FUSION SIMULATION PROGRAM (FSP)

SCIENCE DRIVER CONSIDERATIONS

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FSP MISSION & VISION

***VISION*: The Fusion Simulation Program (FSP) will enable scientific discovery of *important new plasma phenomena* with associated understanding that *emerges only upon integration*. It will provide a *predictive integrated simulation capability* for magnetically-confined fusion plasmas that are *properly validated against experiments* in regimes relevant for producing practical fusion energy.**

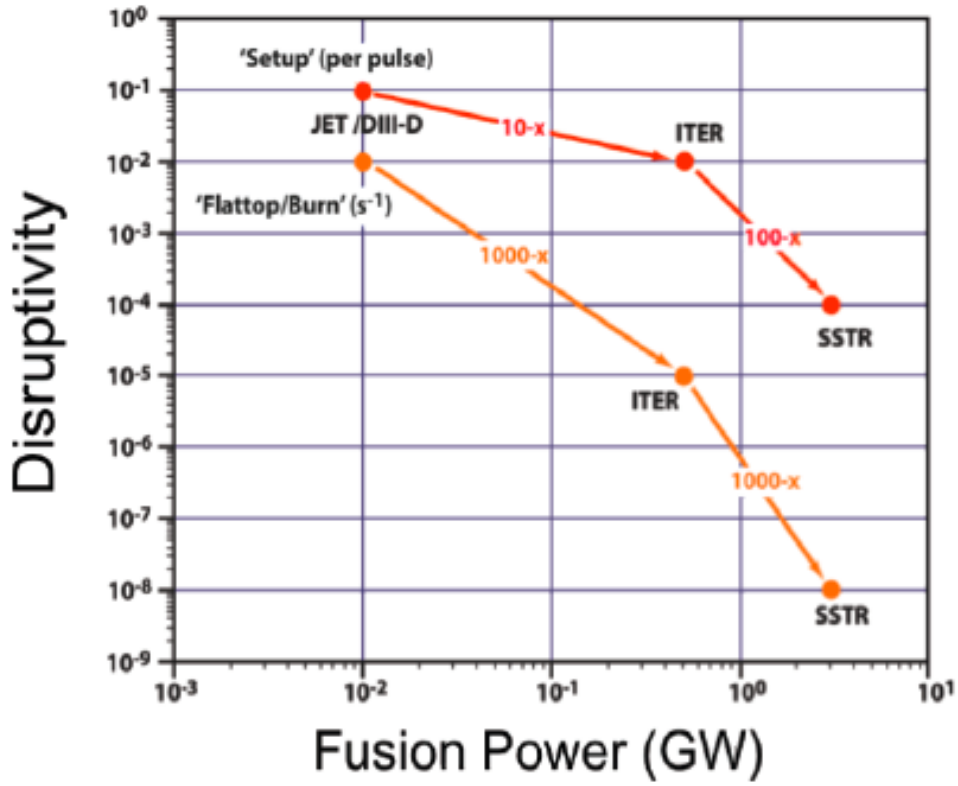
***MISSION*: The Fusion Simulation Program (FSP) will provide the capability to confidently predict toroidal magnetic confinement fusion device behavior with comprehensive and targeted science-based simulations of nonlinearly-coupled phenomena in the core plasma, edge plasma, and wall region on time and space scales required for fusion energy production.**

Provisional Science Drivers (1)

Detection, Avoidance, and Mitigation of Disruptions

– Macroscopic instabilities, rapidly terminating plasma confinement in tokamaks.
– Very large heat loads and forces on wall
– Can accelerate high energy electron beams

– **Need reliable predictions of:**
  - Triggering conditions leading to disruption
  - Nonlinear evolution of disruptions including rapid evolution of temperature, plasma density, and current density profiles, relativistic electron production
  - Interaction with plasma facing wall
- – Requires integration of MHD instability modeling, atomic and radiation physics, plasma wall interactions, and relativistic electron physics – all with ***realistic*** boundary conditions



ITER will provide an important test of the ability to reduce the frequency of allowable disruptions ("disruptivity") in high-performance discharges, compared to that in current facilities. SSTR is a conceptual design for a steady-state tokamak reactor. (Figure from J. Wesley / ReNeW)

Provisional Science Drivers (2)

Wave-Particle Interactions (esp. for Burning Plasmas/ITER)

– Nonlinear interaction of alphas and energetic particles with "sea of Alfven modes" and other instabilities
– External RF heating systems launch and damp waves

– **Need reliable predictions of:**
  - Transport of fast ions due to many unstable modes
  - RF antenna coupling; wave propagation and damping; RF sheaths
  - Plasma response — heating, current drive; flow drive; loss or redistribution of fast particles;
  - Effects of background turbulence from thermal plasma

– Requires integrated analysis of wave coupling and propagation, nonlinear wave-particle interactions and plasma responses, generation of waves from non-Maxwellian distributions

