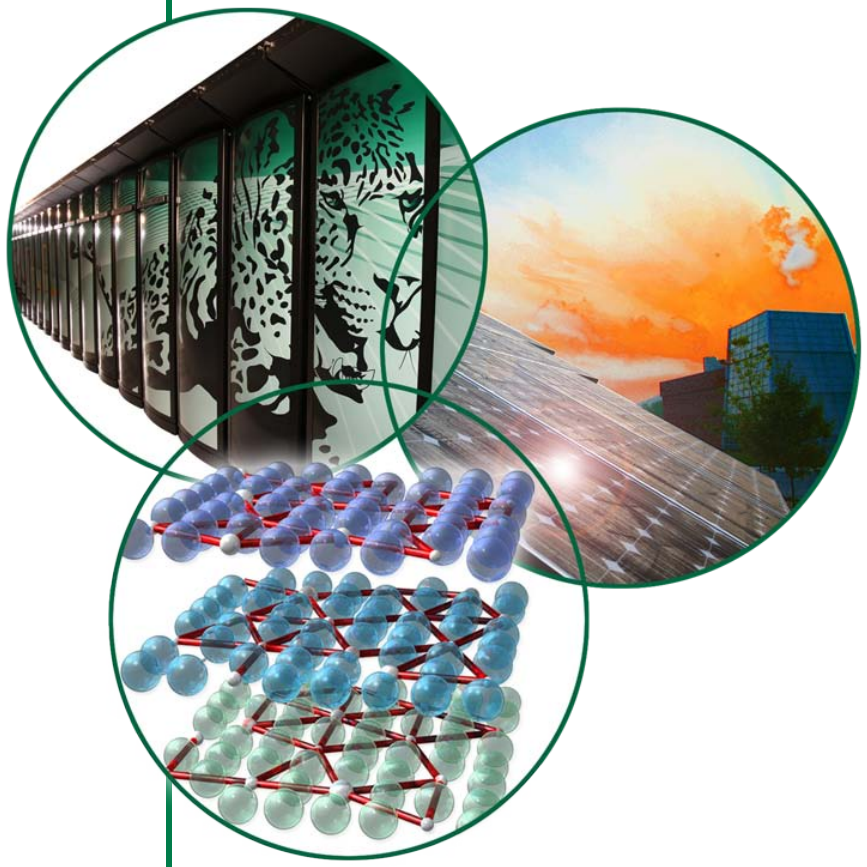
Overview of ORNL Fusion Program

S. L. Milora

Fusion Power Associates Annual Meeting

December 3, 2009



U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

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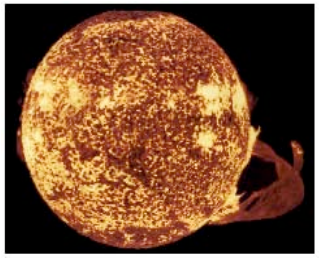
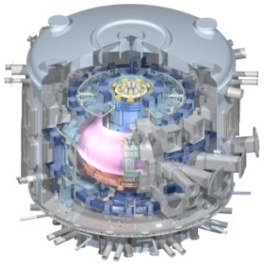
Fusion Energy Program mission

Develop the understanding required for an attractive fusion energy source through integrated research





ITER

— and —

Pursue near-term applications of plasma science and technology in support of national goals.

Development and deployment of superconducting power transmission cables

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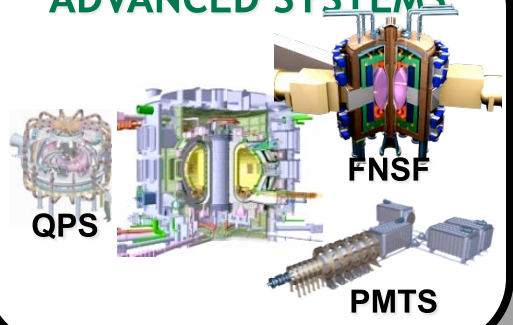
The mission is carried out in several interrelated core competencies across four directorates

ATOMIC PHYSICS for FUSION[1,2,3,4]

PLASMA THEORY and SIMULATION[5,2,3,4]

FUSION MATERIALS[7,8,9,10]

ADVANCED SYSTEMS



EXPERIMENTAL PLASMA PHYSICS[5,6]

PLASMA TECHNOLOGIES and ENGINEERING[5,6]

1 Physics Division
2 Computer Science and Math. Div.
3 National Center for Computational Sciences
4 Leadership Computing Facility
5 Fusion Energy Div.
6 Measurement Science and Systems Div.
7 Materials Science and Technology Div.
8 Nuclear Science and Technology Div.
9 Research Reactor Div.
10 High Flux Isotope Reactor

