arpa·e
CHANGING WHAT'S POSSIBLE

FUSION workshop overview

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Burlingame, CA

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U.S. DEPARTMENT OF ENERGY

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Outline

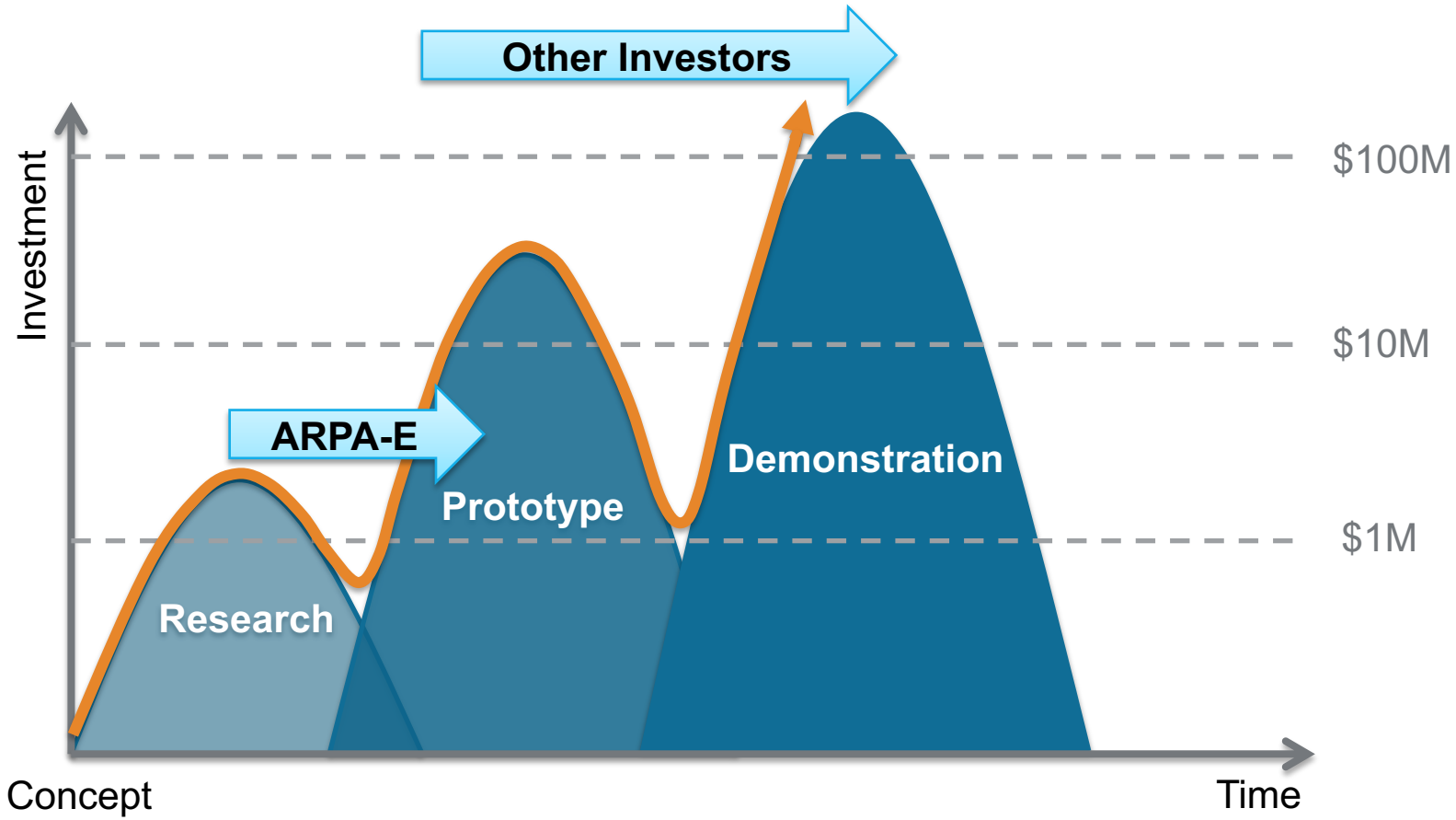
- Introduction to ARPA-E
- Framing the problem: Enabling timely, commercially viable fusion energy
- Workshop overview and objectives

