



# *U.S. Fusion Energy Sciences Program*

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Presented at the

**French Embassy**

By

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Office of Science  
Department of Energy

October 8, 2002

[www.ofes.fusion.doe.gov](http://www.ofes.fusion.doe.gov)

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**Excellent Science in Support of Attractive Energy**

# *National Energy Policy*

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## National Energy Policy



Report of the  
National Energy Policy Development Group

May 2001

"The NEPD Group recommends that the President direct the Secretary of Energy to develop next-generation technology--including hydrogen and **fusion**."

# *Why Develop Fusion Energy*

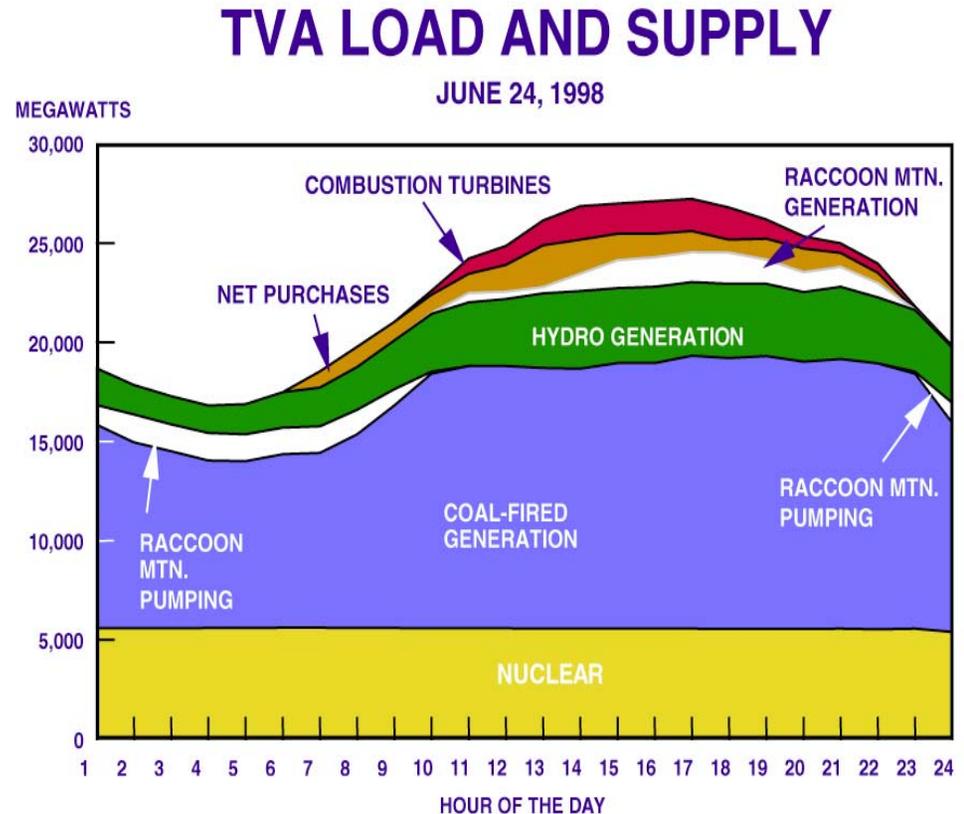
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Fusion is a unique energy option with:

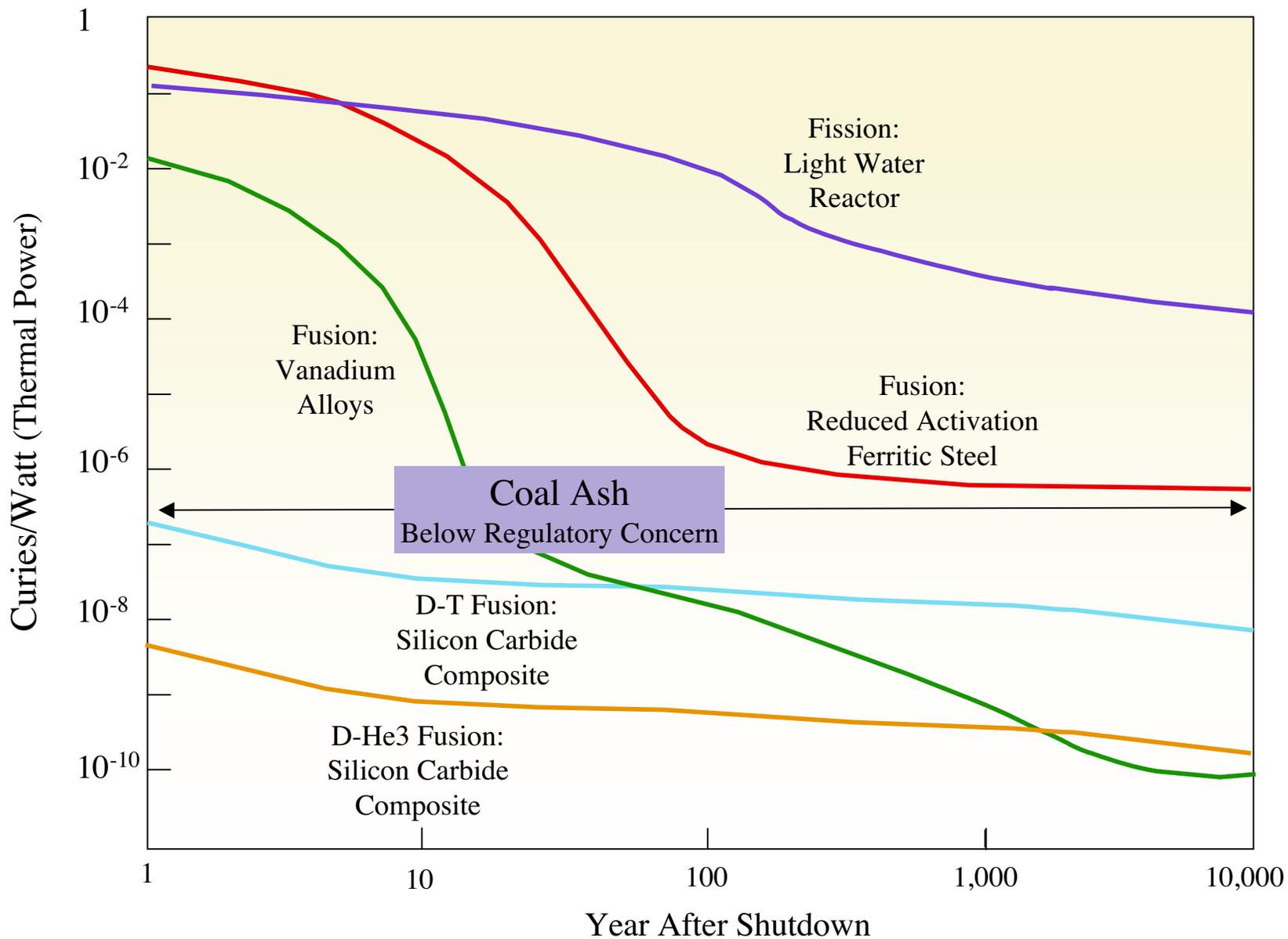
- o **Secure inexhaustible fuel reserves**
  - Fuel obtained from seawater
  - One pound of fusion fuel = 25,000 barrels of oil
- o **Multiple end uses**
  - Electricity
  - Fissile fuel
  - Hydrogen production
- o **Attractive environmental and safety features**
  - No long-lived reaction products
  - Radioactive structure is relatively easy to manage
  - No combustion pollutants are produced
  - No possibility of runaway reaction
- o **Ancillary Benefits**, such as, advanced science and technology/spinoffs/education