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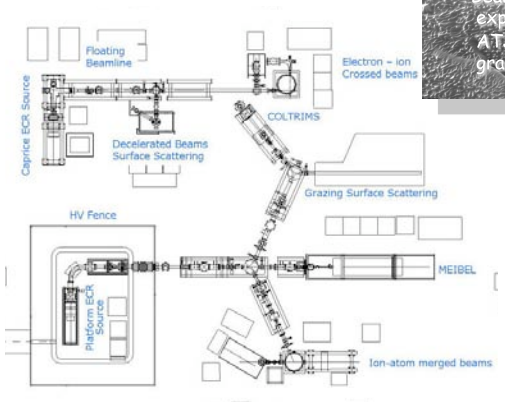
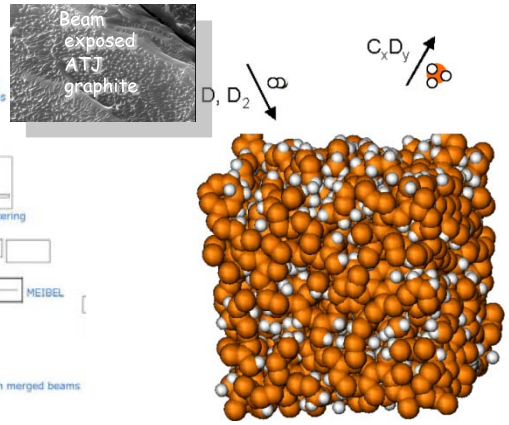
The *Atomic Physics* program provides basic atomic, molecular and PSI data to our science community

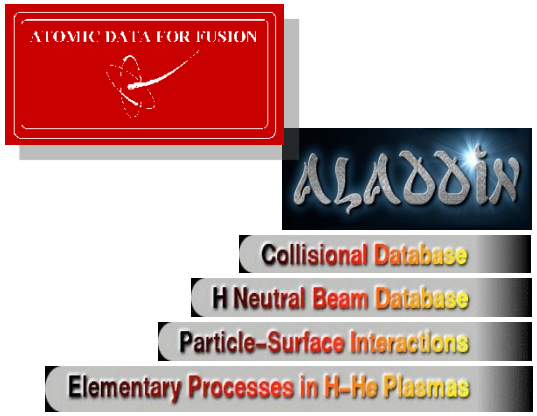
- ***Study fundamental interactions among electrons, ions, atoms, molecules, and materials; develop and apply advanced computational methods in data production; collect, evaluate, and disseminate data to the plasma science community***



Multi-charged Ion Research Facility



Molecular dynamics simulation of particle surface interactions



Controlled Fusion Atomic Data Center

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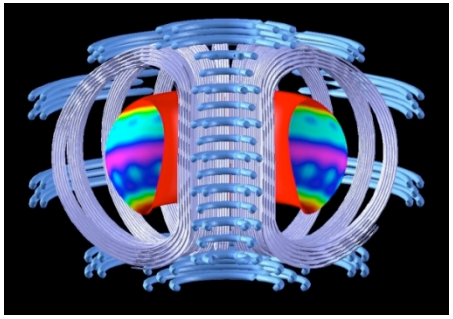
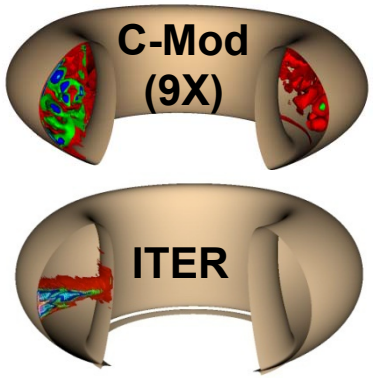
Plasma Theory and Simulation guides and integrates our understanding.

- ***Develop fundamental plasma theory and the computational base needed to understand plasma behavior in fusion devices, to understand and exploit improved confinement regimes, and to develop new confinement configurations and technologies***