ARPA-E is an agency within the U.S. Dept. of Energy modeled after DARPA

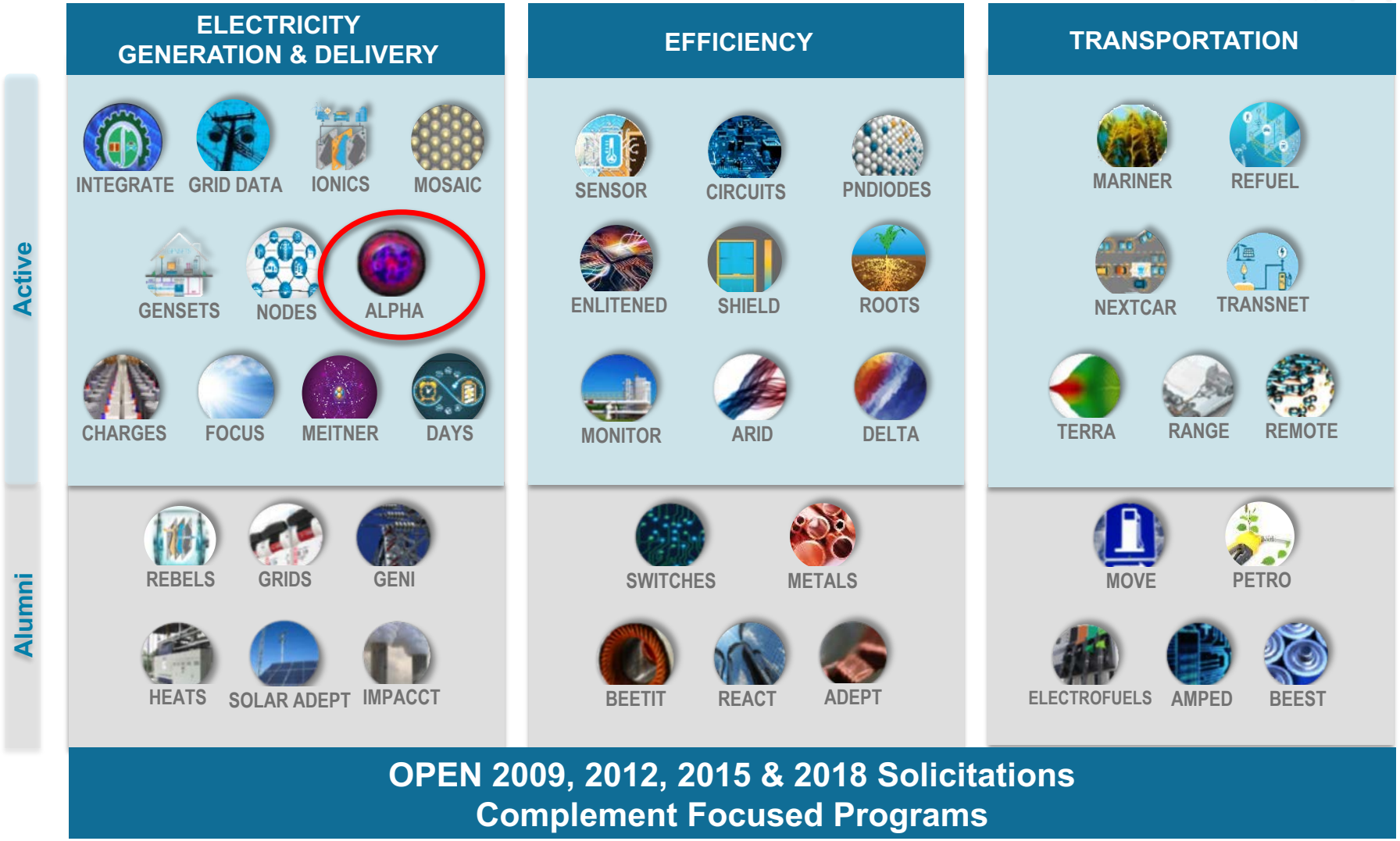
Mission: To overcome long-term and high-risk technological barriers in the development of energy technologies by providing R&D funding for transformational ideas

FY19 budget: $366M

ARPA-E aims to create a “mountain of opportunity” for energy technology development

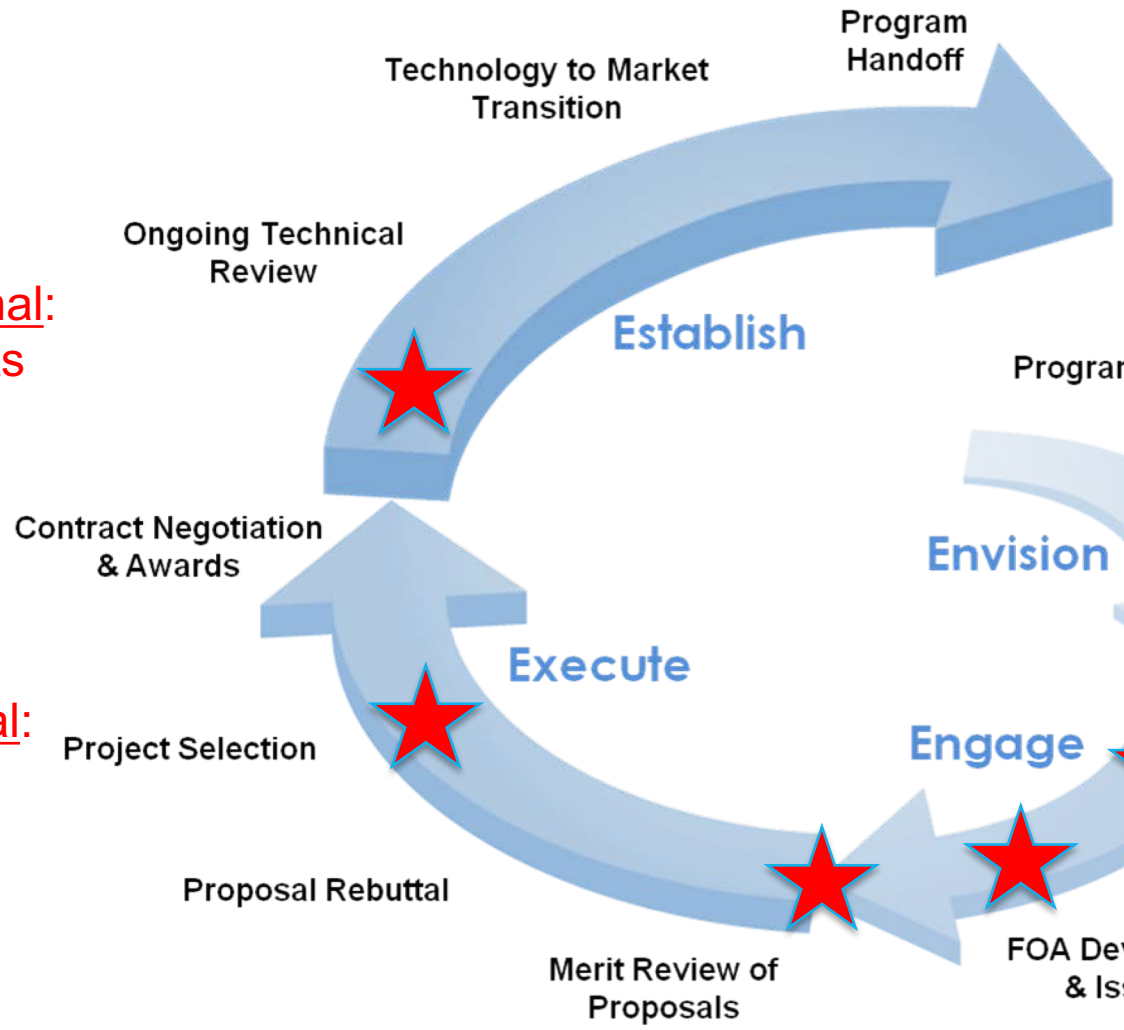


Focused programs are formulated through extensive debate, and aim to move the needle in a field with a finite investment



