U.S. Department of Energy's

Office of Science

Fusion Energy Sciences Program

House Science Committee
Energy Subcommittee

Office of Fusion Energy Sciences
Excellent Science Attractive Energy

www.ofes.fusion.doe.gov

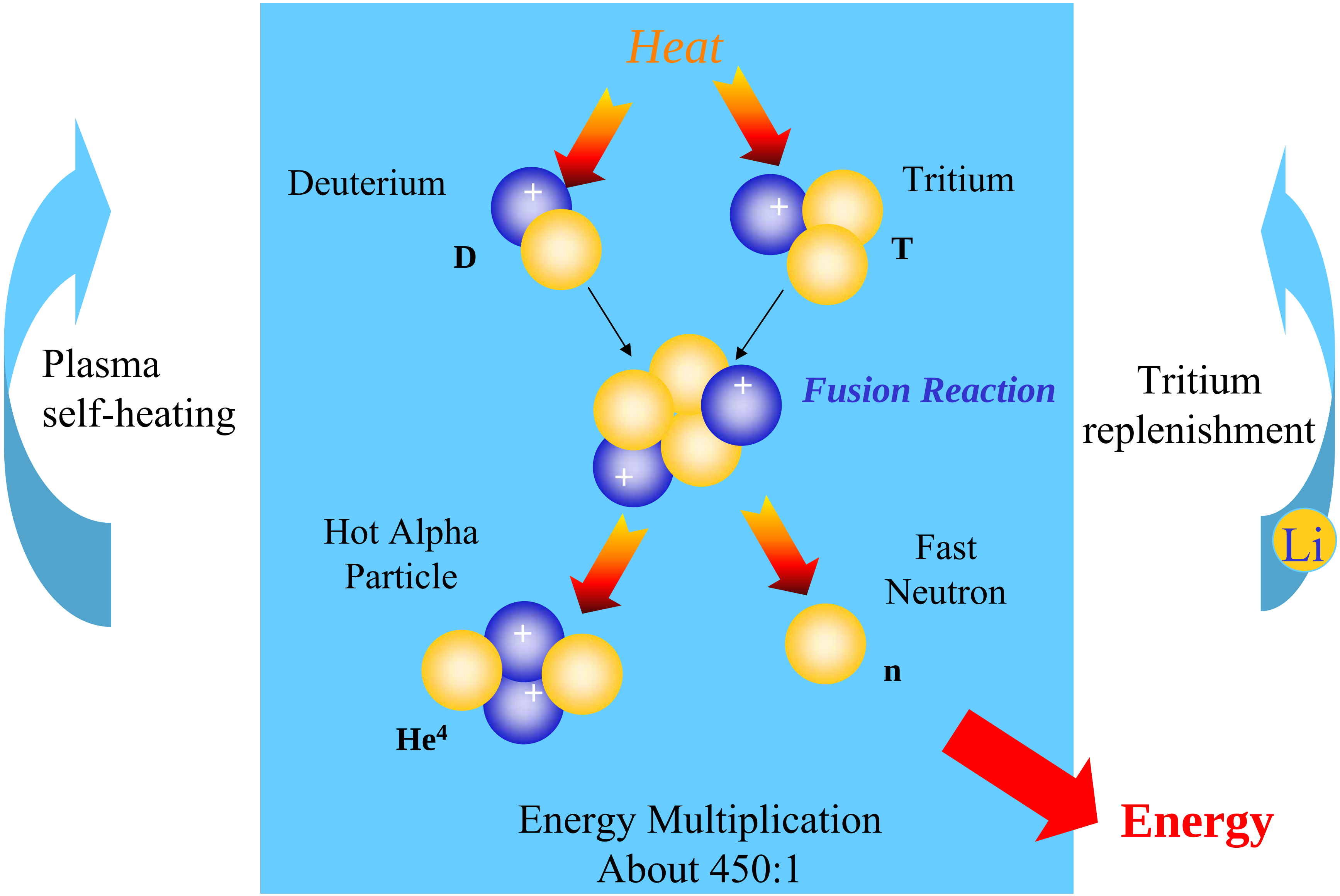
Dr. N. Anne Davies
Associate Director
for Fusion Energy Sciences

March 19, 2004

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."

