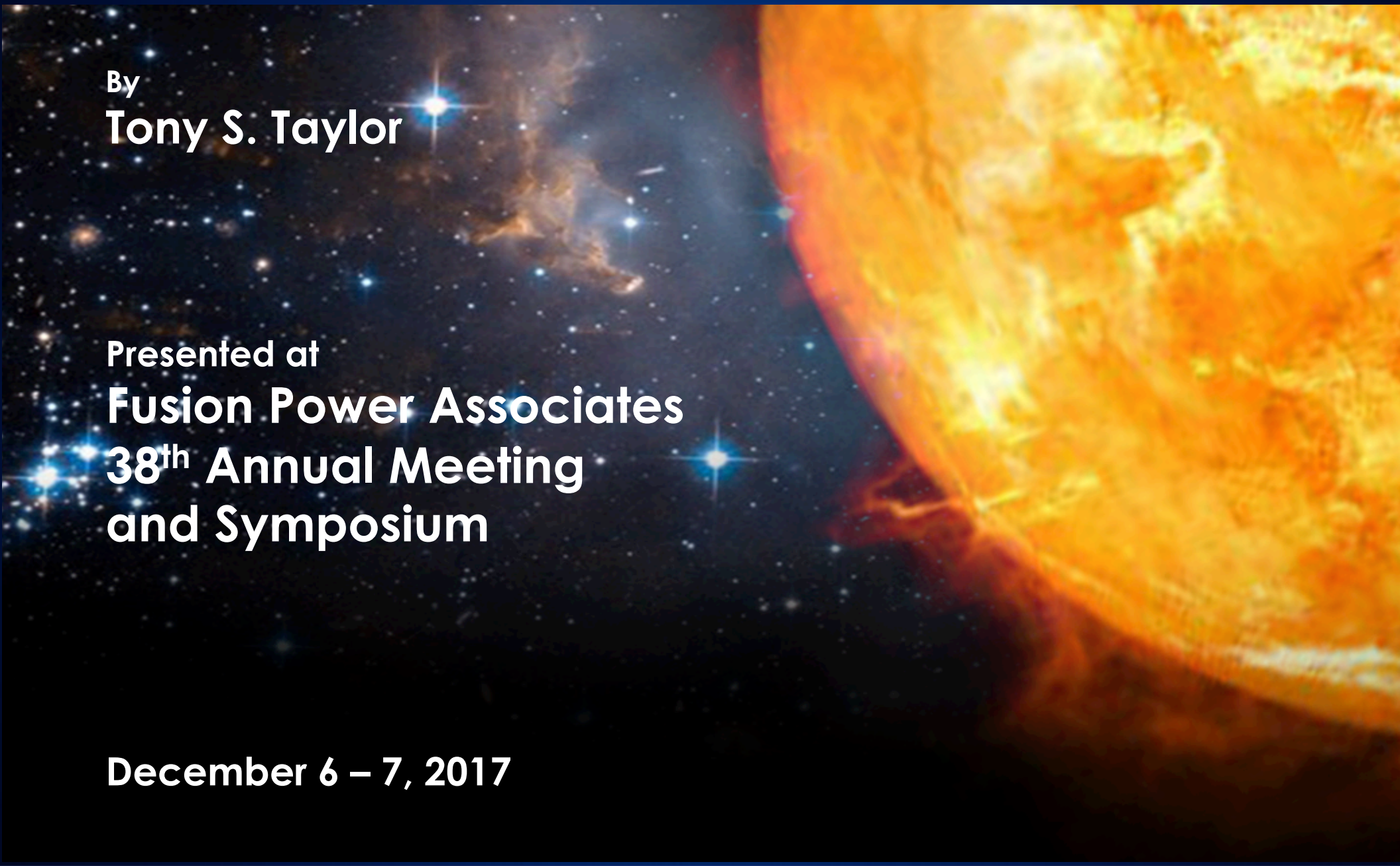
Perspective on Pathways and Progress Toward Fusion Power