# *Fusion in a Hydrogen Economy*

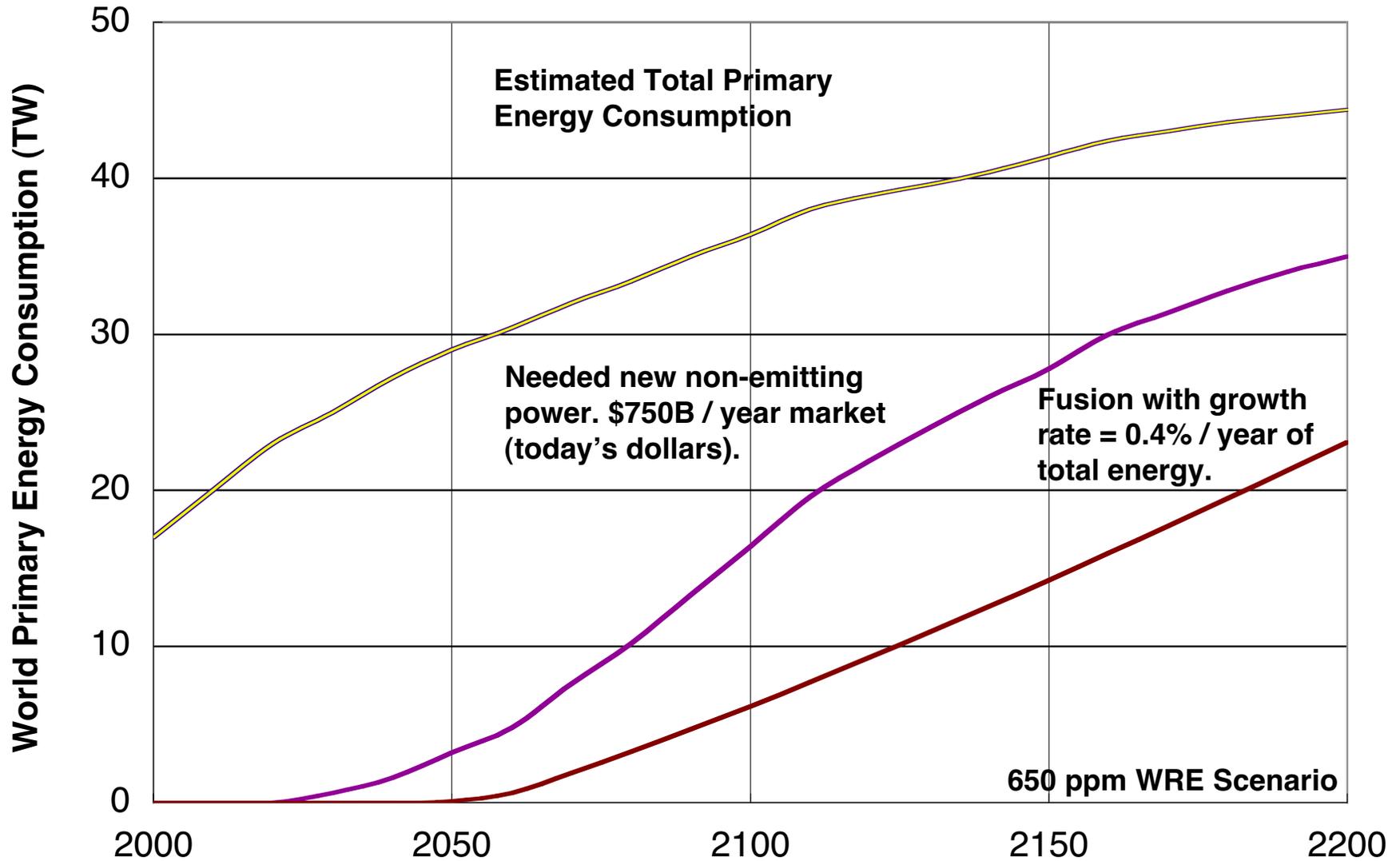
- o Electricity demand varies strongly during the day
- o Fusion systems have near-zero fuel costs
  - Off-peak operation has low marginal cost
- o Off-peak H<sub>2</sub> production from fusion is an attractive option
  - Local production at the power plant
  - Distributed production at refueling station