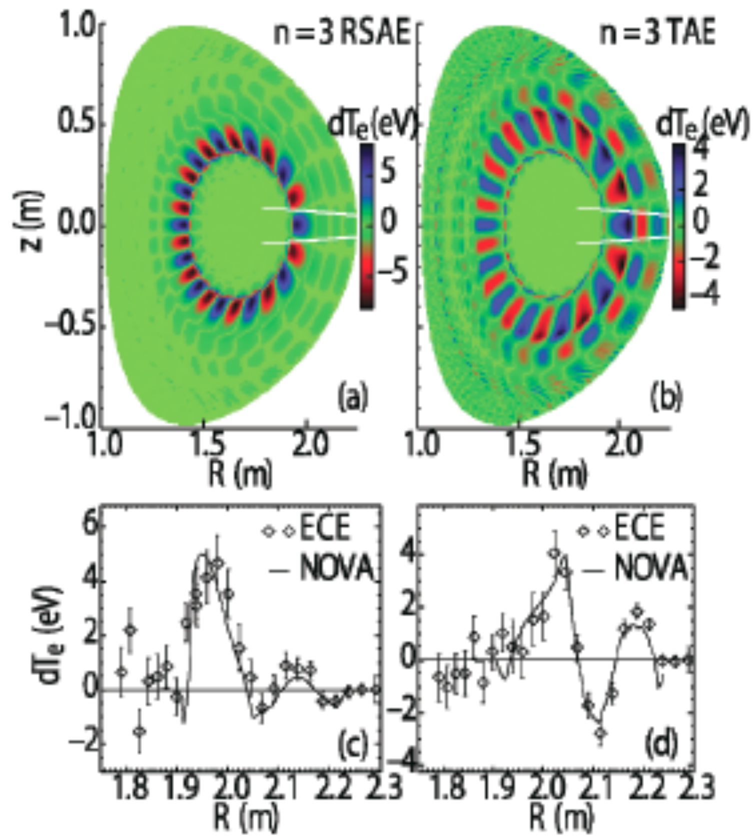


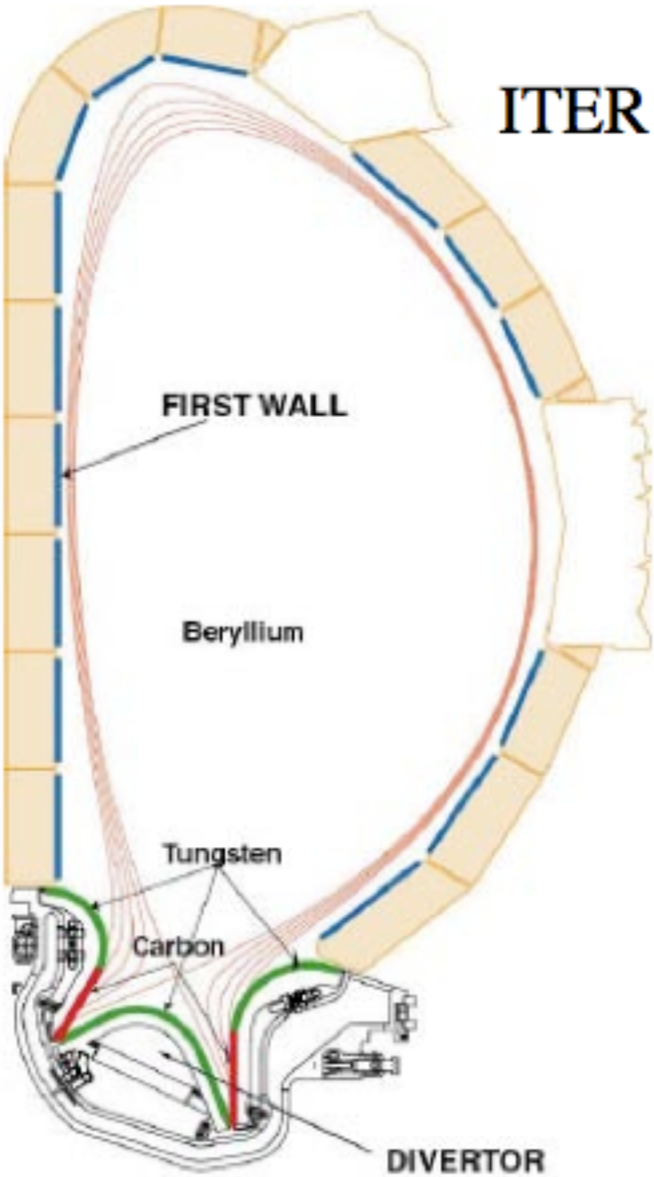
Figure 4. Radial structure of toroidal Alfvén eigenmodes measured in DIII-D with electron cyclotron emission diagnostic and compared to NOVA-K synthetic diagnostic simulation predictions. (Figure reproduced from M.A. Van Zeeland et al., Phys. Rev. Lett. 97 [2006] 135001.)

