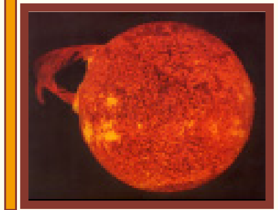
Contributions to and Cooperation with the International Community

- Research contributions made by the U.S. facilities to:
  - International program in burning plasma research
  - Future plans with emphasis on ITER
- FESAC Priorities Panel Themes:
  - "Create a Star on earth"
  - "Develop the science and technology to realize fusion energy"
- Coordinating framework is International Tokamak Physics Activity
  - Over 50 U.S. scientists, overall head is a U.S scientist
  - ITPA addresses comprehensive set of science issues, including:
    - Confinement database and modeling
    - Transport
    - Pedestal and Edge Physics
    - Divertor and Scrape-Off Layer
    - MHD control and disruptions
    - Steady-state operation
    - Diagnostics



Science on U.S. facilities will prepare us for full and effective participation in ITER

- Increase confidence in current ITER design
  - e.g., Choice of wall materials
- Provide information for design decisions not yet finalized
  - e.g., Details of heating systems
- Suggest possible improvements to baseline design
  - e.g., Magnetic control coils for stabilizing MHD modes
- Develop new measurement techniques, diagnostics and control systems
  - e.g., Sensing and mitigation of plasma disruptions
- Enhanced theory and integrated modeling
  - Design experiments for ITER

→ ***Integration of the fundamental science and technology issues discussed in the rest of the report***

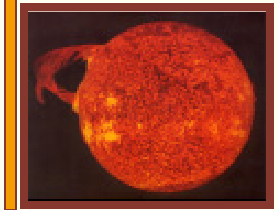
Strength of the three U.S. facilities *in combination* will be demonstrated by a few examples Example 1: Transport Basis for ITER

- Transport basis for ITER operating scenarios
  - U.S. effort focused around Transport Task Force (TTF) and ITPA
- Strong diagnostic effort on all three machines
  - C-Mod studies confinement at high n_e with T_e~T_i and novel PCI diagnostic
  - DIII-D has comprehensive diagnostic set and has developed the most comprehensive transport code for experiment-theory comparisons
  - NSTX examines how transport scales with aspect ratio at high β, commissioning fluctuation diagnostics
- Data from all three machines are important for accurate determination of relevant scaling variables
  - ITPA confinement scaling database

The U.S. Transport program has improved - and will continue to improve - the reliability of transport predictions for ITER

Example 2: Wall Lifetime with Bursts of Heat and Particles

- Heat loads from transient phenomena such as ELMs
- U.S. Facilities have:
  - Developed and benchmarked models of the ELM
    - All three have world-class diagnostics
  - Developed operational regimes with tolerable ELMs
    - C-Mod has developed the enhanced D-alpha H-mode
    - DIII-D has developed quiescent H-mode
    - NSTX has found a new small-ELM regime
  - Pioneered the use of edge resonant magnetic perturbations to avoid ELMS altogether
    - DIII-D pioneered use of internal coils to eliminate ELMs
    - NSTX doing similar experiments
    - Leading to research on other machines like JET