# Comparison of Fission and Fusion Radioactivity After Shutdown

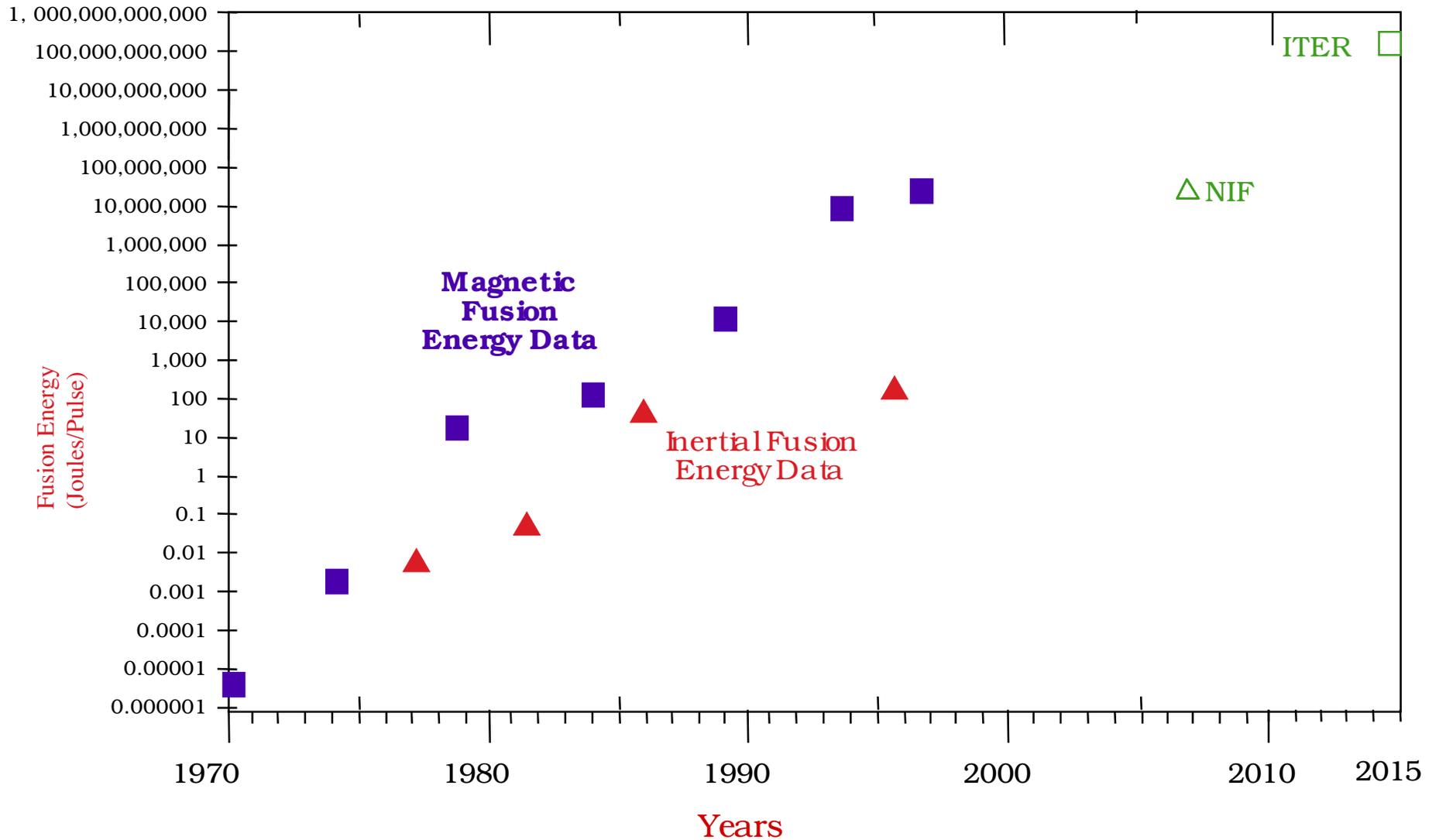


# *Fusion Can Contribute to Carbon Management on a Timely Basis*

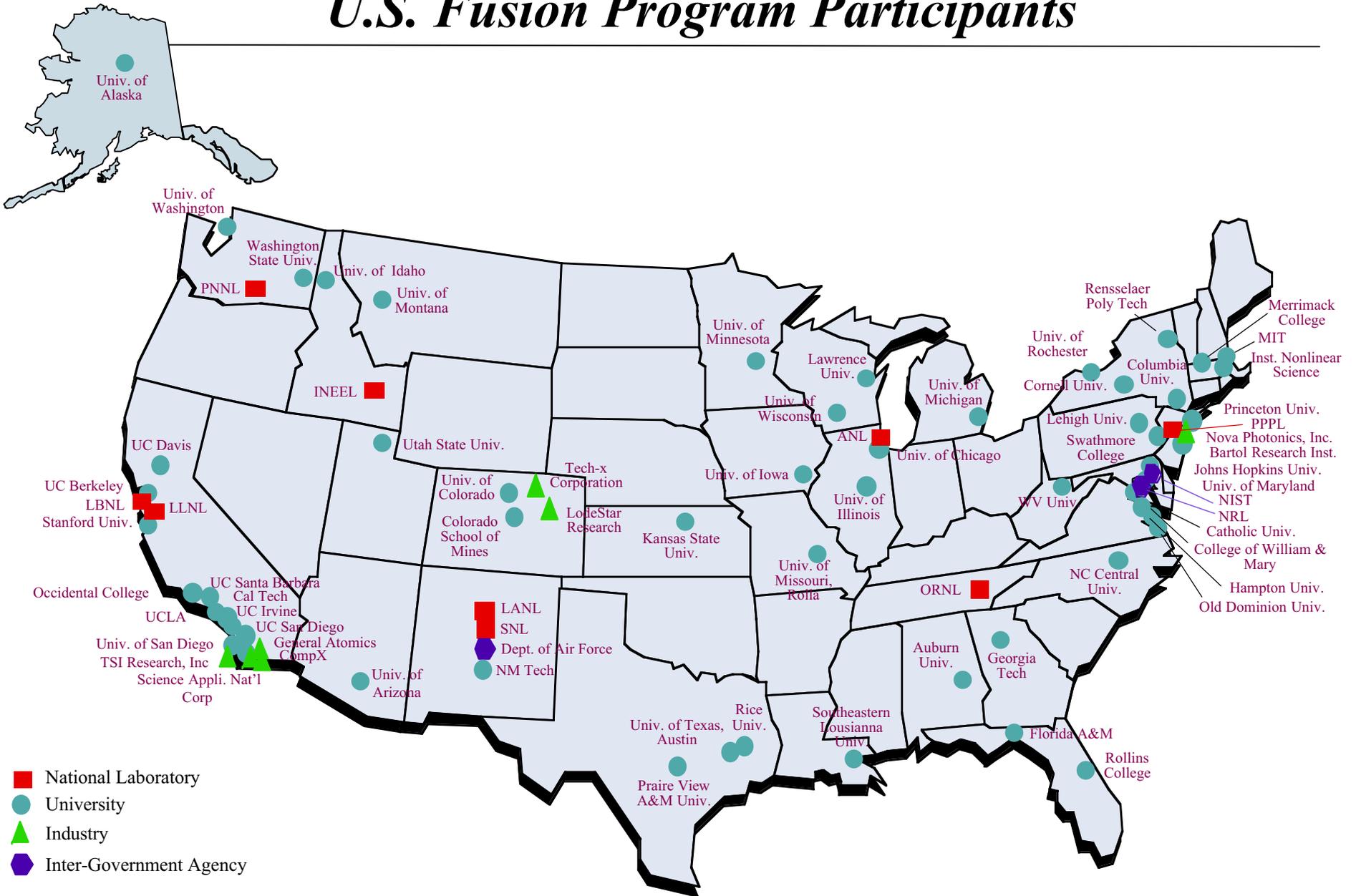


***World population growth will be in cities and "megacities," requiring large new power stations.***

# *Progress in Fusion Energy has been Dramatic*

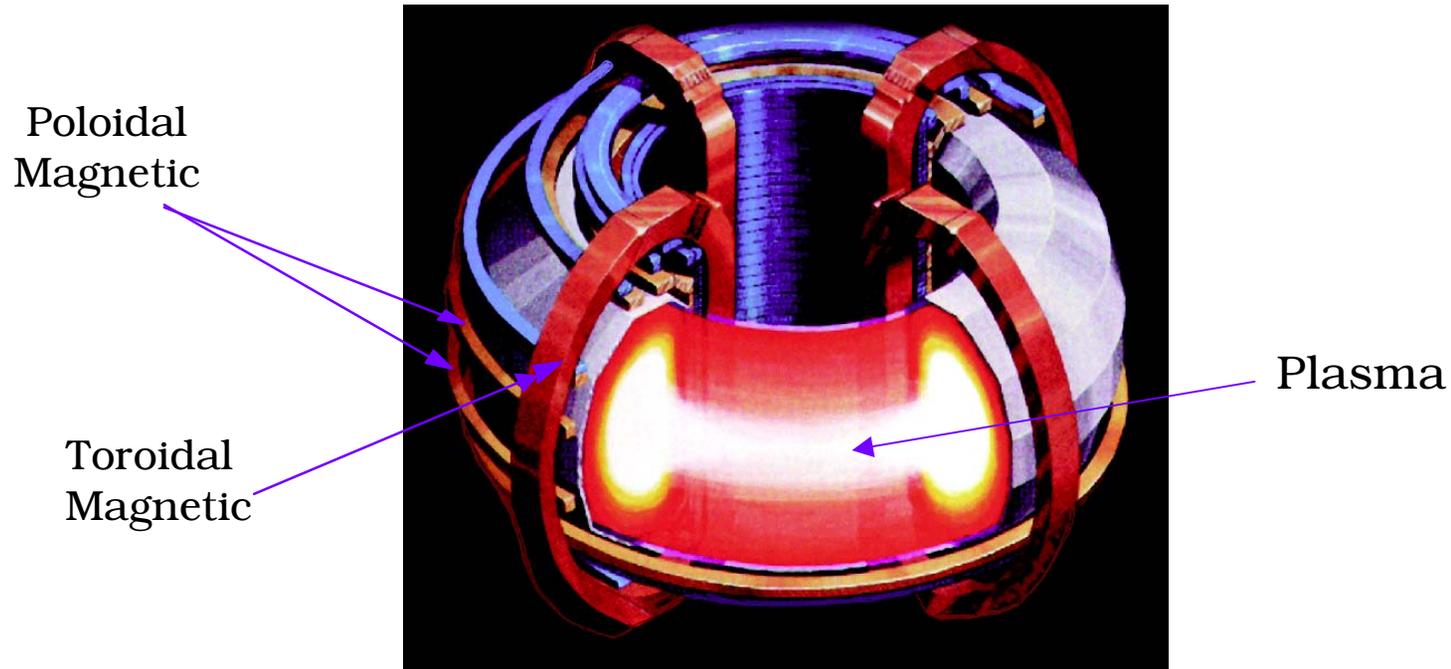


# U.S. Fusion Program Participants



# *The Tokamak -- The Workhorse of Fusion Science*

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## Science Issues

Configuration Stability

Confinement and Transport

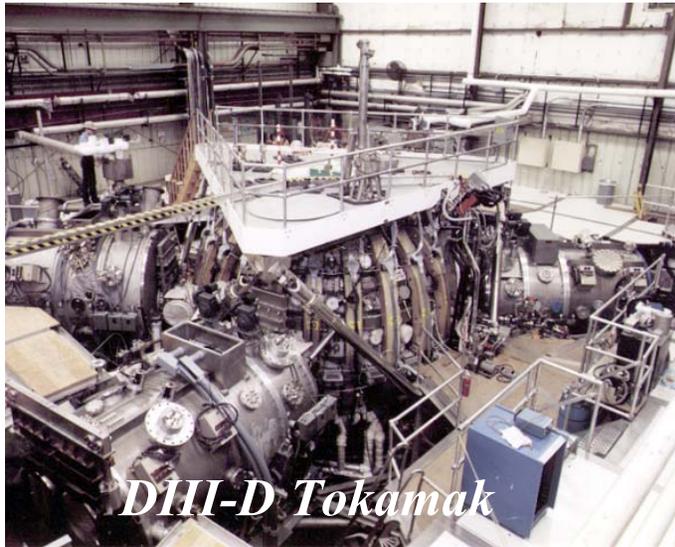
Heating, Fueling, Current Drive

Boundary Physics

Integration

Burning Plasma Physics

# Major U.S. Magnetic Fusion Facilities



*DIII-D Tokamak*

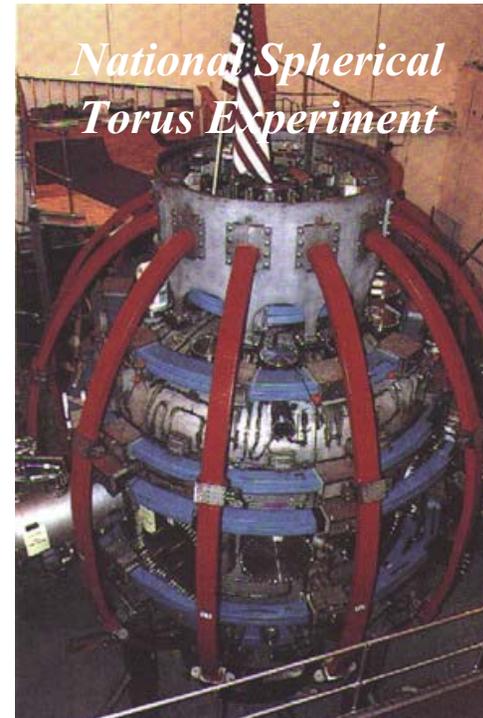
**General  
Atomics**

Doublet III  
Started  
Operations  
In 1978

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



