# Breaking the Mold for a (new?) (US-MFE) Strategy*

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*24th Symposium on Fusion Engineering (SOFE)*
*Town Hall Meeting:*
Accelerating the Development of Fusion Power

July 27, 2011
Chicago, IL

*(* not my title…)*

University of
Wisconsin-Madison

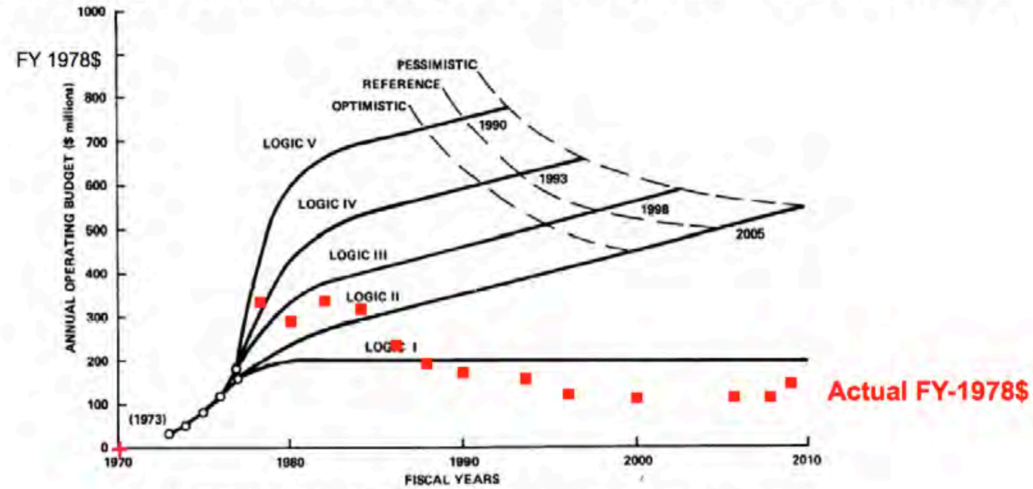
# MY VIEWS ARE BIASED BY MY ASSUMPTIONS

- MFE progress towards fusion energy is more resource-limited than knowledge-limited

- We cannot get to fusion energy with our present program funding

- The decision to significantly increase funding to realize fusion energy will be driven by external events
  - No one is going to fund fusion energy development because we say they should

Fusion Power by Magnetic Fusion Program Plan July 1976 ERDA – 76/110/1




FUSION R&D PROGRAM OPERATING BUDGET AND LOCI OF DEMO OPERATING DATES FOR LOGIC I THRU V

- Logic IV became the basis for the MFE Act of 1980.
- The US Fusion Program evolved on to Logic I - we never get there.

- Our job is to prepare technically correct answers to: “can you do it now, how long, and how much?”
  - Not: “what do you need to develop those answers?”

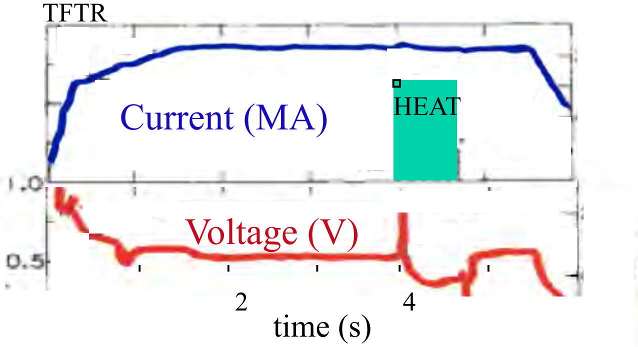
# It is time to Reposition How We Present the U.S. MFE Program

- Need to develop, and consistently make, the case that the U.S. MFE program can break out into a directed energy development program when desired
  - Show that the program can be put on path to “succeed” on the ITER (Q ~ 10) timescale
    - Success = requisite background work done to justify step to DEMO construction with “acceptable” risk

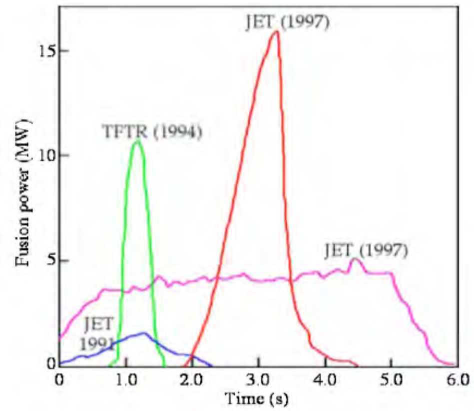
- Design and pursue a near-term program to support that direction
  - With the international program moving forward, the status quo will not hold…