Links to ALPHA retrospective and JASON report

ARPA-E program process



NOTE: There is no FOA at present nor guarantee of an FOA. This slide shows an aspirational program timeline.

Aspirational: work starts Aug 2020

Workshop TODAY

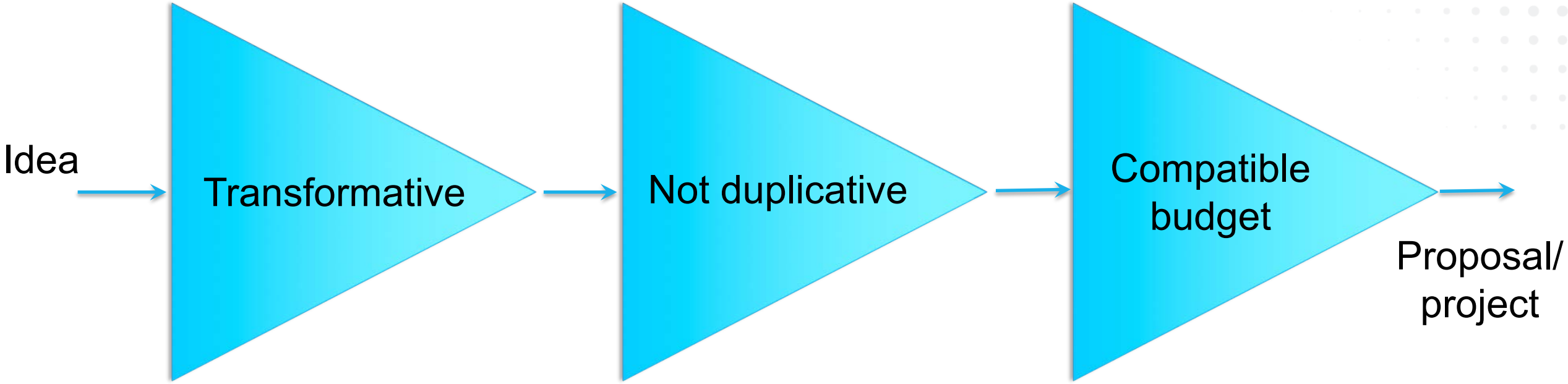
Aspirational: May, 2020

Aspirational: Sep, 2019

Aspirational: Oct, 2019

Aspirational: Full proposals due Feb, 2020 (following concept-paper stage)

What makes a good ARPA-E proposal/project?



Potential to disrupt development trajectory based on present state-of-the-art projections

Impactful project result for ≤$10M (federal funds), ≤3 years that will catalyze further support/effort

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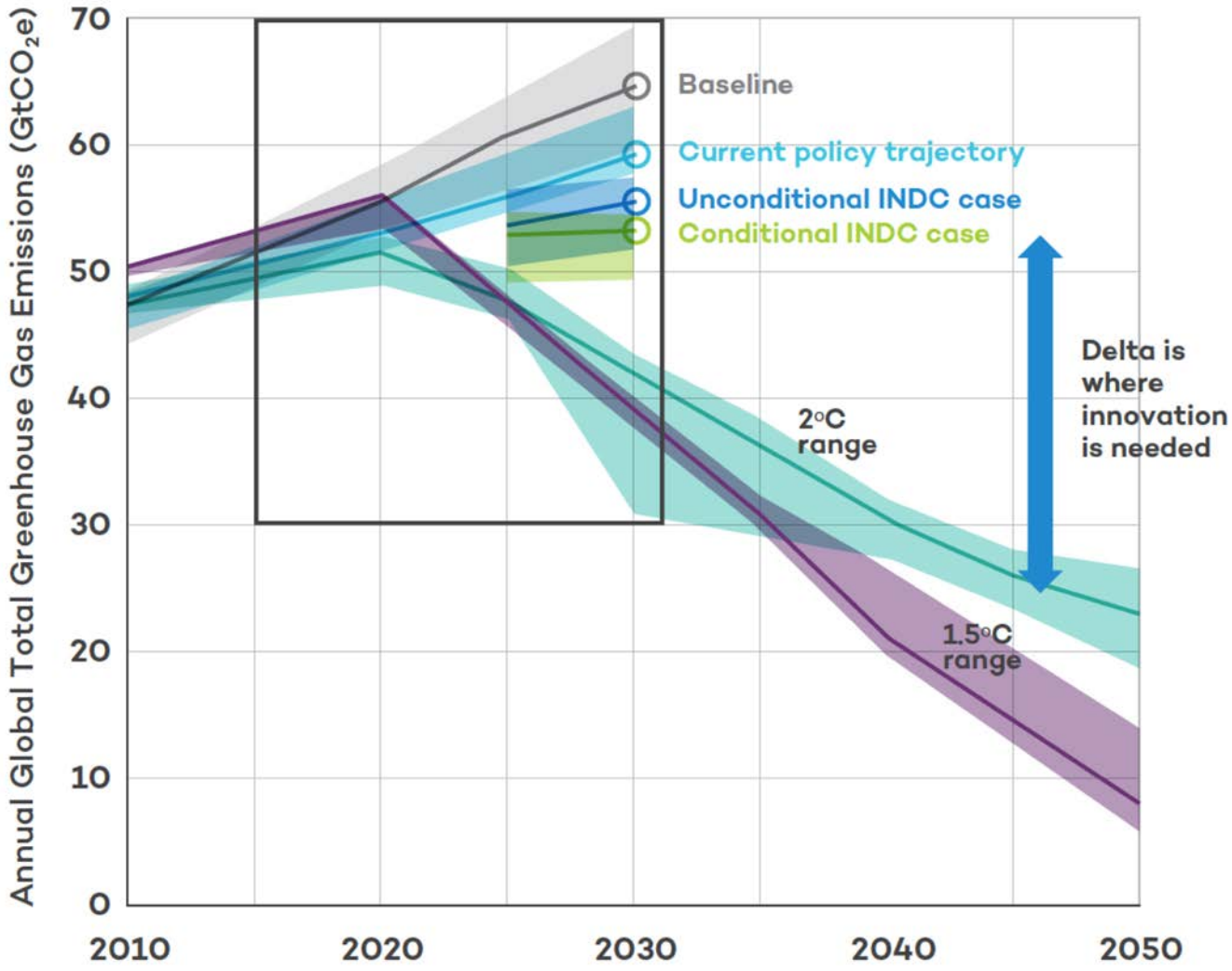
Fusion can significantly improve our chances of meeting mid/late-century carbon-emissions targets



