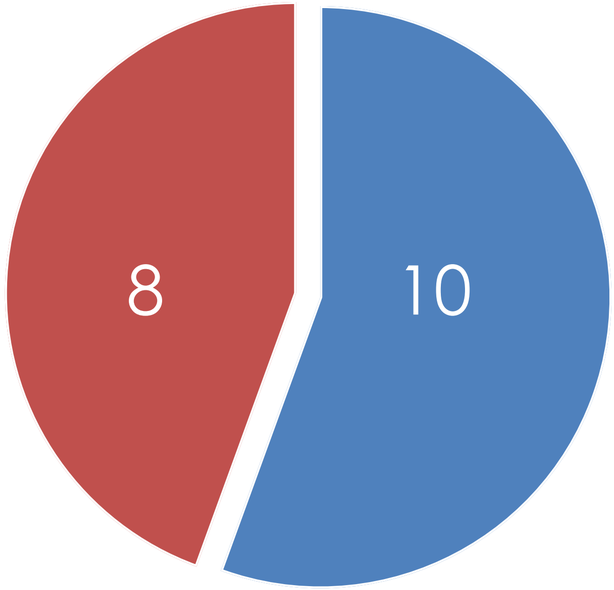
Award Phase

- Award notification
- ~~Lab submits Field Work Proposal (FWP) and receives funding~~
- ~~Establish standardized CRADA~~
- University submits proposal to SC Open Notice
- DOE awards funding via grant/cooperative agreement
- Begin work