*Alcator C-MOD*

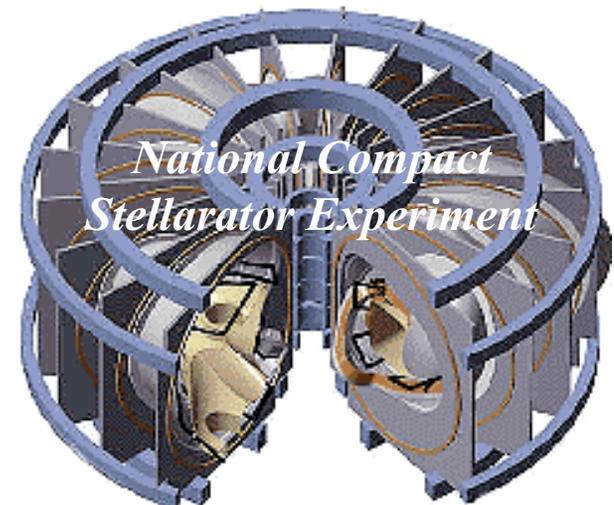


*National Spherical  
Torus Experiment*

**Princeton  
Plasma  
Physics  
Laboratory**  
NSTX started  
Operations in  
1999

**Princeton  
Plasma  
Physics  
Laboratory**

NCSX  
Fabrication:  
FY 2003-2007



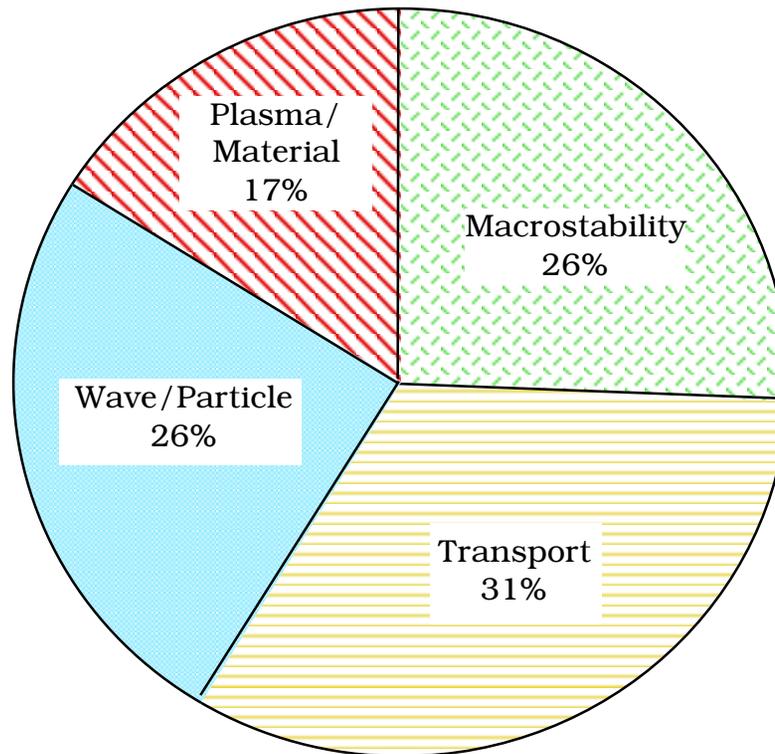
*National Compact  
Stellarator Experiment*

# ***Fusion Energy Sciences Budget***

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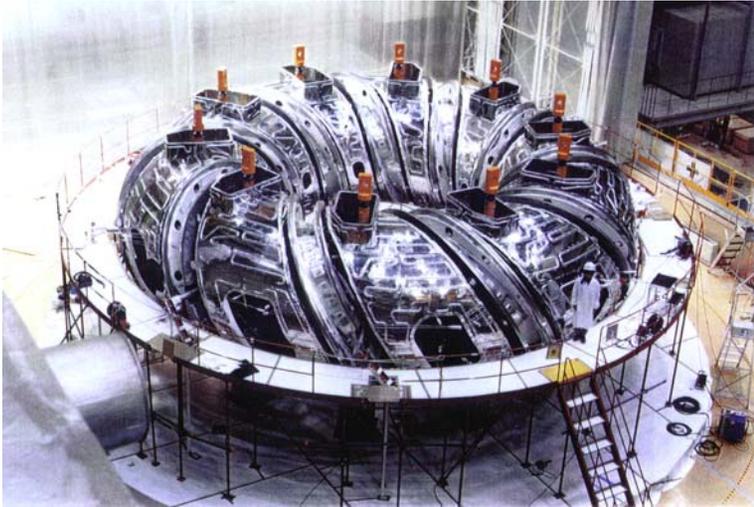
FY 2003 Congressional

## Science Issues



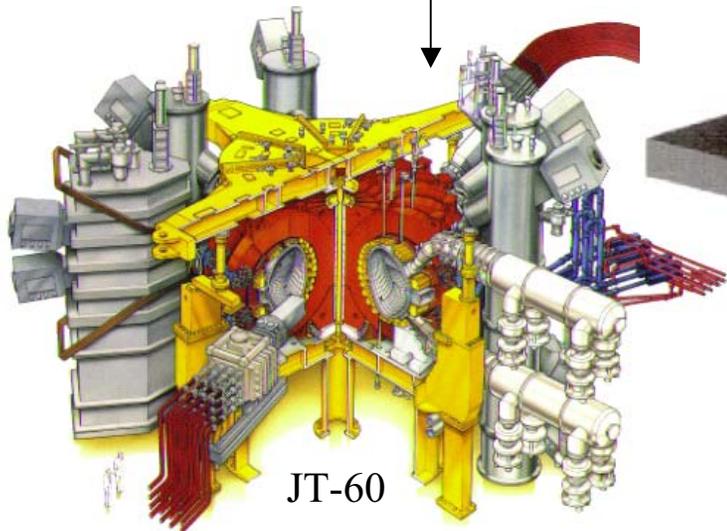
Includes science sub-elements only,  
Does not include facility operations.

# Major International Facilities

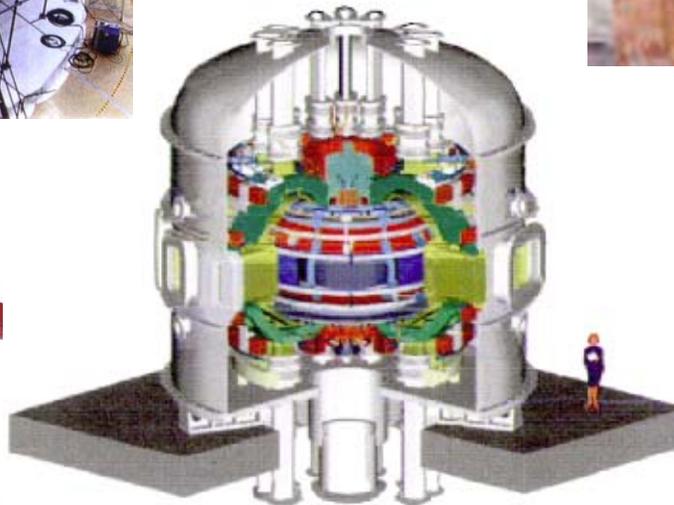


Large Helical Device (LHD)

Japan



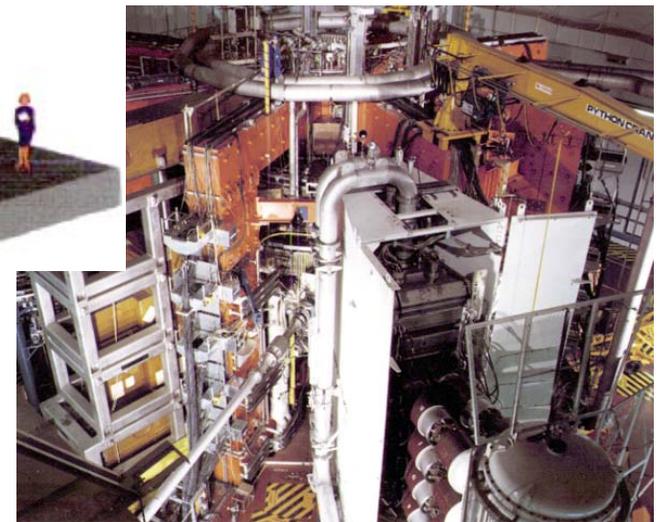
JT-60



KSTAR (Korea)



Wendelstein 7-X  
(Germany)



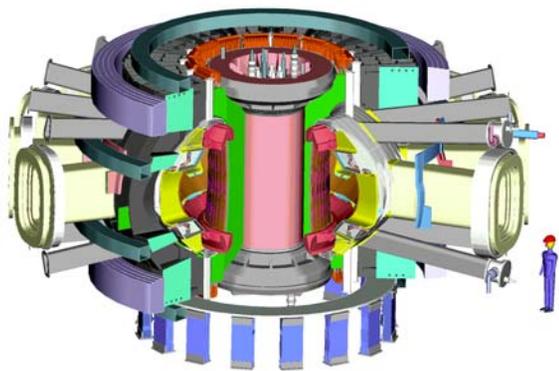
Joint European Torus (JET)

