ARPA-E Updates & Overview of Fusion "Capability Teams"

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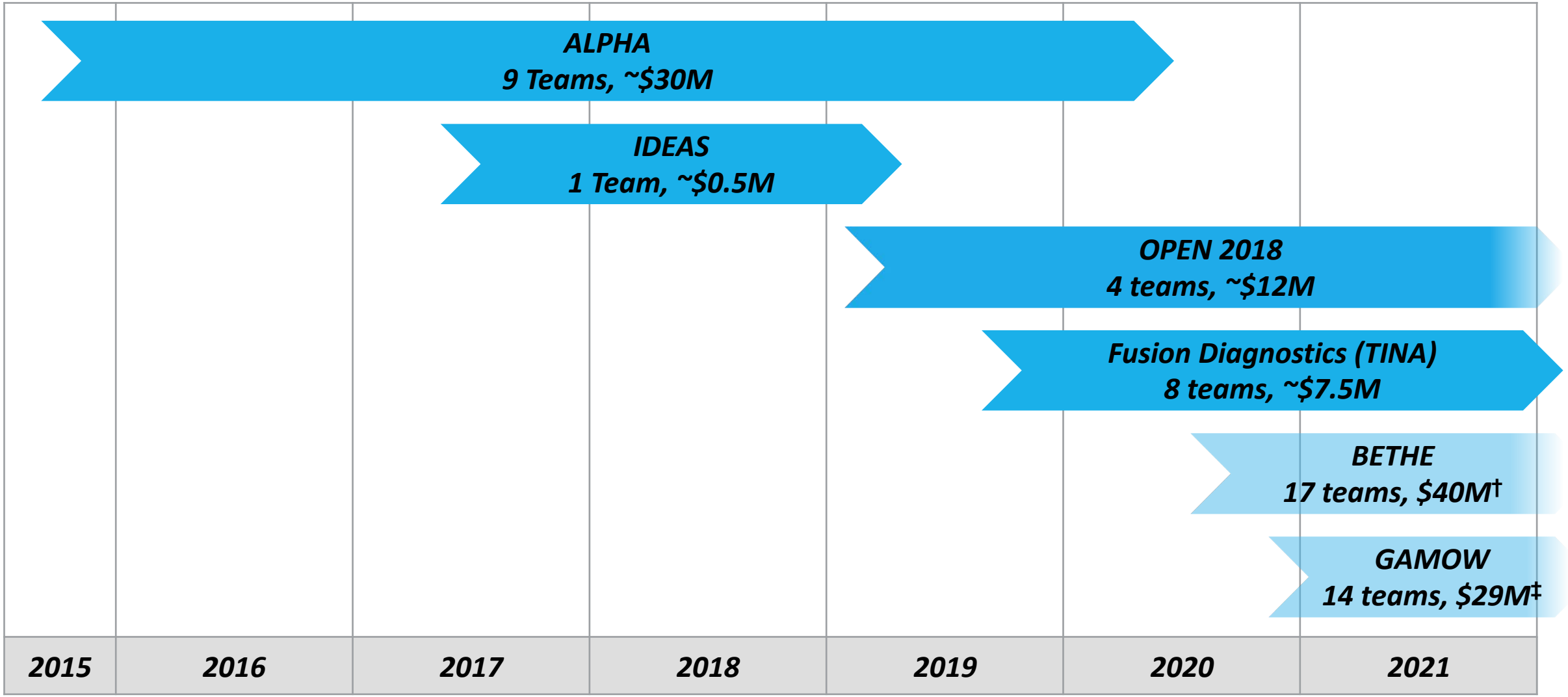
INFUSE Workshop
December 2, 2020

Outline

- Updates
  - BETHE, GAMOW project selections
  - T2M activities (market report, updated costing study)
- Overview of capability teams
  - TINA fusion diagnostic teams
  - BETHE capability teams
  - Costing team
- Plans

ARPA-E FUSION PROGRAM UPDATES

The ARPA-E Fusion Portfolio



†Includes $5M from SC-FES for 4 of the BETHE projects.
‡Joint program with SC-FES.