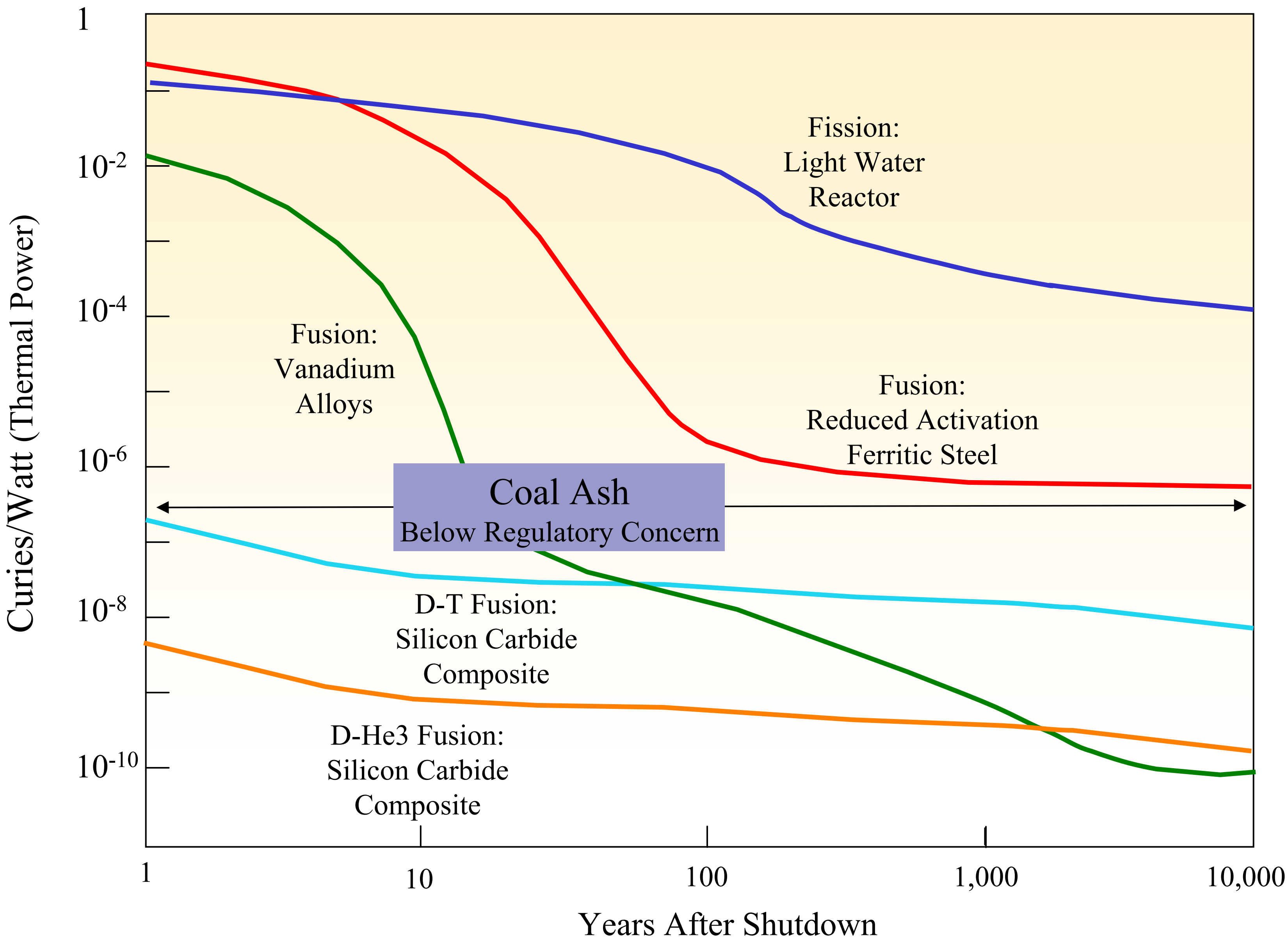
Deuterium-Tritium Fusion Reaction



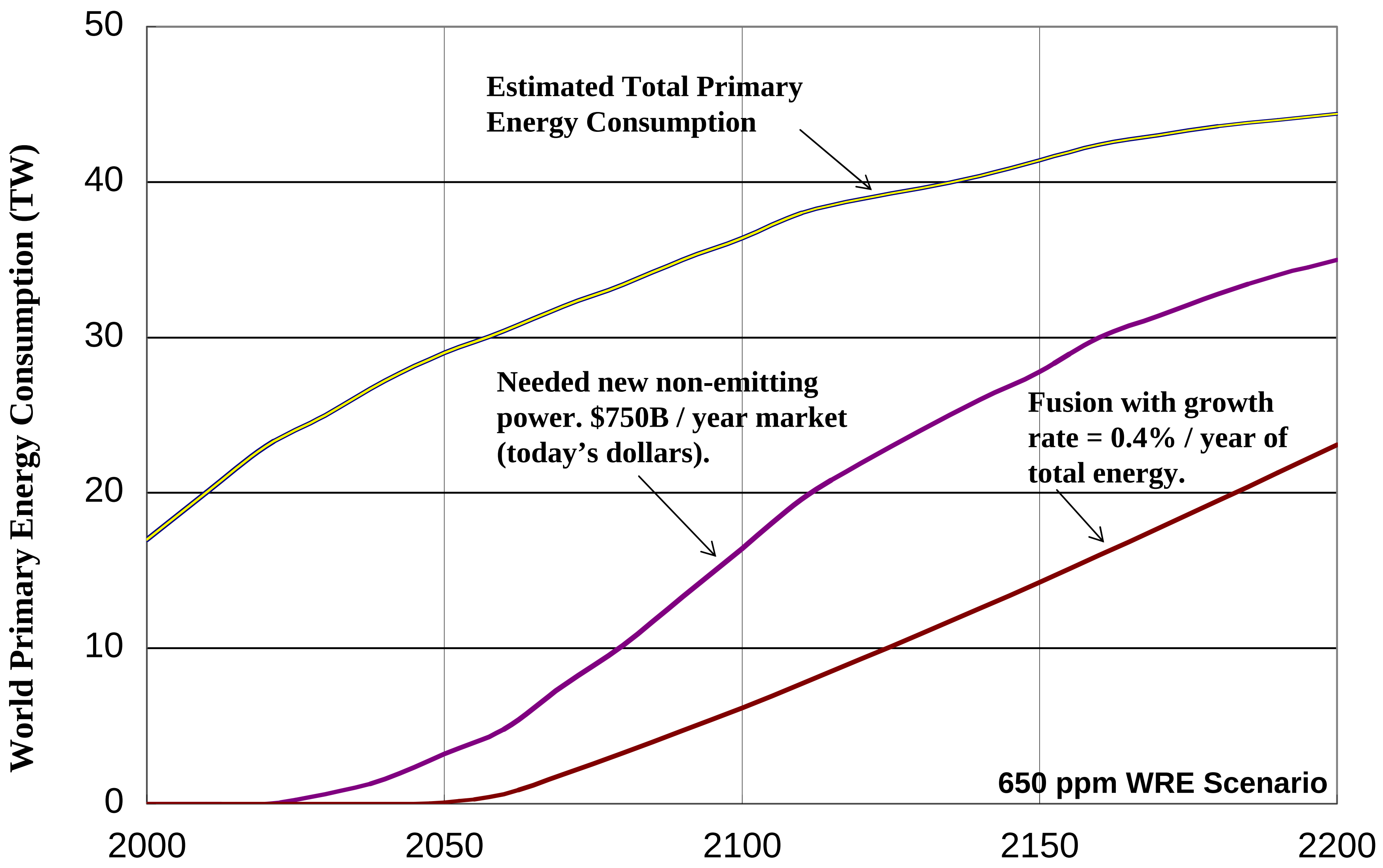
Fusion is an Attractive Domestic Energy Source

- Abundant fuel, available to all nations
  - Deuterium and lithium easily available for thousands of years
- Environmental Advantages
  - No carbon emissions, short-lived radioactivity
- Can’t blow up, resistant to terrorist attack
  - Less than 5 minutes of fuel in the chamber
- Low risk of nuclear materials proliferation
  - No fissile or fertile materials required
- Compact relative to solar, wind and biomass
  - Modest land usage
- Not subject to daily, seasonal or regional weather variation
  - No large-scale energy storage nor long-distance transmission
- Cost of power estimated similar to coal, fission
- Can produce electricity and hydrogen
  - Complements other nearer-term energy sources

Comparison of Fission and Fusion Radioactivity After Shutdown



Fusion Could Contribute on a Timely Basis



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

Fusion Energy Sciences Ten-Year Goals

1. Predictive Capability for Burning Plasma

   Develop a predictive capability for key aspects of burning plasmas using advances in theory and simulation benchmarked against a comprehensive experimental database of stability, transport, wave-particle interaction, and edge effects.

2. Configuration Optimization

   Demonstrate enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.

3. Inertial Fusion Energy and High Energy Density Physics

   Develop the fundamental understanding and predictability of high energy density plasmas.

FY 2003 FES Completed Targets

- Completed installation of internal coils for feedback control of plasma instabilities on DIII-D
- Conducted a first set of experiments demonstrating the effectiveness of these coils in controlling plasma instabilities and compare the results with theoretical predictions
- Produced high temperature plasmas with five megawatts of Ion Cyclotron Radio Frequency (ICRF) power for pulse lengths of 0.5 seconds in the Alcator C-Mod
- Assessed the stability and confinement properties of these plasmas, which would have collision rates in the same range as those expected for a burning plasma
- Completed testing of the High-Power Prototype advanced ion-cyclotron radio frequency antenna that will be used at the Joint European Torus (JET)
- Completed preliminary experimental modeling investigation of nano-scale thermodynamic, mechanical, and creep-rupture properties of nanocomposited ferritic steels

FY 2004 and FY 2005 Targets

- Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%

- Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%

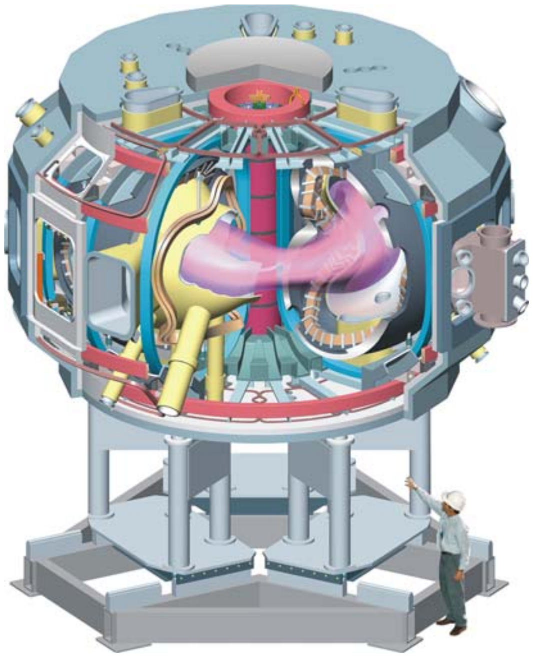
NCSX FY 2004 and FY 2005 Targets

FY 2004 Target Milestone:

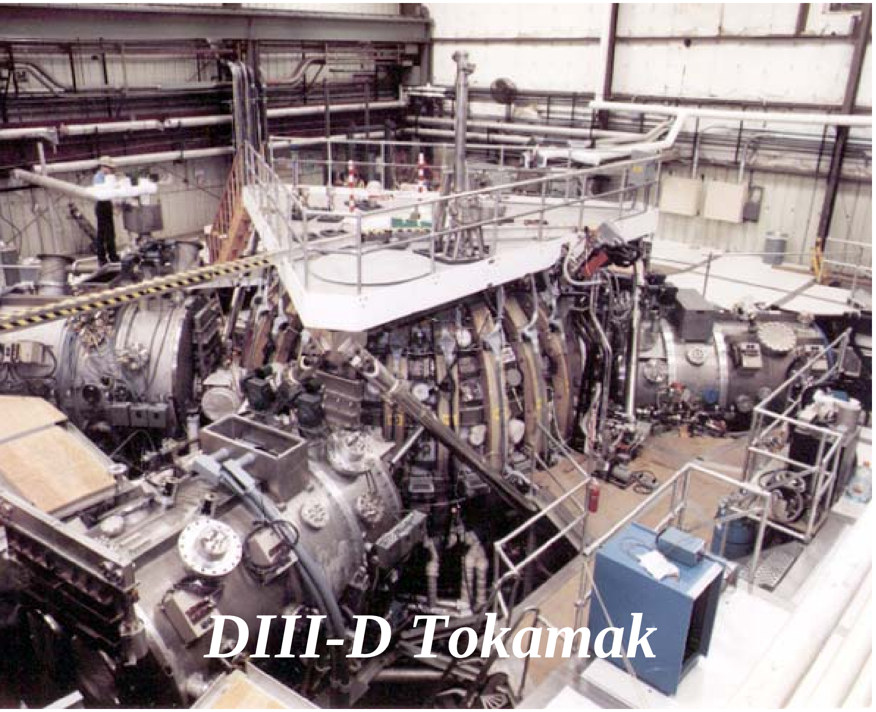
Established, in February 2004, the performance baseline (i.e. cost, schedule and technical scope) of the National Compact Stellarator Experiment (NCSX). The Total Estimated Cost for NCSX is $86.3M with completion in May 2008.