# *Burning Plasma Physics*

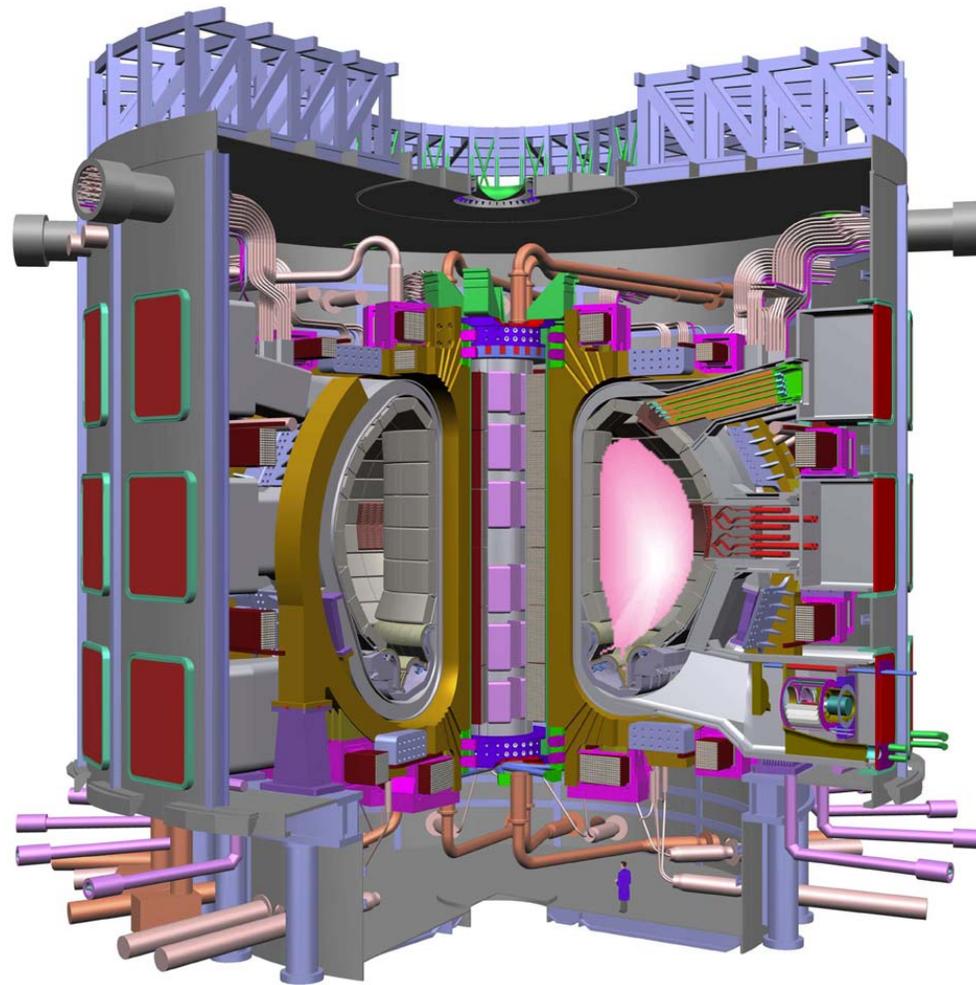
## *The Next Frontier*

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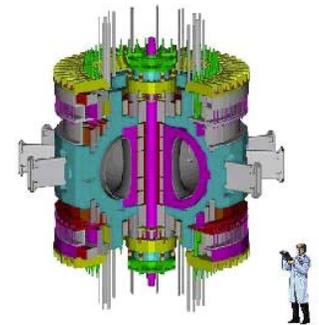
Three Options  
(Different Scales)



FIRE



ITER



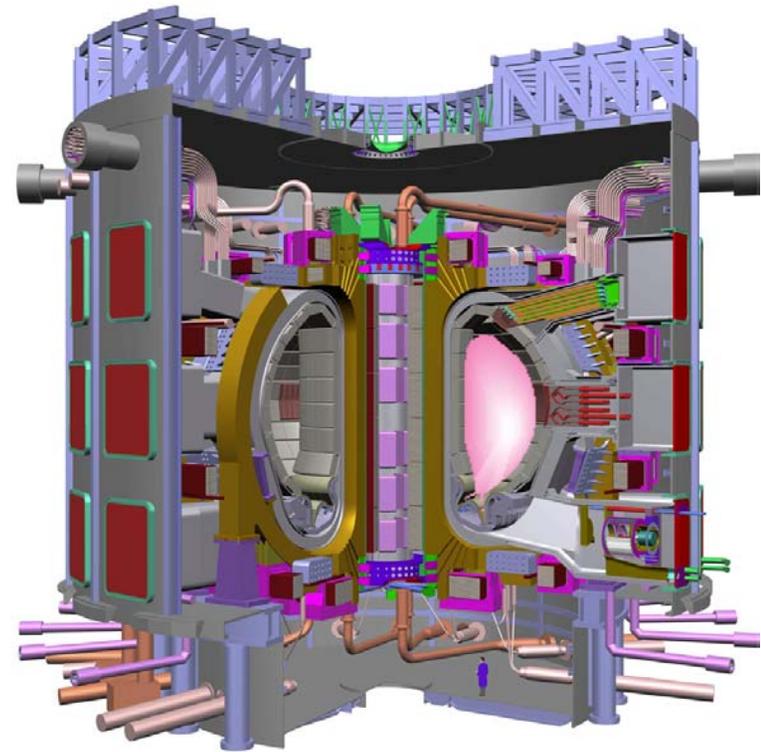
IGNITOR

# *Upcoming ITER Decision is Crucial for Fusion World-wide*

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Merging of Fusion Science and Fusion Energy  
Burning Plasma Physics & Power Plant Relevant Technologies

- o ITER Parties (EU, JA and RF) have completed design for reduced cost (~\$5B) and technical objectives (same mission)
  - ITER would be first burning plasma physics device
- o ITER Parties (now EU, JA, RF and Canada) want the U.S. to join ongoing negotiations



Fusion Power: 500MW  
Burn Pulse: 400-3600 sec

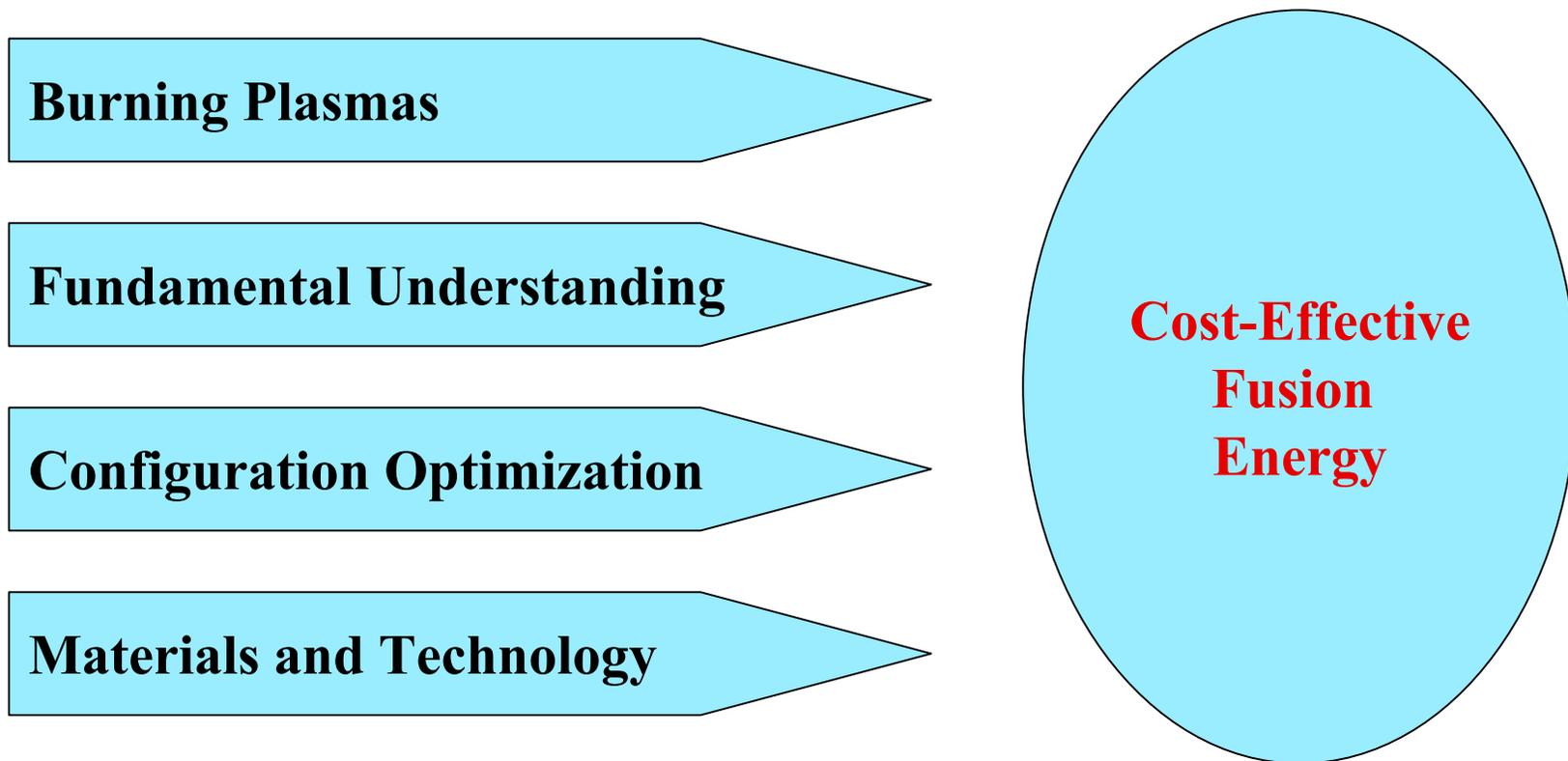
## *Why the U.S. Left ITER*

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- o “**ITER won’t work**” --“Science” article, 12/96
  - Physics of Plasmas paper, 3/00 -- extensive analysis showed critical 12/96 article was wrong
- o “**ITER costs too much**” -- \$10B
  - Now \$5B after revision to reduce costs through reduction in detailed technical objectives, thereby--reduced size, mass, power and cost.
- o “**Partners will never agree to move forward**” -- EDA extension
  - Negotiations underway
  - Multiple sites offered