By
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Presented at
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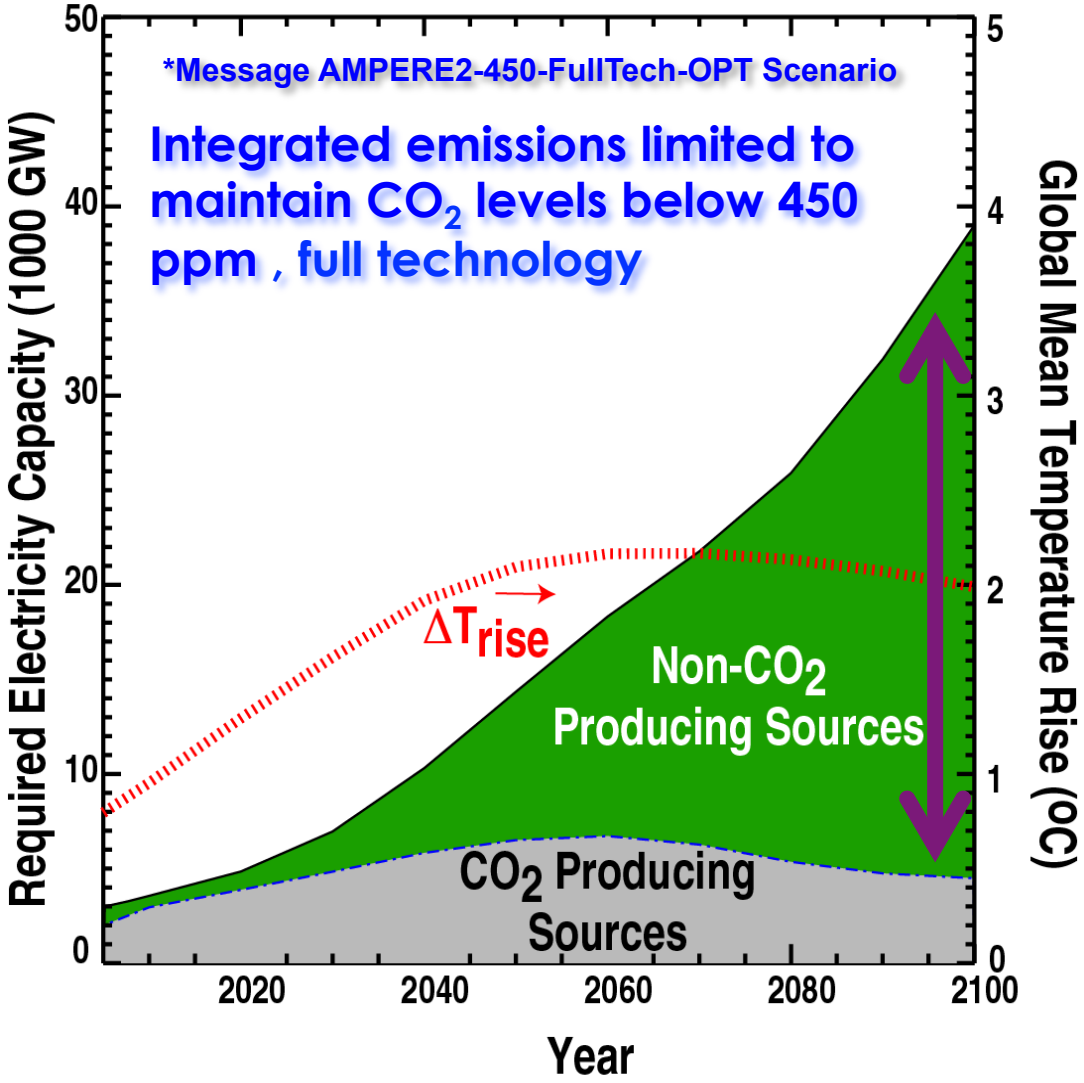
38th Annual Meeting
and Symposium

December 6 – 7, 2017

Electricity Demand in Next 100 Years Presents Major Challenges and Also Tremendous Opportunity