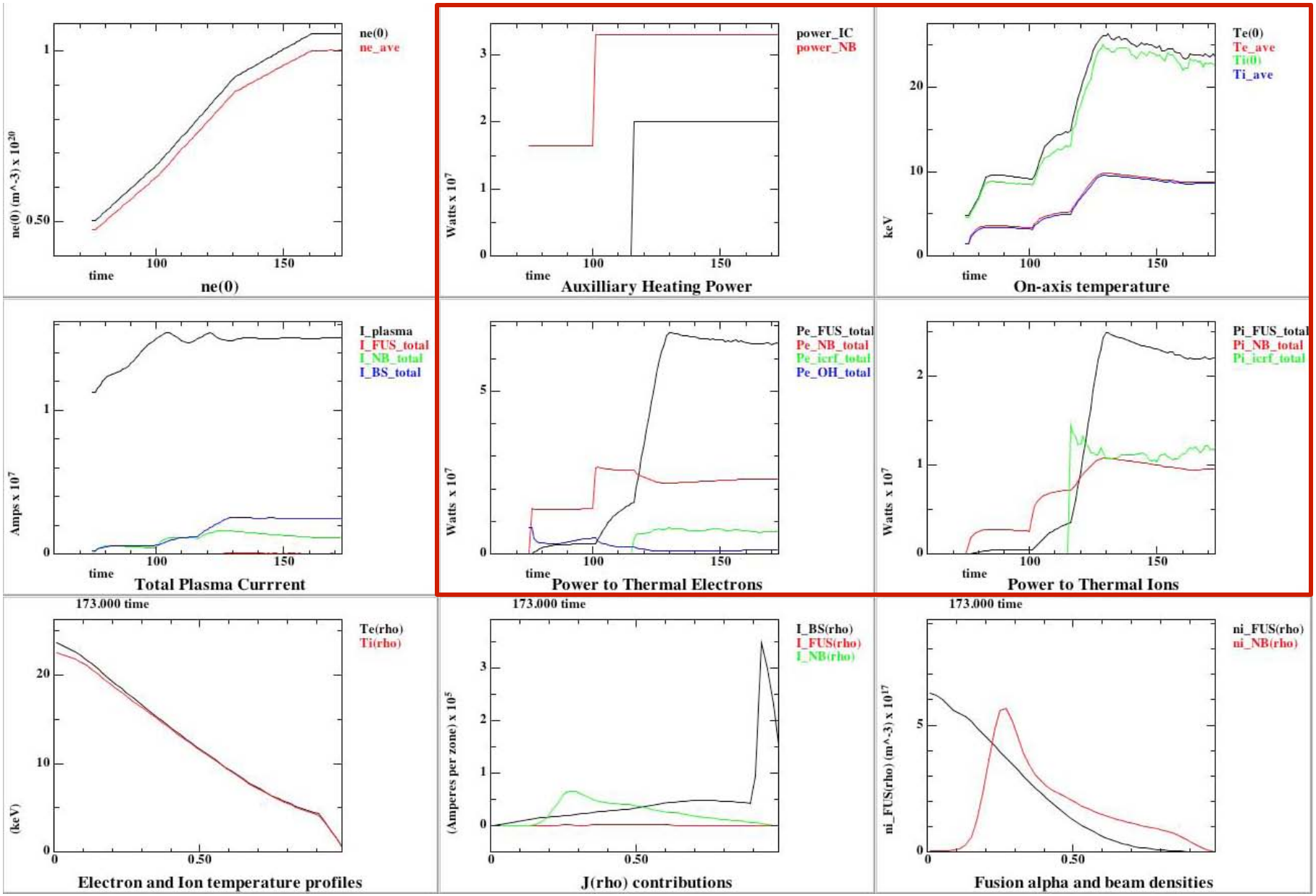


3-D ITER equilibrium ($\nabla P = JxB$)



SciDAC: AORSA 3-D simulation of rf heating in ITER

SciDAC: RF + MHD integrated plasma simulation of ITER


ne(0)
ne_ave
ne(0) (m^-3) x 10^20
time
ne(0)
power_IC
power_NB
Watts x 10^7
time
Auxilliary Heating Power
Te(0)
Te_ave
Ti(0)
Ti_ave
keV
time
On-axis temperature
I_plasma
I_FUS_total
I_NB_total
I_BS_total
Amps x 10^7
time
Total Plasma Currrent
Pe_FUS_total
Pe_NB_total
Pe_icrf_total
Pe_OH_total
Watts x 10^7
time
Power to Thermal Electrons
Pi_FUS_total
Pi_NB_total
Pi_icrf_total
Watts x 10^7
time
Power to Thermal Ions
173.000 time
Te(rho)
Ti(rho)
(keV)
Electron and Ion temperature profiles
173.000 time
I_BS(rho)
I_FUS(rho)
I_NB(rho)
(Amperes per zone) x 10^5
J(rho) contributions
173.000 time
ni_FUS(rho)
ni_NB(rho)
ni_FUS(rho) (m^-3) x 10^17
Fusion alpha and beam densities