FY 2005 Target Milestone:

Begin NCSX fabrication (i.e. Critical Decision 3) and award, through a competitive process, production contracts for the NCSX Modular Coil Winding Forms and Vacuum Vessel.

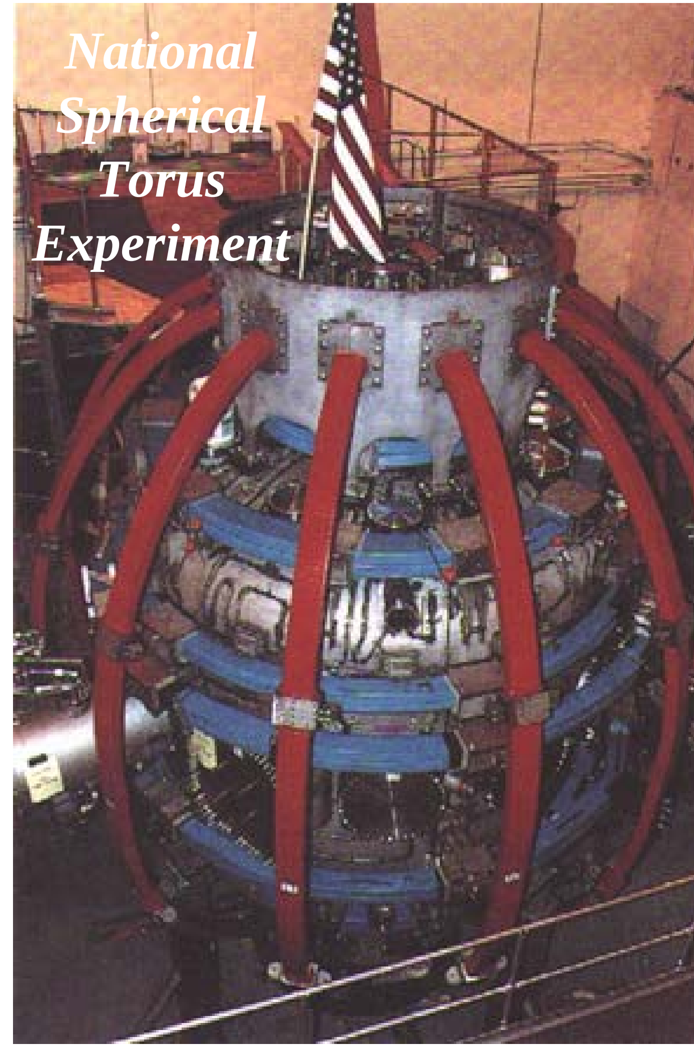


NCSX



General Atomics

Doublet III Started Operations In 1978



Princeton Plasma Physics Laboratory

Torus started Operations in 1999

Massachusetts Institute of Technology

C-MOD Started Operations in October 1991

ITER

Science Benefits:

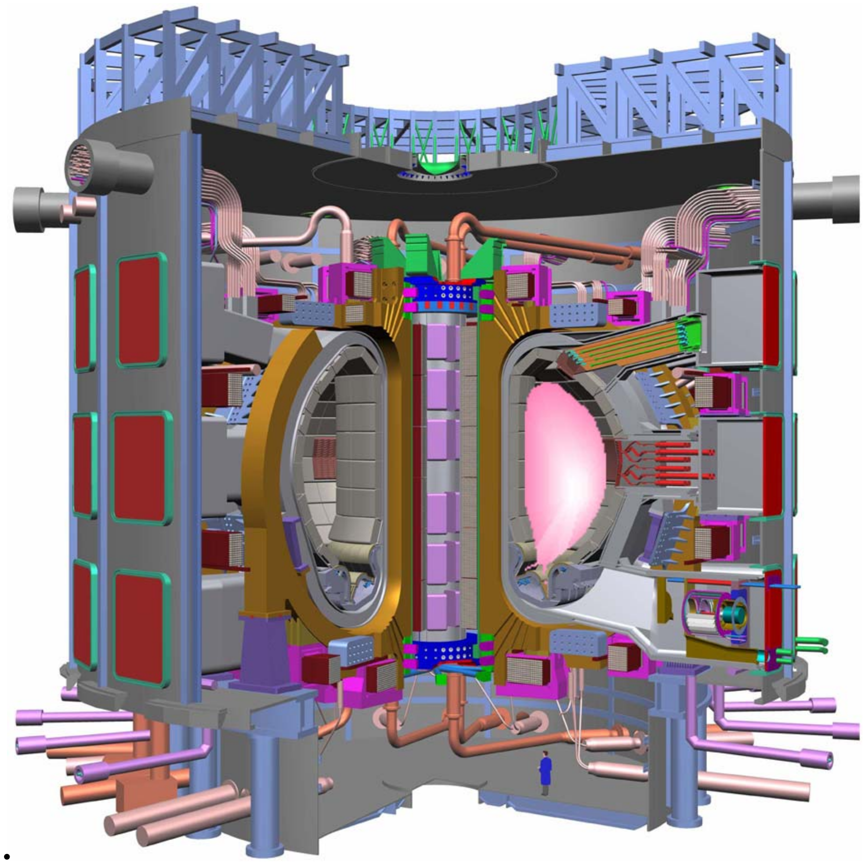
Extends fusion science to larger size, burning (self-heated) plasmas.

Technology Benefits:

Fusion-relevant technologies.
High duty-factor operation.

Goal:

To demonstrate the scientific and technological feasibility of fusion energy.



U.S. has had major impact on ITER design
500 – 700 MW thermal fusion power
400sec – 1 hr pulse length

