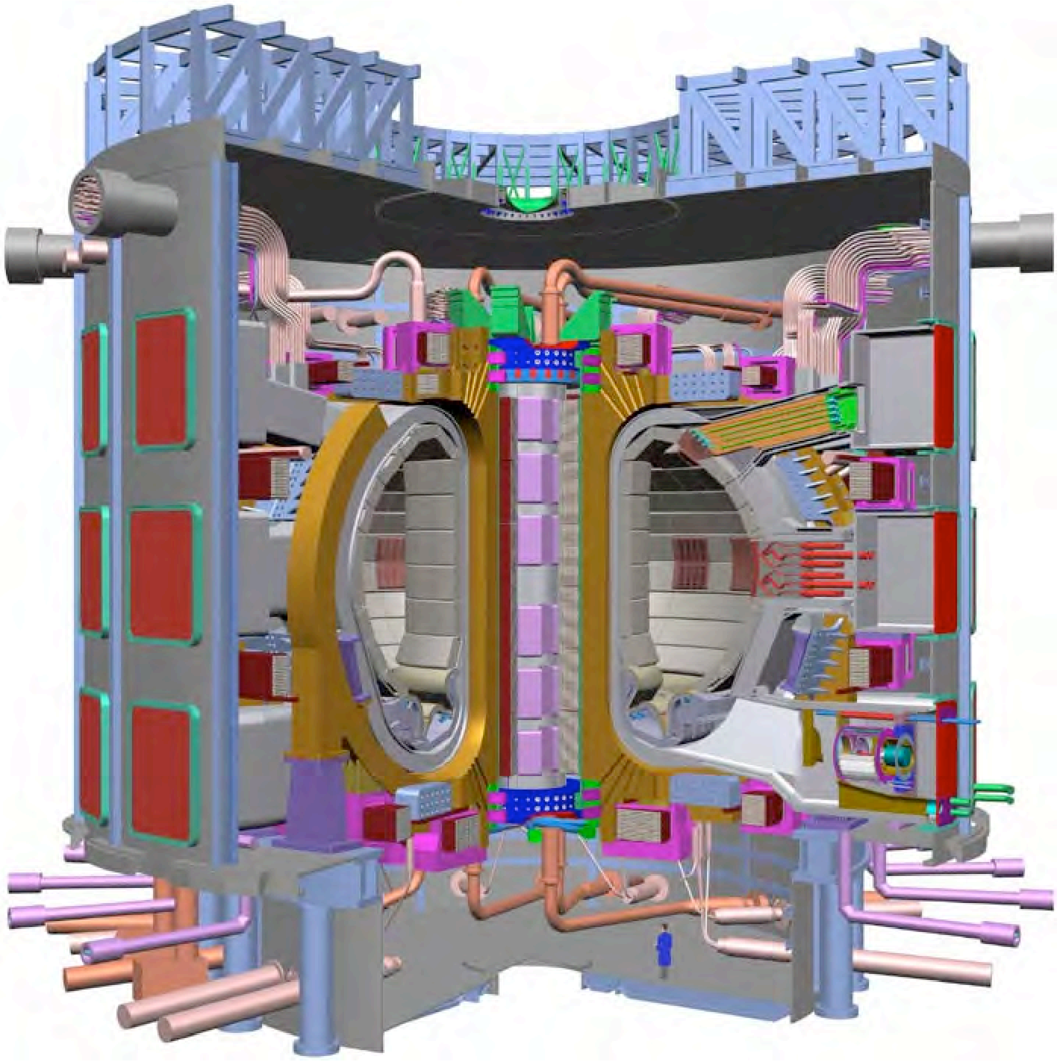
Bold Step by the World to Fusion Energy: ITER



Gerald A. Navratil

Columbia University

2006 Con Edison Lecture

Fu Foundation School of Engineering and Applied Science

21 March 2006

The 1985 Con Edison Lecture

NUCLEAR WASTE DISPOSAL IN PREHISTORIC TIMES

Dr. Goldstein's lecture will focus on the effectiveness of geologic isolation for disposal of nuclear wastes, and will explore the case study of a two-billion-year-old natural fission reactor in Africa.