Limited "solution space" for both techno-economic and socio-political reasons

Graph: Energy Futures Initiative, 2018 (modified from UNEP Emissions Gap Report, 2017).
INDC = Intended Nationally Determined Contribution (Paris, 2015)

Goal: Enable timely, commercially viable fusion energy

FUSION INDUSTRY ASSOCIATION

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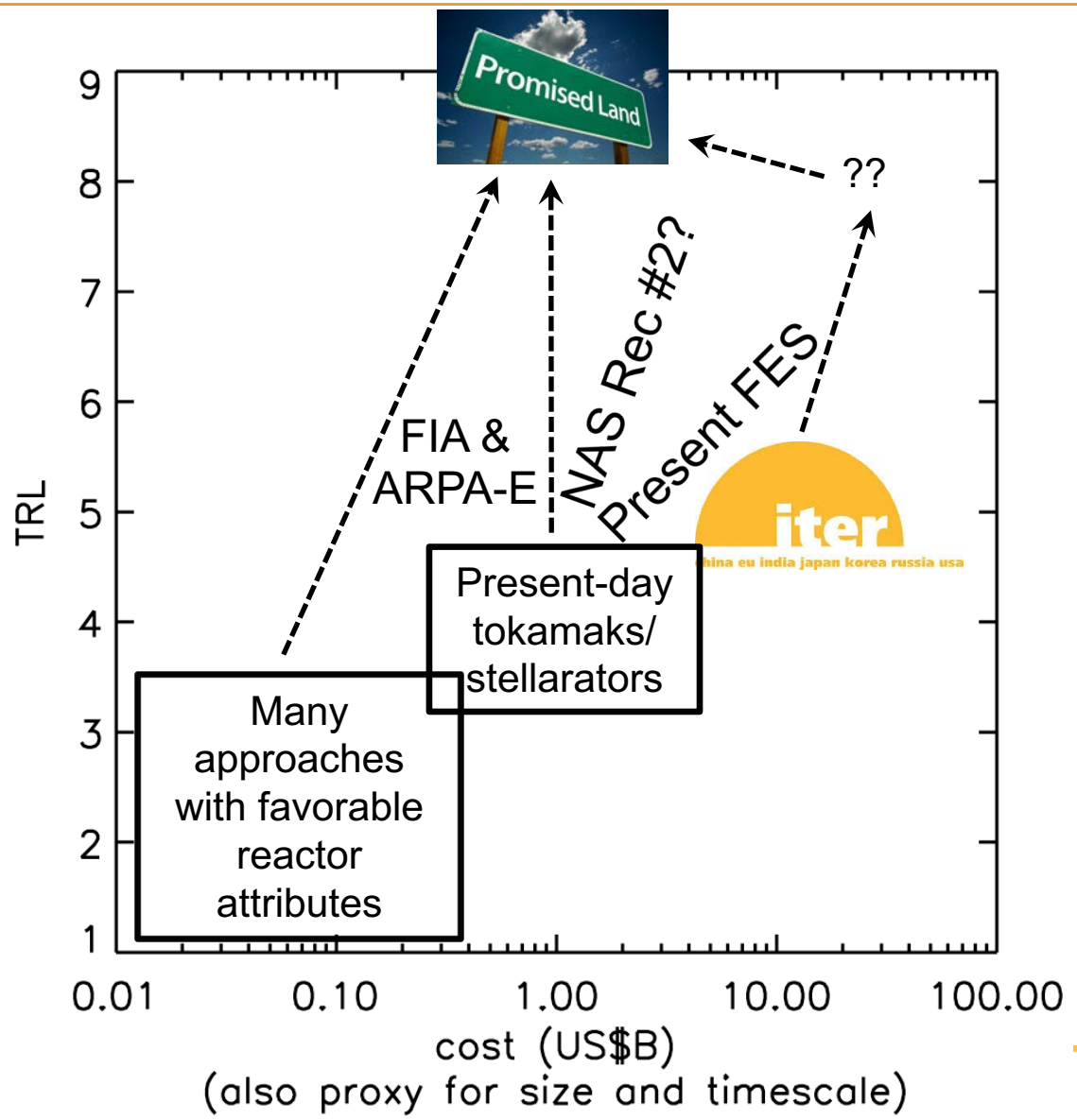
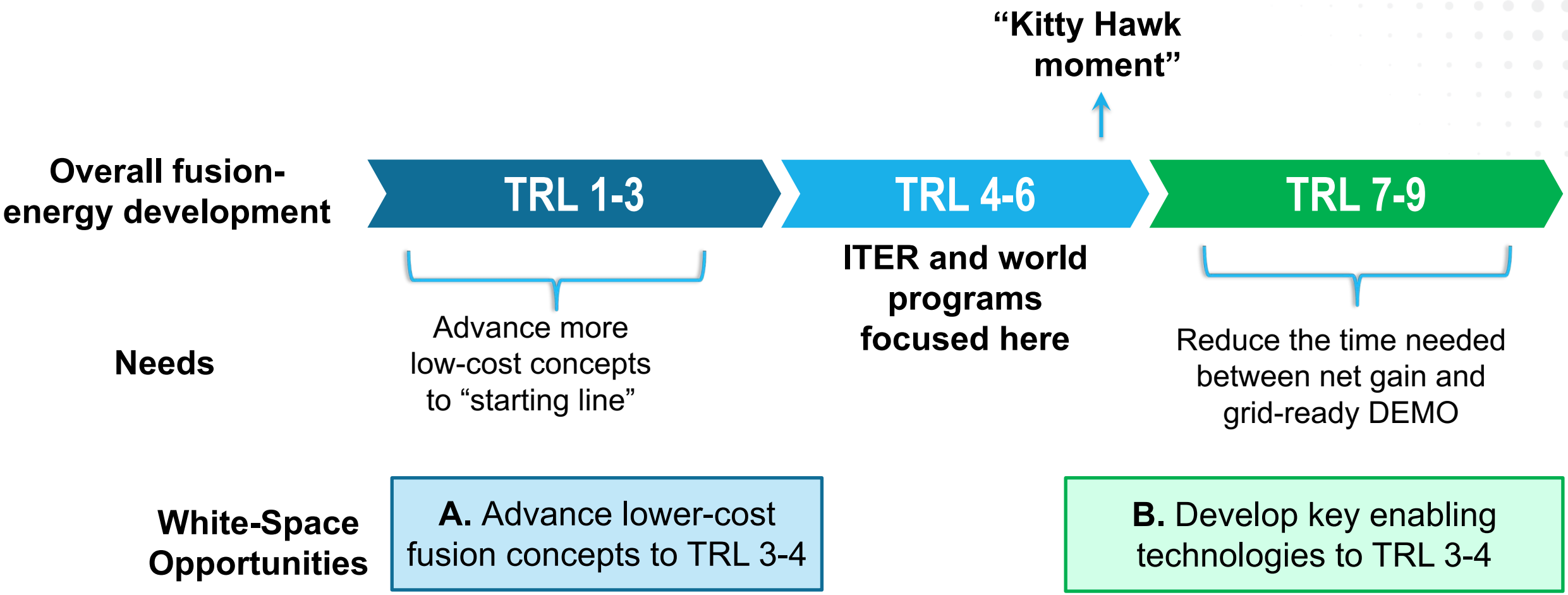
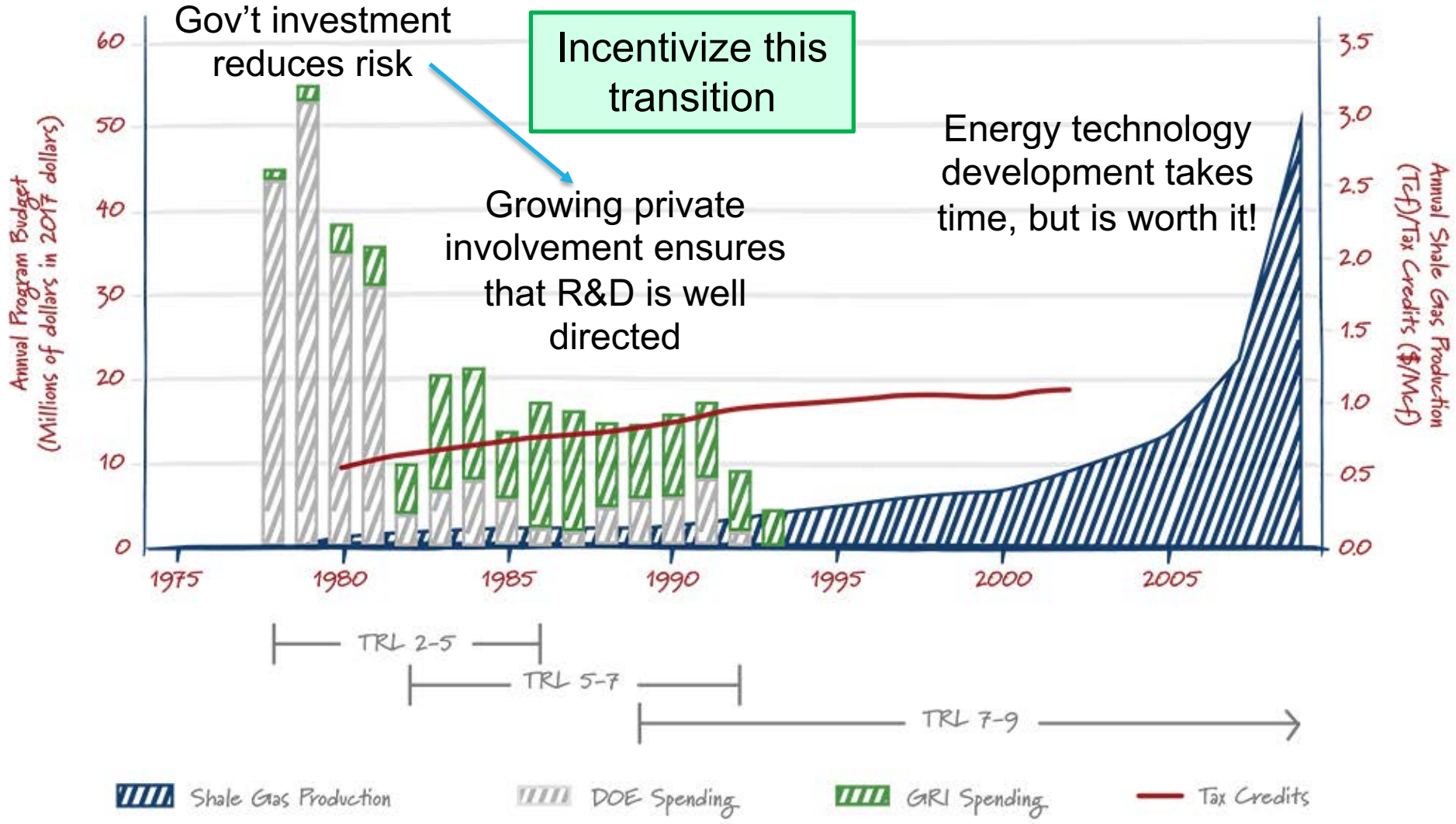