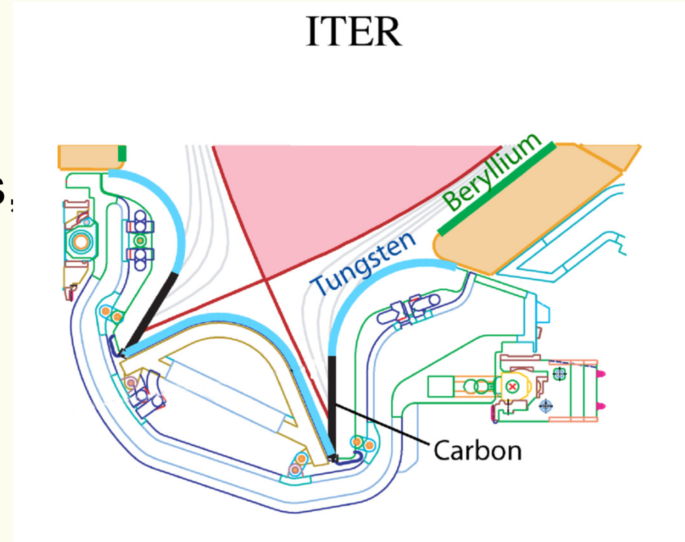


Example 3: Machine damage due to sudden disruptions

- ITER plasma can be quickly lost, in a "disruption", resulting in:
  - Large forces on the tokamak mechanical structure
  - Large heat loads to the wall
- The U.S. has been a leader in disruption experiments and modeling:
  - Detect a disruption, and
  - Apply a large puff of gas to safely extinguish the plasma
  - DIII-D did the first experiments
  - Work expanded by C-Mod to high absolute pressure plasma
  - Both experiments and modeling, along with JET, are being used to develop ITER scenarios
  - NSTX shows moderate resilience against disruptions: science understanding

Example 4: Tritium inventory and choice of wall materials

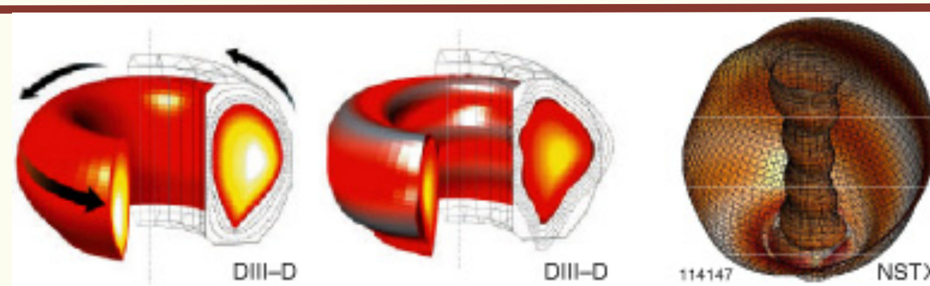
- Current ITER has Beryllium walls, with Tungsten and carbon in the divertor
- Carbon can handle high transient heat loads,
  - But is co-deposited with tritium
  - Can lead to large in-vessel tritium inventory



U.S. machines are attacking the problem in different ways, complement JET & ASDEX-U

- Carbon: DIII-D and NSTX (with lithium)
  - Further characterize carbon erosion and redeposition
  - Study tritium removal techniques
- Metal: C-Mod
  - Molybdenum and Tungsten do not lead to tritium accumulation
  - Can melt with disruptions and radiate strongly in the core

Example 5: MHD Stability, Plasma Rotation, and Feedback Control with Magnetic Coils



- Resistive Wall mode (DIII-D and NSTX)
  - Stabilized by rotation, but ITER rotation uncertain
- C-Mod discovered plasma rotation with no momentum input
- Neoclassical Tearing mode stabilization
  - Closed-loop, and pre-emptive feedback stabilization on DIII-D
  - Scaling studies on DIII-D, JET, and ASDEX-U to extrapolate to ITER
- Non-rotating tearing modes due to error fields
  - ITPA experiments on scaling results from C-Mod, DIII-D, and JET
  - All three machines have error correction coils
  - JT-60 is installing upgrades to improve symmetry

Examples 6: Energetic Particles, Heating, and Current Drive and 7: Hybrid modes

- The U.S. facilities can examine mixed heating/current drive regimes:
  - Neutral beam and radio frequency waves (DIII-D and NSTX)
  - Radio frequency waves (C-Mod)
- U.S. has strong capability for modeling these results
- Three directions for improving the tokamak concept:
  - DIII-D is highly shaped, double-null divertor plasma at high normalized pressure β_N and high confinement
  - C-Mod has the highest absolute pressure (high field)
  - NSTX has the highest pressure normalized to the magnetic field β with strong plasma shaping
- DIII-D has led effort on “hybrid” modes
  - Between conventional ITER scenarios and “advanced” tokamak

The U.S. Program has emphasized tokamak innovations that have improved the ITER design