Strategic Interest for the U.S. and the World

- **Projected need for ~ 35,000 GW from non-CO2 producing sources**

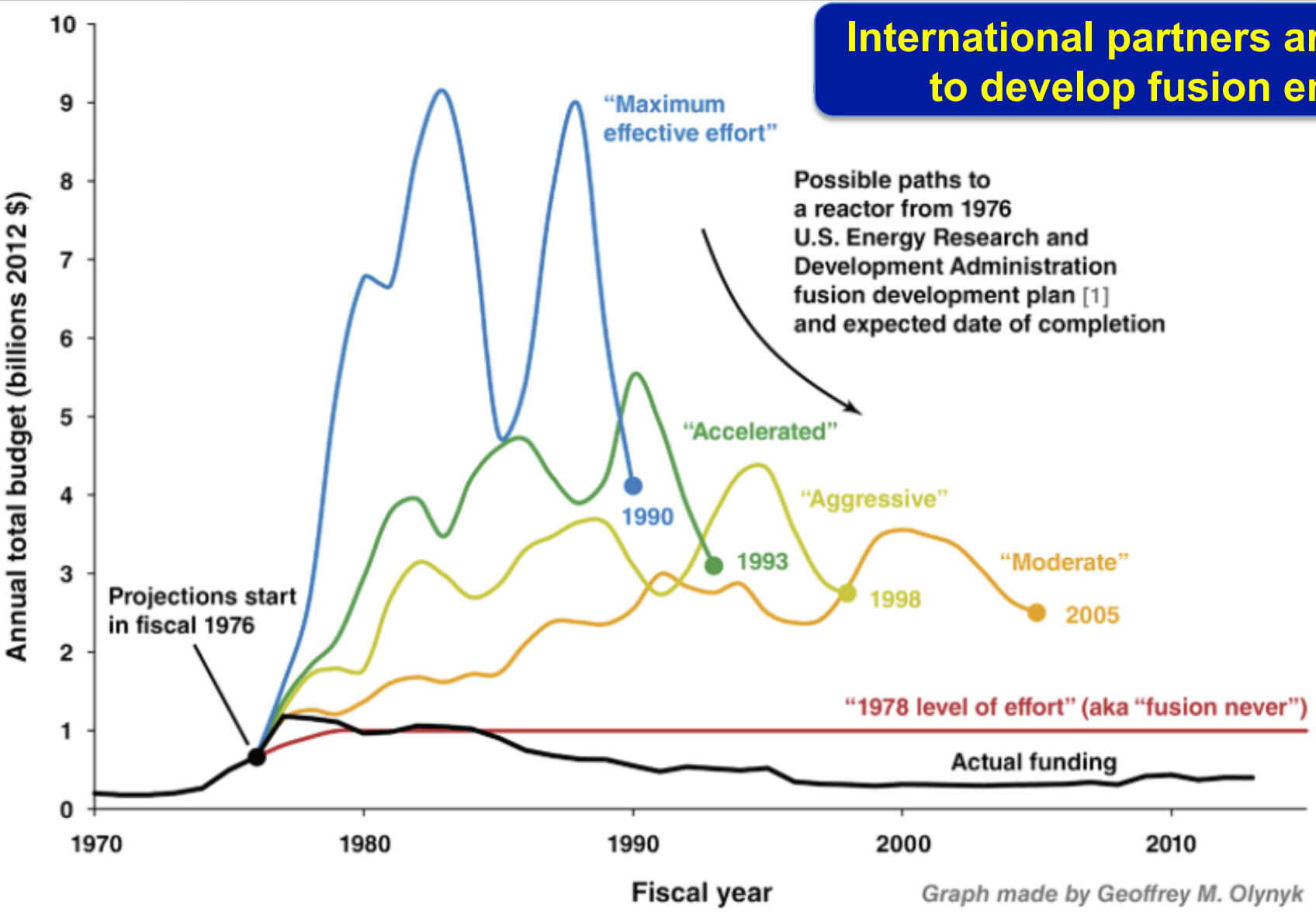
35,000 1 GW-e plants !!!

- **Consequently, annual investment in energy projected to explode**
  - $0.8T by 2050
  - $2.5T by 2100

→ ***Timely positioning is key***

Substantive Progress Towards Fusion Energy Requires Increased Funding

International partners are needed to develop fusion energy



[1] U.S. Energy Research and Development Administration, 1976. "Fusion power by magnetic confinement: Program plan" ERDA report ERDA-76/110. Also published as S.O. Dean (1998), *J. Fus. Energy* **17**(4), 263–287, doi:10.1023/A:1021815909065

Koepke, 2014

Accelerating the Path to Burning Plasmas and Fusion Energy Development

- **The Challenge**
  - Very challenging problem → Robust funding required
  - Multiple challenges must be resolved→ Strategic plan required
  - Staging of elements essential → Community consensus needed

Ages-old quip: ***"Fusion is 50 years away and always will be."***

How to reconcile?