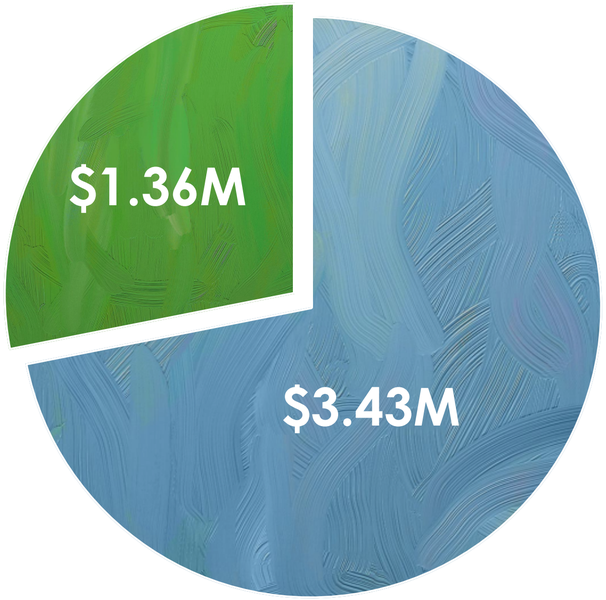
Recent FY22-A cycle

Awards by Institutions



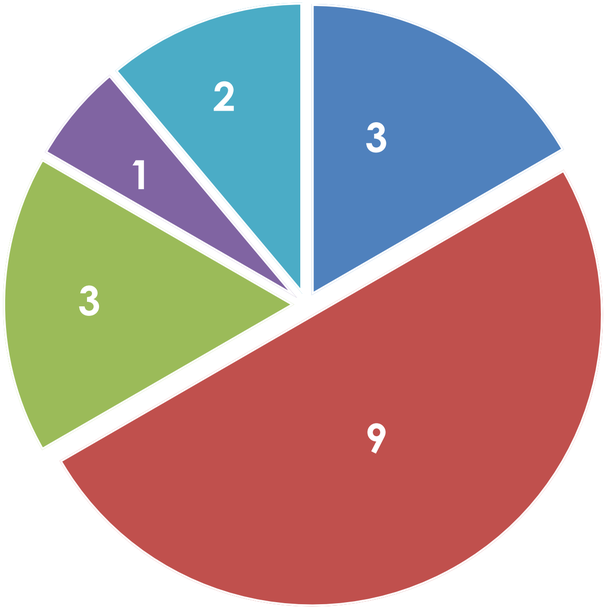
University
DOE Laboratory

Funding



DOE share
company share

Topical area



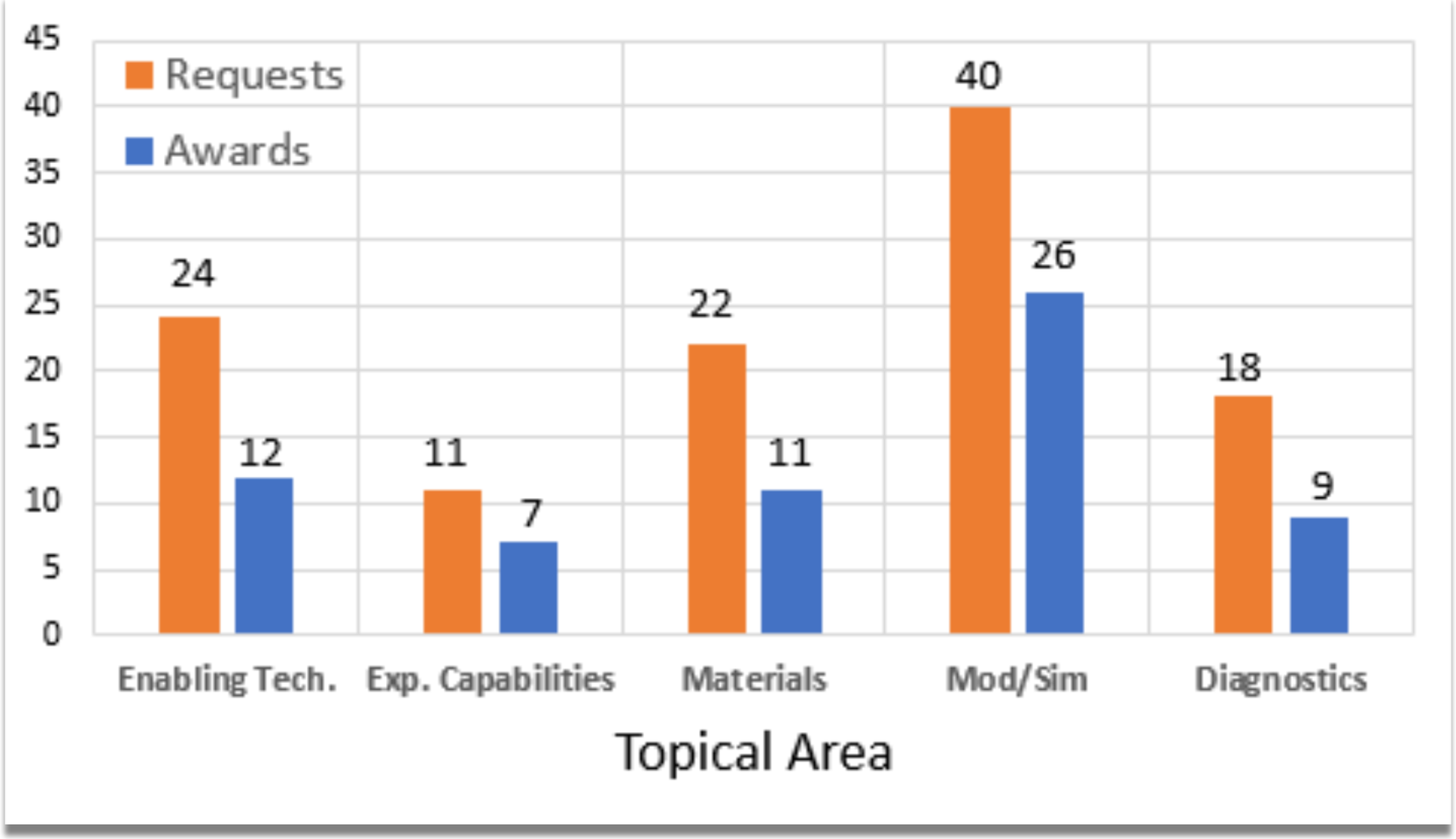
diagnostics
materials
expt'l capabilities
mod/sim
enabling tech

