Office of Fusion Energy Sciences

Excellent Science in Support of Attractive Energy

# *U.S. Fusion Energy Sciences Program*

Presented to

# National Research Council
# Burning Plasma Assessment Committee

By

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for Fusion Energy Sciences
Office of Science
Department of Energy


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**www.ofes.fusion.doe.gov**

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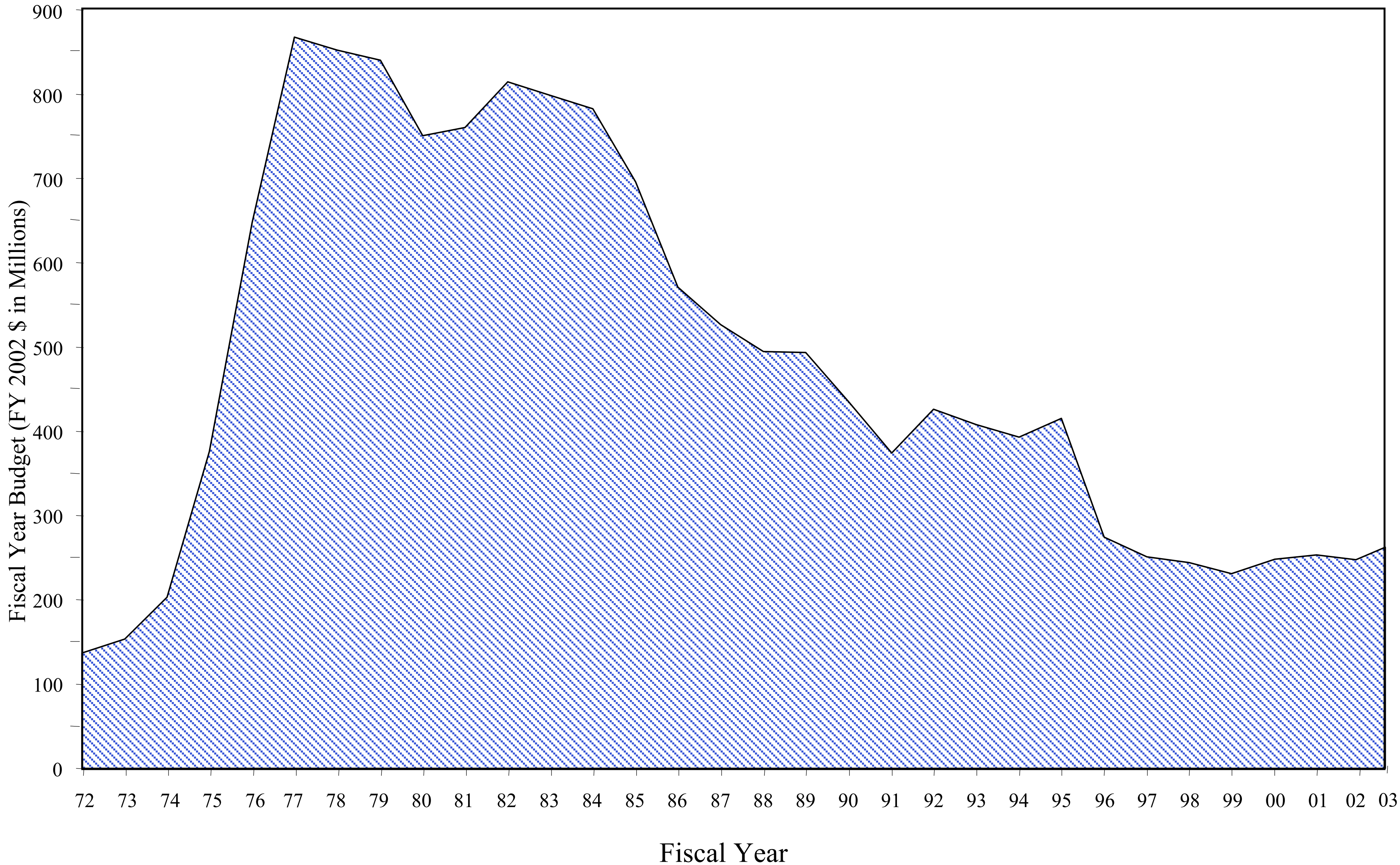
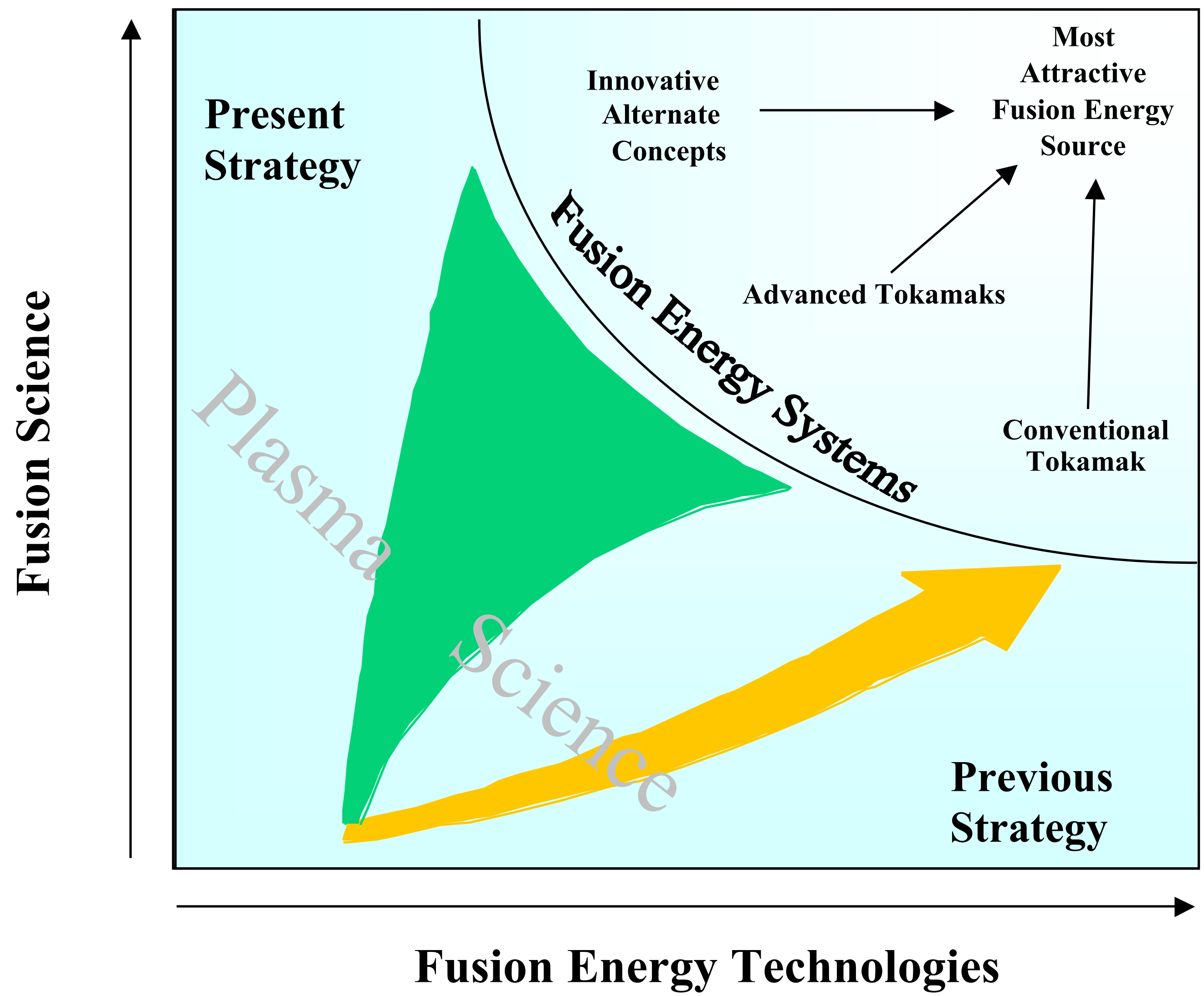
**Excellent Science in Support of Attractive Energy**

# *U.S. Fusion Energy Sciences Budget History*



# *Restructuring of the U.S. Fusion Energy Sciences Program*



# *U.S. Fusion Energy Sciences Program Mission*

"Advance plasma science, fusion science, and fusion technology-- the knowledge base needed for an economically and environmentally attractive fusion energy source."