Status on ITER – Remaining Issues

1. **Site Selection Pending**

Rokkasho, Japan

Cadarache, France, EU

Parallel Activities to Position the US to Act Following Site Selection

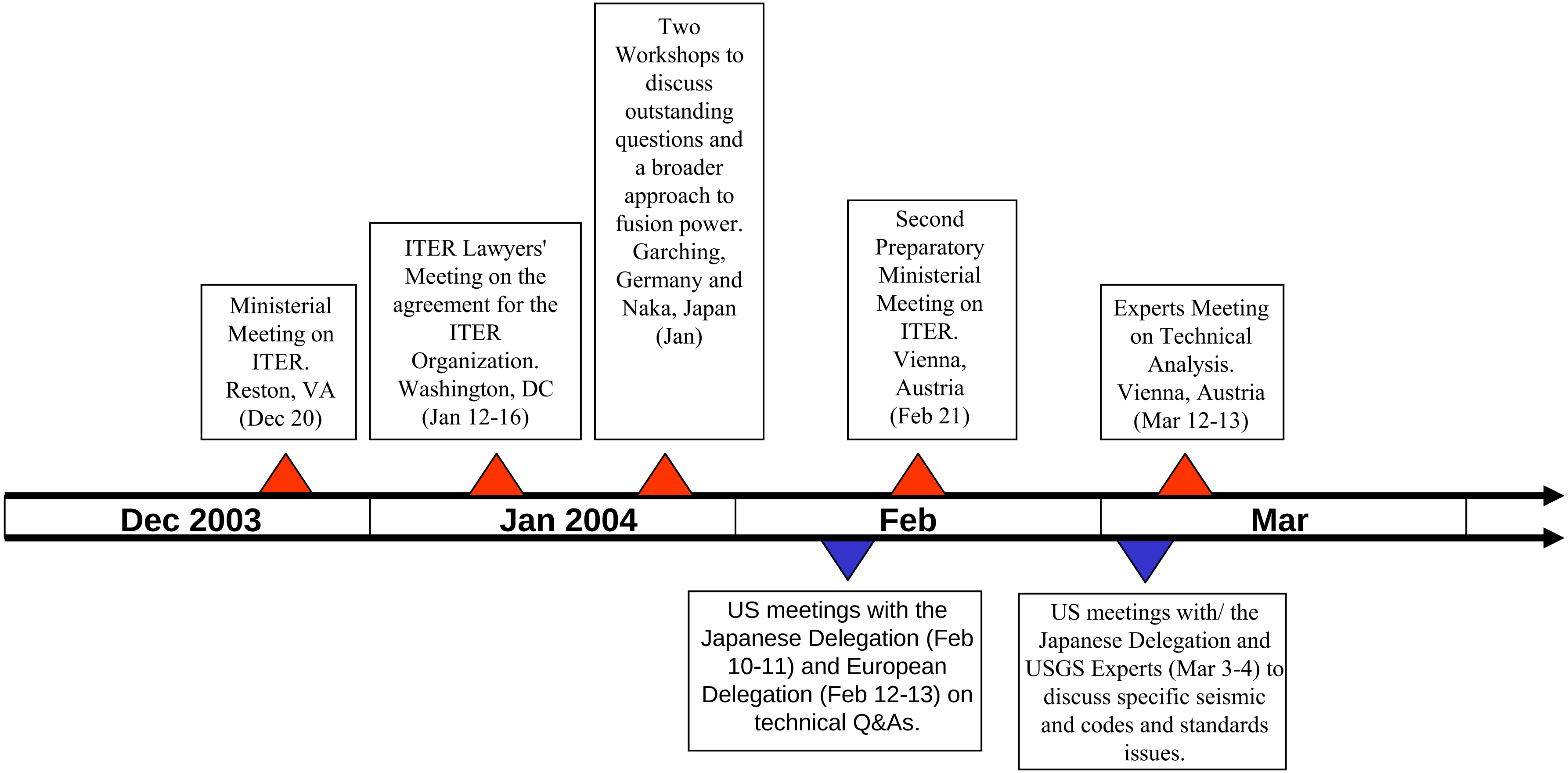
2. **Agreement Text Pending – legalities and interpretations**
3. **Key Personnel – Secondees, US ITER Project Office, ITER Organization**
4. **OFES Program and Community Positioning for ITER**
5. **Licensing – responsibility of host site**
6. **Funding – executing FY 04, defending FY05, and planning FY06**
7. **Construction Start – 2006?**

Remaining Issue #1

Status on ITER – Site Selection

Timeline of Major Activities Related to ITER Host Sites Negotiations

(Rokkasho, Japan and Cadarache, France, EU)



Denotes meetings where all six ITER parties were present.

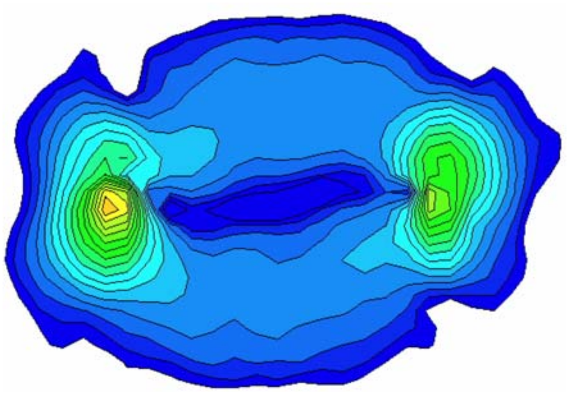
Denotes meetings where the US met with another ITER party.

Scientific Discovery Thru Advanced Computing

Three Principal Projects

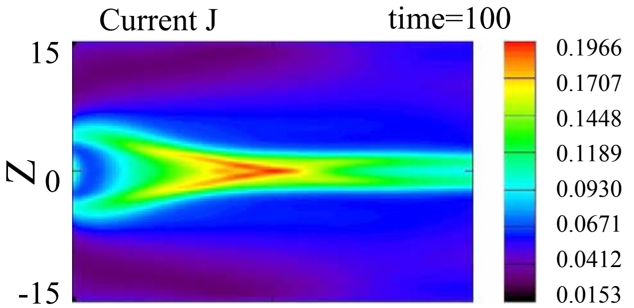
Terascale Atomic Physics

Auburn, Rollins, ORNL



Magnetic Reconnection Code

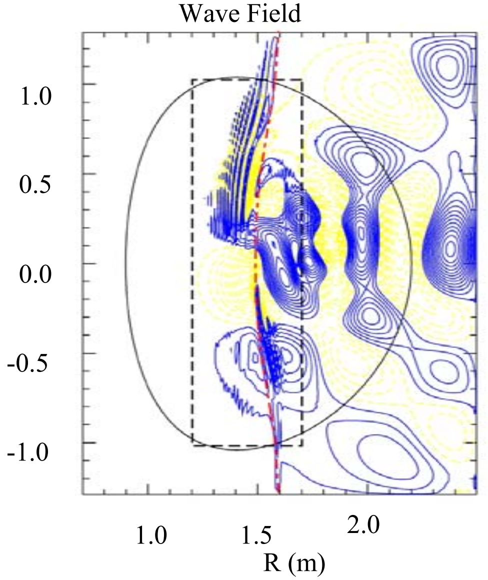
U. Iowa, U. Chicago, U. Texas



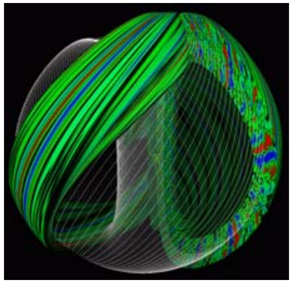
Substorm in the Magnetotail

Computation of Wave Plasma Interactions

ORNL, PPPL, MIT, Lodestar, CompX

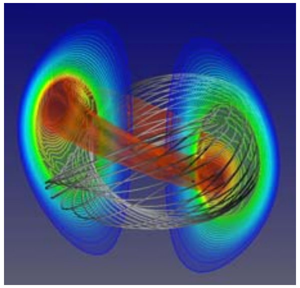


Two Pilot Projects



Plasma Microturbulence

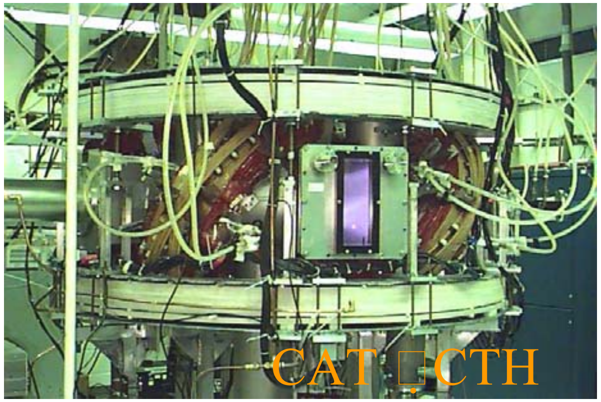
LLNL, GA, PPPL, U. Maryland, U. Texas, U. Colorado, UCLA



Extended MHD Modeling

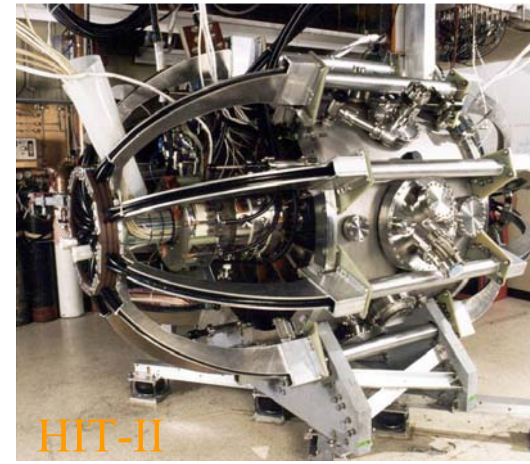
PPPL, SAIC, U. Wisconsin, NYU, U. Colorado, MIT, Utah State U., GA, LANL, U. Texas