Award Announcement

RFA over the Years

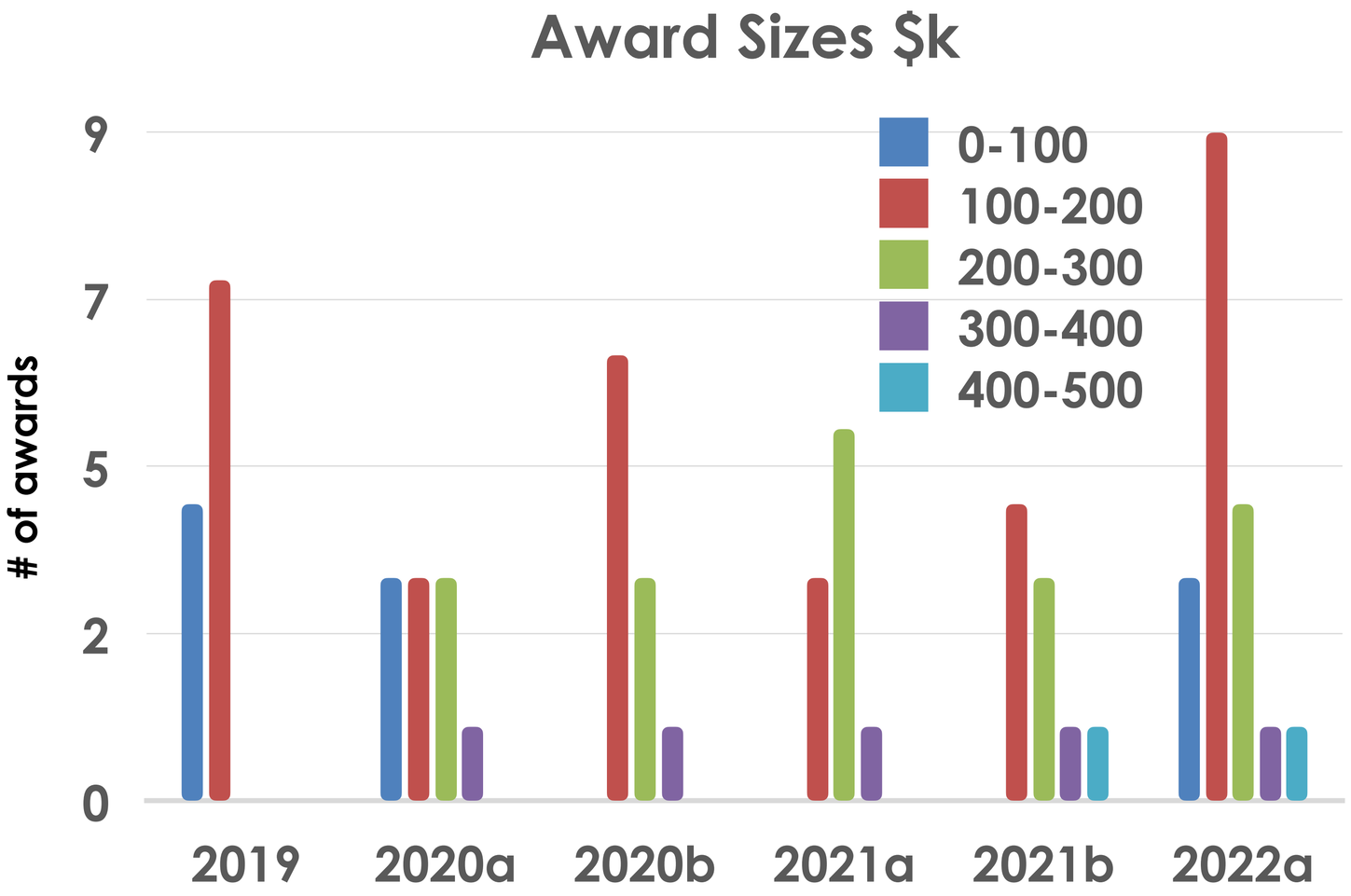
	Requests	Awards	Rate
All RFA's	*115*	*65*	*51%*
FY19*	21	11	52%
FY20-A	25	10	40%
FY20-B	16	10	63%
FY21-A	16	8	50%
FY21-B	11	8	73%
FY22-A	26	18	69%