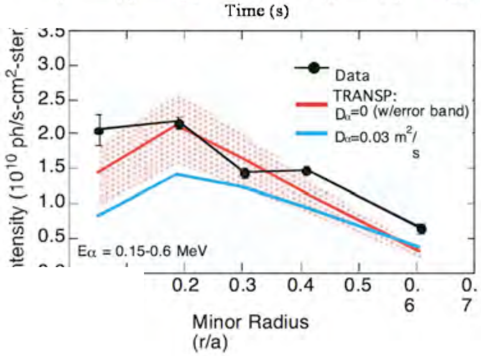
# Progress in Fusion Science Motivates Addressing More Energy-Specific Issues

**Current Drive & Sustainment**

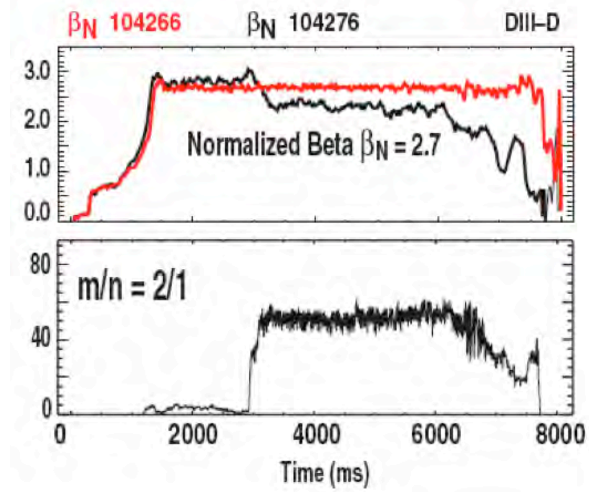



**Low-Q DT Fusion Demonstration**

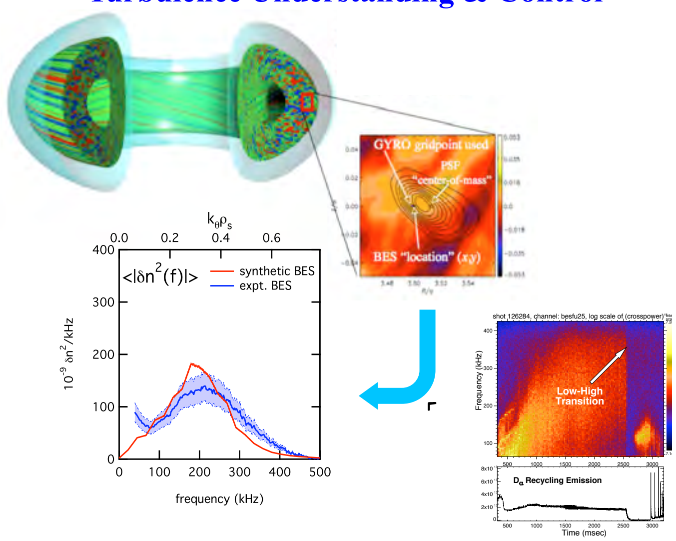


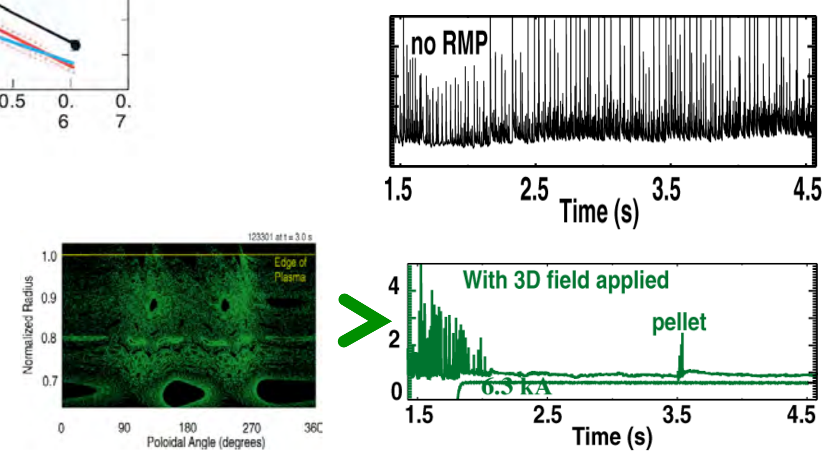

**Disruption Limits & Avoidance**




**Turbulence Understanding & Control**




**ELM suppression**

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# Scientific Progress and ITER Commitment Motivate Program Evolution

- Many studies have confirmed scientific progress and excellence

- ITER = the science of a high gain (Q~10) burning plasma
  - Reactor-scale plasma science: confinement; stability
  - Reactor-relevant technologies: SC magnets; Heating and Diagnostics; initial TBM tests, etc.