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BETHE* program: Catalyze R&D to deliver a larger number of lower-cost fusion concepts at higher performance levels

- Projected net-gain experiment for ≲ $100M
- Specify entry/exit milestones
- Funding ceiling commensurate w/ achieved performance
- Leverage capability teams
- Selected projects include mirrors, spheromak, MIF, Z pinch, μ-catalyzed fusion

Advance the performance of lower-cost concepts

- Concept development
- Capability teams

Lower the cost of more-mature concepts

- Component technology development

- Potentially enable overnight capital cost <$2B, <$5/W
- Selected projects include fast-ramping tokamak HTS central solenoid, new approaches to stellarator magnets, next-gen high-bandwidth lasers

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*Breakthroughs Enabling Thermonuclear-fusion Energy; click here for program overview

BETHE portfolio ($35M + $5M FES): 17 projects across 3 technical categories

Category A: Concept development

Category B: Component technology development

Category C: Capability teams

Commonwealth Fusion Systems

Jointly funded with FES

SapientAI, LLC

Prime recipients: 7 universities, 5 private companies, 5 national labs; click here for full list of project teams.

GAMOW* program: Accelerate R&D in fusion enabling technologies to support commercially viable fusion concepts

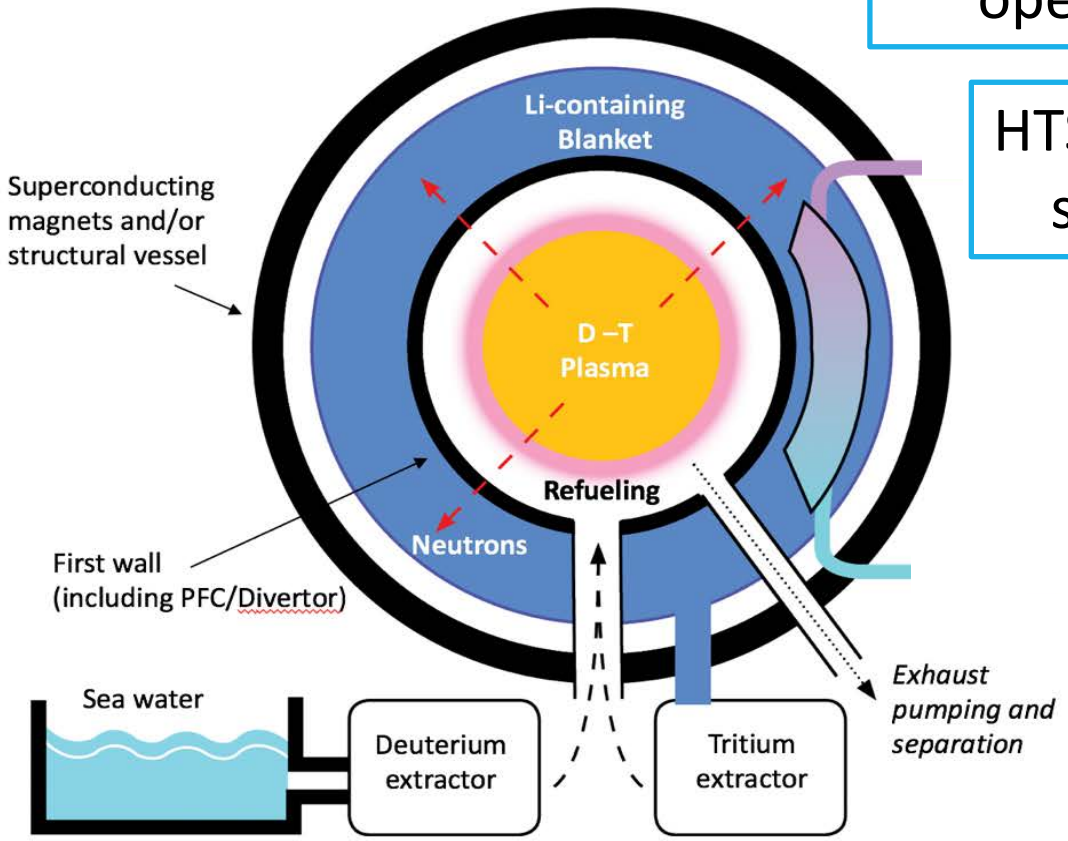
Deployable in experiments well within a decade

Device simplification or elimination of entire subsystems

Significant cost reduction

Improvements in RAMI, safety, sustainability

Joint program with FES



>900-K blanket operation

HTS tape <$10/kA-m, substrate >3 GPa

<1000-Ci (100-mg) T annual release

>10-MW/m^2 continuous power handling at 1st wall

<0.75-kG T inventory for 500-MW_{th} system

*Galvanizing Advances in Market-aligned fusion for an Overabundance of Watts; click here for program overview.