Open to the public

Reception immediately following the lecture

will be delivered by

HERBERT GOLDSTEIN

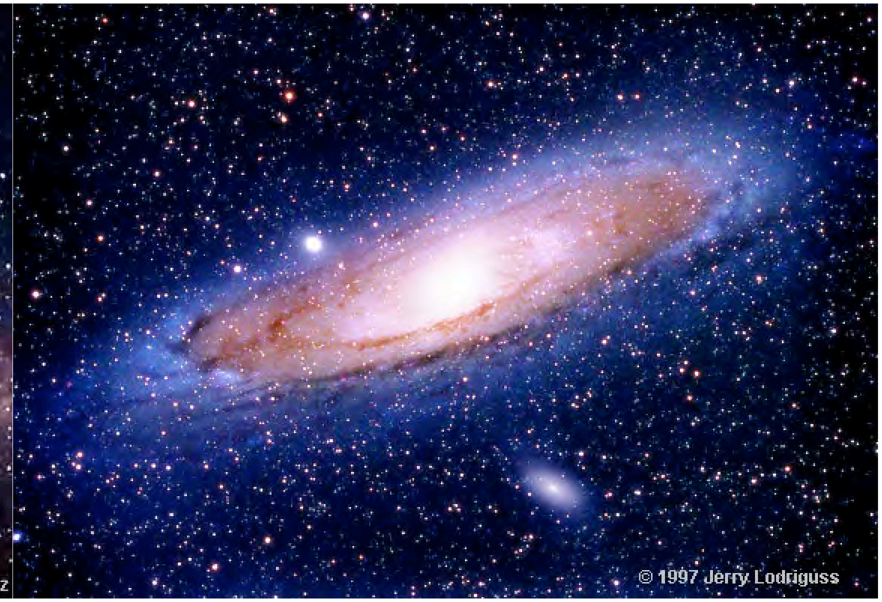
Thomas Alva Edison Professor
of Nuclear Science and Engineering
Columbia University

◆

Monday, March 4
7:30 p.m.
The Kellogg Conference Center
International Affairs Building,
Fifteenth Floor

Natural Fusion Reactors Are Abundant

Milky Way Galaxy Core View



Andromeda Galaxy

Every Morning We Get a Close-Up View of Natural Fusion

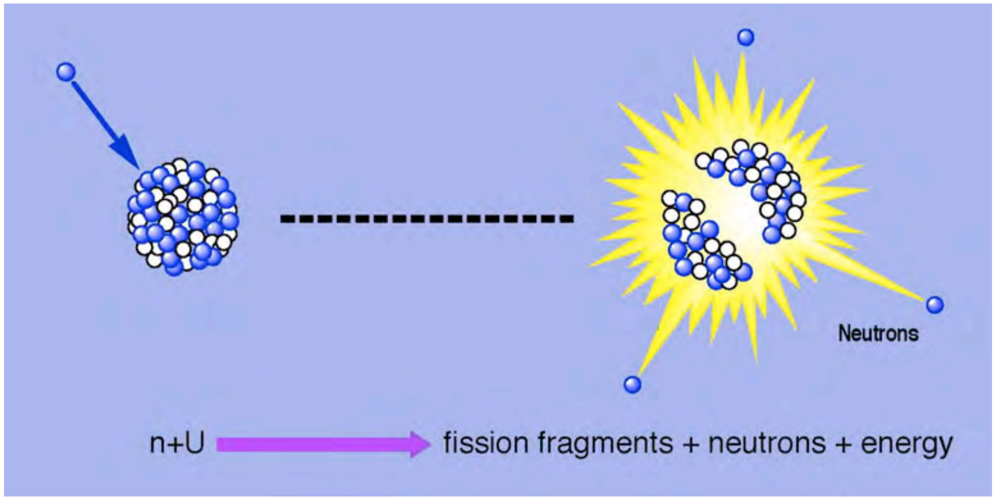
If Fusion Is So Common In Nature Why Can't We Do This?