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

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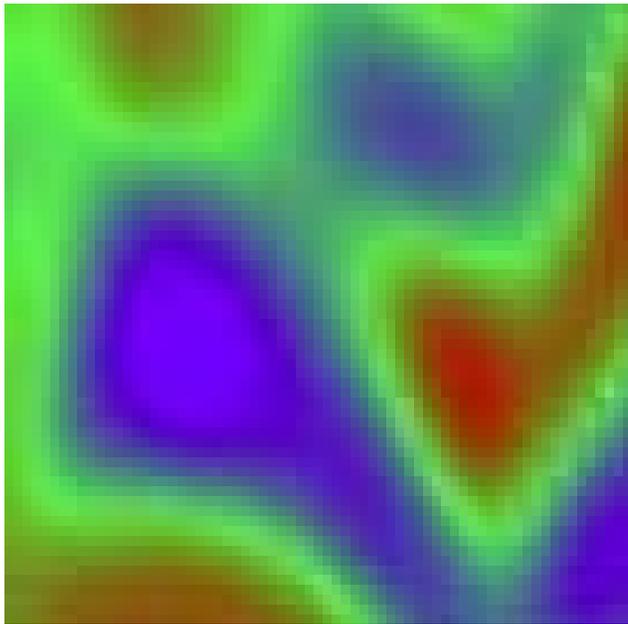


**Areas defined by the  
Fusion Energy Sciences Advisory Committee.**

# *Scientific Understanding of Fusion Plasmas has Increased Dramatically*

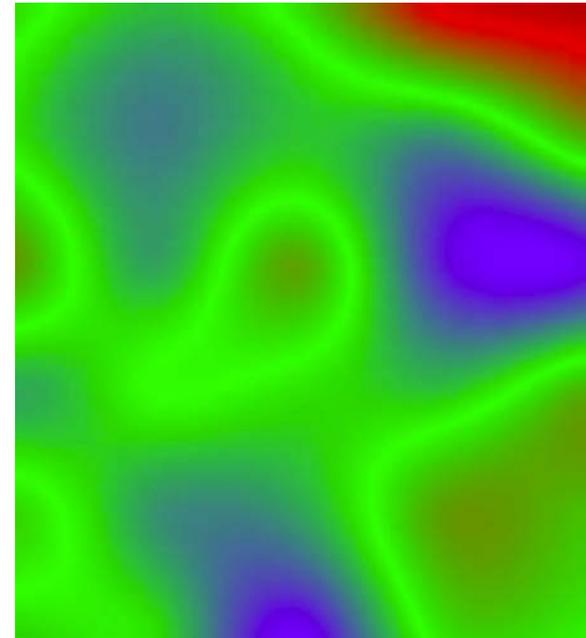
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## Advanced Computing



Simulation of turbulence in magnetic fusion plasma.

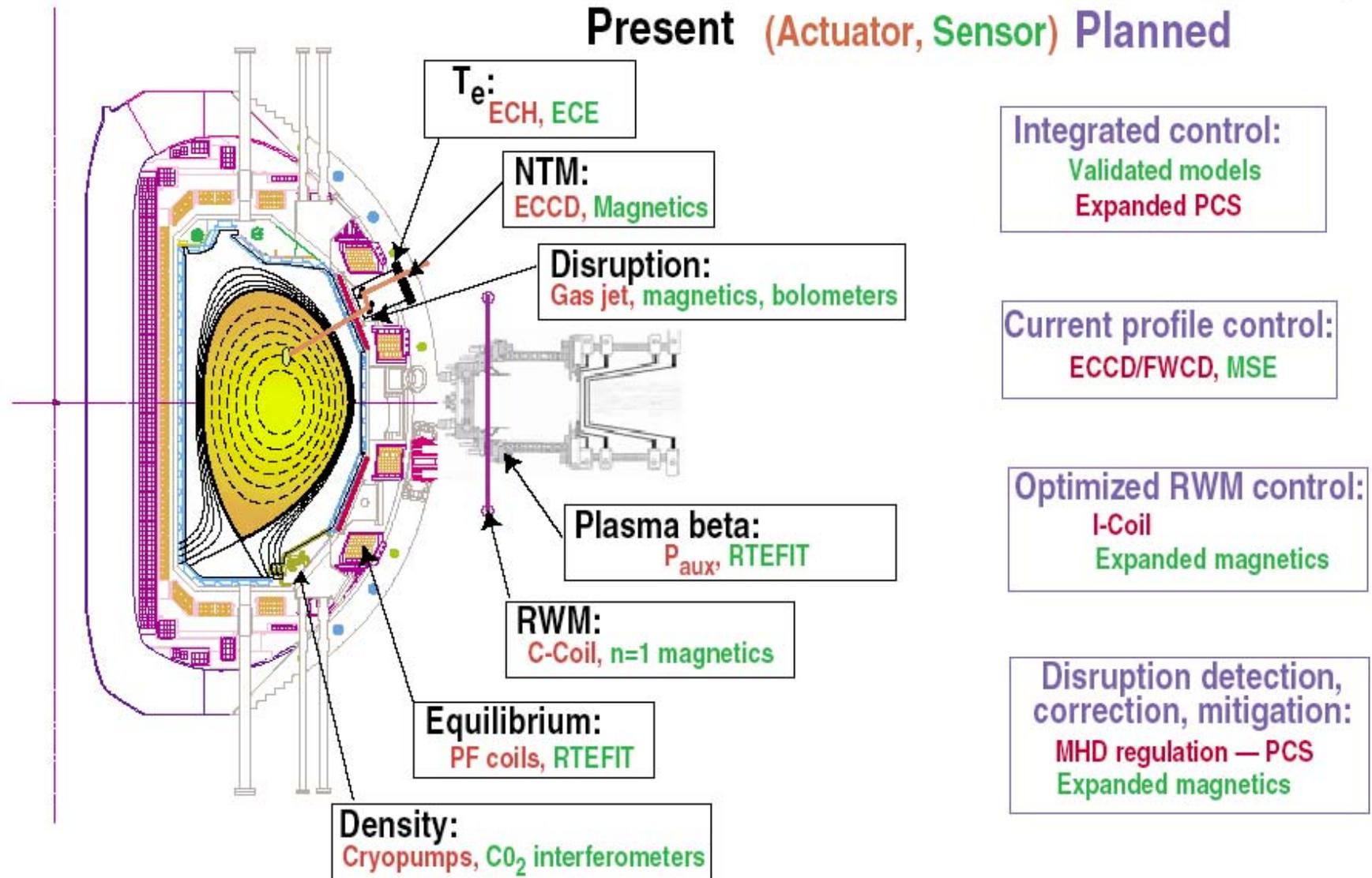
## Plasma Measurements



Fast imaging of plasma turbulence.

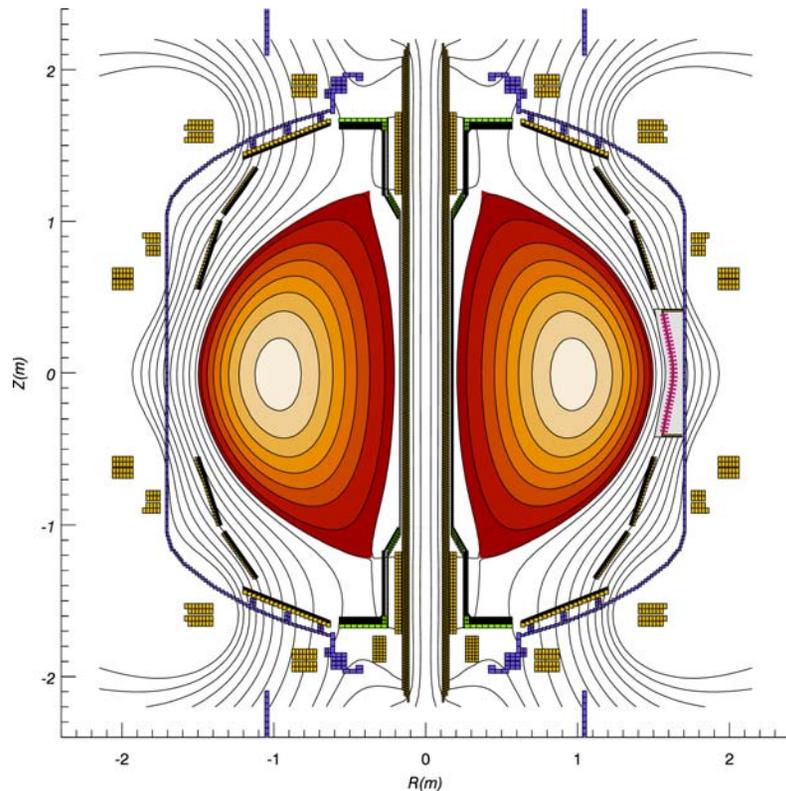
**Goal:** Practical fusion energy through high-quality science.