Office of Fusion Energy Sciences
Excellent Science Attractive Energy

Where is the technical R&D “white space”?



Where is the tech-2-market (T2M) “white space”?



from Hydraulic Fracturing: a Public-Private R&D Success Story, Clearpath and Cogentiv Solutions, January, 2019.

Fusion commercialization will require tackling much more than demonstrating technical feasibility

- Conducting ongoing market and techno-economic analysis (TEA)
- Securing finance scaling

Malcolm Handley's talk

- Earning public acceptance
- Achieving regulatory certainty

Jane Hotchkiss' talk

For timely fusion commercialization, all these long-lead-time tasks must be pursued in parallel alongside the pursuit of a grid-ready DEMO and continuously guide R&D choices.

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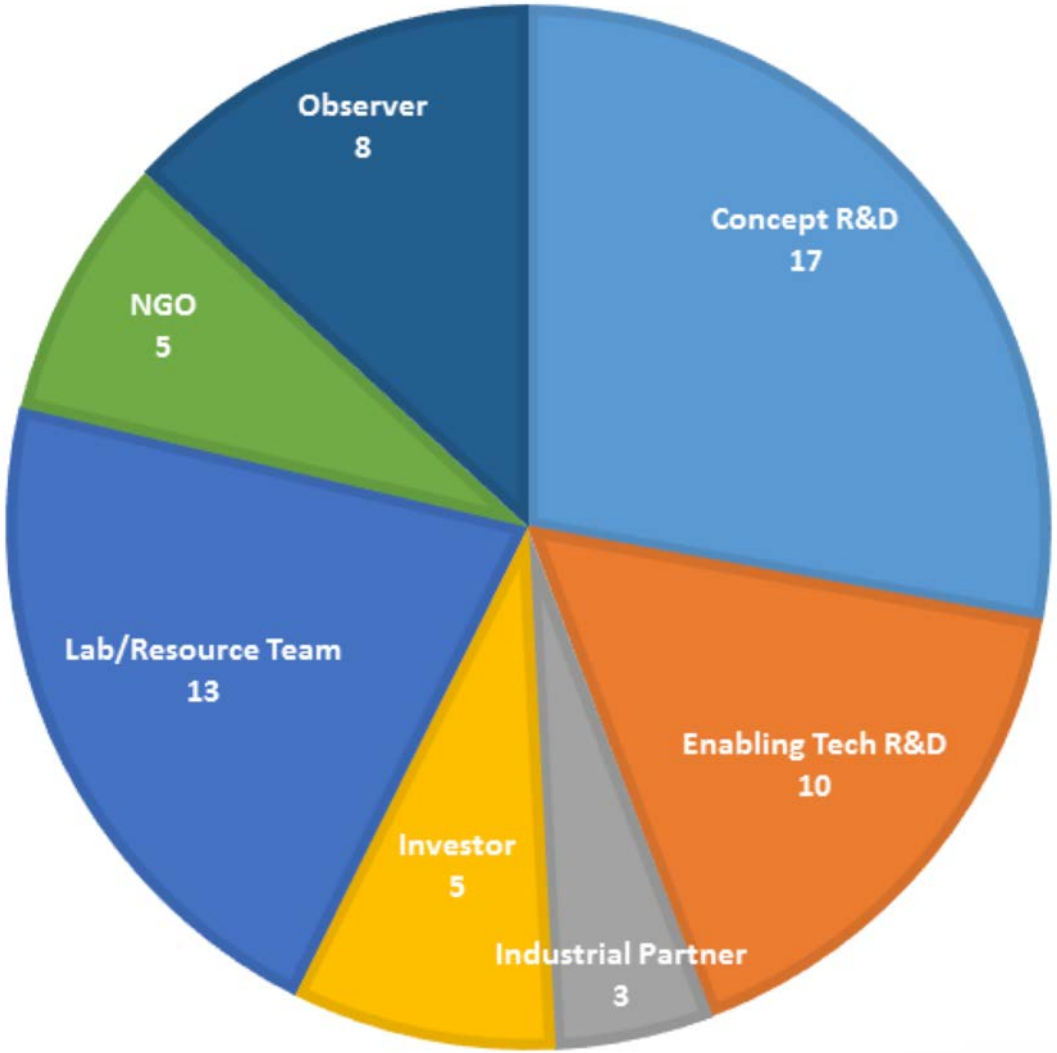
Agenda overview/rationale (three parts)

- T2M: Building the runway for fusion development and commercialization
  - Short talks
  - Structured breakout discussion

- Networking and team building
  - Networking session: “fusion ecosystem” available for discussion
  - Poster session: mostly technical teams present ideas, capabilities, needs