Back to the Future II - 1989

If Fusion Is So Common In Nature Why Can't We Do This?

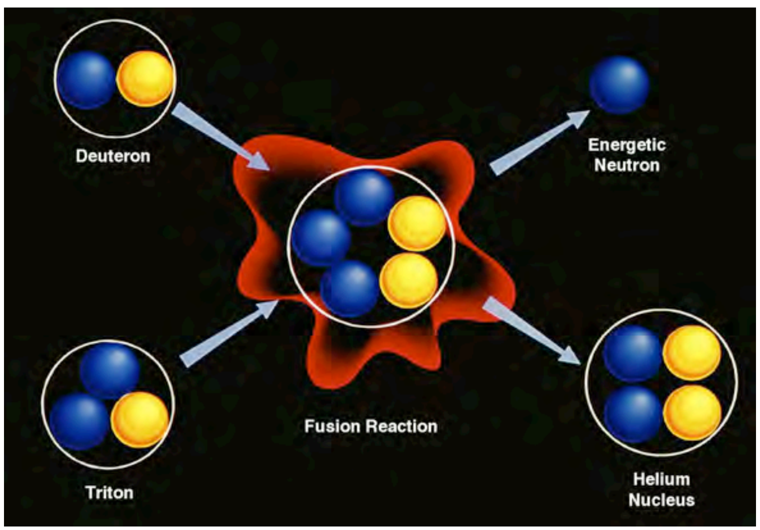
Fission is "EASY" and Fusion is "HARD"

FISSION



Fission initiated by electrically neutral particle [neutron] and can occur at room temperature in a solid: "pile" the right stuff up and a chain reaction will occur!

FUSION



Fusion initiated by collision electrically charged particles at very high energy: Threshold temperature for most reactive fusion reaction is about 200 million ˚F!

Madison Avenue Senses We Must Be Close

Jump Ahead to Conclusion

- Dramatic progress in 1990's has established a sound basis for exploration of the 'Burning' Fusion Plasma regime.
- US working with International Community is now ready to build the worlds first magnetically confined burning fusion plasma experiment: ITER
- ITER Success would represent for Fusion Energy the same milestone as the first nuclear chain reaction by Fermi under the University of Chicago Stadium in 1942 was for Fission Energy.