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



Funding Statistics

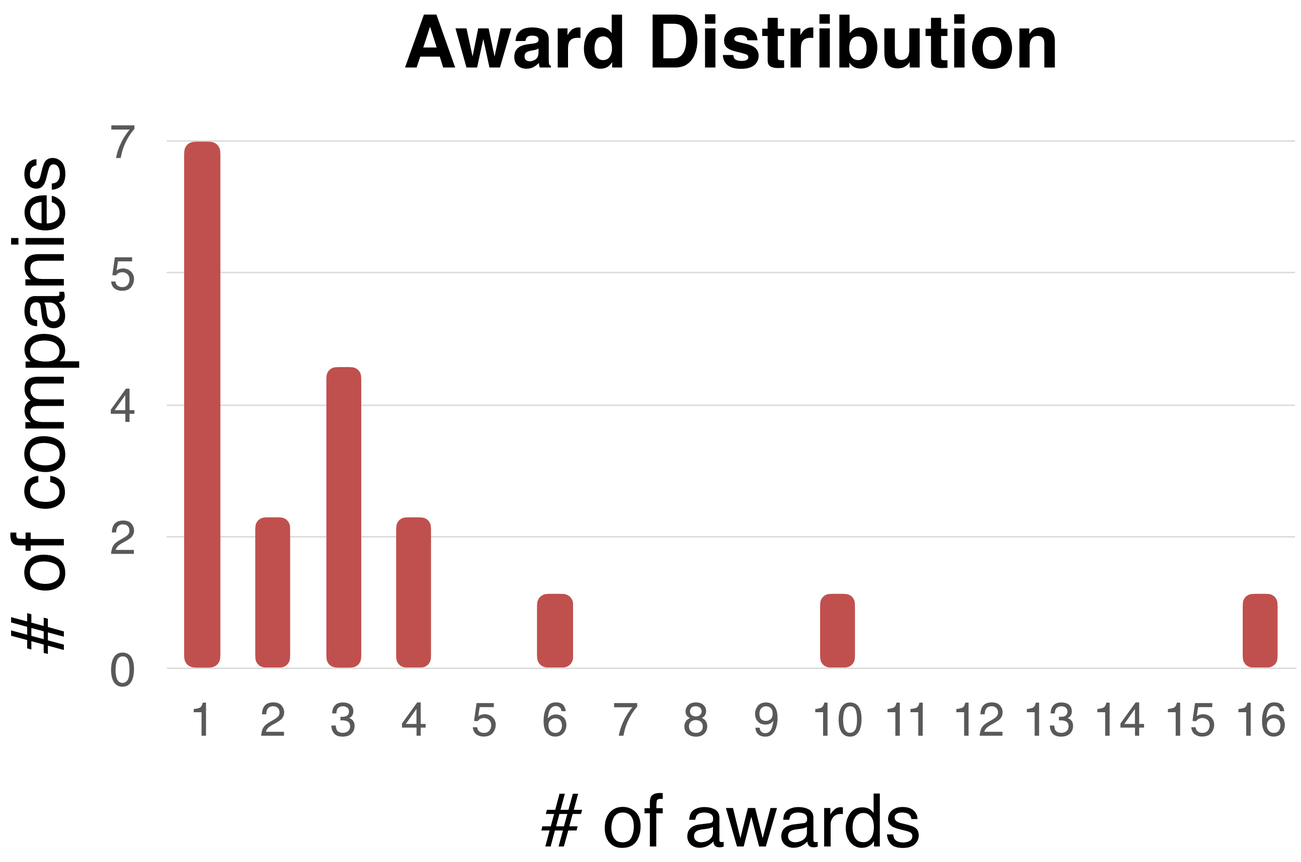
Lab funds	Total Requested	Total Awarded	Average Size
All RFA's	$22,108 k	$12,965 k	$199 k
FY19	$2,870 k	$1,543 k	$137 k
FY20-A	$4,481 k	$1,949 k	$179 k
FY20-B	$3,426 k	$2,150 k	$214 k
FY21-A	$3,824 k	$2,131 k	$237 k
FY21-B	$2,522 k	$1,712 k	$214 k
FY22-A	$4,985 k	$3,430 k	$192 k



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

Company Diversity

	Total Requests	Unique Requesters	Unique Awardees
All RFA's	115	26	19
FY19	21	11	5
FY20-A	25	13	6
FY20-B	16	10	8
FY21-A	16	9	6
FY21-B	11	8	6
FY22-A	26	13	10



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.