GAMOW portfolio ($29M): 14 projects across 7 technical categories

Integrated First-Wall and Blanket Technology

- Fusion Energy Reactor Models Integrator (FERMI), *Oak Ridge National Laboratory*

Plasma-Facing Components (PFC) and Divertor

- Renewable low-Z wall for fusion reactors with built-in tritium recovery, *University of California: San Diego*

Tritium Fuel Cycle

- Interfacial-Engineered Membranes for Efficient Tritium Extraction, *Colorado School of Mines*
- Direct LiT Electrolysis Process Modeling & Scale up, *Savannah River National Laboratory*
- EM-Enhanced HyPOR Loop for Fast Fusion Fuel Cycles, *Savannah River National Laboratory*

Joint program with FES

Superconducting Magnets

- Advanced HTS Conductors Customized for Fusion, *University of Houston*

High-efficiency electrical-driver systems

- Wide Band Gap Semiconductor Amplifiers for Plasma Heating and Control, *Princeton Fusion Systems*
- AMPERE - Advanced Materials for Plasma-Exposed Robust Electrodes, *University of California: Los Angeles*
- High Efficiency, Megawatt Class Gyrotrons for Instability Control of Burning Plasma Machines, *Bridge 12 Technologies*

Novel Fusion Materials

- Advance Castable Nanostructured Alloys for First-Wall/Blanket Applications, *Oak Ridge National Laboratory*
- Ultra High Flux DT Neutron Source for Accelerated Testing of Fusion Materials and Subsystems to Reactor-relevant DPA Levels, *Phoenix LLC*
- ENHANCED Shield: A Critical Materials Technology Enabling Compact Superconducting Tokamaks, *Stony Brook University*

Advanced and Additive Manufacturing

- Plasma Facing Component Innovations by Advanced Manufacturing and Design, *Oak Ridge National Laboratory*
- Microstructure Optimization and Novel Processing Development of ODS Steels for Fusion Environments (MONDO-FE), *Pacific Northwest National Laboratory*

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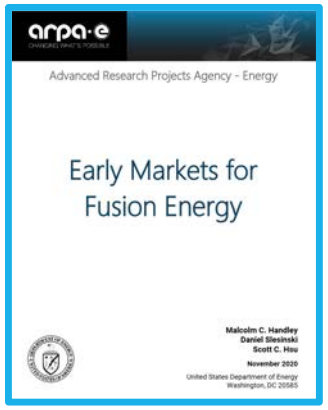
Prime recipients: 5 universities, 3 private companies, 6 national labs; click here for full list of project teams.

Tech-to-Market (T2M) priorities for the ARPA-E fusion portfolio

- Investor engagement
- Market studies
- Updated reactor-costing tool, studies, and support of concept teams
- Engaging NGOs (who will be the advocates for the ultimate commercial adoption of fusion)
- Supporting/coaching our project teams (on development plans, securing follow-on funding, etc.)



Reports to be released imminently!

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Brief summary of findings from fusion market report

- Most-promising early markets are high-priced electricity markets around the world (up to $110/MWh)
  - Eventually, fusion may need to cost <$50/MWh to access very large markets (to compete with natural gas w/CCS and $50/ton carbon tax)
- Load-following may not be economically feasible for fusion (it cannot afford to sit idle half the time due to large capital cost)
  - Integrated thermal storage may be needed so plant can run at high capacity factor
- Process heat and hydrogen production will be tough early markets (also, fusion may not be able to achieve the needed high temperatures)
- Desalination & direct air capture alongside power generation, or retrofitting coal power plants may help make fusion more economically competitive

See Malcolm Handley's talk from BETHE kickoff, and read the report when it is posted at the BETHE program highlights website.