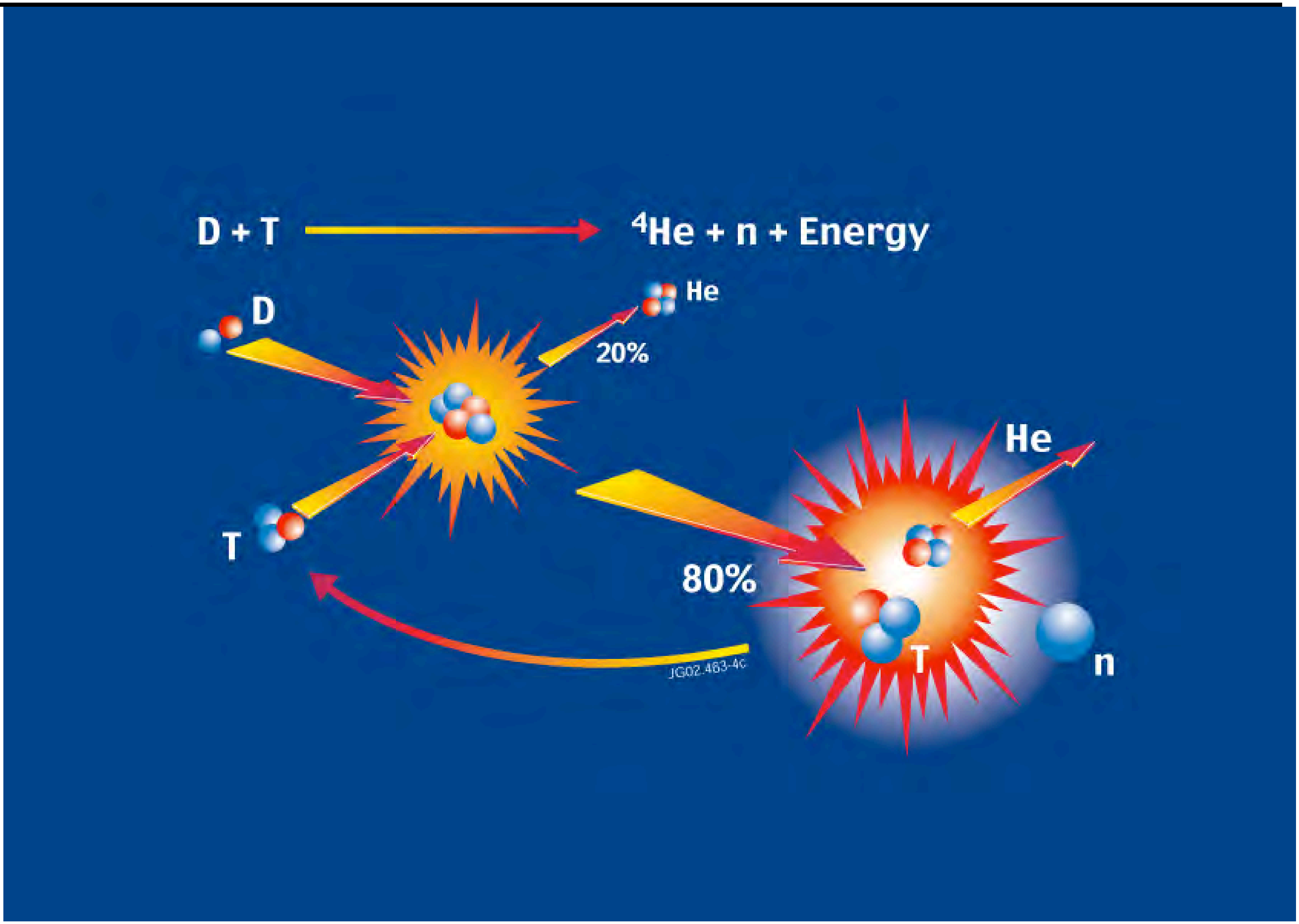
OUTLINE

- FUSION 101
- INTERNATIONAL FUSION PROGRAM LEADING TO START OF THE ITER DESIGN PROJECT (~1988)
- ADVANCES IN PLASMA SCIENCE UNDERLYING THE DESIGN OF ITER
- ITER PROJECT & ROLE OF THE UNITED STATES
- PATH FROM ITER TO PRACTICAL FUSION POWER