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

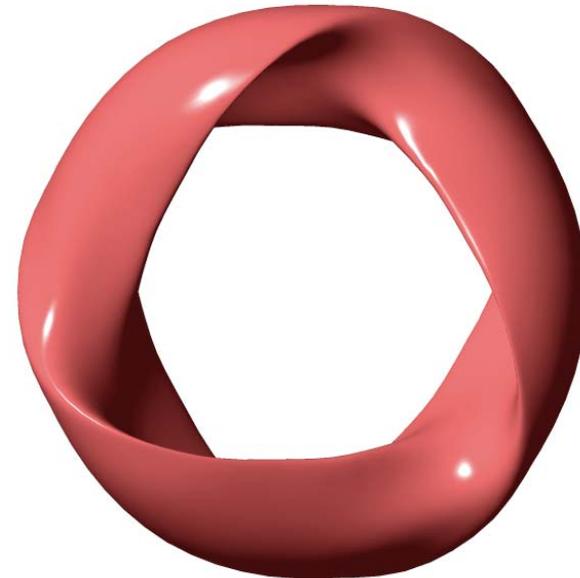


# *Variations of the Toroidal Plasma Configuration Address Key Fusion Issues*

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



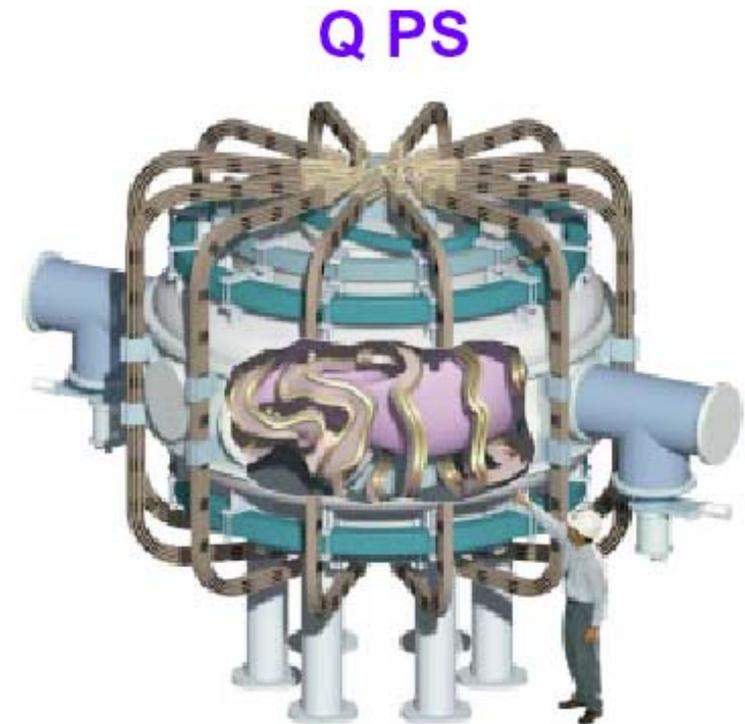
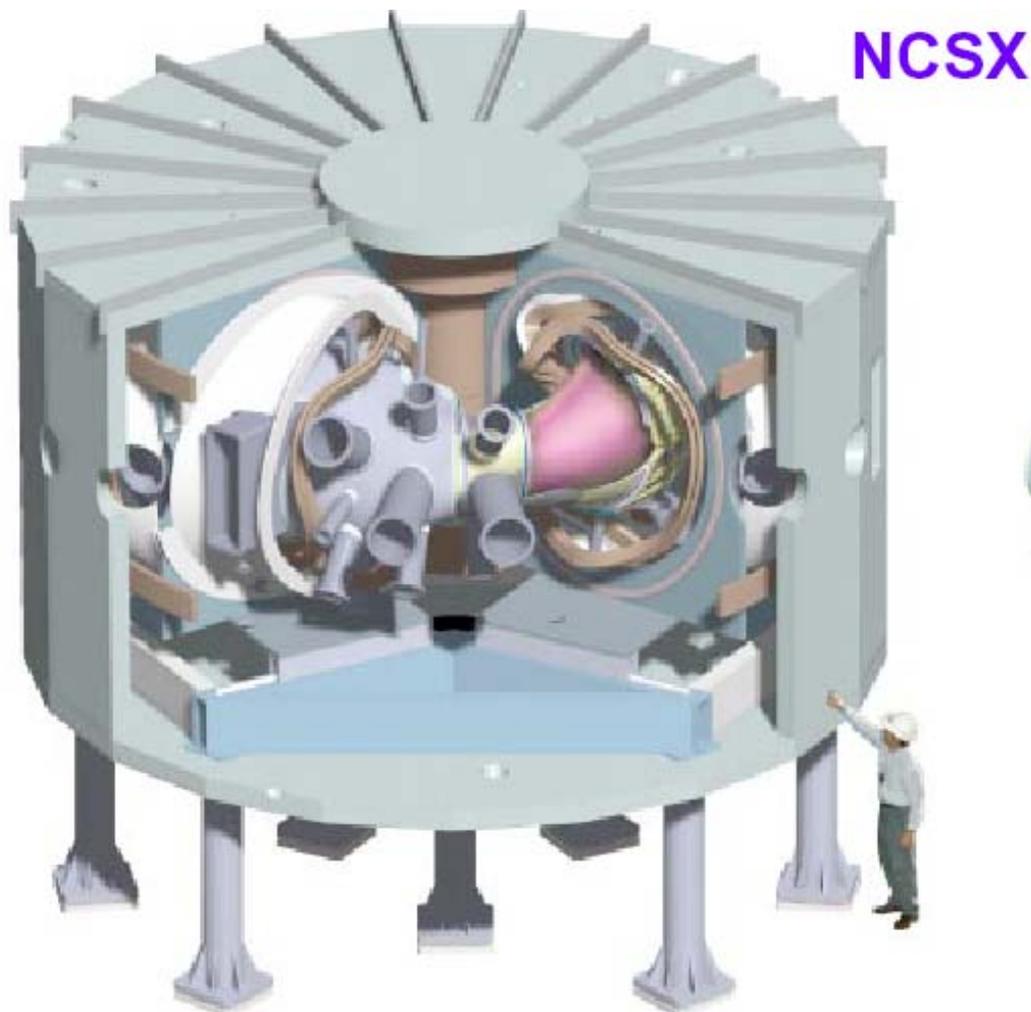
Compact Stellarator design optimizes plasma stability and steady-state properties.

**Goal:** Combine with ITER results for better fusion energy.

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

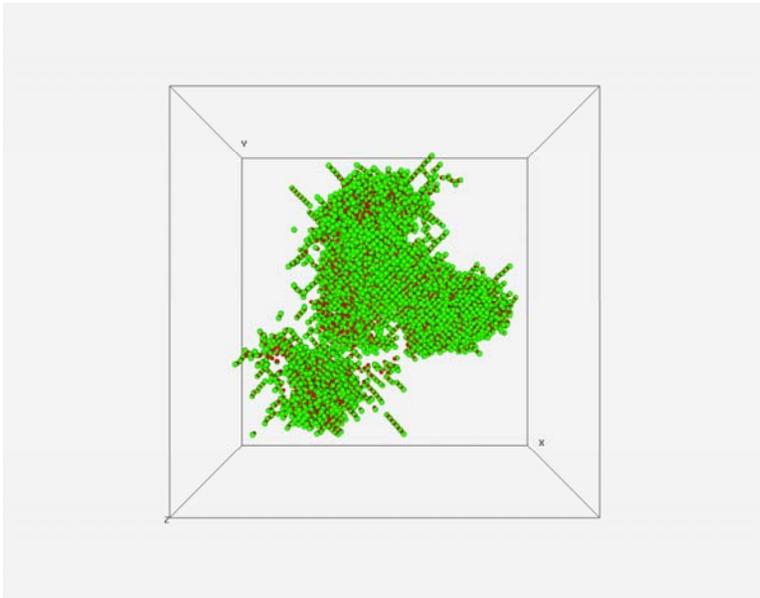
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Different configuration and design approaches are used