Brief summary of findings from updated ALPHA cost study

- Revisited 2017 Bechtel/WSI cost study of four ALPHA concepts (pulsed, intermediate density)
- Update balance-of-plant (BoP) costing methodology based on new reactor-costing paradigms by E. Ingersoll et al.
- Public summary report plus four proprietary reports to the four ALPHA PIs
- Modular design/construction can significantly shorten construction times and lower indirect (interest) costs
- Cost savings realized by centralized manufacturing and shipping complete subsystems
- Total capital cost are approximately half of those from the 2017 study
- For 400-MWe power plant, average capex of $800M and $2/W, average LCOE = 47 $/MWh (range of 34–54 $/MWh)

Public report will be posted in the near future at the ALPHA program highlights website.

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OVERVIEW OF CAPABILITY TEAMS

Objectives of 2019 TINA* FOA on “diagnostic resource teams”

- State-of-the-art transportable diagnostics: design, construction, deployment, data analysis

- Validate performance and identify R&D issues/needs of ARPA-E-sponsored fusion experiments
  - Become a resource for the entire fusion R&D community via INFUSE and/or direct contracting by concept teams/companies

- Leverage expertise of the broader fusion R&D community in support of ARPA-E fusion-program objectives

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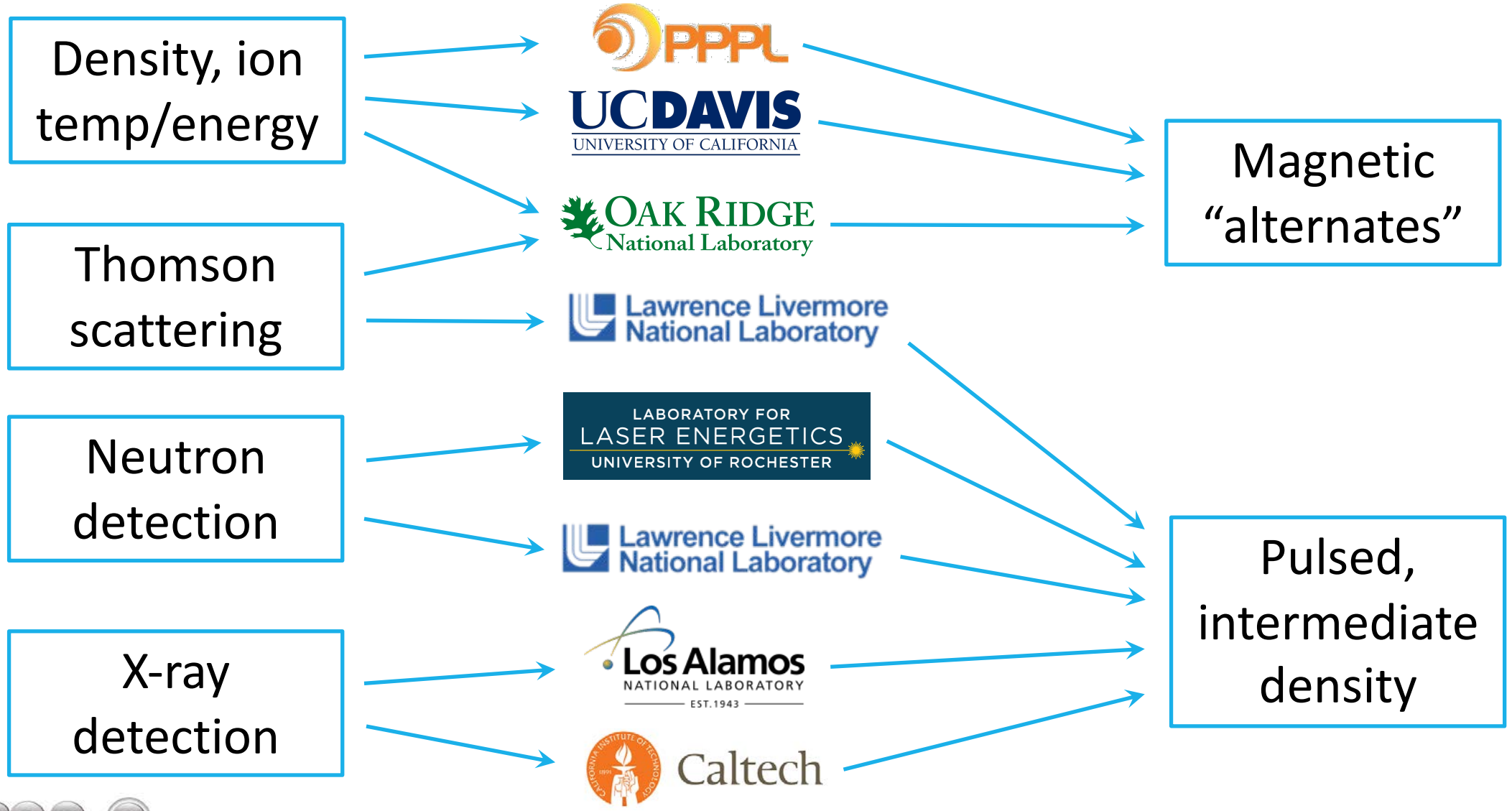
*See Topic D of *Solicitation on Topics Informing New Program Areas* (TINA), DE-FOA-0001953.