## ***Policy Goals***

- Advance plasma science in pursuit of national science and technology goals
- Develop fusion science, technology, and plasma confinement innovations as the central theme of the domestic program
- Pursue fusion energy science and technology as a partner in the international fusion effort

## *10 Implementing Principles*

- Science focus
- Energy goal
- Reliability as an international partner
- Complementary to the international effort
- Leadership in selected areas
- Scientific excellence
- Facility balance
- Importance of a national laboratory for fusion science
- Education and human resources
- Diversity of participation

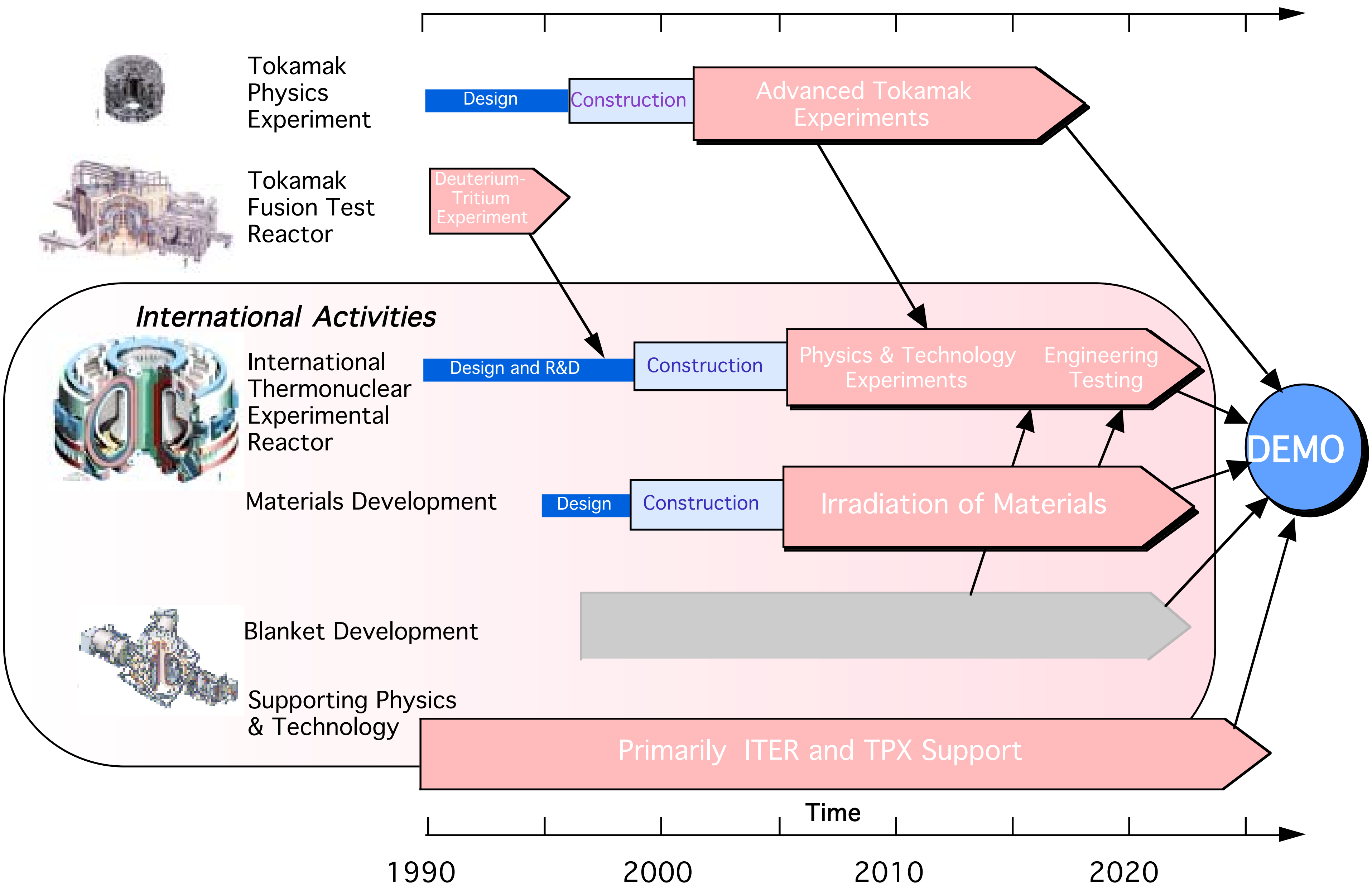
# *U.S. Fusion Energy Sciences Program Response*

- Focused on innovation and science
  - Initiated plasma science program
  - Increased scientific productivity of existing facilities
  - Increased emphasis on exploring alternative concepts
  - Enhanced theory and modeling research
- Shutdown and decommissioned TFTR to free up funds for growth in other efforts
- Enhanced research on radiation-resistant materials
- Maintained commitments to ITER until Congress directed U.S. withdrawal
- Continue minimal inertial fusion energy program in coordination with Defense Program's ICF program

The underlying theme of the restructuring of the fusion program was to redirect it away from "the expensive development path to a fusion power plant to focus on the less costly critical basic science and technology foundations."

*A Restructured Fusion Energy Sciences Program, FESAC, 1996*

# *U.S. Magnetic Fusion Strategy (1991-1996)*

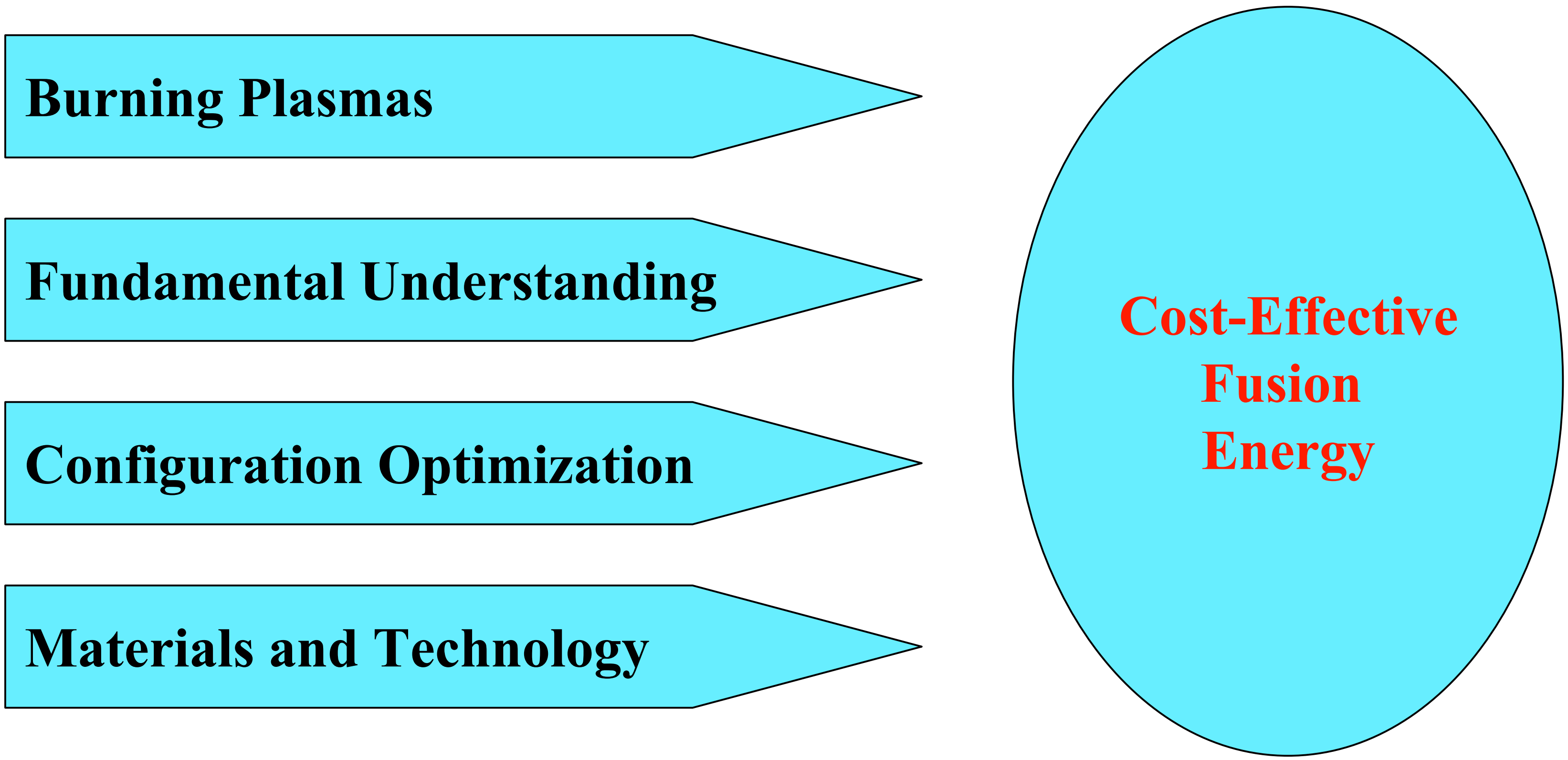


# *U.S. Fusion Energy Sciences Program Goals*

The present base program is configured to:

- o Contribute to the scientific and technical basis for a burning plasma experiment
- o Provide the U.S. with the knowledge and tools to participate in and benefit from a burning plasma experiments, and
- o Acquire the broad understanding of plasma science and technology needed to design an economical and environmentally attractive fusion power source (a very demanding goal)