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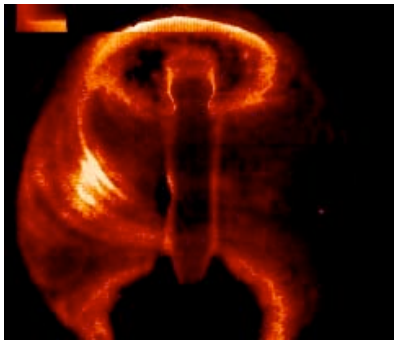
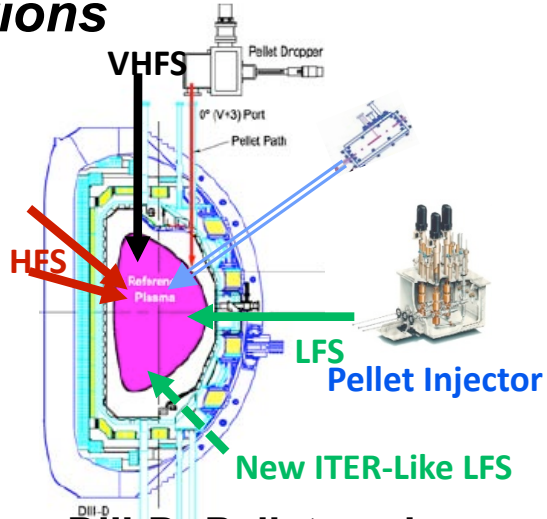
Experimental Plasma Physics performs topical research across the portfolio of confinement approaches.

- ***Collaborative research in boundary physics, fueling and particle transport, confinement and stability, wave -plasma interactions***

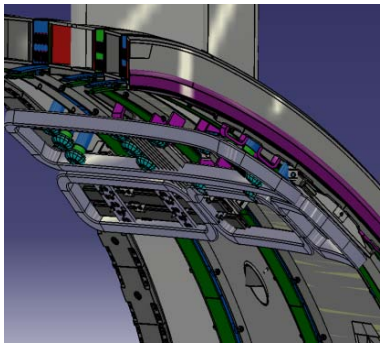


NSTX boundary physics: Pedestal and ELM characterization

ELM control (RMP coils, Li)



DIII-D: Pellet pacing, fueling, disruption mitigation for ITER



JET: RMP coil feasibility studies for ITER

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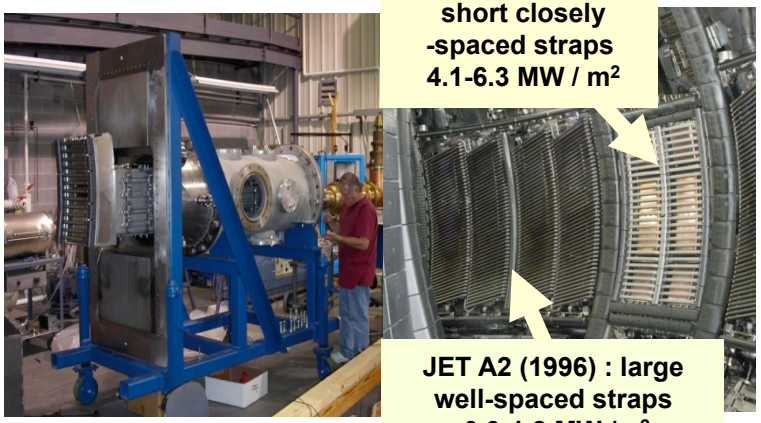
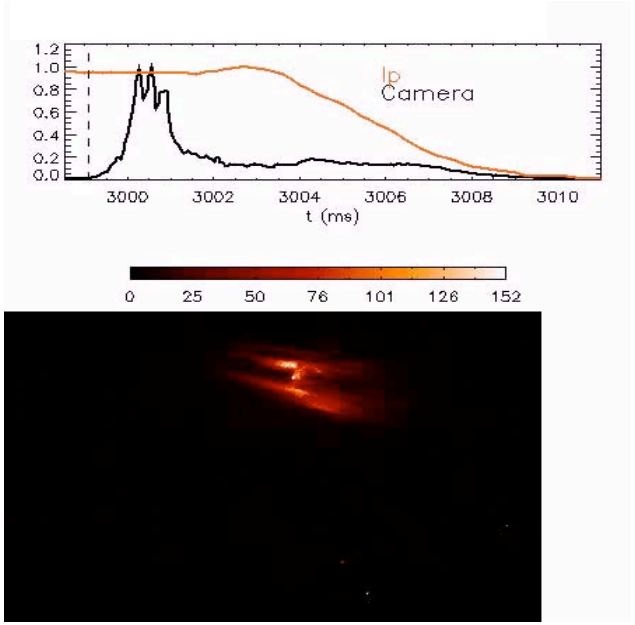
Plasma Technologies enable key experimental activities.