- ITER was claimed to be the "penultimate step to fusion energy"

- Our challenge: figure out how to make that so for the U.S.
  - What else has to be done in parallel with ITER to motivate construction of a fusion DEMO (agnostic to detailed features or who does it)?

# Challenges in Addition to ITER BP Identified for MFE

- Fesac, ReNew, etc. as most recent assessments
- The Big 4 Themes
  - Demonstrating and exploring the burning plasma state
  - Creating predictable, high-performance steady-state plasmas
  - Taming the plasma-material interface
  - Harnessing fusion power
- Assuming sufficient progress in each of these areas, we can credibly argue that moving to DEMO is an acceptable risk
  - Devil in details of "acceptable" risk: will not be determined solely by fusion community

# Broadening the Fusion Portfolio to Enable a Future Energy Development Program

- Need to evolve and be ready to motivate expansion from OS to include an energy development program
  - Recognize that leads for Themes 1 & 2 likely to reside in new and existing programs in international portfolio
    - Explore mods to ITER program to take more advantage of reactor scale?
  - Need to increase our emphasis on 3rd and 4th Themes to make case for readiness and position US program for future

- A Fusion Nuclear Science & Engineering Program (FNSEP)
  - PWI, materials, TBM, etc.
  - Fusion engineering education and development (critical weakness?)
  - "Out-of-pile" engineering science developments
  - Integrated D-T Fusion Nuclear Science Experiment/Facility
    - Future lead national facility

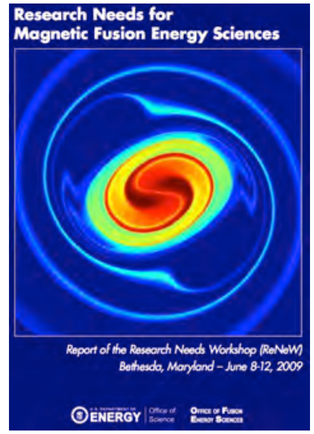
# Metrics for Success of an FNSP are Available from Past & Recent Work…

**How Initiatives Could Address Gaps**

Legend

| | |
|---|---|
| Major Contribution | 3 |
| Significant Contribution | 2 |
| Minor Contribution | 1 |
| No Important Contribution | |

| | G-1 Plasma Predictive capability | G-2 Integrated plasma demonstration | G-3 Nuclear-capable Diagnostics | G-4 Control near limits with minimal power | G-5 Avoidance of Large-scale Off-normal events in tokamaks | G-6 Developments for concepts free of off-normal plasma events | G-7 Reactor capable RF launching structures | G-8 High-Performance Magnets | G-9 Plasma Wall Interactions | G-10 Plasma Facing Components | G-11 Fuel cycle | G-12 Heat removal | G-13 Low activation materials | G-14 Safety | G-15 Maintainability |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I-1. Predictive plasma modeling and validation initiative | 3 | 2 | | 2 | 2 | 3 | 1 | | 2 | | | | | | |
| I-2. ITER – AT extensions | 3 | 3 | 3 | 3 | 3 | | 2 | | 2 | 2 | 1 | 1 | | 1 | 1 |
| I-3. Integrated advanced physics demonstration (DT) | 3 | 3 | 3 | 3 | 3 | 1 | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 |
| I-4. Integrated PWI/PFC experiment (DD) | 2 | 1 | | 1 | 2 | | 2 | 1 | 3 | 3 | 1 | 1 | | 1 | 1 |
| I-5. Disruption-free experiments | 2 | 1 | | 2 | 1 | 3 | | 1 | 1 | 1 | | | | | |
| I-6. Engineering and materials science modeling and experimental validation initiative | | | | | | | 1 | 3 | 1 | 3 | 2 | 3 | 3 | 2 | 1 |
| I-7. Materials qualification facility | | | | | | | 1 | | | 3 | 2 | 1 | 3 | 3 | |
| I-8. Component development and testing | | | 1 | | | | 2 | 1 | | 3 | 3 | 3 | 2 | 2 | 2 |
| I-9. Component qualification facility | 1 | 1 | 2 | 1 | 2 | | 3 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |