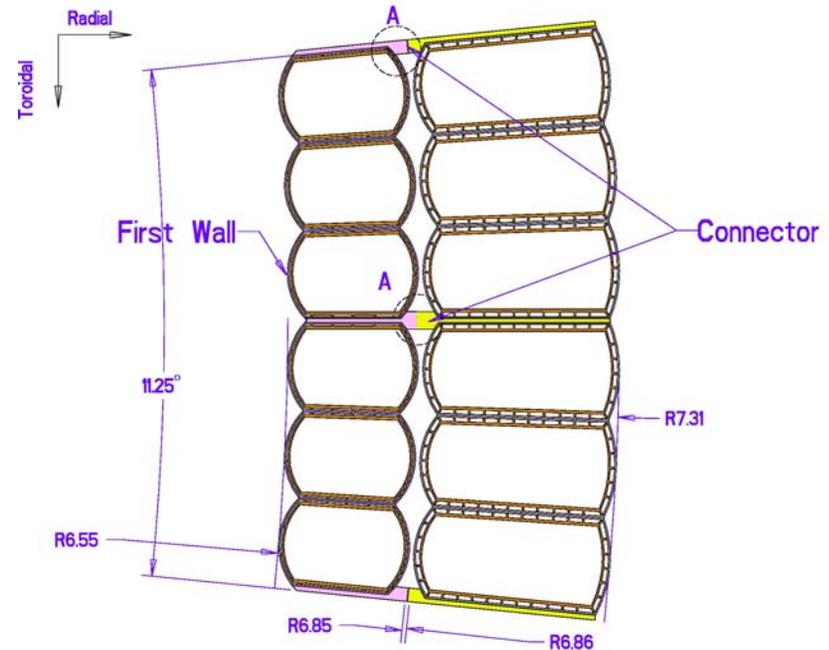


# *Nanoscience and New Designs are Advancing Fusion Materials and Technologies*

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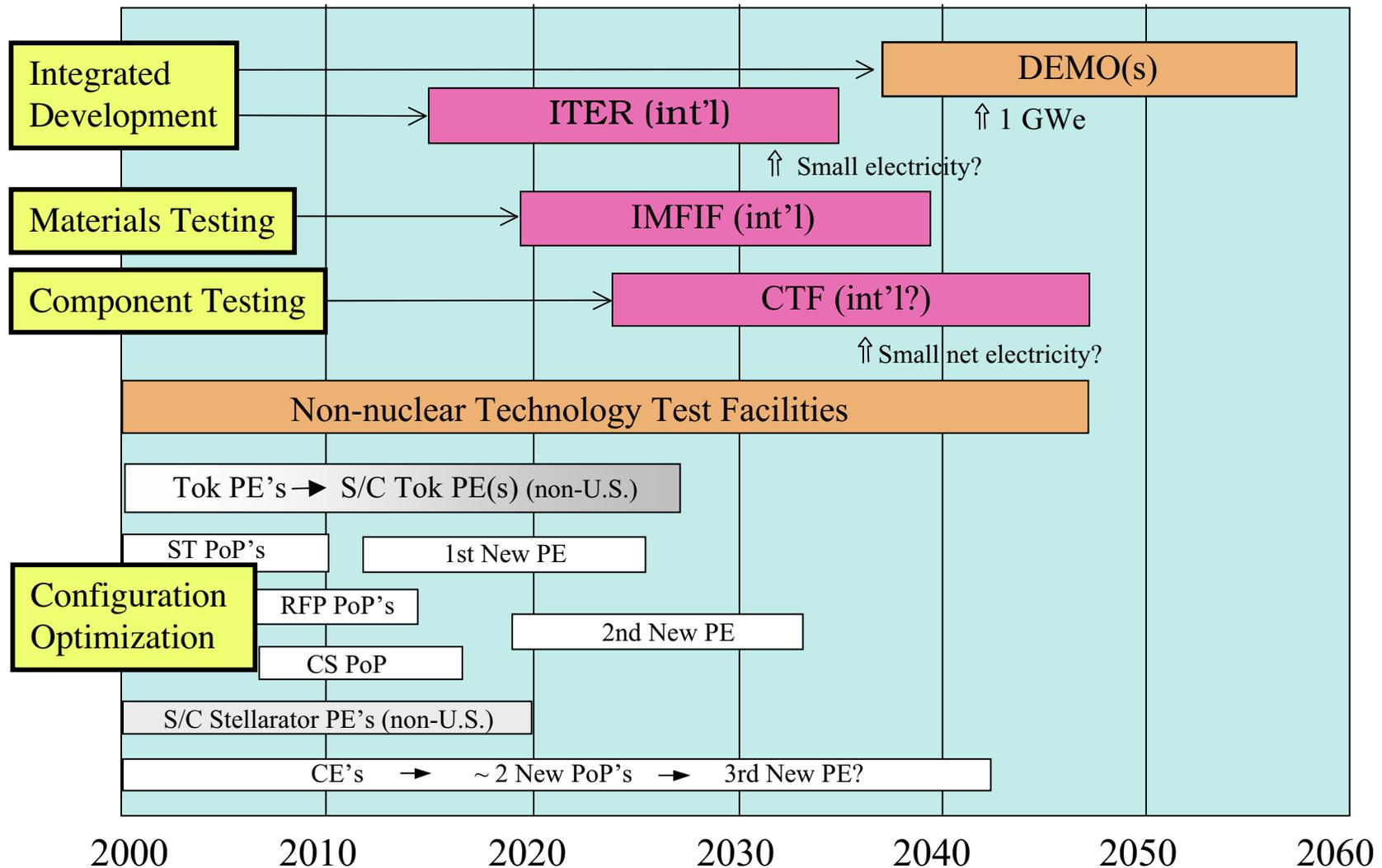
Molecular Dynamics calculation of atomic displacements due to neutron impact.



Simplified blanket designs allow high electrical efficiency and low radioactivity.

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

# *U.S. MFE Program Leaders have Developed an Optimized Plan to Put Fusion on the Grid*



Being reviewed by FESAC

## *Burning Plasma Consensus Building*

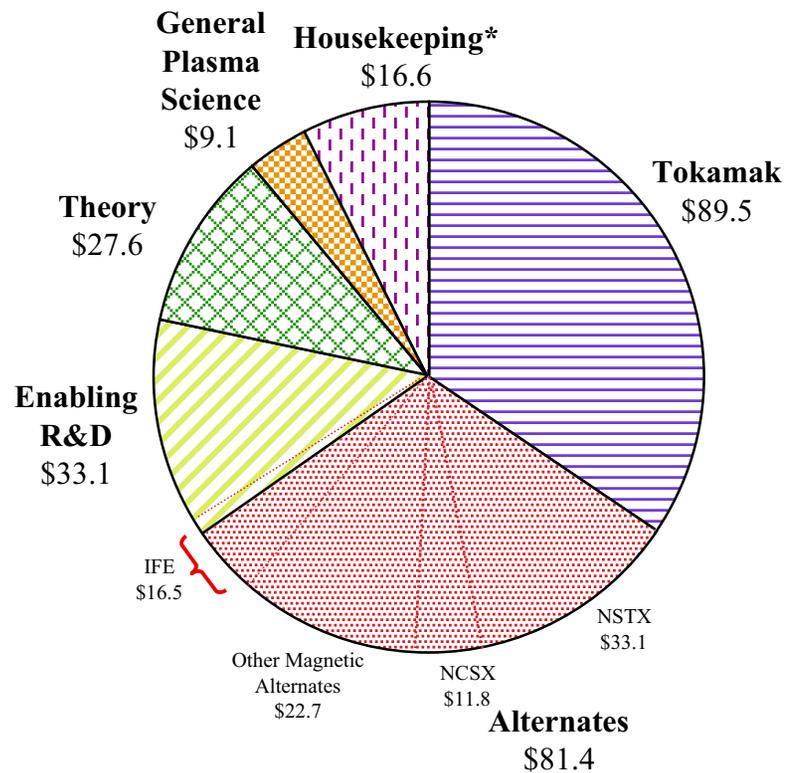
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|----------------|--|
| September 2001 | FESAC <b>Report on Burning Plasma Physics</b>                                      |
| July 2002      | Fusion Community Workshop to <b>assess options</b> for a Burning Plasma Experiment |
| September 2002 | FESAC <b>Recommendations</b> for a Burning Plasma Program Strategy                 |
| December 2002  | NRC <b>Letter Report on Strategy</b>   |
| December 2002  | FESAC <b>Preliminary Report on Development Path</b>                                |

# *Fusion Energy Sciences Budget*

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FY 2003  
Congressional  
**\$257.3 M**



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