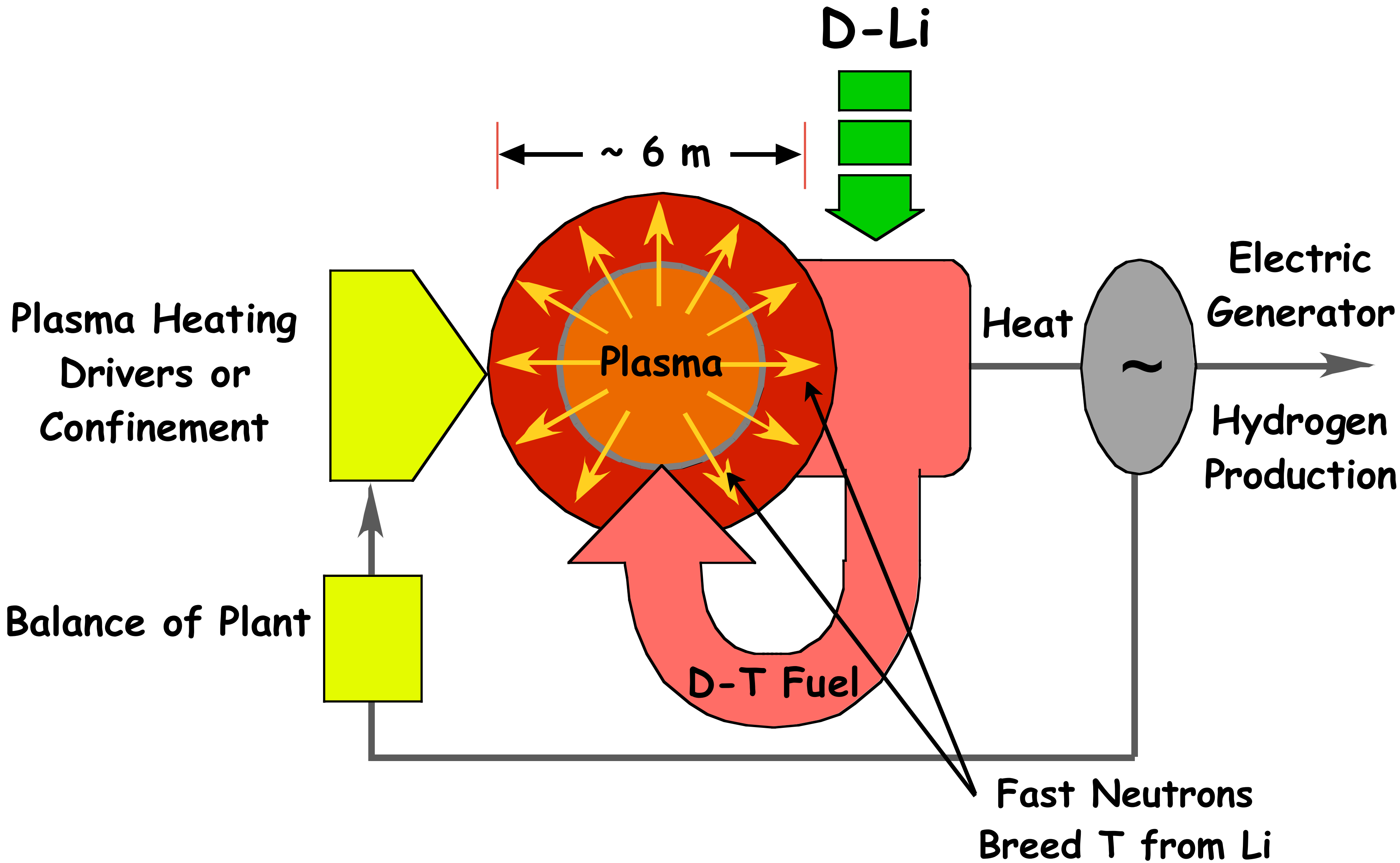
Fusion 101:

What do we need to make fusion energy?