Innovative Confinement Concepts

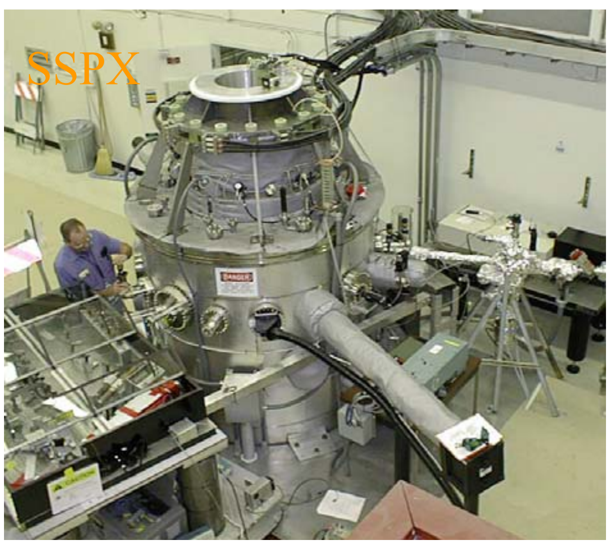


Compact Auburn Torsatron becoming
Compact Toroidal Hybrid
Auburn University, Auburn Alabama

Levitated Dipole Experiment
Columbia University/Massachusetts Institute of Technology

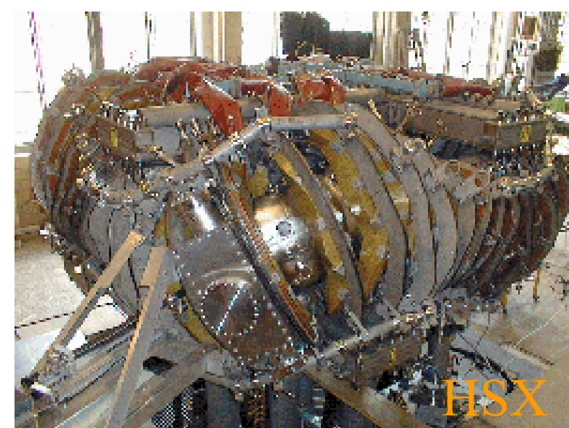


Helicity Injected Torus-II Experiment
University of Washington, Seattle



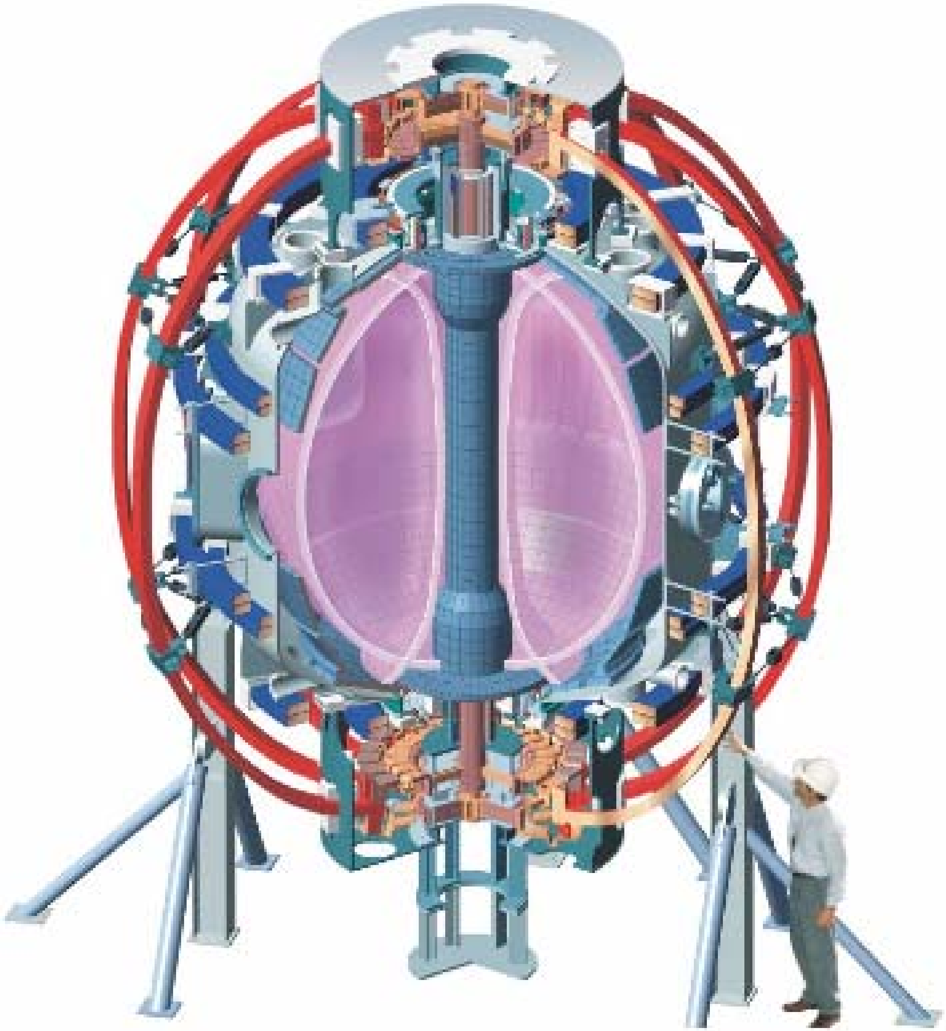
Sustained Spheromak Plasma Experiment
Lawrence Livermore National Laboratory

Electric Tokamak
University of California, Los Angeles



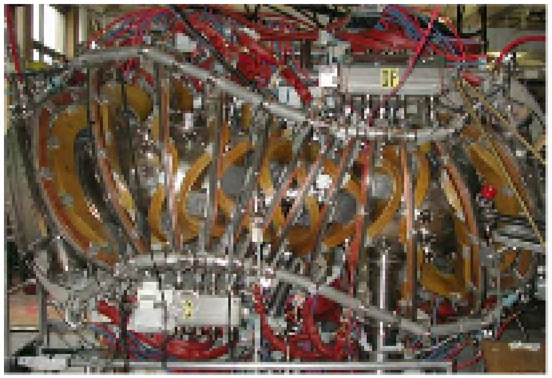
Helically Symmetric Experiment
University of Wisconsin, Madison

NSTX Facility Capability Steadily Improved

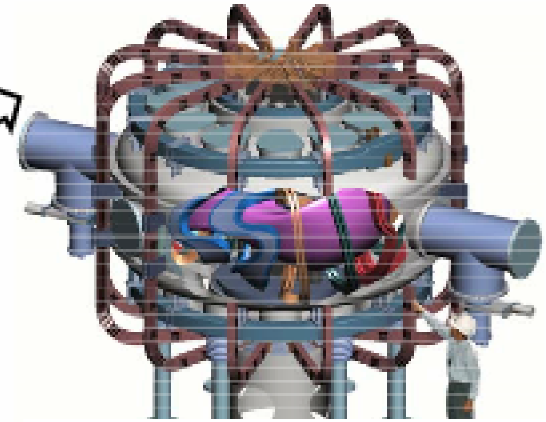


Capabilities	
PFC bakeout	***350°C***
Gas fueling	***HFS/LFS***
Aspect ratio	1.27
Elongation	2.5
Triangularity	***0.8***
Plasma Current	1.5MA
Toroidal Field	***0.6T***
NBI ***(100kV)***	***7 MW***
HHFW (30MHz)	6 MW
- full antenna phase control	
Pulse Length	***1s***
Reduced PF error field	