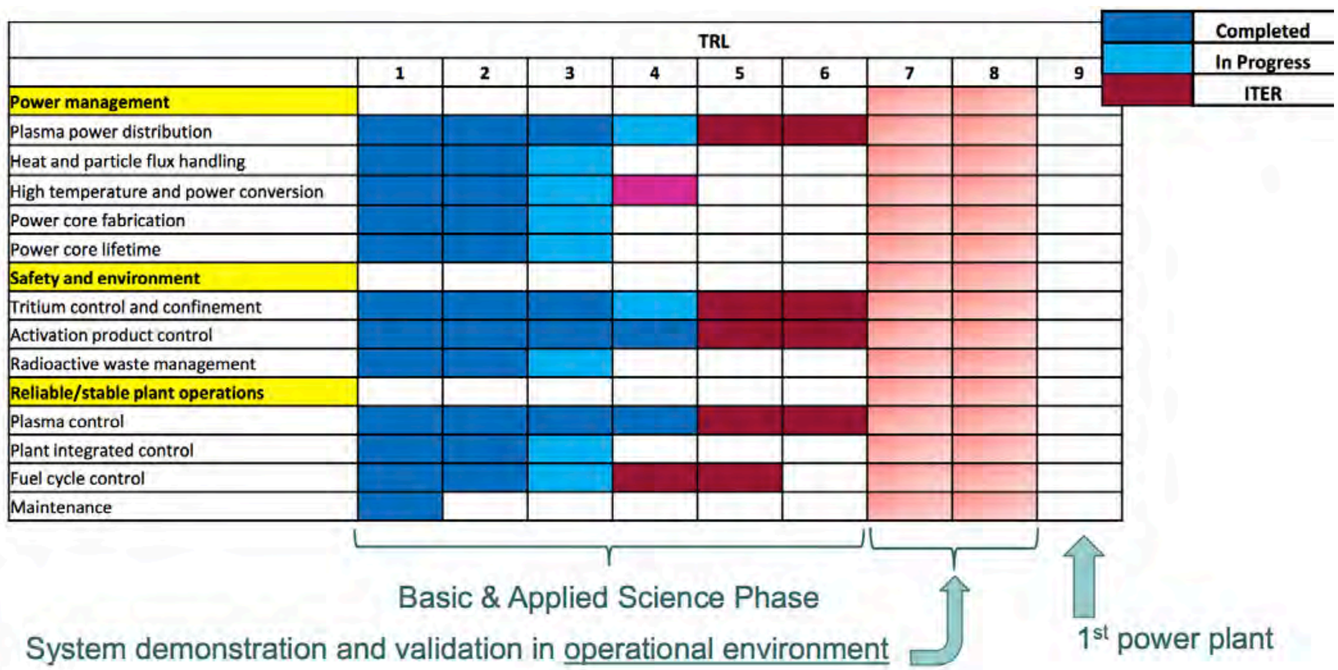



*FESAC "Gaps", ReNew:*

What has to be done and how it could be done…

*ARIES TRL analyses:*

Impact of specific elements on end goal; elucidation of risks…

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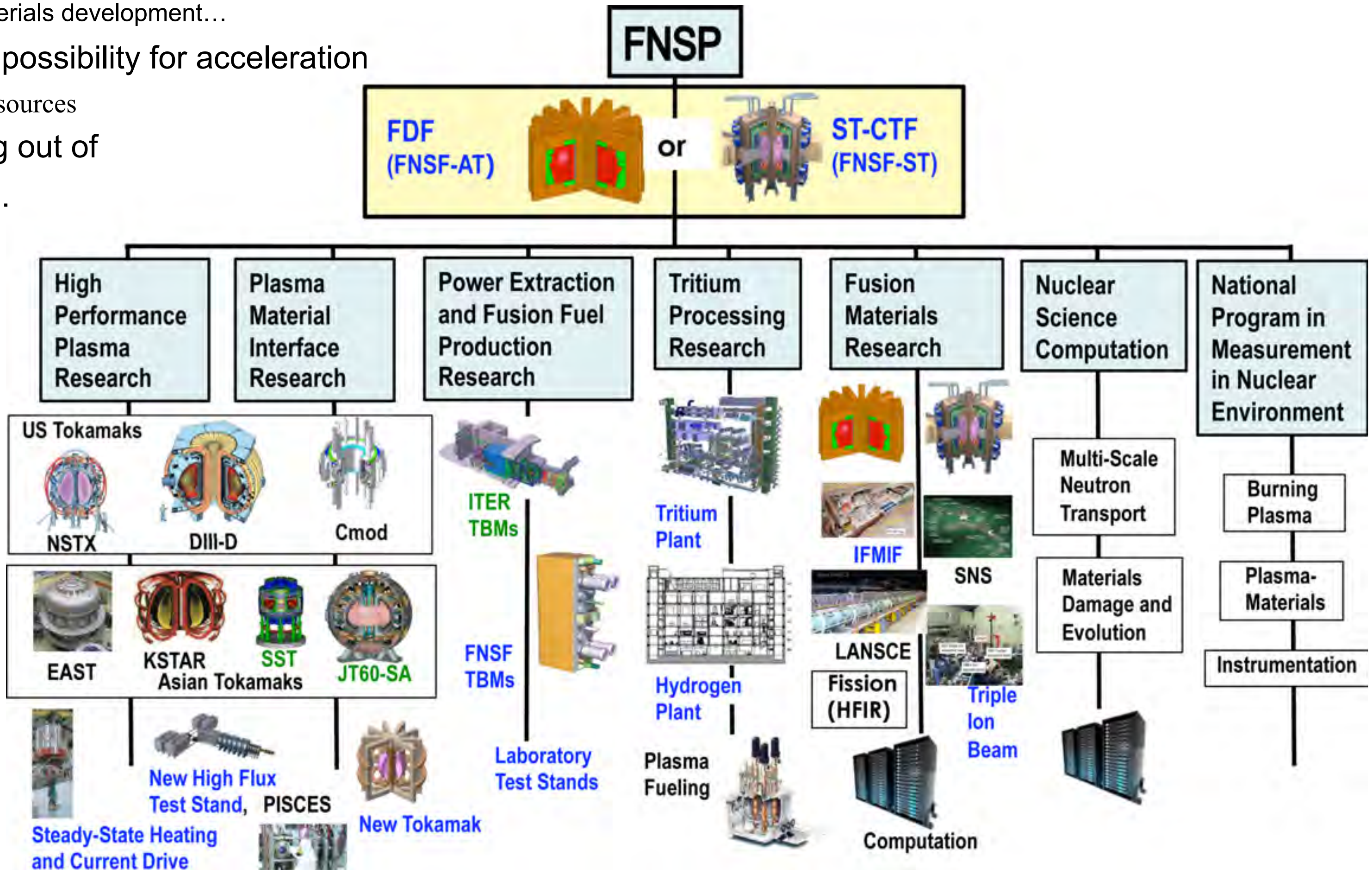
# US-MFE Roadmap Elements

- US should aspire to leadership in new fusion frontiers
  - Themes/Challenges 3&4 as increasing focus: add FNSEP
  - In international context
    - BP and ss covered by existing and new machines
    - Watch on materials development…