# *Four Thrust Areas are Required for Practical Magnetic Fusion Energy*



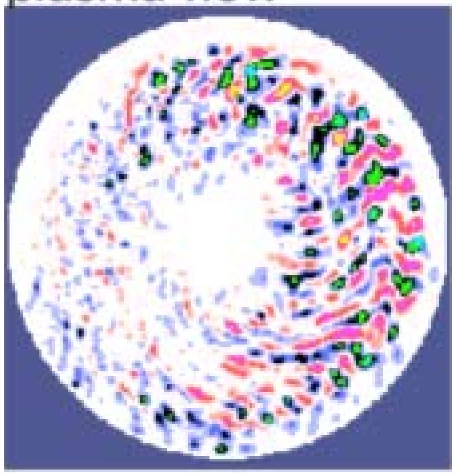

**Areas defined by the**
**Fusion Energy Sciences Advisory Committee.**

# *Turbulent Fluctuations Suppressed When ExB Shearing Rate Exceeds Maximum Linear Growth Rate of Instabilities*

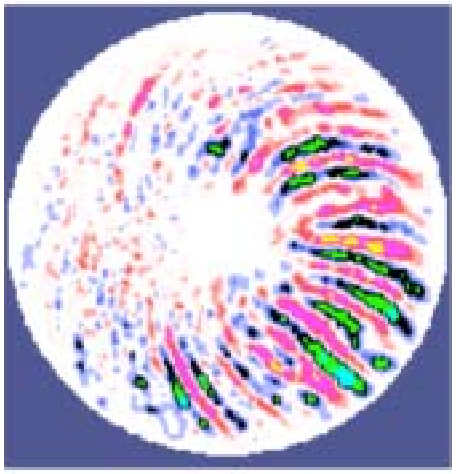
## Gyrokinetic Theory

Simulations show turbulent eddies disrupted by strongly sheared plasma flow

With Flow

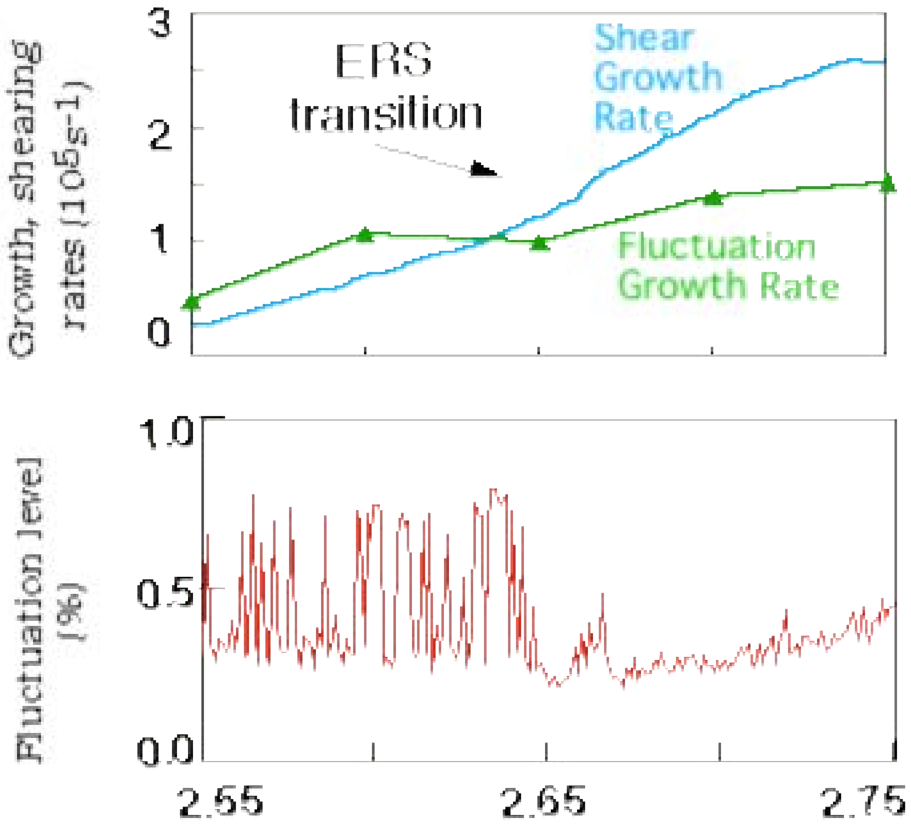


Without Flow



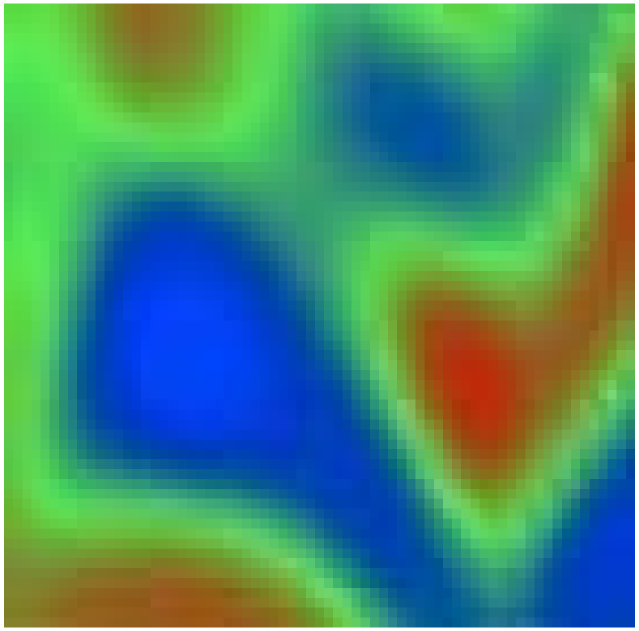
## Experiment

Turbulent fluctuations are suppressed when shearing rate exceeds growth rate of most unstable mode



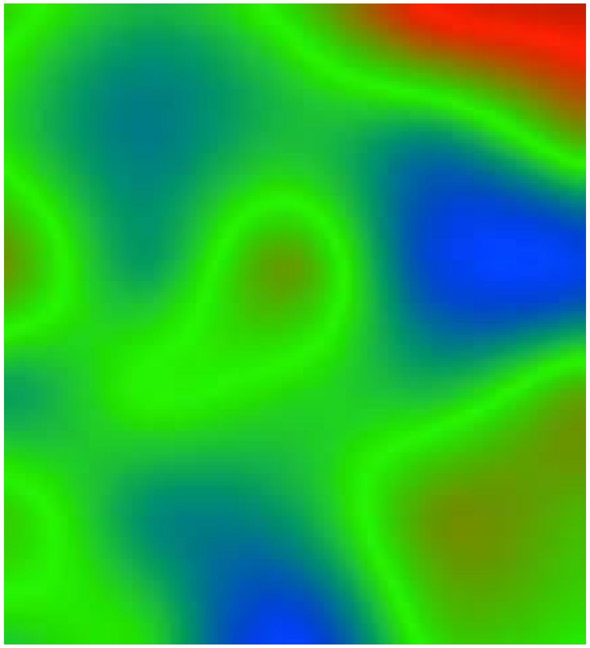
# *Scientific Understanding of Fusion Plasmas has Increased Dramatically*

Advanced Computing



Simulation of turbulence in magnetic fusion plasma.

Plasma Measurements



Fast imaging of plasma turbulence.

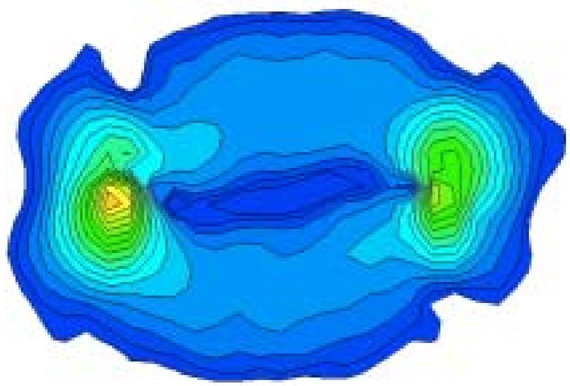
**Goal: Practical fusion energy through high-quality science.**