US Compact Stellarator *Program*



HSX, University of Wisconsin

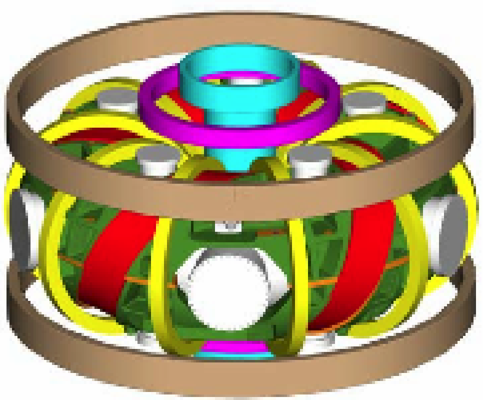


QPS, Oak Ridge National Lab

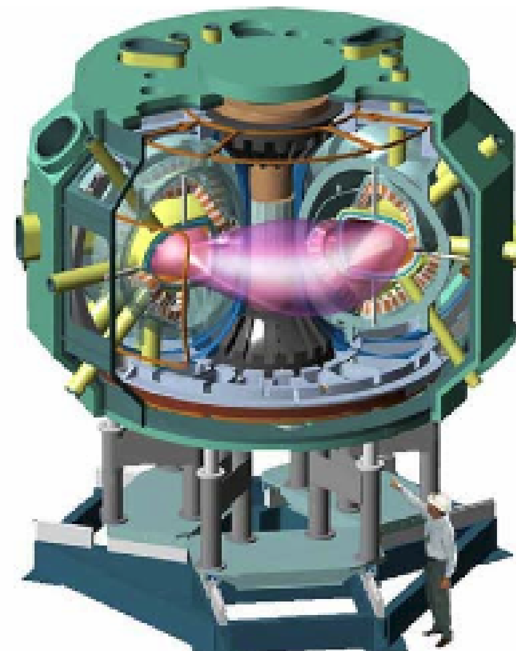
Theory and Modeling

3-D Plasma Science
Improved Understanding of Toroidal Confinement
Benefits of 3-D Shaping

Improvements in Toroidal Fusion Reactor Systems



CTH, Auburn University

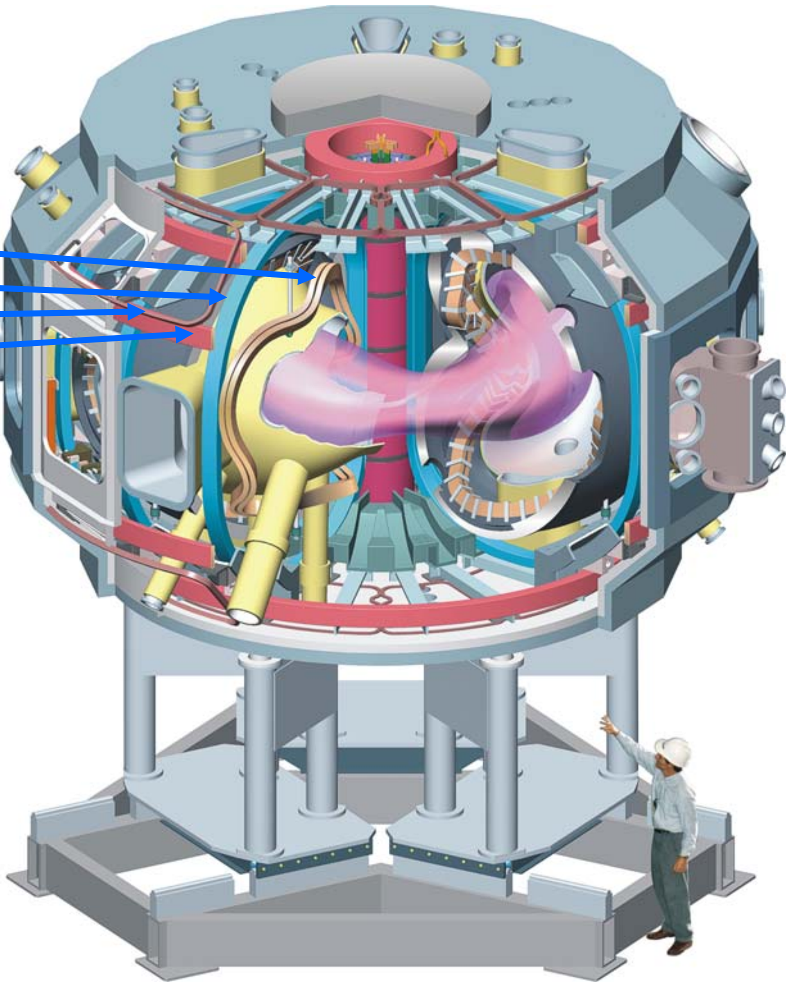


NCSX, Princeton Plasma Physics Lab

NCSX Magnetic Configuration has Unique Properties and Flexibility

- **NCSX designed to flexibly access a wide range of magnetic configurations**
  - Unique feature of NCSX design
  - 3 modular coil types
    + TF coils
    + trim coils
    + 6 poloidal field coils
  - Will allow systematic study of 3D confinement and stability physics

- **NCSX configuration designed for improved confinement and stability**
  - Quasi-axisymmetry
  - 3D shaping of magnetic field distribution to increase pressure limit
  - Need to measure characteristics of range of configurations as first stage of research investigations.



NCSX

NCSX Project

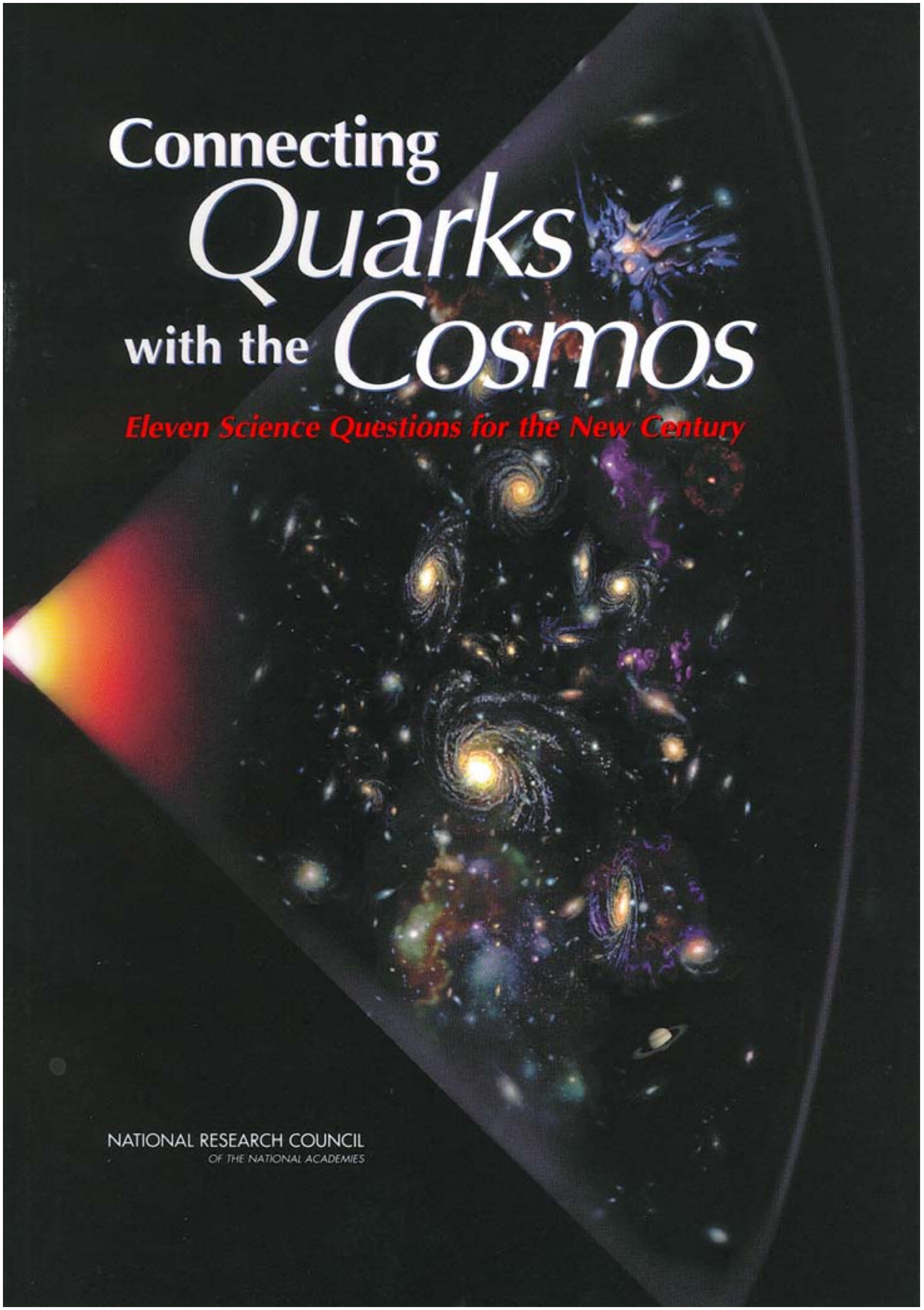
- Evolution of design and response to design reviews raised project cost to $83M