- Identify elements and possibility for acceleration
  - Accordion plan by resources
- Note activities growing out of community already…

- On-going plasma science and BP physics



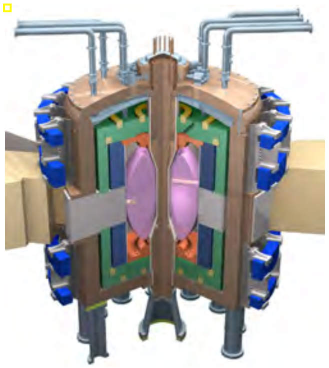

*(courtesy R. Stambaugh, FNS Pathways, 3/11/11)*

# FACILITY CONCEPTS ARE UNDER CONSIDERATION FOR FNSP AND BEYOND…

- *<u>Program</u> Mission:*

  Fill the gaps in ITER and existing fusion programs to support a FOAK DEMO construction with acceptable risk

## FNSF-ST

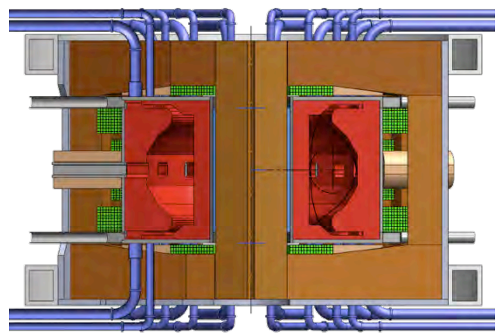


(copper)