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Fast-ion physics in SPARC

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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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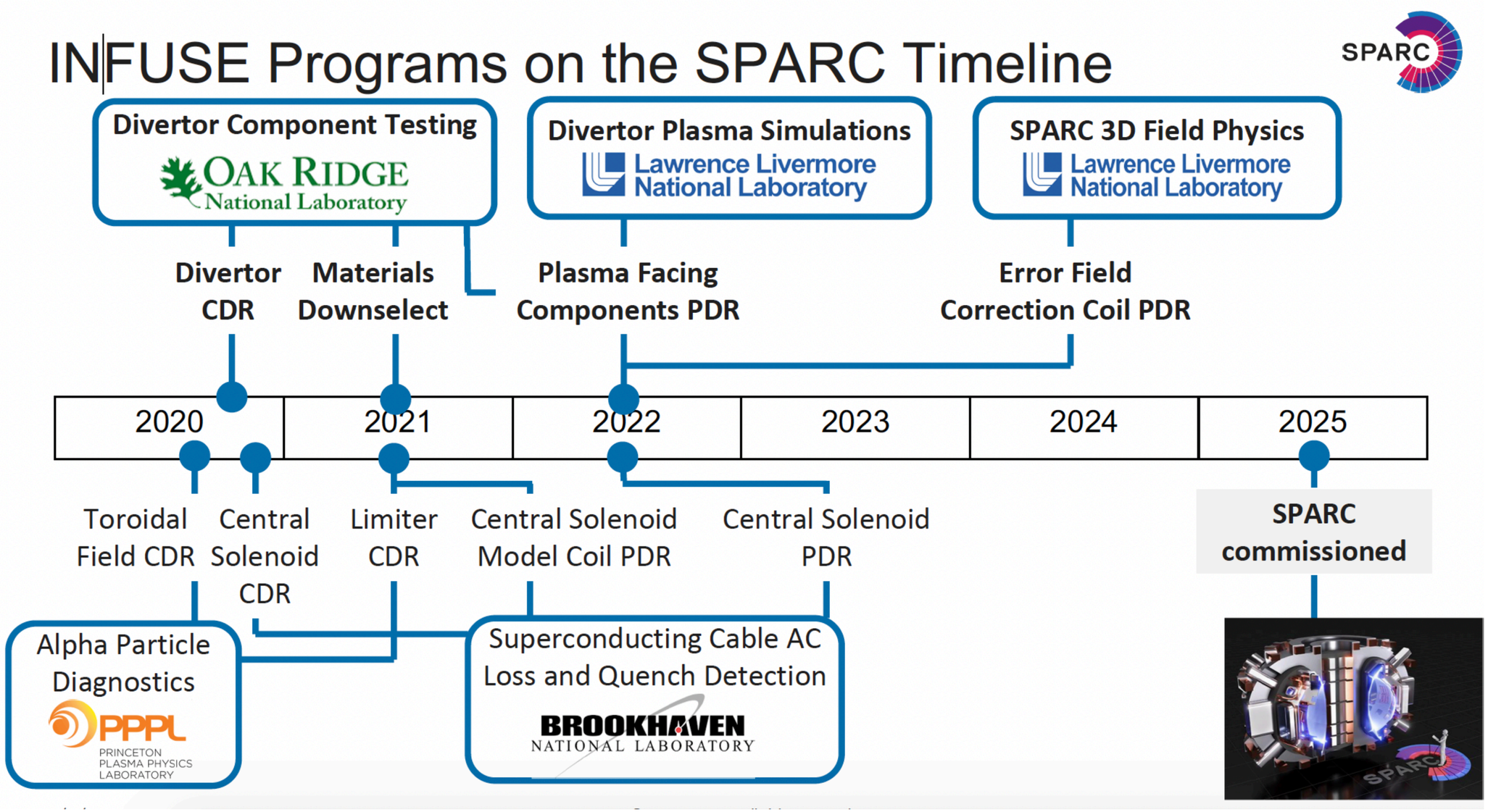
INFUSE Impact on Fusion Industry: Example



Summary - Outlook

- **FES and the INFUSE Team are continuing to evaluate the INFUSE Program to ensure success.**
  - 2019 pilot projects have completed- Awardees posted final reports, including highlights, publications, and other metrics of success
- **Three INFUSE Workshops have been held to help bring the labs, universities and private industry together as well as to provide feedback for improvement**
  - FY21 Workshop was co-hosted 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 was held in December 2021 with 171 participants
- **INFUSE expanded in 2022 to include:**
  - U.S. university participation
  - All 17 national laboratories
- **FES is participating in new milestone program for direct funding of private demonstration projects**

Slides