Closure of DT Fusion Cycle Requires Lithium



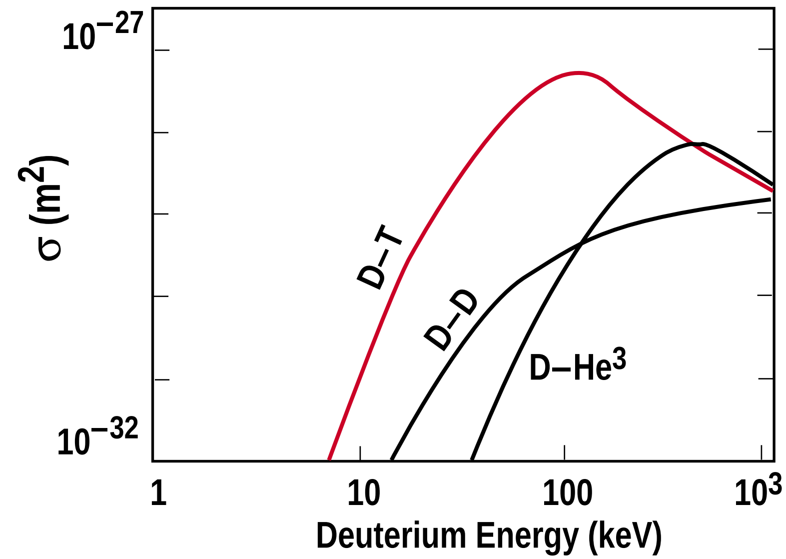
Elements of a D-T Fusion Energy System



DT FUSION

$${}_1D^2 + {}_1T^3 \rightarrow \underbrace{{}_2He^4}_{(3.5\ \mathrm{MeV})} + \underbrace{{}_0n^1}_{(14.1\ \mathrm{MeV})}$$

Energy/Fusion: $\varepsilon_f = 17.6$ MeV

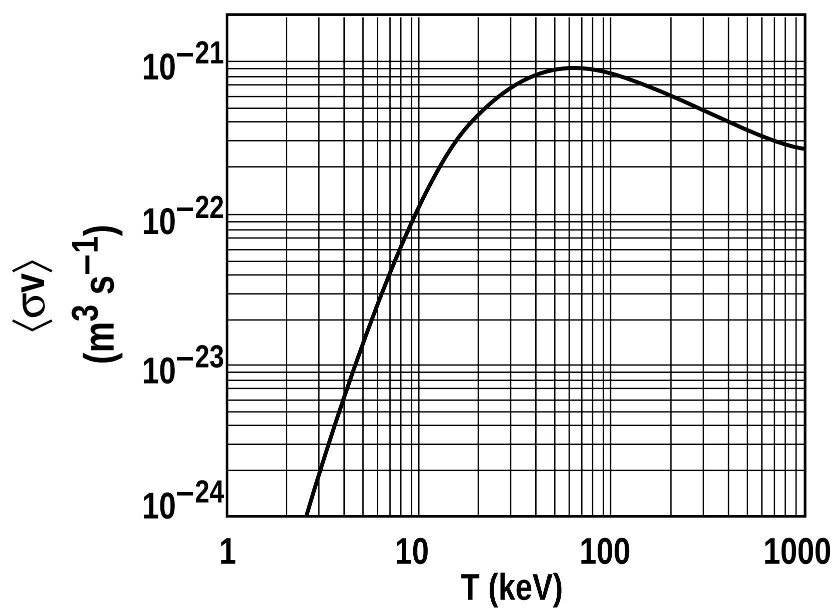


Fusion Reaction Rate, R
for a Maxwellian

$$R = \iint \sigma(v')\, v' f_D(\vec{v}_D)\, f_T(\vec{v}_T)\, d^3\vec{v}_D\, d^3\vec{v}_T$$

where $\vec{v}' \equiv \vec{v}_D - \vec{v}_T$

$$R = n_D n_T \langle \sigma v \rangle$$



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FUSION " SELF-HEATING" POWER BALANCE

FUSION POWER DENSITY: $p_f = \mathcal{R}\varepsilon_f = \frac{1}{4} n^2 \langle\sigma v\rangle \varepsilon_f$ for $n_D = n_T = \frac{1}{2} n$

TOTAL THERMAL ENERGY IN FUSION FUEL, $W = \int \left\{ \frac{3}{2} nT_i + \frac{3}{2} nT_e \right\} d^3x = 3nTV$