Goal: ***economical fusion energy within the next several decades***

- **The Solution**
  - Compelling vision for energy mission → Gain Interest of community, funding agencies and politicians
  - Vetted strategic plan → Inform prioritization of available funding
  - Broad community consensus → Unified purpose and messaging
  - Bold leadership → Implement & execute difficult priority choices

--- All done in partnership with Office of Science and FES -

➜ **Increase available funding**

Strategic Plan
Assertions and Principles

Assertions

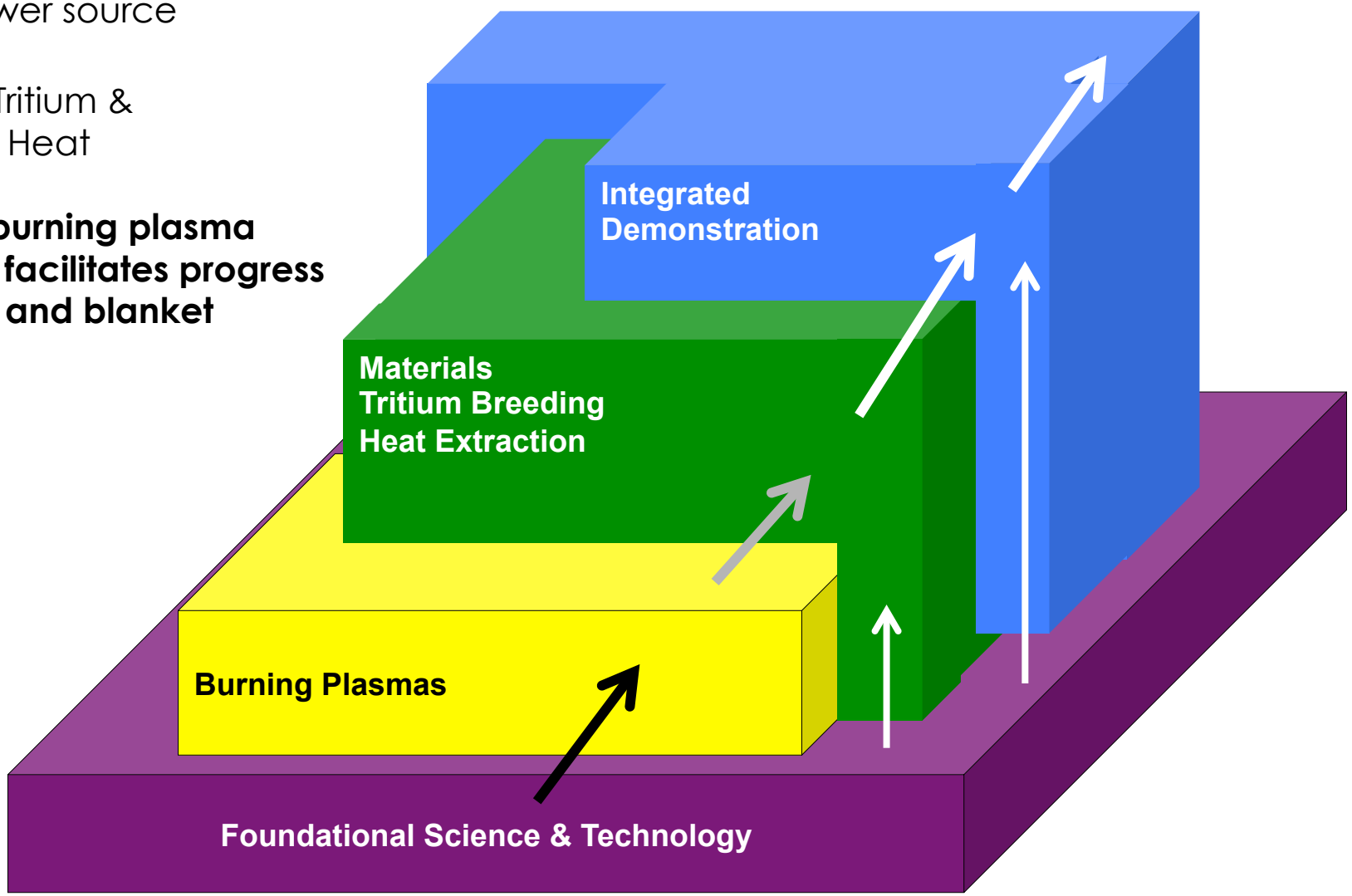
- Burning plasma R&D is the next major step for fusion development
- ITER represents the most timely, capable option for a U.S. burning plasma experiment
- Materials and nuclear science challenge is formidable and early resolution of key challenges is critical for timely delivery of fusion energy
- Tokamak is the most expedient path to fusion energy