- ***Develop plasma heating/current drive, and fueling technologies to create and control high temperature plasmas***



ITER-like RF antenna deployed on JET



ITER disruption mitigation technologies deployed on DIII-D

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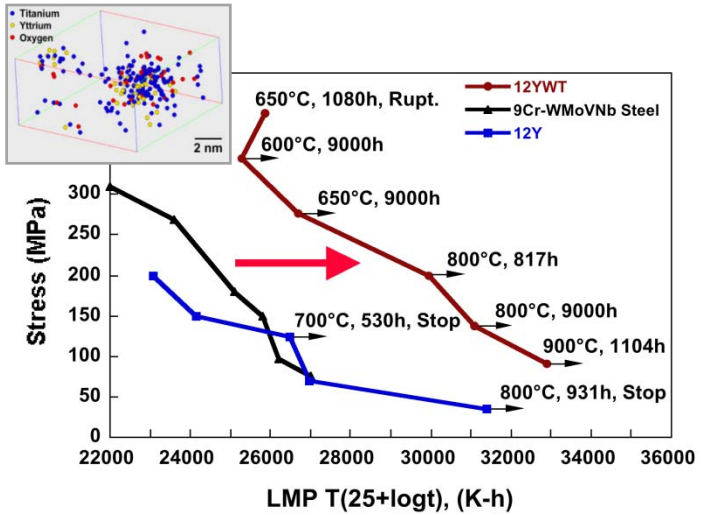
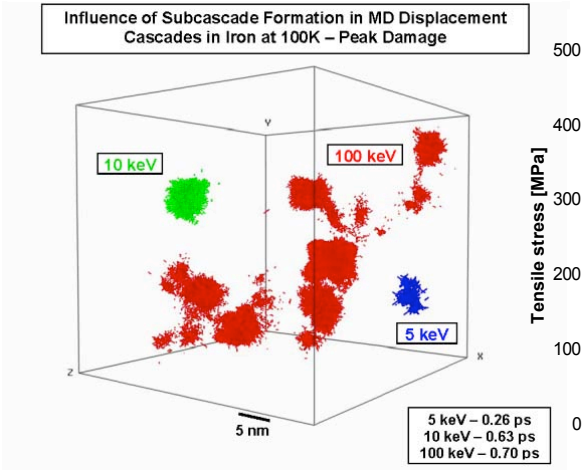
Fusion Reactor Materials program applies a science based approach to developing advanced materials

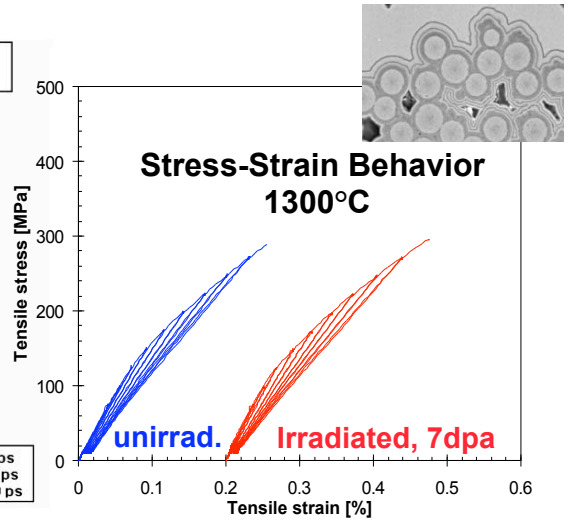
- ***Computational materials science and atomic scale characterization; advanced materials for higher temperatures; nanoscale microstructural modifications developed to mitigate irradiation and He effects***