# *Scientific Discovery Thru Advanced Computing*

## Three Principal Projects

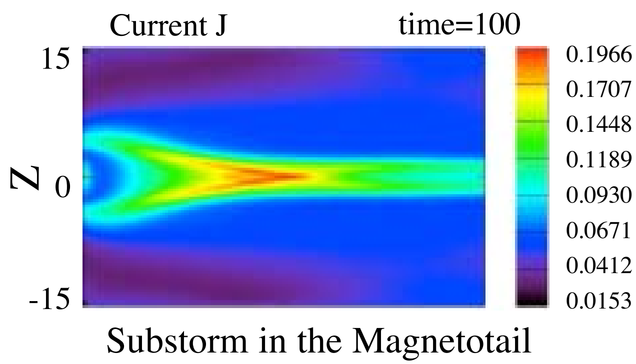
### Terascale Atomic Physics

Auburn, Rollins, ORNL



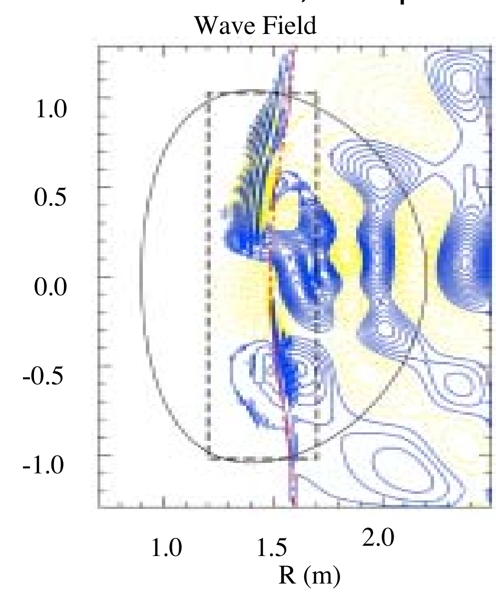
### Magnetic Reconnection Code

U. Iowa, U. Chicago, U. Texas

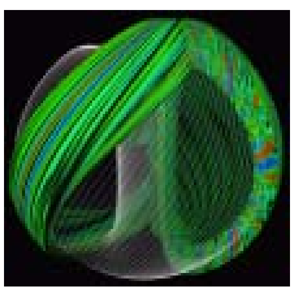



### Computation of Wave Plasma Interactions

ORNL, PPPL, MIT, Lodestar, CompX

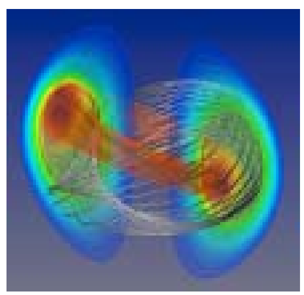



## Two Pilot Projects



### Plasma Microturbulence

LLNL, GA, PPPL, U. Maryland, U. Texas, U. Colorado, UCLA



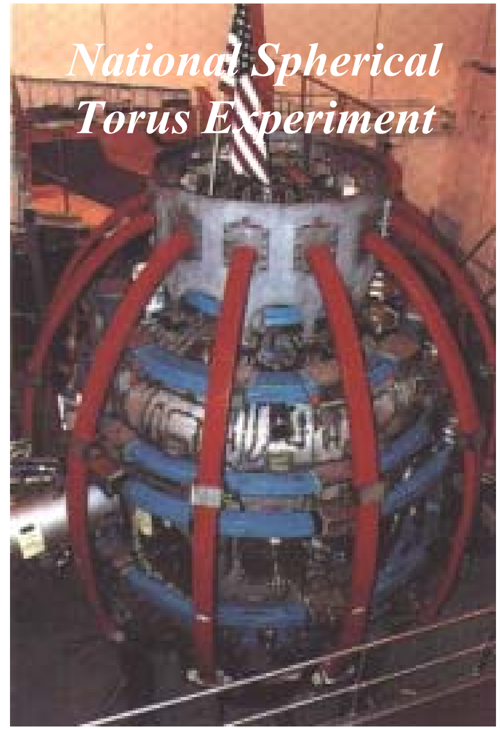
### Extended MHD Modeling

PPPL, SAIC, U. Wisconsin, NYU, U. Colorado, MIT, Utah State U., GA, LANL, U. Texas

# *Major U.S. Magnetic Fusion Facilities*


**General Atomics**

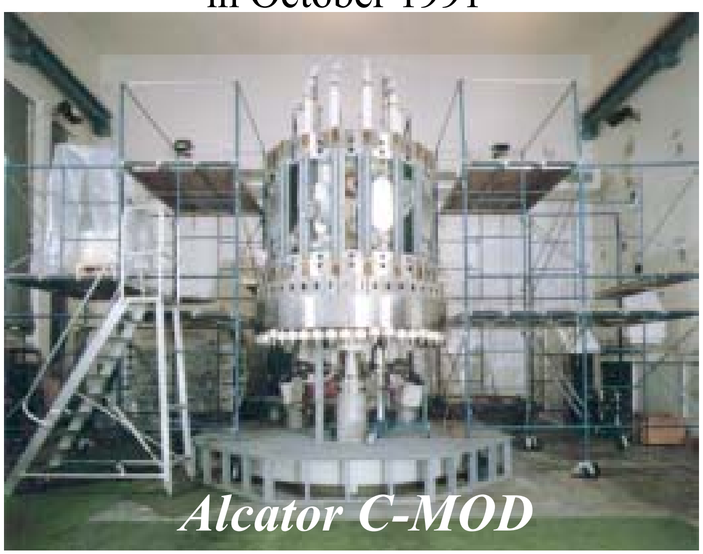
Doublet III Started Operations In 1978




**Princeton Plasma Physics Laboratory**

NSTX started Operations in 1999

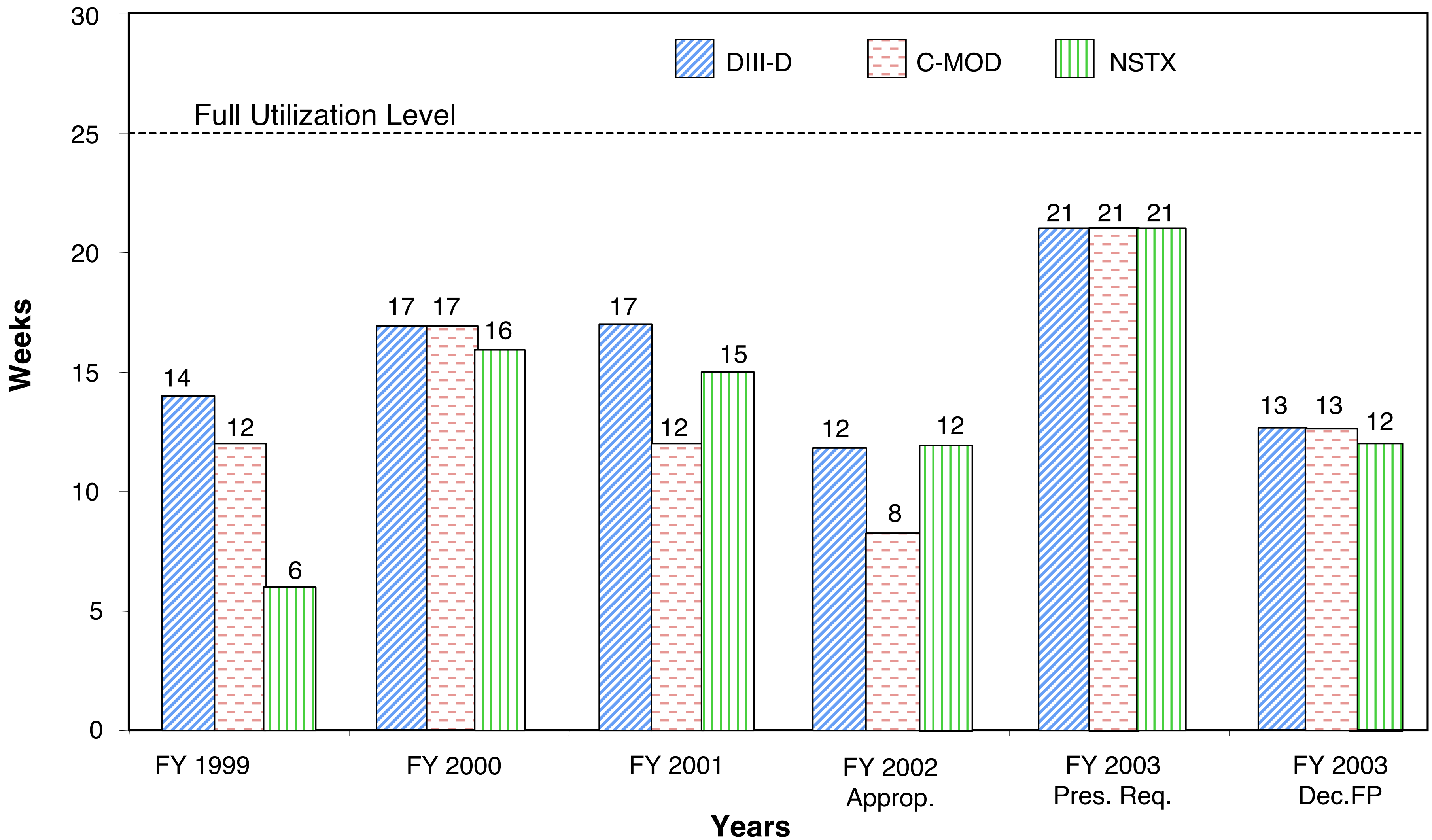
**Massachusetts Institute of Technology**
C-MOD Started Operations in October 1991