Principles

- Enable development of attractive fusion energy as soon as possible
- Timeliness over attractiveness of end product (power plant)
- Build on existing strengths
- Maintain high level of scientific excellence, and energy goal
- Value innovation
- Leverage capabilities of international partners

Burning Plasma: First Major Step on Path to Fusion Energy
Other Steps: Build on a Burning Plasma to Complete

- **For DEMO, technical readiness must be established for:**
  - Fusion power source
  - Materials
  - Breeding Tritium & Extracting Heat
- **Successful burning plasma experiment facilitates progress in materials and blanket technology**



Realization of Attractive DEMO Will Require Closing the Feasibility Gap in Three Areas Required for Fusion Energy*

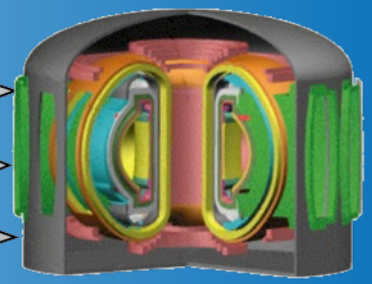
* Priorities, Gaps, Opportunities … 2004

Fusion Power Source (Neutrons)

Materials for Fusion Environment

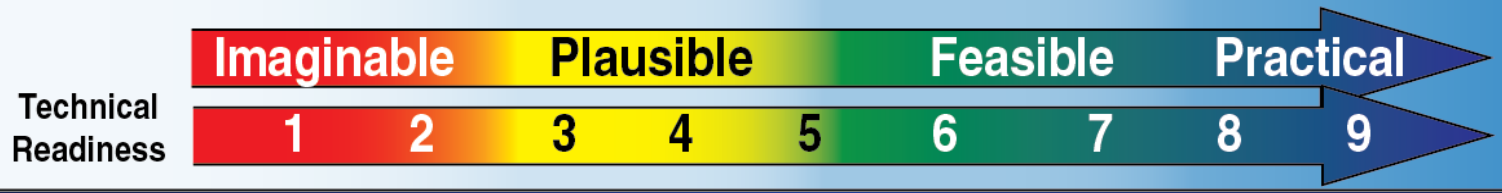
Harnessing Fusion Power

A successful burning plasma experiment will leave significant gaps in fusion materials and blankets



DEMO

Approximate Technical Readiness Level



Developing Key Elements of a Strategic Plan

Support a community/FES process (follow-on to present community workshops) to develop a long term fusion strategy/roadmap

- **Fully participate in ITER as the U.S. Burning Plasma Experiment**
- **Develop a strategic plan with exciting staged milestones targeting a U.S. cost-attractive DEMO in the next several decades**
- **Strategy should include**
  - Robust support for engaging in burning plasma physics
  - Solid foundational physics program that engages the broader community; universities, industry and national labs
  - A strong theory and computation program
  - New U.S. fusion facilities including transition plan from existing ones
  - A growing effort in fusion material development and testing
  - A growing effort in fusion blanket research

The U.S. Strategic Plan Should Include a Robust Tokamak Effort

Mission Elements for a compelling U.S. tokamak program

- **Support and prepare for burning plasma research (ITER) → exploitation**
- **Prepare for a cost-attractive DEMO**
- **Train fusion scientists and engineers for the future**

Key research elements of a tokamak program should include

- **Platform for excellent plasma and fusion science**
- **Plasma exhaust, disruptions, steady-state, predictive simulation**
- **Optimize performance (nT τ /IaB)**
  → enabled by improving scientific understanding
  - Proposals for cost-attractive Demos include significantly improved confinement (H ~ 1.6 - 1.8) and stability.
- **Enabling Technologies**
  - Magnet Development program →demonstrate large, high field magnet with high temperature superconductors
  - Innovative current drive