Provisional Science Drivers (3)

Plasma Scrape-off Layer, Divertor, Plasma Wall Interactions

– **Need reliable predictions of:**
  - Power and particle loads on divertor and wall
  - Impurity generation, erosion, transport, & re-deposition;
  - Dust generation and migration; tritium uptake & retention
  - Fuel recycling and pumping; and density limit;
  - Effect of material & temperature choices for wall;
  - Effects of high transient heat loads (disruptions, instabilities)
  - Boundary conditions for temperatures, density, turbulence, and flow at last closed flux surface

– Requires integrating turbulent perpendicular transport, parallel transport physics, atomic physics, and plasma-material interactions



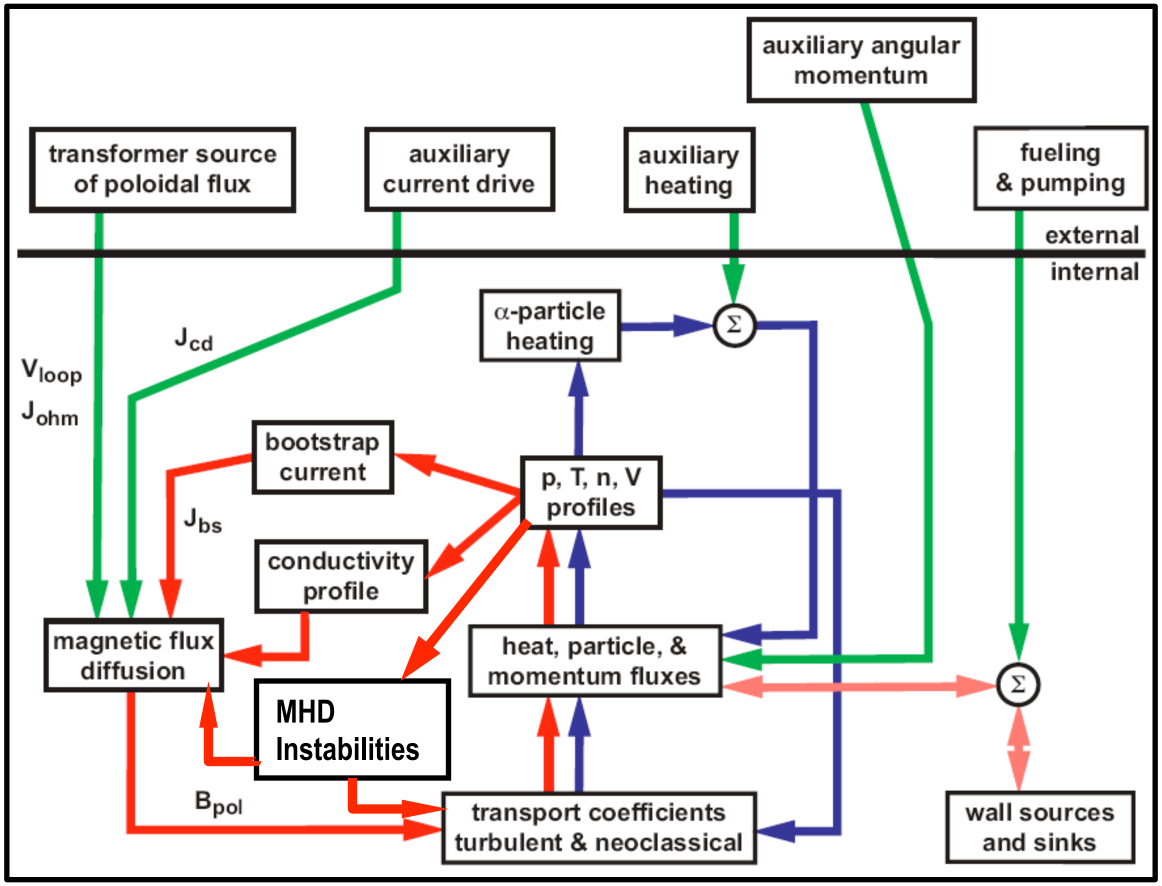
Provisional Science Drivers (4)

Integrated Whole-Device Modeling

– Nonlinear interactions of turbulence, plasma-wall-dynamics, external sources, fusion reactivity, & macroscopic instabilities

– **Need reliable predictions of:**

- Discharge evolution in burning plasmas and experiments; e.g. for ITER
- Effect of feedback & control strategies
- Theoretical expectations for comparison with experiment
- Diagnostic interpretation



Politzer, 2005

– ***Requires integration of all relevant physical models across spatial and temporal scales.***

<u>"ROADMAPS"</u>

outline plan for each provisional science driver (*including path of development for science in each topic – not implementation details*)

Scope: starting with current status, extending over 5 yr – periods to 15 yrs.

- *Open physics questions – requiring new theory development*
- *Tool requirements – including code components development*
- *Strategy for physics/code coupling/integration with associated requirements*
- *Science questions to be addressed at each stage of development*
- *FSP deliverables/capabilities to be produced at each stage of development*
- *Potential customers for the FSP tools produced at each stage of development*
- *Opportunities for experimental validation at each stage of development*
- *Estimates of resources (FTE's. $$$, computing support, …..)*