**Princeton Plasma Physics Laboratory**

NCSX Fabrication: FY 2003-2007

# Major Fusion Facilities Operating Times

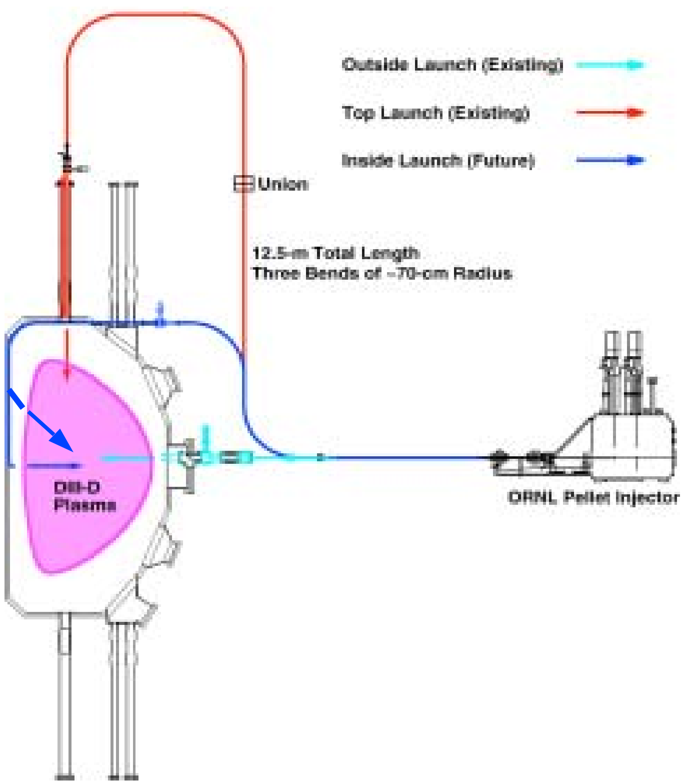



09/04/02

09/04/02

# *Enabling Technologies Program*

Pellet Injector in DIII-D for Plasma Fueling

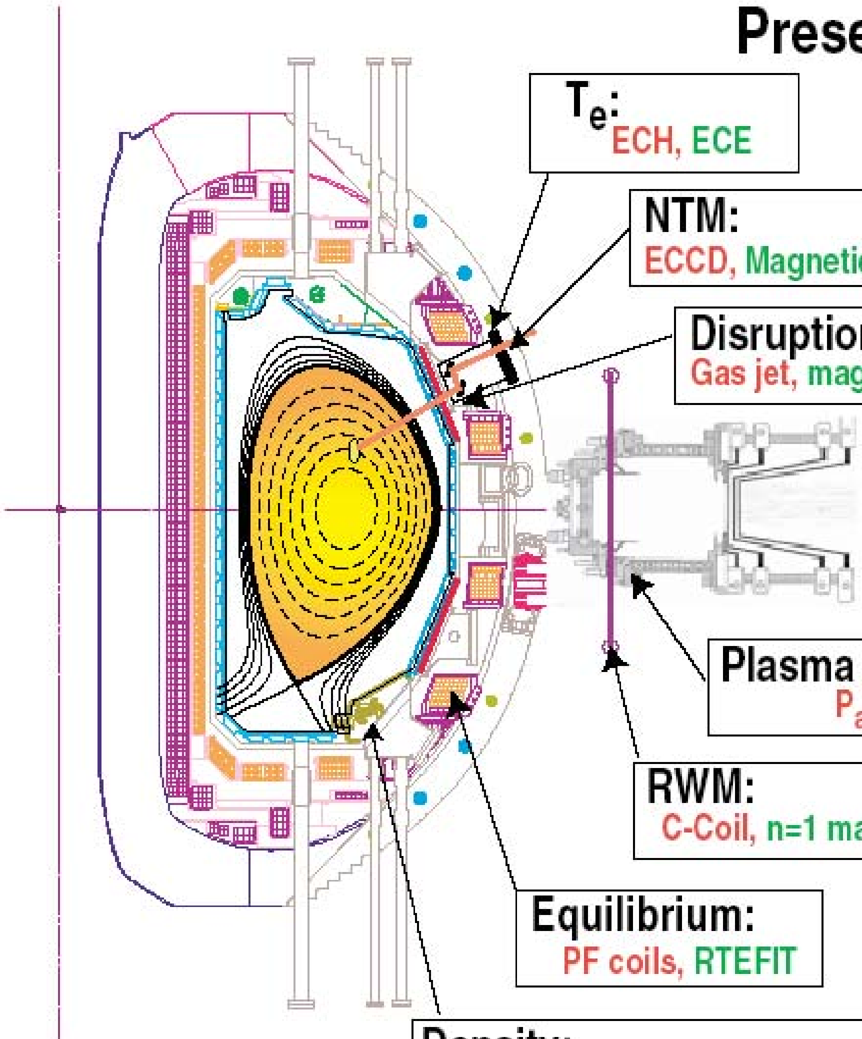



100 GHz Gyrotron Tube (1MW power in 1 second pulse) for Plasma Heating and Control

DiMES probe in DIII-D provides data on plasma material interactions

# A NEW ERA IN PLASMA CONTROL: KEY TO THE DIII–D AT PROGRAM

**Present** (Actuator, Sensor) **Planned**



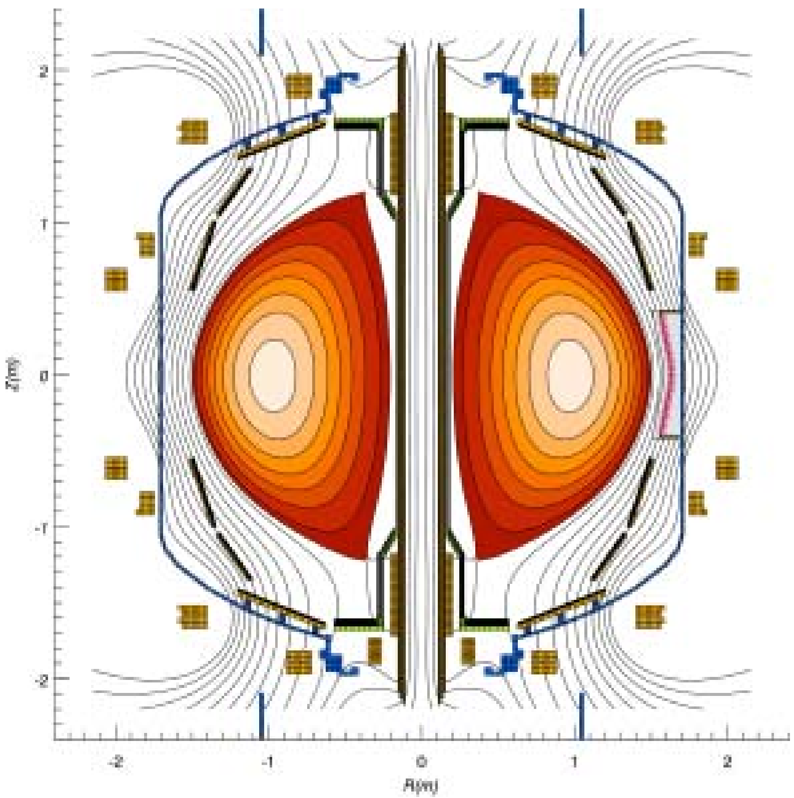

**Integrated control:**
Validated models
Expanded PCS

**Current profile control:**
ECCD/FWCD, MSE

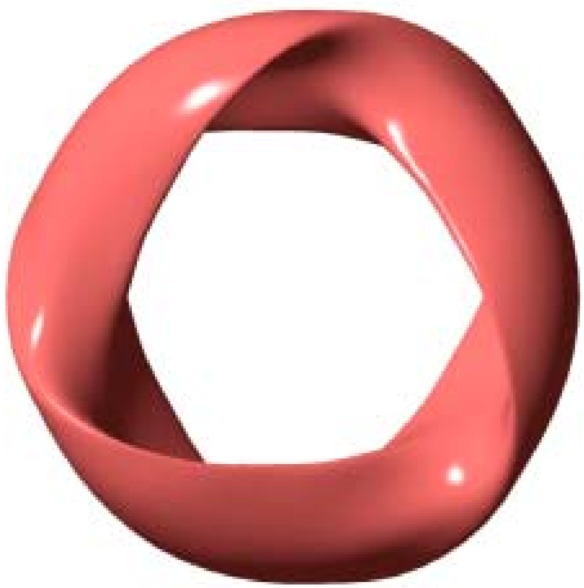
**Optimized RWM control:**
I-Coil
Expanded magnetics

**Disruption detection, correction, mitigation:**
MHD regulation — PCS
Expanded magnetics

## *Variations of the Toroidal Plasma Configuration Address Key Fusion Issues*




Spherical Torus offers high fusion power density at low magnetic field.