DEFINE " ENERGY CONFINEMENT TIME" , $\tau_E \equiv \frac{W}{P_{loss}}$

ENERGY BALANCE

$$\frac{dW}{dT} = \Big\{ \underbrace{\frac{1}{4} n^2 \langle\sigma v\rangle \varepsilon_\alpha V}_{\alpha\text{-heating power}} + \underbrace{P_{heat}}_{\text{Additional heating input}} \Big\} - \underbrace{\frac{W}{\tau_E}}_{\text{loss rate}}$$

274-01/rs

STEADY-STATE FUSION POWER BALANCE

$$\frac{dW}{dt} \rightarrow 0 \implies P_\alpha + P_{heat} = \frac{W}{\tau_E}$$

Define fusion energy gain, $Q \equiv \dfrac{P_{fusion}}{P_{heat}} = \dfrac{5\,P_\alpha}{P_{heat}}$

Define α-heating fraction, $f_\alpha \equiv \dfrac{P_\alpha}{P_\alpha + P_{heat}} = \dfrac{Q}{Q+5}$

Scientific Breakeven	$Q = 1$	$f_\alpha = 17\%$
Burning Plasma Regime	$Q = 5$	$f_\alpha = 50\%$
	$Q = 10$	$f_\alpha = 60\%$
	$Q = 20$	$f_\alpha = 80\%$
	$Q = \infty$	$f_\alpha = 100\%$

274-01/rs

PARAMETERIZATION OF Q VERSUS $nT\tau_E$ OR $p\tau_E$

Recast power balance: $P_\alpha + P_{heat} = \frac{W}{\tau_E}$

$$nT\tau_E = p\tau_E = \frac{12T^2}{\langle\sigma v\rangle\, \varepsilon_\alpha \left(1 + \frac{5}{Q}\right)}$$