Nanoclusters in advanced oxide-dispersion strengthend steels



Molecular dynamics simulations elucidate primary radiation damage mechanisms



Radiation-resistant advanced SiC-SiC composites for high temperatures

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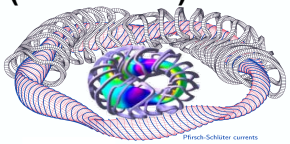
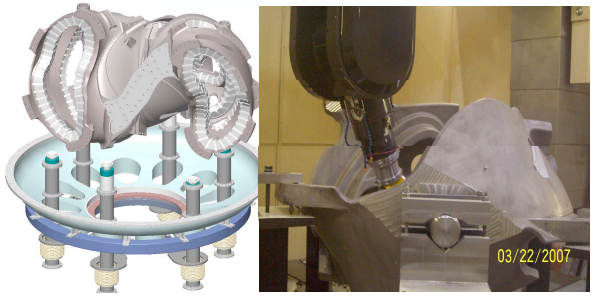
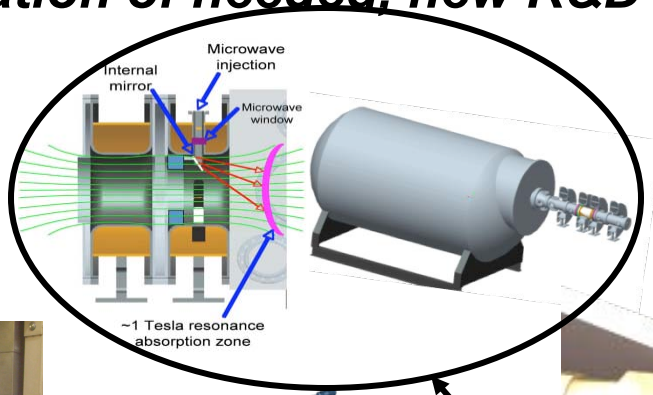
Advanced Design utilizes our science, technology and engineering expertise to support OFES goals.

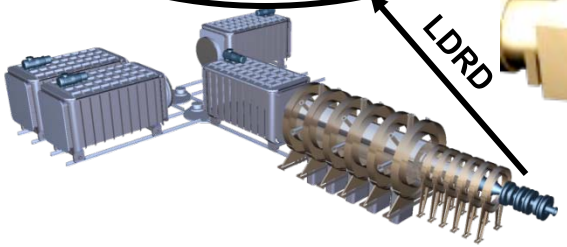
- ***Leads to the realization of needed, new R&D facilities***

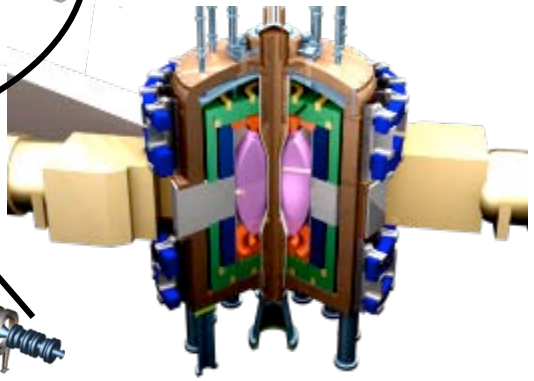
Magnets :
20 QPS vs. 50 W7-X
(lower cost)











Compact stellarator optimization and R&D (QPS)

Plasma Materials Test Station (>20 MW/m^2, >10^{23}/m^2/s). All rf system.

Fusion Nuclear Sciences Facility

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Technology and Science Applications integrates our science, technology and engineering activities.

- ***Pursue near term applications of plasma science and technology in support of national goals***

World's first fault current limiting cable-DHS

Microwave plasma processing of carbon fibers-EERE

High density helicon plasmas for space propulsion-NASA

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We are working to make ITER a success in the construction and follow-on research phase.

OFES Core Research

Virtual Lab for Technology

Stan Milora, Director and US ITER Chief Technologist

U.S. Burning Plasma Organization

Jim Van Dam (U. Texas) Director and US ITER Chief Scientist

- Burning plasma R&D (USBPO)
  - Modeling and simulation *Batchelor*
  - Energetic particles *Spong*
  - Enabling technologies/Engineering sciences *Uckan*
  - TBM sciences *Uckan*
- ITPA activities etc.
  - Energetic particles *Spong*
  - Pedestal *Maingi*
  - Diagnostics *Hillis*
  - Integrated scenarios *Murakami*
  - Disruption mitigation *Baylor*

Other ITER project opportunities → Disruption mitigation, pellet ELM pacing, ELM coils, LHCD

ITER Project

U.S. ITER Project Office

Ned Sauthoff (ORNL), Director

Engineering Manager

Brad Nelson

WBS Mgr

Dave Rasmussen

Diagnostics

Dave Johnson

- Pellet injection system *Combs*
- Pumping & Leak check systems *Gardner*
- ICH transmission lines & tuners *Goulding*
- ECH transmission lines *Bigelow*
- Reflectometer *Hanson*
- RGA *Gardner*