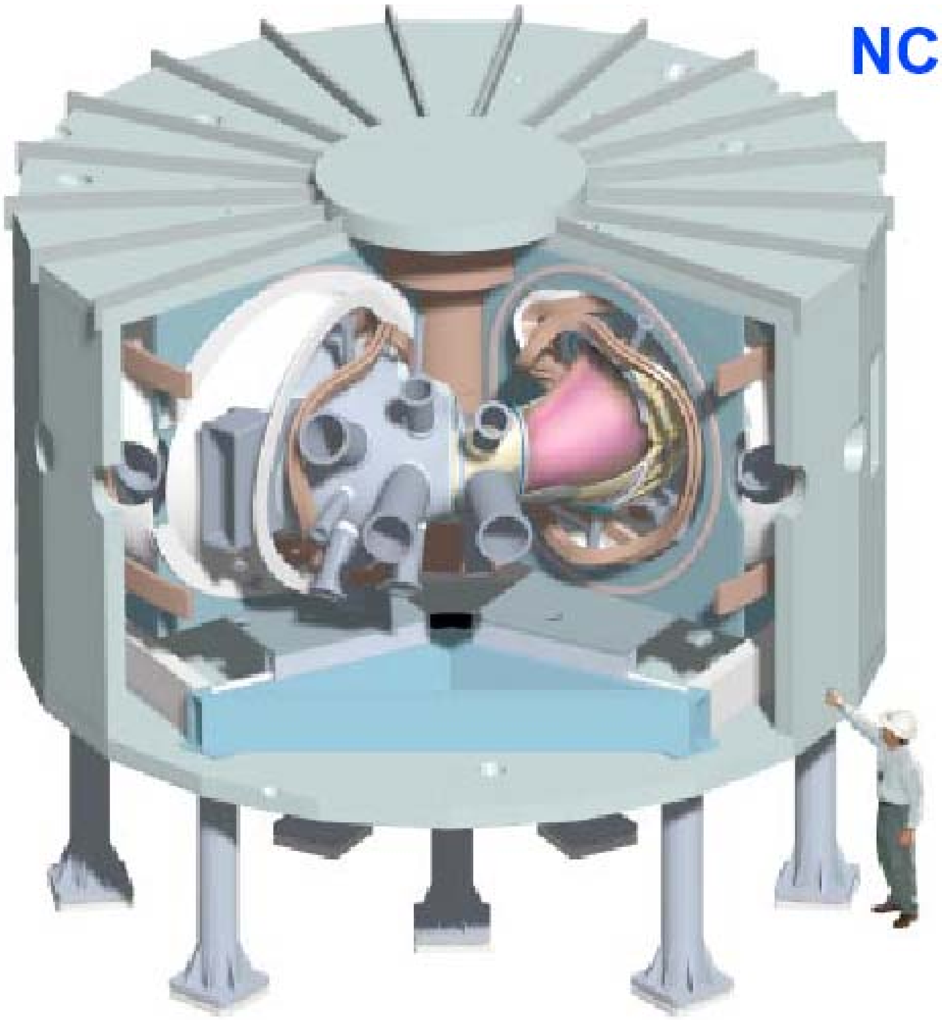


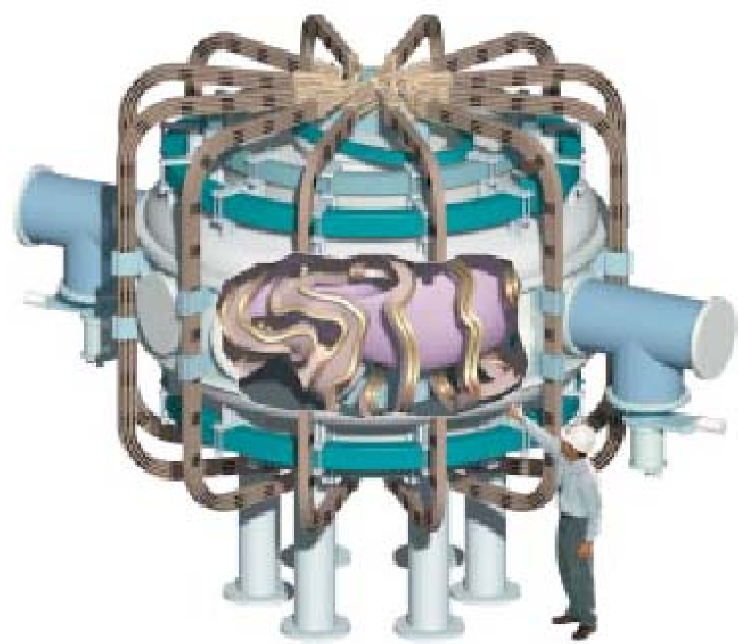
Compact Stellarator design optimizes plasma stability and steady-state properties.

Goal: Combine with ITER results for better fusion energy.

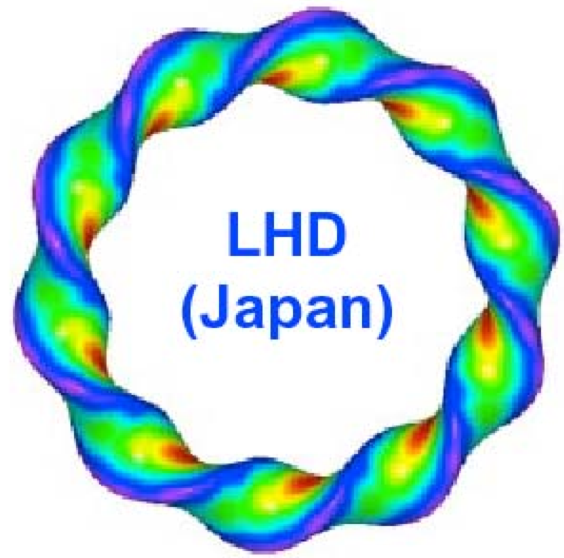
# *The U.S. is Planning Two Compact Stellarators*

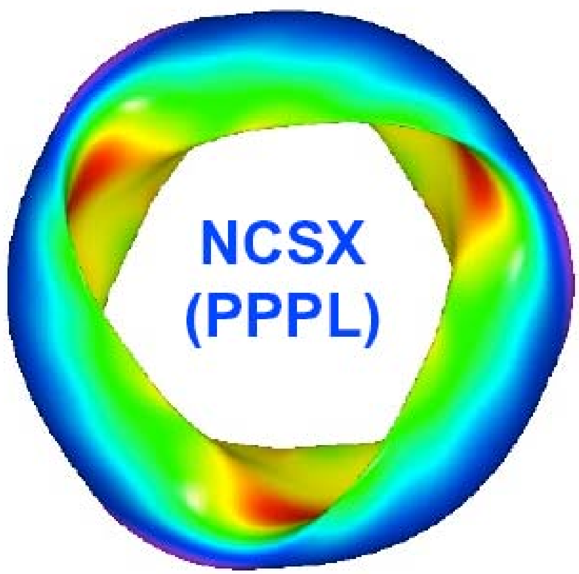
Different configuration and design approaches are used

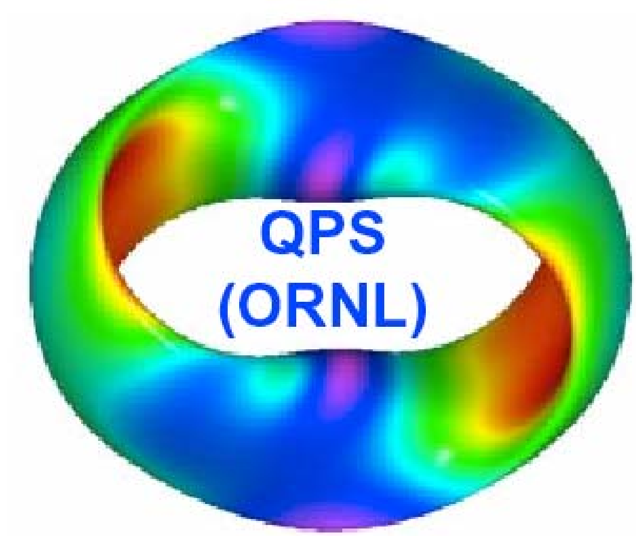


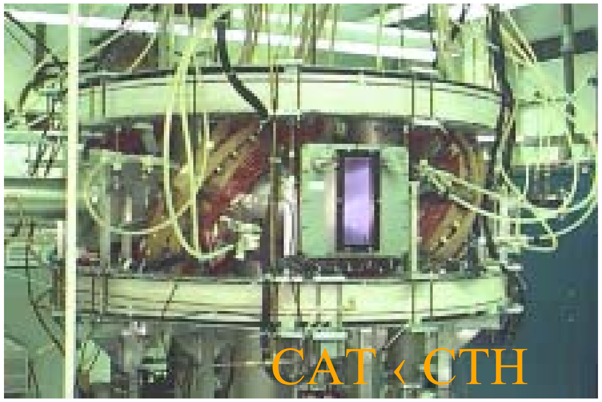
# *Compact Stellarators Allow Larger Plasmas*

# *Innovative Confinement Concepts*



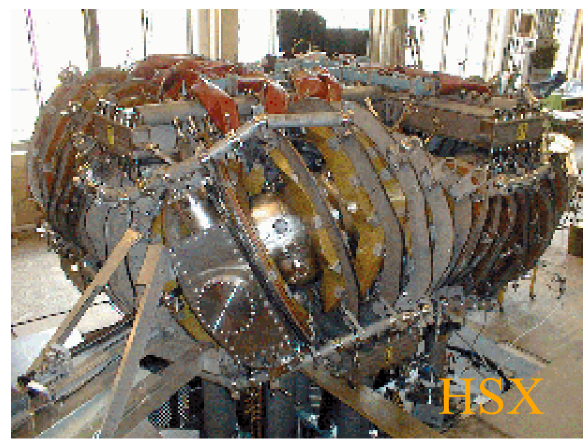

**Compact Auburn Torsatron** becoming
**Compact Toroidal Hybrid**
Auburn University, Auburn Alabama

**Levitated Dipole Experiment**
Columbia University/Massachusetts Institute of Technology


**Helicity Injected Torus-II Experiment**
University of Washington, Seattle


**Sustained Spheromak Plasma Experiment**
Lawrence Livermore National Laboratory


**Electric Tokamak**
University of California, Los Angeles




**Helically Symmetric Experiment**
University of Wisconsin, Madison

## *Inertial Fusion Energy*

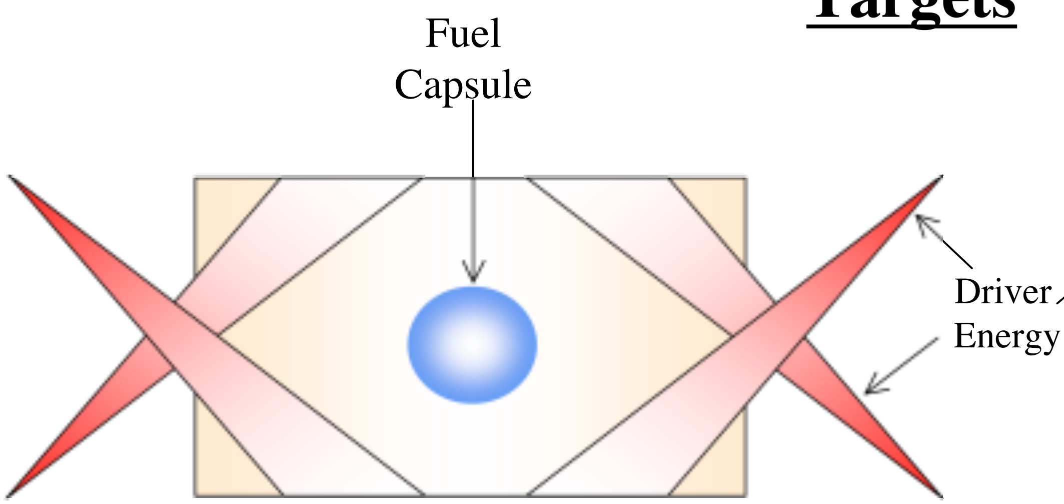
- Defense Programs conducting high energy density physics using OMEGA, and NIKE lasers; National Ignition Facility under construction; results are used by Science in designing energy producing targets

- SC developing components for energy applications, especially accelerator-based driver and target chamber technologies