*<u>FNSF</u> Objectives:*

- 2-6 MW/m$^2$ neutron fluxes for long times
- Test/validate materials
  (low activation, high strength,
  high temperature, radiation resistant)
- Tritium breeding; self-sufficiency
- Produce high-grade process heat

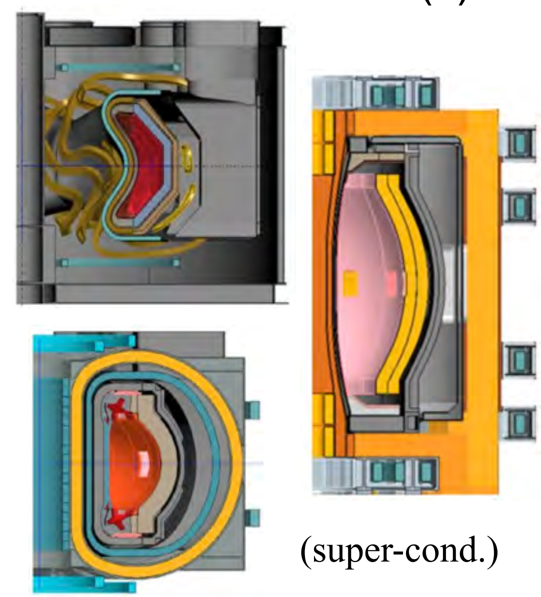
## FNSF-AT



*Add:*

- Enable DEMO-class high-performance plasma research

## FNSF-Pilot Plant(s)



(super-cond.)

*Add:*

- Generate net electricity
- Reactor maintenance schemes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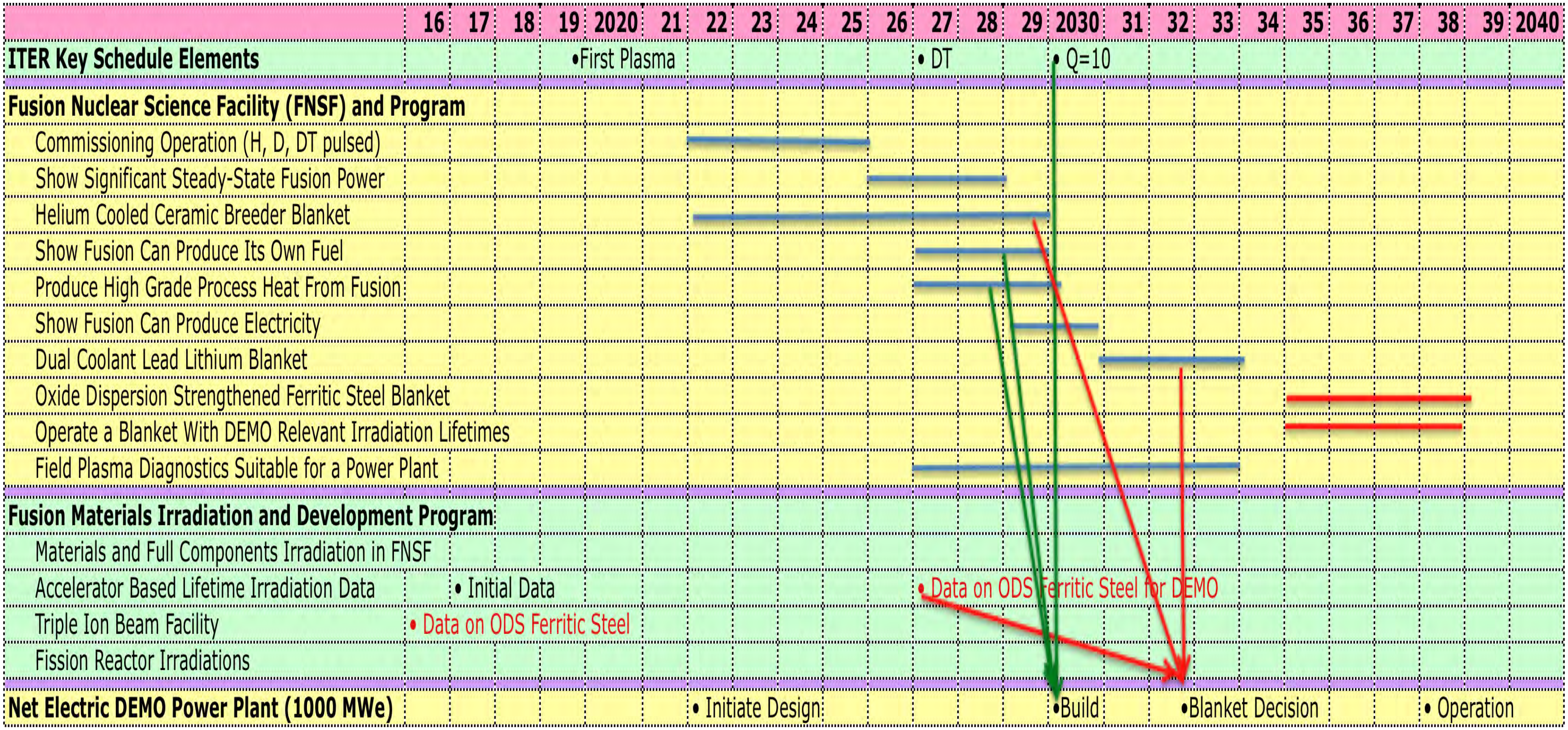
# A Fast Track Plan to Get to a Net Electric DEMO