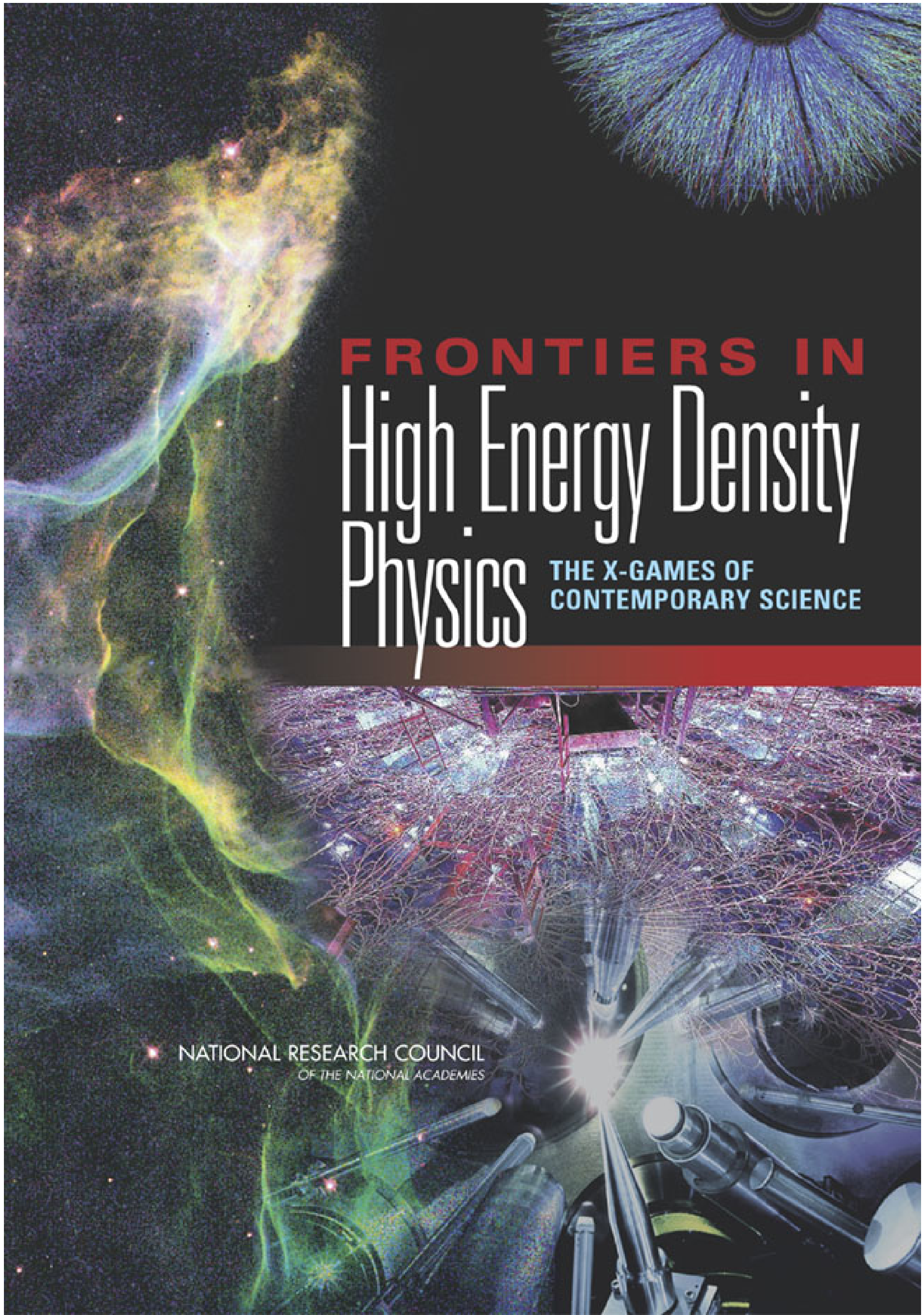
- New definition of project completion and new funding profile result in cost and schedule impact

Total project cost $86.3M, for project completion in FY 2008

($ in 000s)	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
New Profile	7,897	15,921	15,921	22,100	19,400	5,100
Previous Profile	7,897	15,921	20,397	17,800	11,485	

($69M – 83M; completion FY 2007)


Connecting
Quarks
with the Cosmos
Eleven Science Questions for the New Century
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES


FRONTIERS IN
High Energy Density
Physics
THE X-GAMES OF
CONTEMPORARY SCIENCE
NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Evolution of IFE Program

Current Program

SC: Heavy Ion Accelerator Physics

Target Physics (modeling)

Fast Ignition

Chamber, Target Fabrication, System Studies

DP: High Average Power Laser Program

Z for IFE

Evolution of IFE Program (continued)

Future Program

SC: Focus on science issues

Close out technology research

Develop High Energy Density Physics roadmap with DP, NSF

DP: ?

The Office of Science FY05 Budget Request

(dollars in thousands)

	FY 2003 Comparable Approp.	FY 2004 Comparable Approp.	FY 2005 President's Request	FY 2005 Request vs. FY 2004 Appropriation	
Science					
Basic Energy Sciences…………	1,001,941	1,010,591	1,063,530	+52,939	+5.2%
Advanced Scientific Computing Research…………	163,185	202,292	204,340	+2,048	+1.0%
Biological & Environmental Research…………	494,360	641,454	501,590	-139,864	-21.8%
Congressionally-directed projects…………	*(51,927)*	*(140,762)*	*(——)*	*(-140,762)*	*(-100.0%)*
Core Biological and Environmental Research…………	*(442,433)*	*(500,692)*	*(501,590)*	*(+898)*	*(+0.2%)*
High Energy Physics…………	702,038	733,631	737,380	+3,749	+0.5%
Nuclear Physics…………	370,655	389,623	401,040	+11,417	+2.9%
Fusion Energy Sciences…………	240,695	262,555	264,110	+1,555	+0.6%
Science Laboratories Infrastructure…………	45,109	54,280	29,090	-25,190	-46.4%
Science Program Direction…………	137,425	152,581	155,268	+2,687	+1.8%
Workforce Development for Scientists & Teachers…………	5,392	6,432	7,660	+1,228	+19.1%
Small Business Innovation Research/Technology Transfer……	100,172	——	——	——	——
Safeguards and Security…………	61,272	56,730	67,710	+10,980	+19.4%
Subtotal, Science…………	3,322,244	3,510,169	3,431,718	-78,451	-2.2%
Use of prior year balances…………	——	-10,000	——	+10,000	+100.0%
Total, Science…………	**3,322,244**	**3,500,169**	**3,431,718**[a]	**-68,451**	**-2.0%**
Total, excluding Congressionally-directed projects…………	*(3,270,317)*	*(3,359,407)*	*(3,431,718)*	*(+72,311)*	*(+2.2%)*

[a] *Note, when compared to the FY 2004 request (comparable), the FY 2005 request increases $104,885,000 (3.2%).*

FY 2005 Fusion Energy Sciences
President's Budget Request

	FY 2003 Actual	FY 2004 Approp.	FY 2005 Cong.
Science	136.2	143.9	144.0
Facility Operations	66.2	84.5	85.5
Technology	38.3	27.4	27.8
SBIR/STTR	6.2	6.8	6.8
OFES Total	*246.9*	*262.6*	*264.1*
DIII-D	51.9	56.0	54.0
C-Mod	19.2	22.2	21.5
NSTX	30.1	34.7	33.6
NCSX	11.7	16.7	16.7
IFE/HEDP	17.0	15.1	13.9