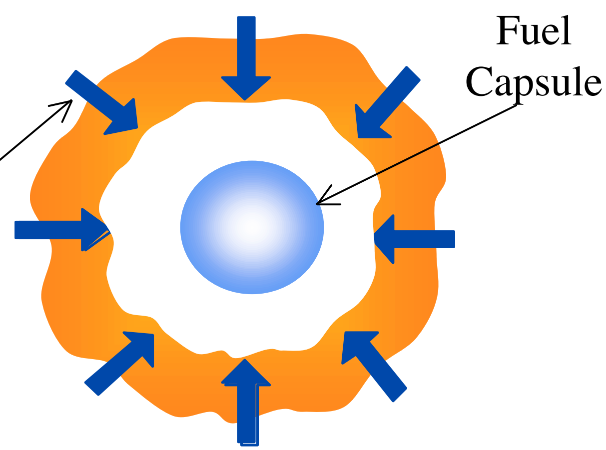
- Developing international collaboration through bilateral agreements

# *Inertial Fusion Energy Options*

## **Targets**




Indirect-drive




Direct-drive

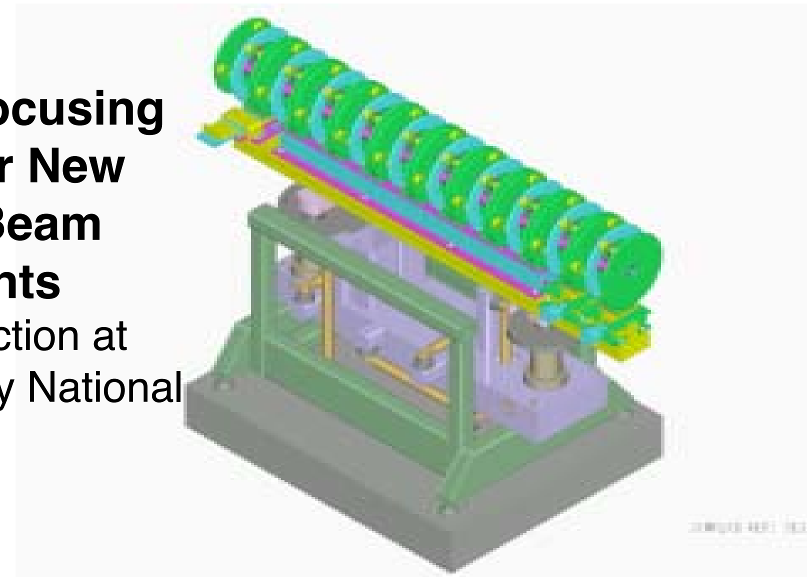
## **Drivers**

Heavy Ions
KrF Laser
Diode Pumped Solid State Laser

# *Inertial Fusion Energy Experimental Facilities*

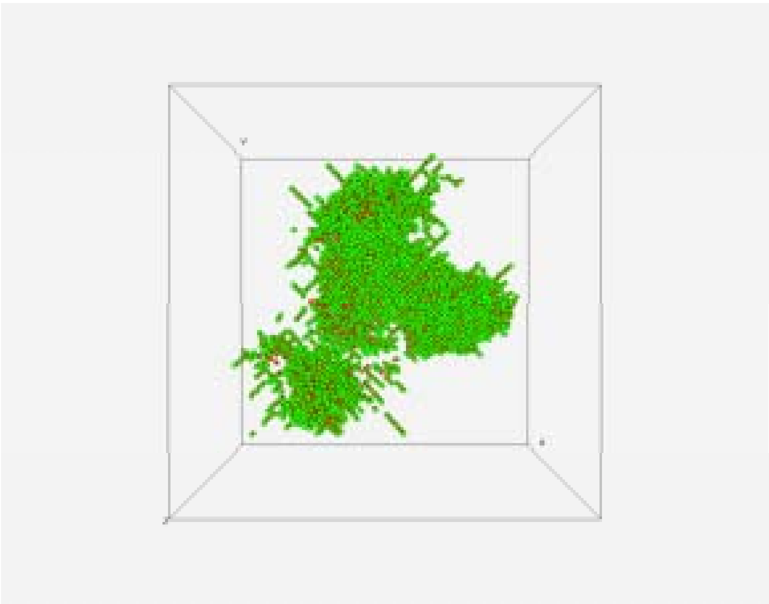
**Liquid wall chamber protection flow experiment**
Georgia Tech

**Quadrupole Focusing Assembly for New Heavy Ion Beam Experiments**
(Under construction at Lawrence Berkeley National Lab)

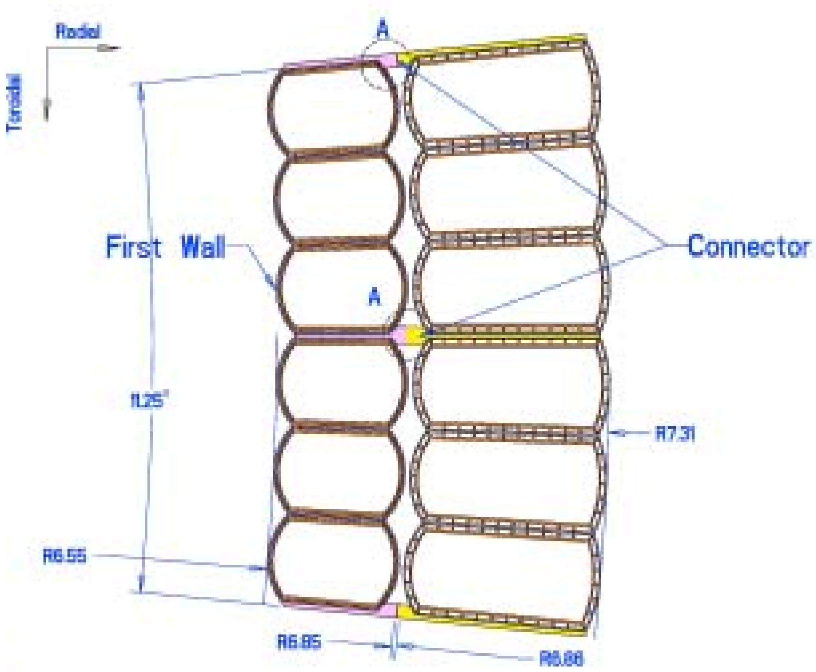


**Multi-beam Transport Experiment**
Lawrence Berkeley National Lab

# *Nanoscience and New Designs are Advancing Fusion Materials and Technologies*



Molecular Dynamics calculation of atomic displacements due to neutron impact.

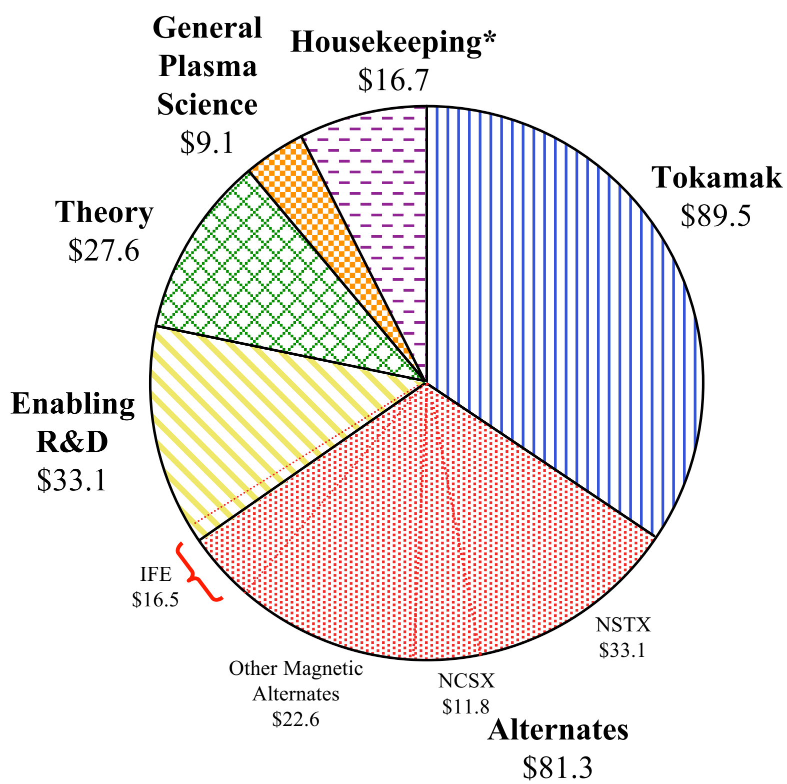



Simplified blanket designs allow high electrical efficiency and low radioactivity.

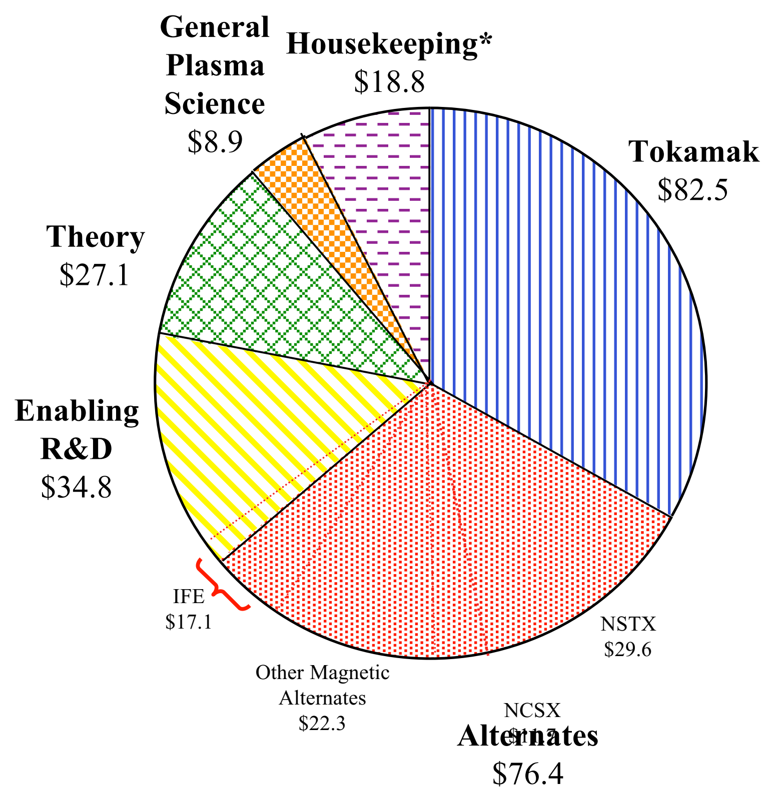
Goal: Convert fusion power to electricity with high efficiency and minimum radioactivity.