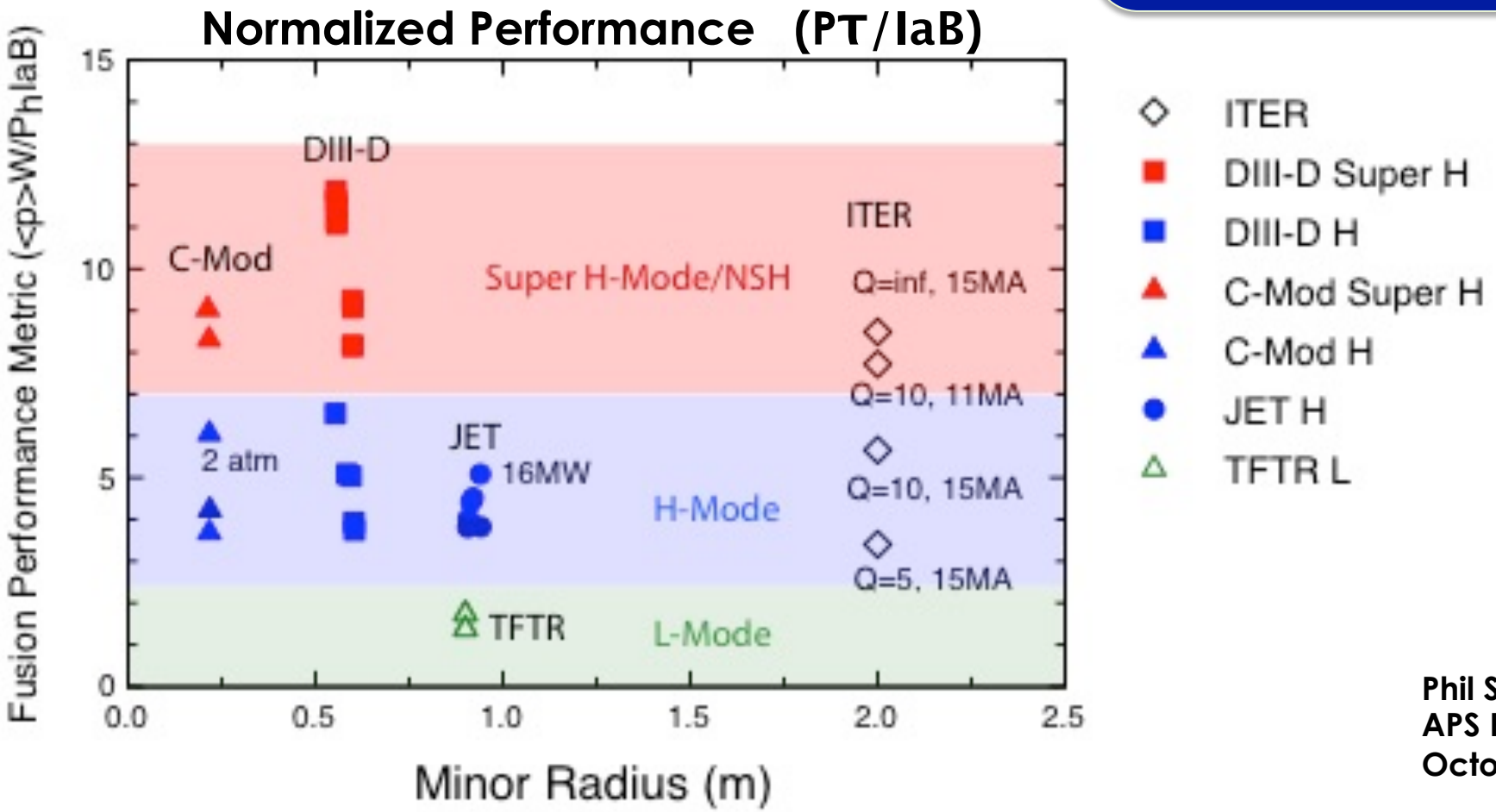
Facility: new tokamak facility or upgraded existing facility

Scientific Understanding → Experiments with Significant Potential for Improved Tokamak Performance

Program effort

- Validate key physics of high performance, and extend to long pulse
- Use for exploitation of iTER and design of a cost-attractive DEMO

Open issues: Challenges for Super H mode operation include sustainment, impurity control, and ELM control. For JET and ITER, compatibility of strong shaping and nearby metal walls



Phil Snyder
APS Review
October, 2017

Concluding Remarks

- **For a continuing vital fusion program + a timely realization of fusion energy, we need**
  - Increased interest and support from the public, the politicians and funding agencies → increased funding
  - A necessary requirement is a unified community working together toward a common goal and working in partnership with FES and SC
- **We must work effectively with international partners to develop fusion energy**

Let's work together to move fusion forward in the U.S. and the world