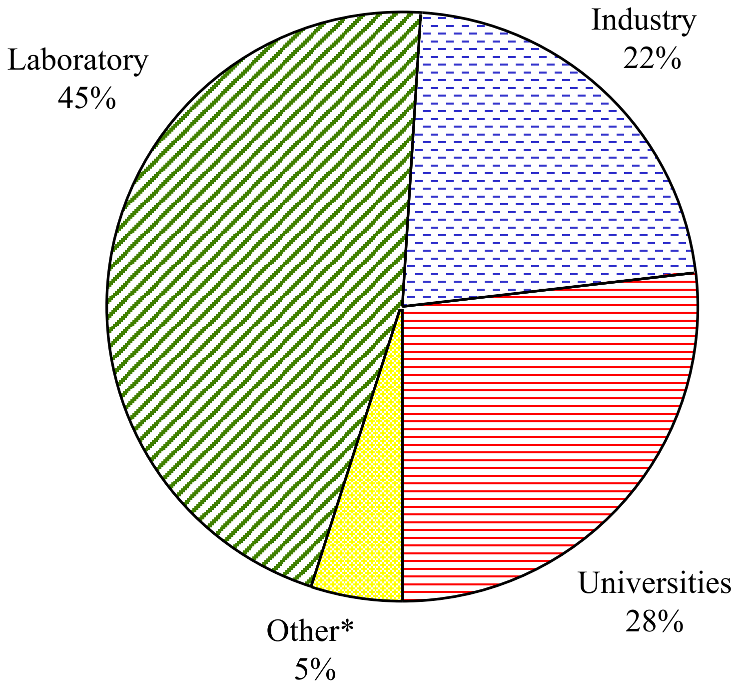
Fusion Program Resources in Preparation for ITER

Elements	FY 2004 Approp.	FY 2005 Cong.
Fusion Plasma Theory and Computation (SciDAC)	$1,000,000	$3,000,000
DIII-D Experimental Program	3,000,000	10,000,000
Alcator C-Mod Experimental Program	1,000,000	5,000,000
ITER Preparations	3,000,000	7,000,000
Plasma Technology	0	13,000,000
Total	*$8,000,000*	*$38,000,000*

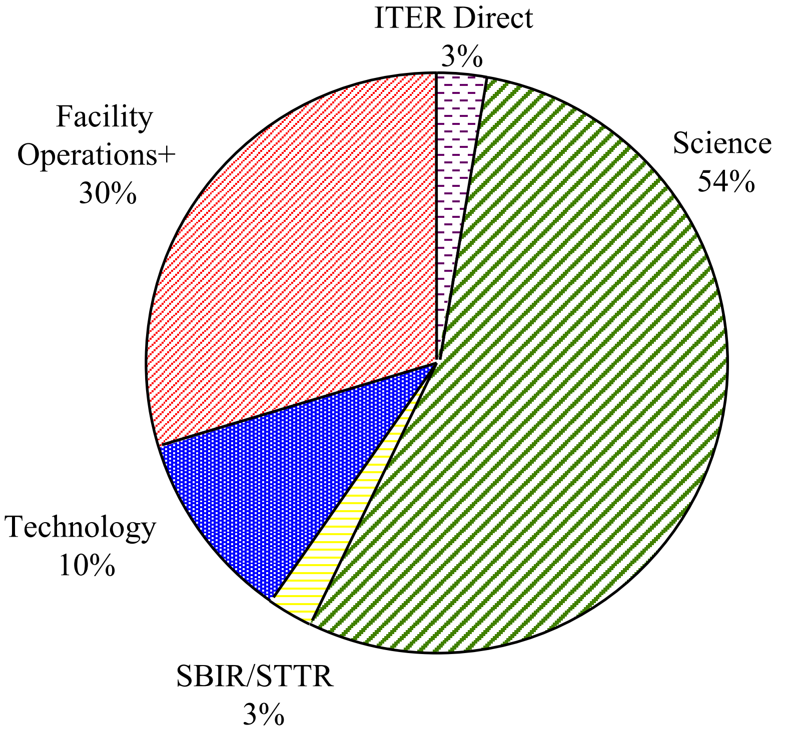
Fusion Energy Sciences Funding Distribution

FY 2005 Congressional
$264.1M

Institution Types



Functions



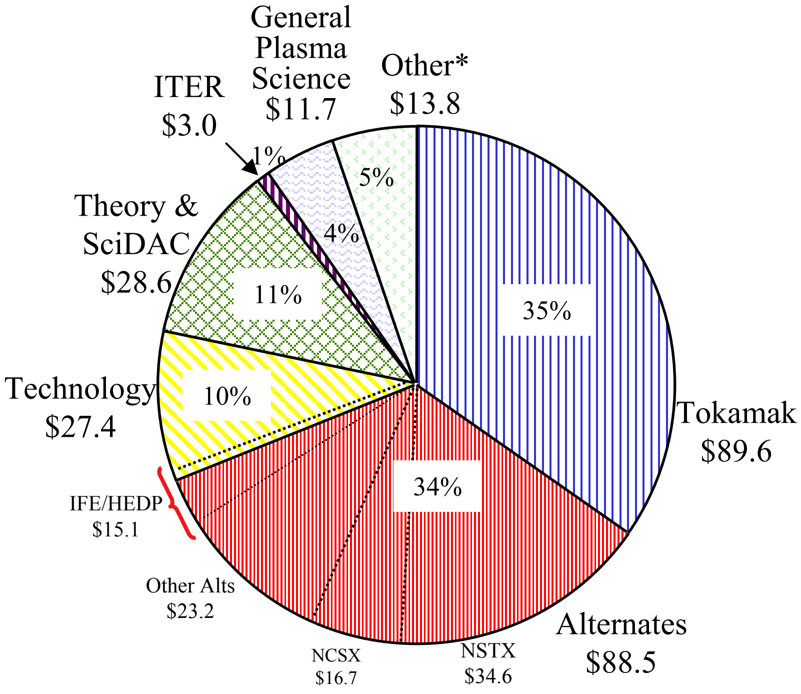
*NSF/NIST/NAS/AF/Undesignated funds

+Includes NCSX Project

Fusion Energy Sciences Budget

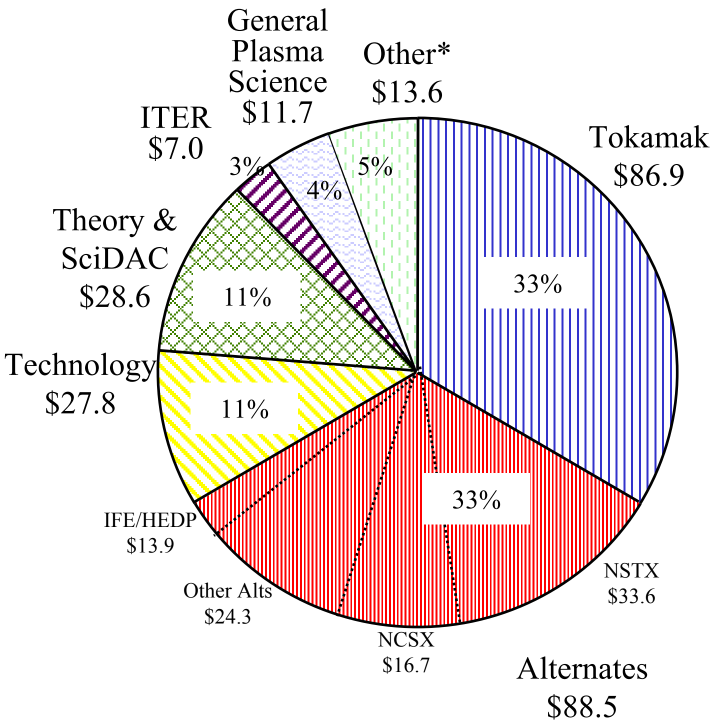
($ in Millions)

FY 2004
Approp.



$262.6 M

FY 2005
Cong.



$264.1 M

*SBIR/STTR
GPP/GPE
ORNL Move
Reserve
Environmental Monitoring

Fusion Energy – The Moral Imperative

- Current world energy usage is not environmentally sustainable
- The potential role of fusion in alleviating poverty is a powerful social good which needs to be explored
- Our legacy for future generations is **clean**, **safe** energy
- All scenarios indicate that energy sustainability is attainable only by a **mix** of policies, plans, technologies, and funding
- Fusion energy is not the **only** solution but should be **part** of a solution