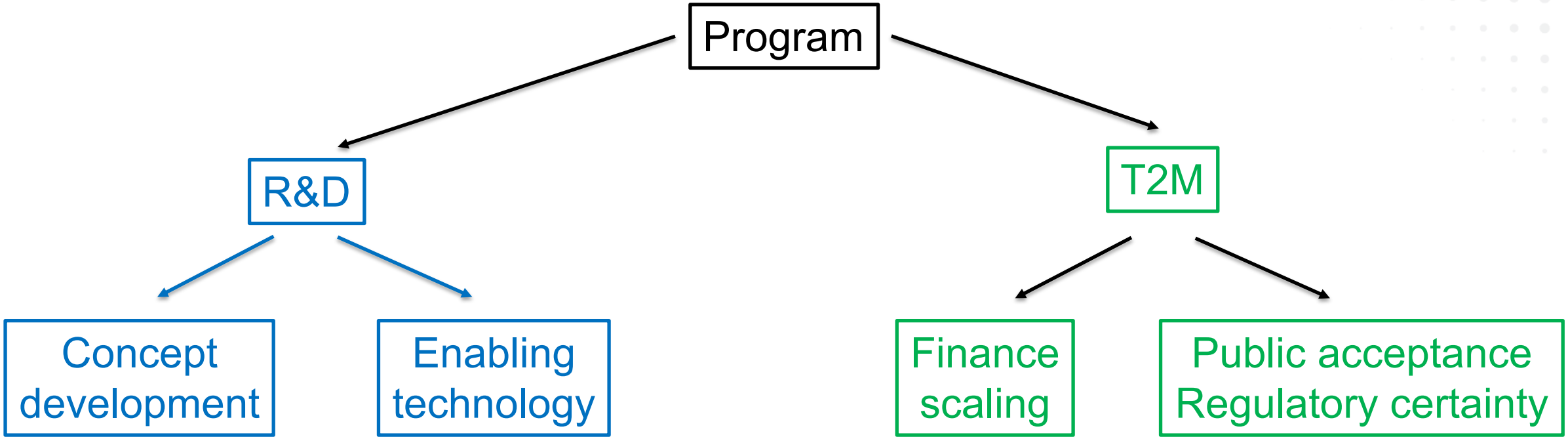
- Technical R&D: Perspectives & opportunities
  - Short talks
  - Structured breakout discussion

Attendee overview



Concept R&D	Tech R&D	Resource team	Investor	NGO	Ind. Partner	Observ-er
Zap	Phoenix	SRNL	Hydrazine Capital	FIA	GE Global Research	DOE/SC
General Fusion	LLE	UCLA	BEV	Pegasus	Wolfspeed /Cree	Anthropoc-ene Inst.
Univ. Wisconsin	SRNL	PPPL	CREO Syndicate	Stellar	Kairos Power	NRC
TAE	LANL	INL	Prime Movers Lab	Triple Product	Infineon	Exelon
Tokamak Energy	PPPL	UT-Austin			Exergy	GoogleX
LANL/ HyperJet	NRL	Sandia				Google
Lockheed Martin	LBNL	LANL				GA
CFS	MIT	LLE				CEERT
PFS	CSM	ORNL				
CTFusion		LLNL				
Woodruff Sci.						
Helicity Space						
PPPL						

Objective: present our thoughts and solicit your feedback/input on the following *to inform and refine my program pitch*



- R&D opportunities
- Metrics (for entry and measuring progress)
- Funding mechanisms
- Incentivizing public/private partnering
- Leveraging federally funded expertise/assets

- Investor engagement
- Market and techno-economic analysis

- Philanthropic, public-advocacy engagement
- Providing technical data for fusion safety analyses and NRC engagement

Technical category A: Concept exploration and development

Fundamental objective: Advance the performance of fusion concepts with **inherently lower cost, size, and/or complexity**