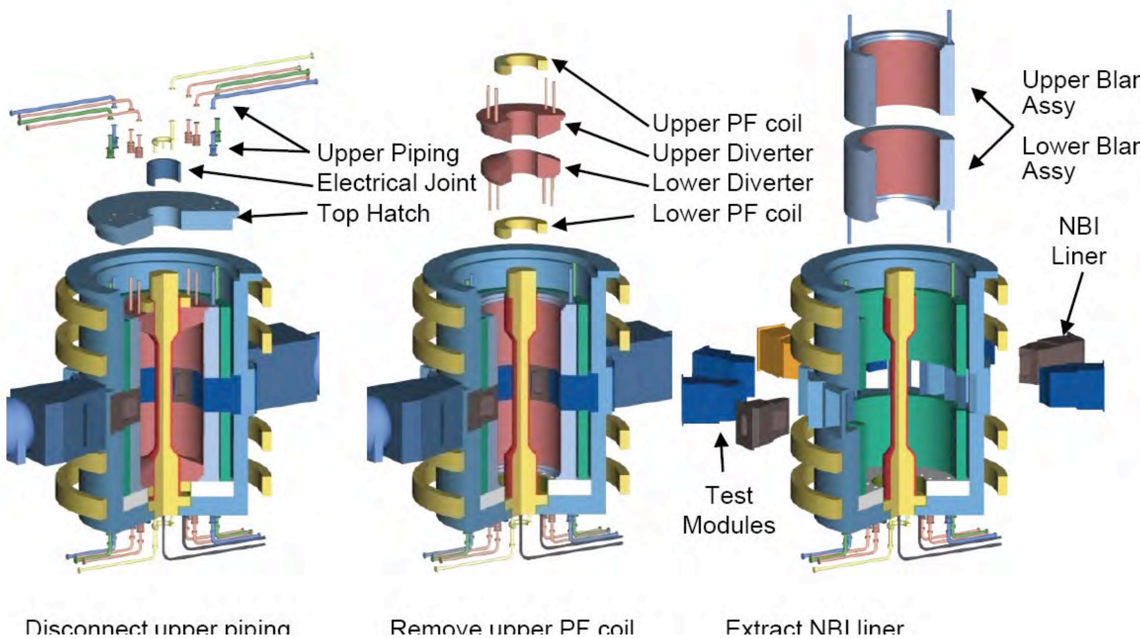

DEMO design initiated by first plasma in ITER. DEMO construction triggered by Q=10 in ITER, first phase accomplishments in FNSF, and materials data on ODS Ferritic Steel. FNSF enables choice between two most promising blanket types for DEMO.