# *Fusion Energy Sciences Budget*

FY 2003
<u>Congressional</u>
**$257.3 M**




FY 2003
<u>Initial Financial Plan</u>
**$248.5 M**



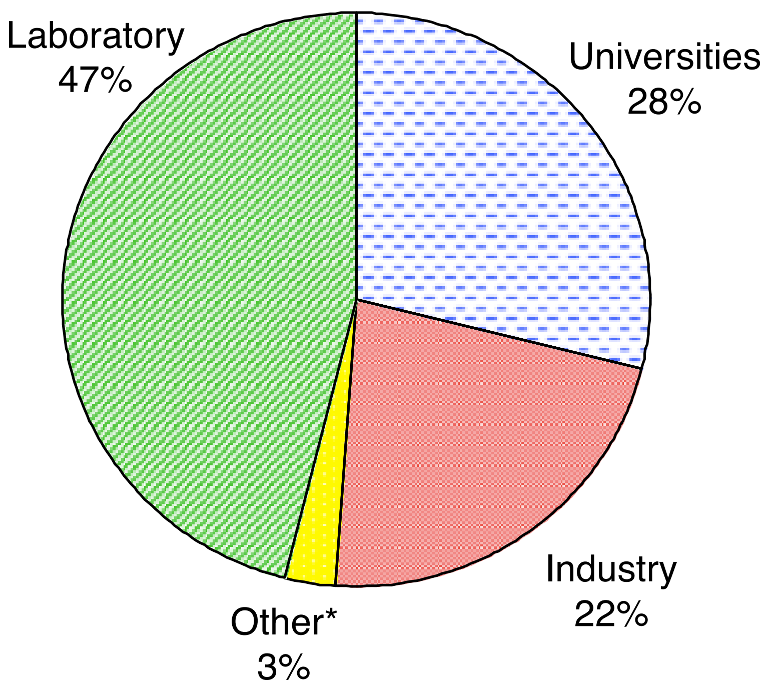

* Housekeeping includes SBIR/STTR, GPE/GPP, TSTA cleanup, D-Site caretaking at PPPL, HBCU, Education, Outreach, ORNL Move, and Reserves

# *Fusion Energy Sciences Funding Distribution*

**FY 2003 Initial Fin Plan**

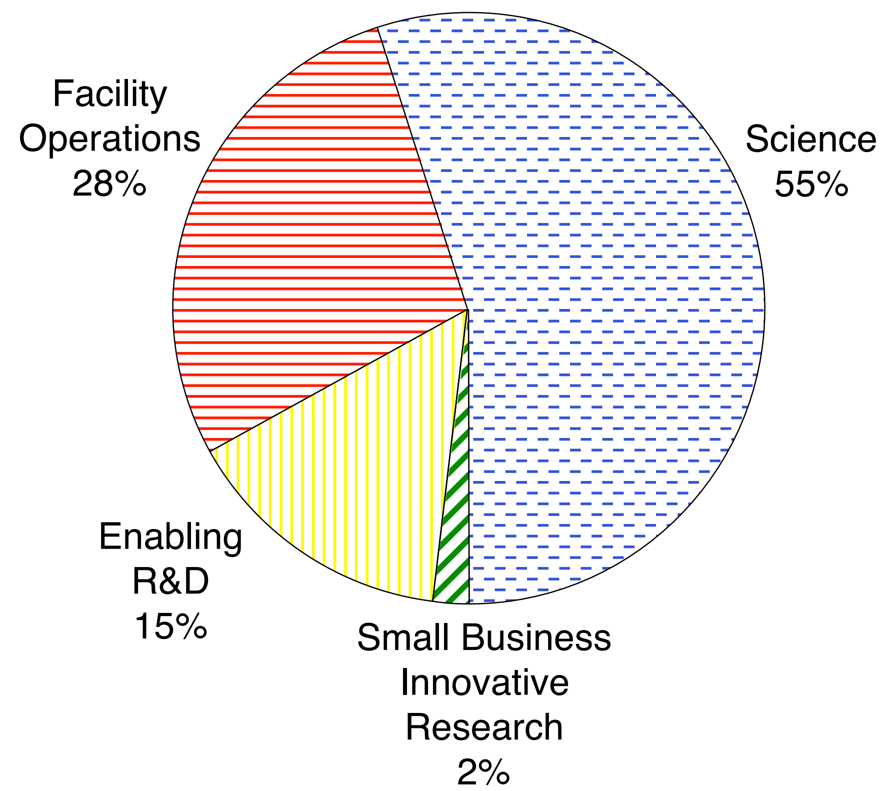
**$248.5M**

## Institution Types

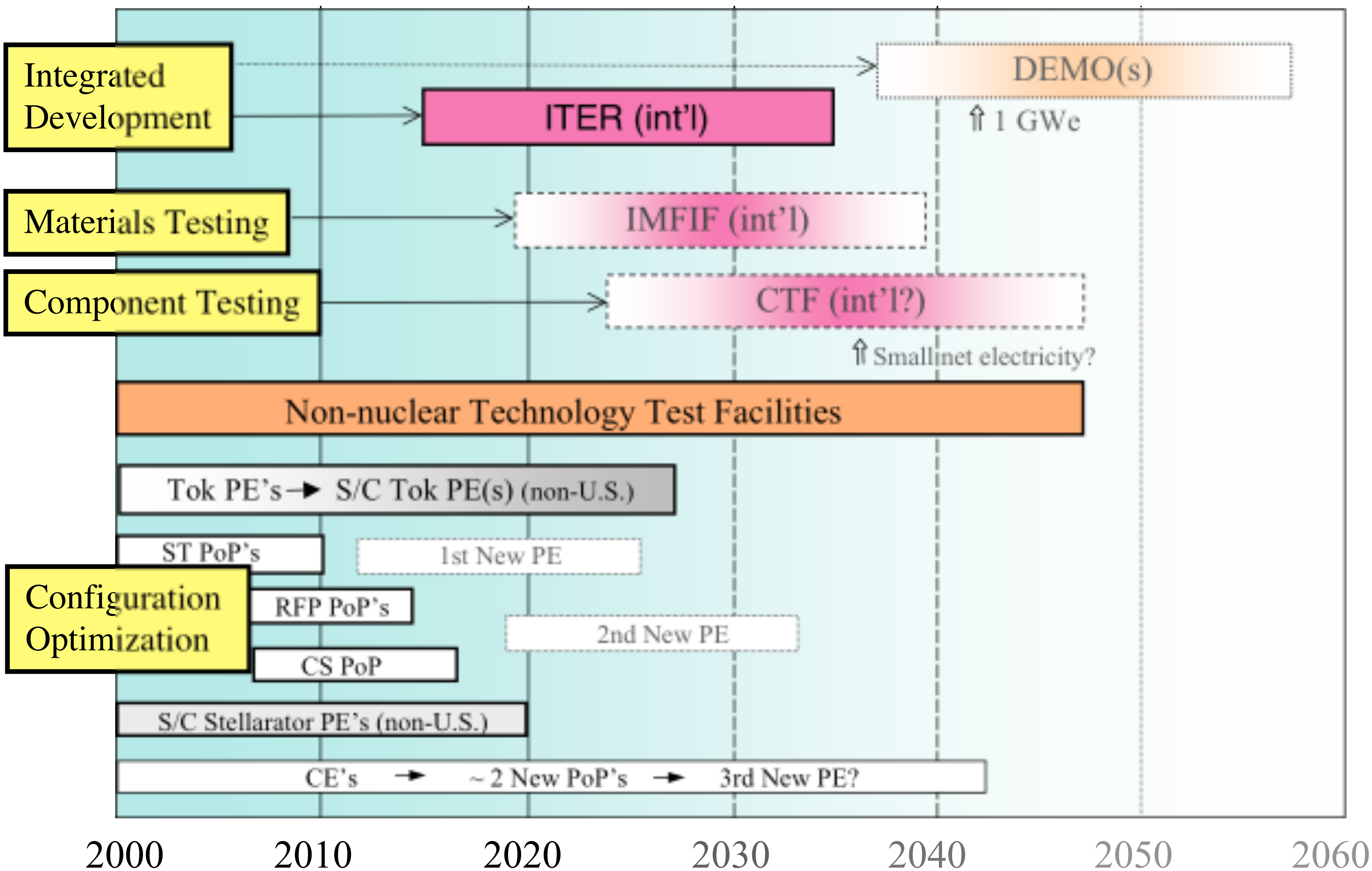



*NIST/NSF/NAS/AF
Undesignated

## Functions



# *U.S. MFE Program Leaders Envision a Plan to Put Fusion on the Grid*




Being reviewed by FESAC