Well-defined, impactful technical milestones

Leveraging scientific expertise of labs and universities

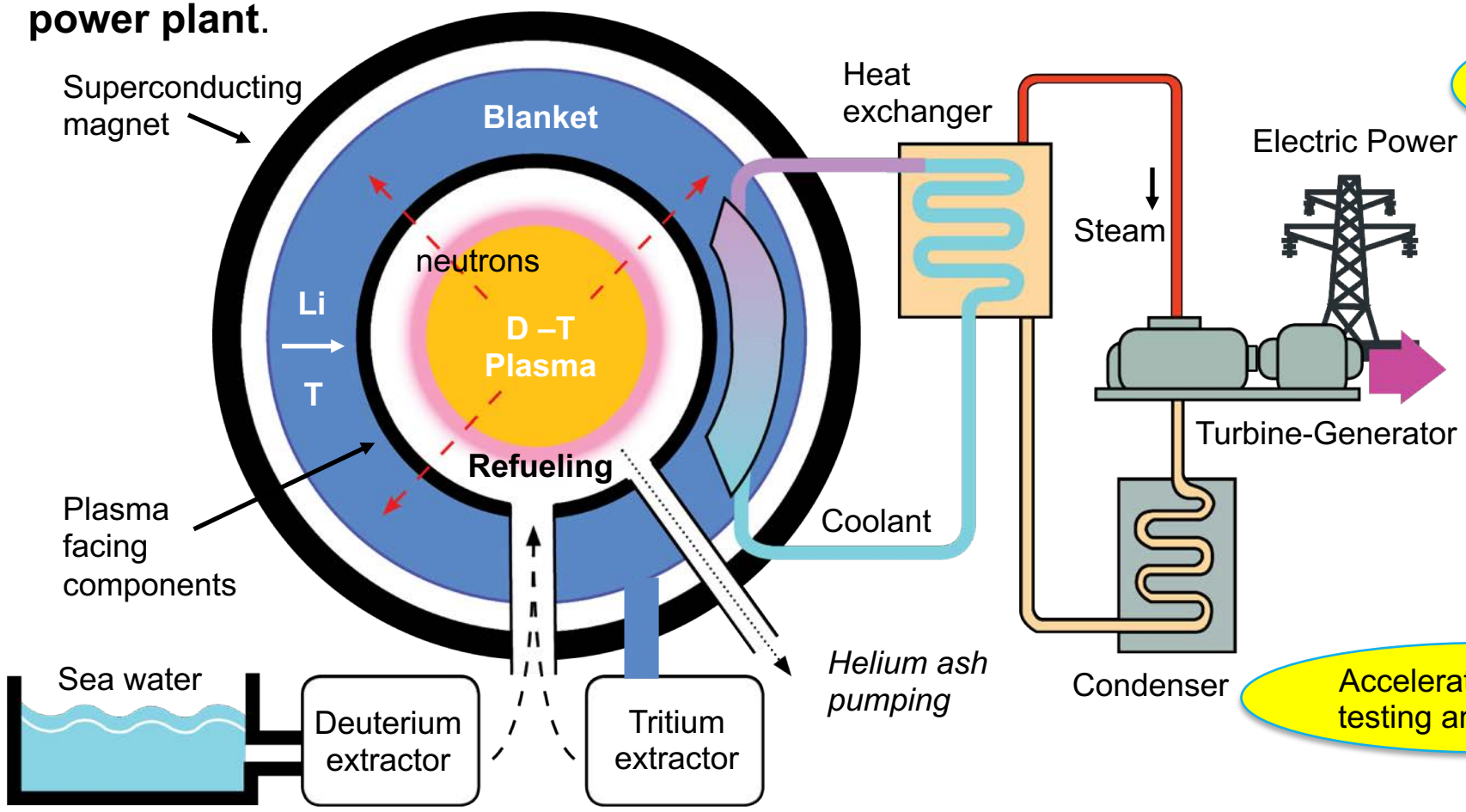
Applying state-of-art tools (diagnostics and HPC simulations)

Transformational applications of machine learning

(credit: R. Volberg and S. Thomas)

Technical category B: Fusion enabling technologies

Fundamental objective: Catalyze enabling-technology solutions needed for a **commercially viable fusion power plant**.



- Handling extreme fusion heat and particle exhaust
- High-temperature molten-salt or liquid-metal systems (up to 1200K)
- Tritium breeding/processing
- Transformational use of additive manufacturing
- Accelerated technology testing and qualification
- High-power, high-efficiency electronics and pulsed power

Figure adapted from: H. Yamada, *Fusion Energy*, in Handbook of Climate Change Mitigation, W.Y. Chen, J. Seiner, T. Suzuki, M. Lackner, eds. (Springer, New York, 2012)

Possible programmatic structure

Category / Team	A: Concept development	B: Enabling technology
Project team	Increase concept TRL/performance	Develop a needed solution/capability
Resource team	Support the above Expand resource capability	Support the above Expand resource capability

Project team: conducts R&D to develop a specific fusion concept or enabling technology.

Resource team: agnostic with respect to concept or enabling technology; offers expertise, hardware, capability to help multiple project teams make progress more quickly (and more cost-effectively).

Example: Selection of diagnostic resource teams to validate the performance of low-cost fusion concepts

- ORNL, $1.1M, Thomson scattering (low density) and visible emission spectroscopy
- LLNL, $2M, Thomson scattering (high density)
- LLNL, $1.3M, neutron activation and nTOF detectors
- Univ. of Rochester/LLE, $1M, neutron activation and nTOF detectors
- UC, Davis, $444k, ultra-short-pulse reflectometry
- PPPL, $290k, passive charge-exchange ion energy analyzer
- LANL, $630k, filtered, time-resolved soft-x-ray imager
- Caltech, $400k, hard x-ray imaging and non-invasive B-field assessment

Please think about “resource teams” for theory/modeling, machine learning, advanced manufacturing, and your ideas, to support fusion development

Fifty responses from recent RFI on enabling technologies for a commercially viable fusion power plant

U.S. Department of Energy
Advanced Research Projects Agency – Energy

Request for Information (RFI)
DE-FOA-0002131
on
Enabling Technologies for a Commercially Viable Fusion Power Plant

- Reduced nameplate generation capacity and capital cost
- Emphasis on solutions that enable thick liquid blankets, non-solid PFCs, sacrificial solid first walls, reduced tritium inventory, compatibility with advanced power cycles, etc.
- Transformational applications of advanced manufacturing
- Accelerated component testing and qualification at reduced cost
- Teaming with R&D communities and industries beyond fusion

Thoughts on funding mechanisms

Stage of development / Funding mechanism	Ending at TRL 2-3	Ending at ≥ TRL 4
Grant Cooperative agreement Work authorization	X	X
Milestone reimbursement Prize Other transaction		X

Setting program metrics (eligibility and measuring progress)

- Category A: concept exploration/development
  - Eligibility: *projected* major-component costs of achieving transient engineering $Q_{DT,equiv} > 1$ (using DD) should be $\lesssim$\$100M (not including building and diagnostics)
  - Measuring progress: identifying concept gain potential, plasma assembly, stability, confinement, $nT\tau$ scaling

- Category B: enabling technology
  - Eligibility: needed by one or more commercially viable fusion concepts; must identify a target quantitative metric and proposed improvement over projected state of the art
  - Measuring progress: based on TRL criteria

Breakout discussions will seek specific feedback on both R&D and T2M needs/opportunities

- Further details to be given in Introduction to Breakouts right before each breakout session
- Every attendee is assigned to a breakout group
- Each breakout group will include a full mix of workshop participants and address the same topics

We are looking for specific feedback that will help impact program formulation and inform budgetary needs.

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