Overview of the selected diagnostic capability teams (~$7.5M)



Click here for full list of project teams.

TINA fusion diagnostic PIs/institutions

Diagnostic	PI	Institution
Passive charge-exchange ion energy analyzer	Sam Cohen	PPPL
Ultra-short-pulse reflectometer	Neville Luhmann	UC, Davis
Thomson scattering, optical emission spectrometer	Ted Biewer	ORNL
Collective Thomson scattering	Clement Goyon	LLNL
Neutron detectors (activation and nTOF)	Jonathan Davies	U. Rochester/LLE
Neutron detectors (activation and scintillator/PMT)	Drew Higginson	LLNL
Filtered x-ray detectors (phosphor/PMT), EUV spectrometer	Glen Wurden	LANL
Coded aperture x-ray imager (using both scintillator/PMT and PIN diodes)	Paul Bellan	Caltech
ALPHA reserve:		
Soft x-ray diagnostic (filtered photodiodes)	Brent Stratton/Luis Delgado-Aparicio	PPPL

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BETHE capability teams (4 theory/modeling & 2 diagnostics)

PI, Lead Institution	Primary Model/Codes or Diagnostic	Teams supported
Bhuvana Srinivasan, Virginia Tech	High-fidelity moment-kinetic models, Gkeyll	Wisconsin, LANL, UMBC, General Fusion
Craig Michoski, SapientAI	Data analytics, machine learning, AI	LANL, General Fusion, CTFusion
Petros Tzeferacos, UR/LLE	Rad-MHD (FLASH), hybrid/kinetic (TriForce), kinetic PIC (OSIRIS)	MIFTI, Princeton Fusion Systems (PFS), LANL, Compact Fusion Systems
John Wright, MIT	Comprehensive RF modeling	Wisconsin, PFS/PPPL, UMBC
Glen Wurden, LANL	Solid-state X-ray imager; multi-chord spectroscopy	tbd
Elijah Martin, ORNL	Doppler-free saturation spectroscopy (*B* and *E*)	PFS, TAE

Fusion costing capability team

- Builds on costing tools developed under ALPHA costing studies by Woodruff Scientific, Inc. (WSI)

- PPPL/WSI will support costing of other ARPA-E-supported fusion concepts (i.e., OPEN 2018 and BETHE projects)
  - Costing tool/models will be benchmarked/calibrated against costs from historical and recent construction of fusion experiments
  - Contacts: Mike Zarnstorff (PPPL) and Simon Woodruff (WSI)

- Intent is for this team to become a resource for all interested fusion concept teams (public and private)

Thoughts on future plans for fusion at ARPA-E

- Potential OPEN 2021 opportunity
  - Contact me SOON to discuss potential proposal ideas that align with prior OPEN FOAs and/or the BETHE/GAMOW FOAs
- Exploring ideas for another possible fusion program
  - Overcoming scientific/technical barriers to fusion with advanced fuels
  - Would love to hear your thoughts
- Support DOE in implementing potential new fusion programs (e.g., public-private partnerships, cost-share programs, etc.)
- Recruit a fusion ARPA-E Program Director (my successor) to start no later than mid-2022
  - Can be a 3–5 year IPA assignment

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https://arpa-e.energy.gov