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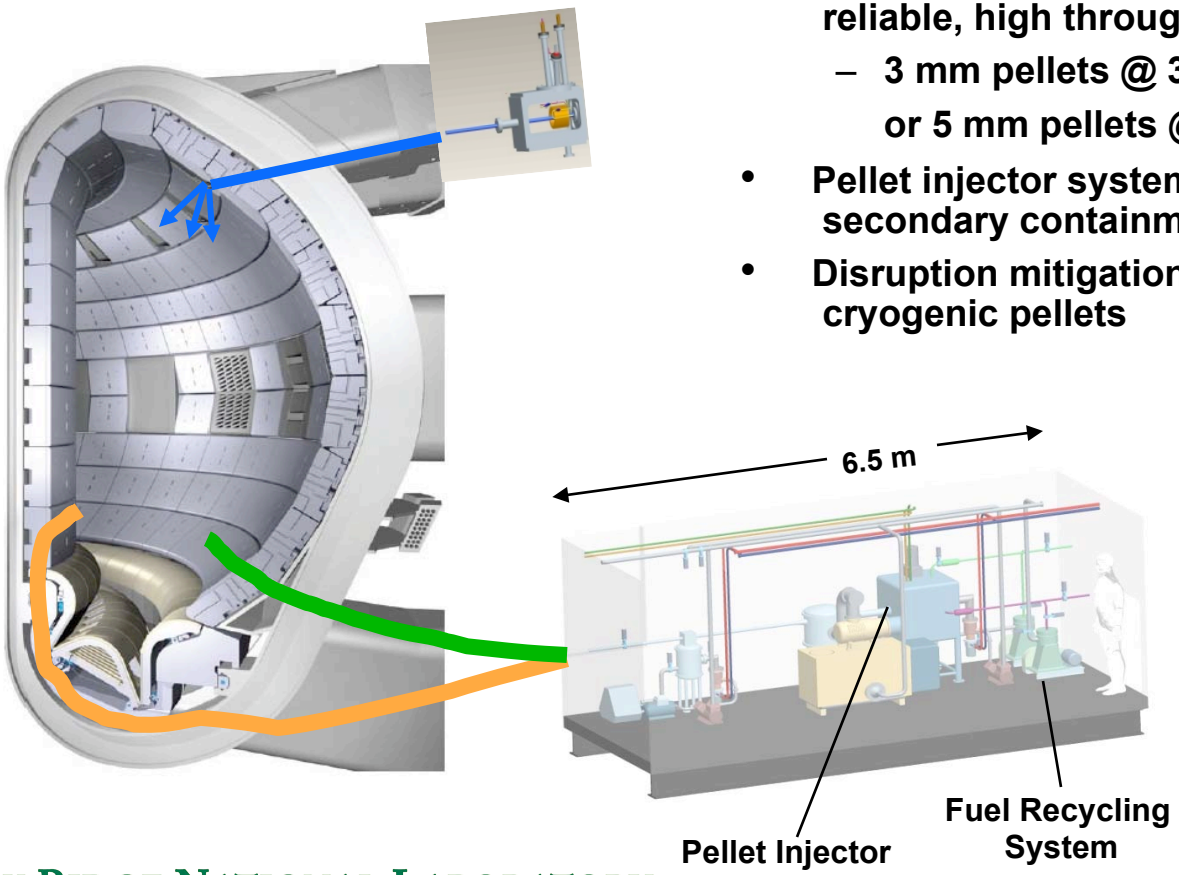
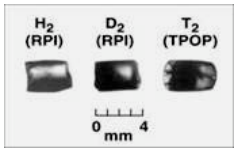
ITER pellet fueling role
D. Rasmussen, WBS manager

- 2 pellet injectors requiring continuous, highly reliable, high throughput DT pellet feed
  - 3 mm pellets @ 30 Hz for ELM pacing
    or 5 mm pellets @ 7 Hz for HFS fueling
- Pellet injector system enclosed in a cask for secondary containment
- Disruption mitigation with large shattered cryogenic pellets





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ITER ICH, ECH transmission system role
D. Rasmussen, WBS manager