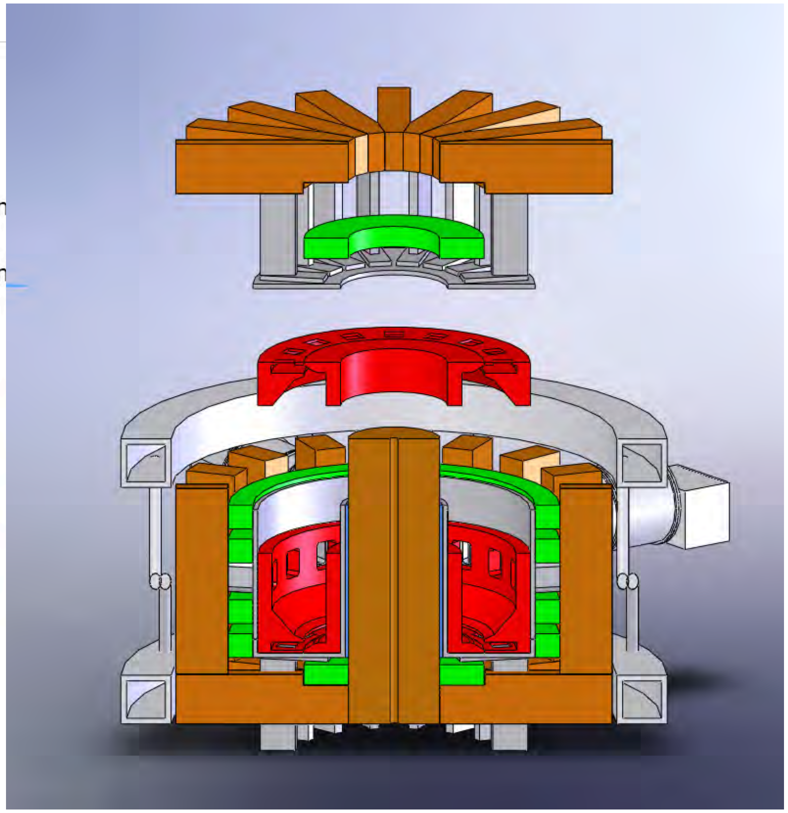
courtesy R. Stambaugh

GENERAL ATOMICS

# A Fusion Nuclear Science Facility Must Be a Research Device, Maintainable, Flexible, Re-configurable




ORNL FNSF-ST



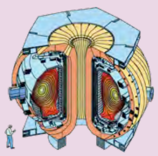
GA FNSF-AT (FDF)

* A defining characteristic of device approaches

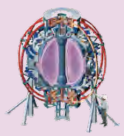


(courtesy R. Stambaugh)

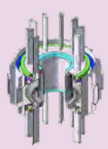
# U.S. MFE Major Facility Roadmap for Success in ITER Timeframe



DIII-D

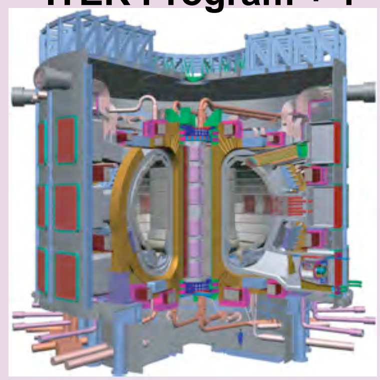


NSTX



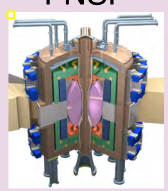
Alcator Cmod

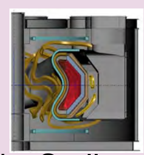
**ITER Program + ?**



**Major Domestic Facilities**

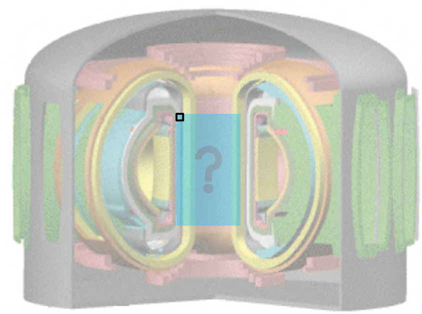
FNSF





Adv. Stellarator?

Major Out-of-Pile Material, TBM, etc.?



**"DEMO"**

Present → ITER timeframe 2020 - 2035 → Construct Decision 2025-2035

Theory, Simulation, Small Expts., International Collabs., Irradiation Fac., etc.

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# US MFE Commmunity Needs to Move Now to New Trajectory

- In international context
  - Burning Plasmas and steady-state covered by existing/new machines
  - US should step up and more aggressively address FNSE issues
- Design, Roadmap, and Prioritization Studies Needed asap
  - Goal: make credible case for fusion next step on the ITER timescale, confirming "penultimate step" designation
  - Evaluate risks/costs/readiness/schedule to support priorities & decisions
  - Deal with reality that facilities & resource allocations need to evolve soon
    - Acknowledge world program and opportunities
- Explicit goals
  - Near term: define and follow a program towards a fusion energy development program, first including more focus on FNSE issues
  - Long-term: achieve science and engineering results to justify and motivate a DEMO construction decision on the ITER Q~10 timescale, if called for…