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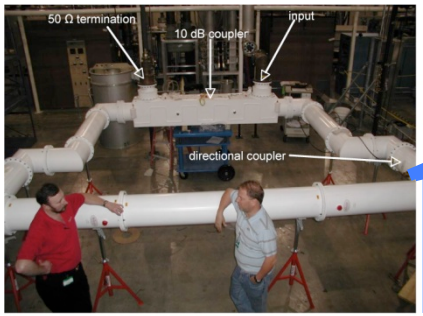
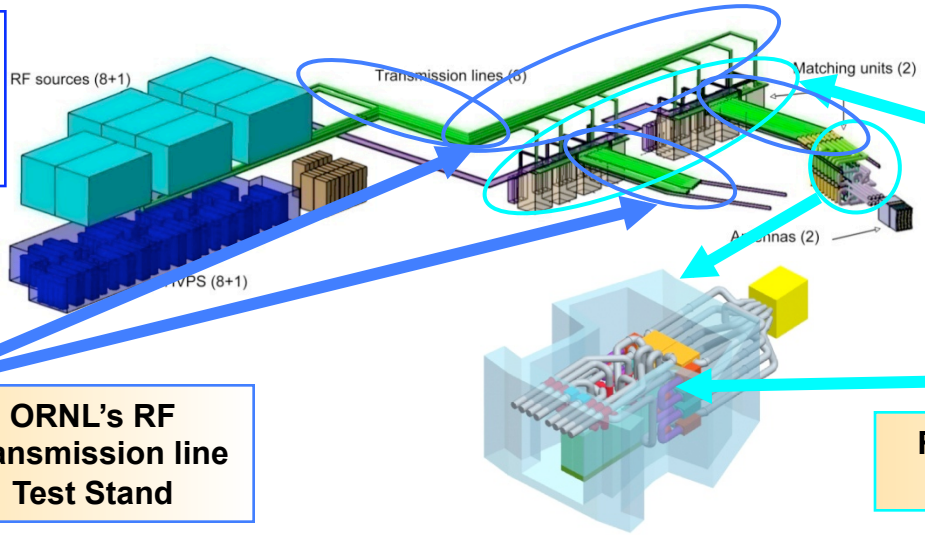
RF ICH Transmission lines
- 2.5 MW per line, 8 lines
- Water-cooled coaxial design
- 1,000 meters

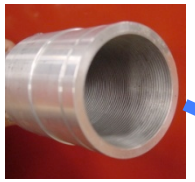


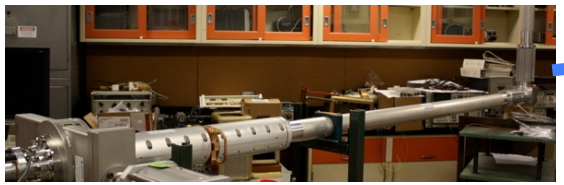
ORNL's RF transmission line Test Stand



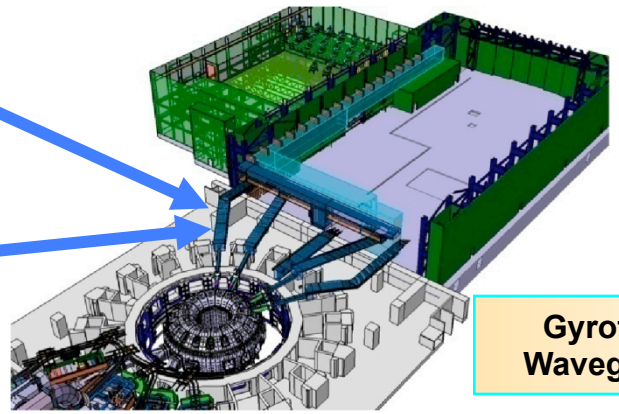
RF tuners at ORNL's RF Test Facility

Microwave ECH Transmission lines
- 1 MW per line, 24 lines
- Overmoded 170 GHz waveguide
- 2,000 meters





Waveguide at ORNL's 170 GHz Test Facility



Gyrotron for ORNL's Waveguide Test Facility

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The Laboratory and DOE have made significant *investments* in fusion at ORNL in recent years

- ***Lab***
  - **Relocate infrastructure(power supplies and equipment) from Y12 to ORNL**
  - **New 25,000 sq. ft. research building (built to house a modest scale experiment).**

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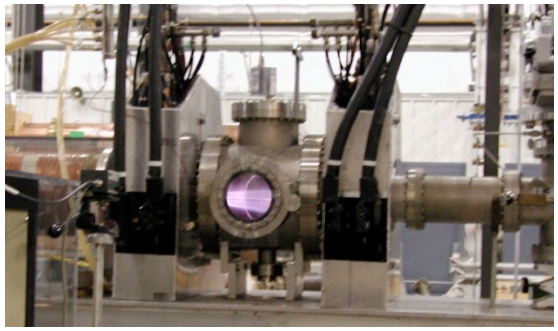
Lab/DOEinvestments cont'd

- ***DOE OFES***
  - **Research equipment installation**



  - **A companion building to house power supplies (73 MVA)**


Fusion Energy Division staff additions since 2005

New R&D Staff		***New R&D Post-docs***
C. Klepper		J-W Ahn
A. Lumsdaine		D. Battaglia (MFE Fellow)
A. Sontag		G. Chen
L. Chacon		N. Commaux
S. Diem		T. Gray (MFE Fellow)
S. Meitner	⇦	D. Green
J. Canik		A. McLean
J-M Park	⇦	E. Unterberg (MFE Fellow)
A. Horton		M. Shafer (ARRA)
R. Sanchez		
T. Biewer		
J. Harris		
K. Freudenberg		