Useful since in 10–20 keV range

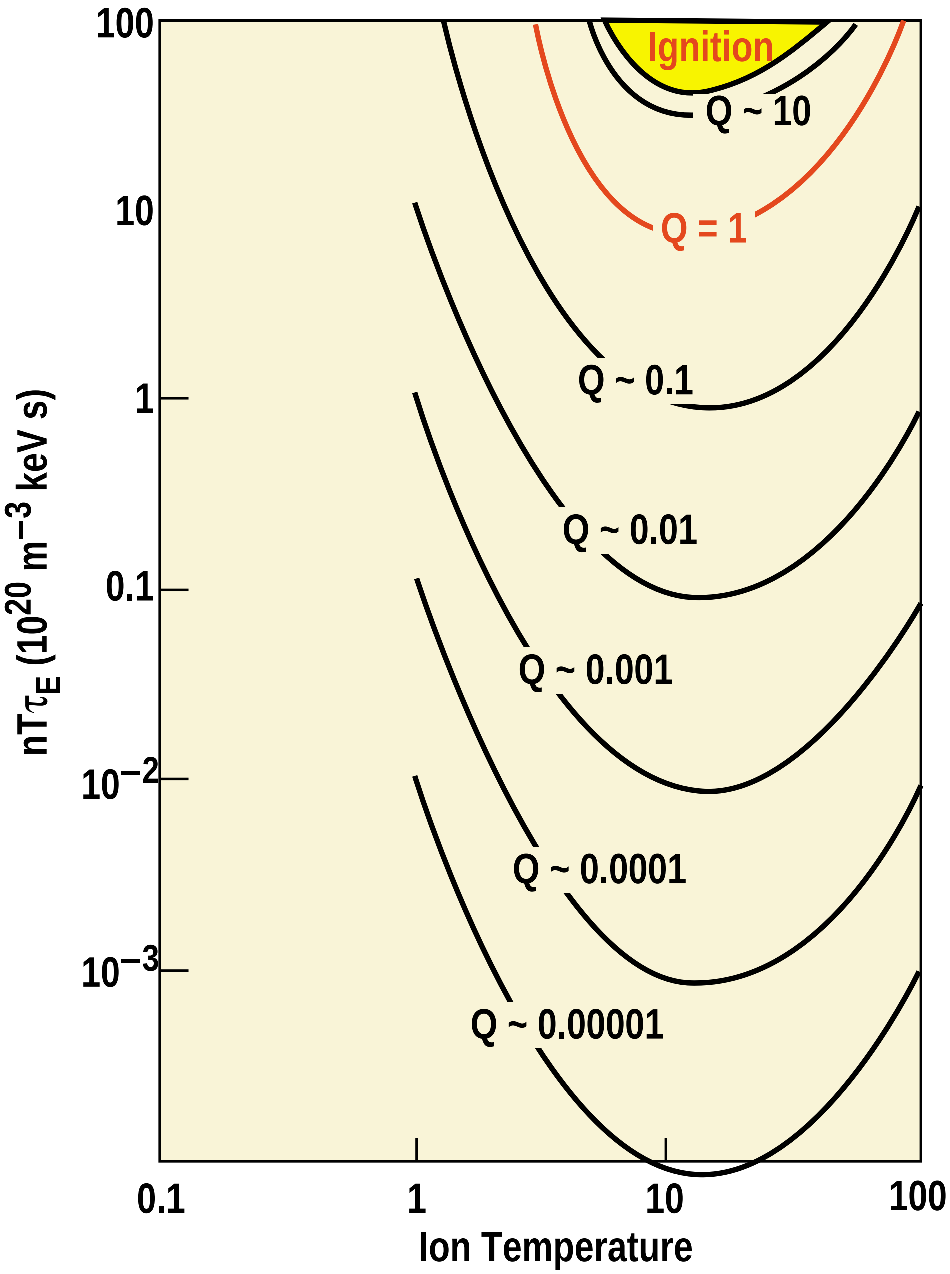
where $p\tau_E$ is minimum for given Q

$\langle\sigma v\rangle \propto T^2$

and p is limited by MHD stability in

magnetically confined plasmas

Ignition $Q = \infty \Rightarrow p\tau_E > \frac{12T^2}{\langle\sigma v\rangle\varepsilon_\alpha}$



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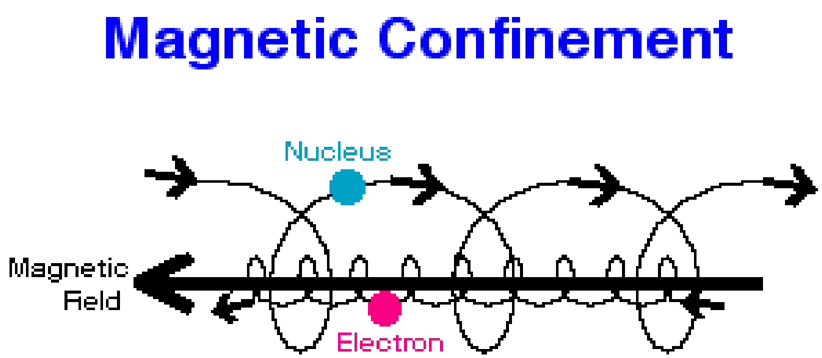
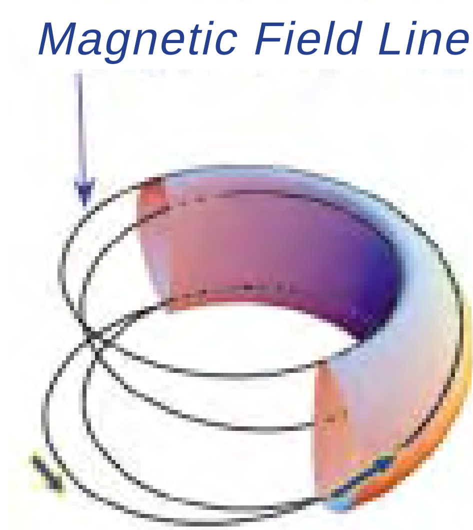
Four Basic Requirements for Fusion Energy

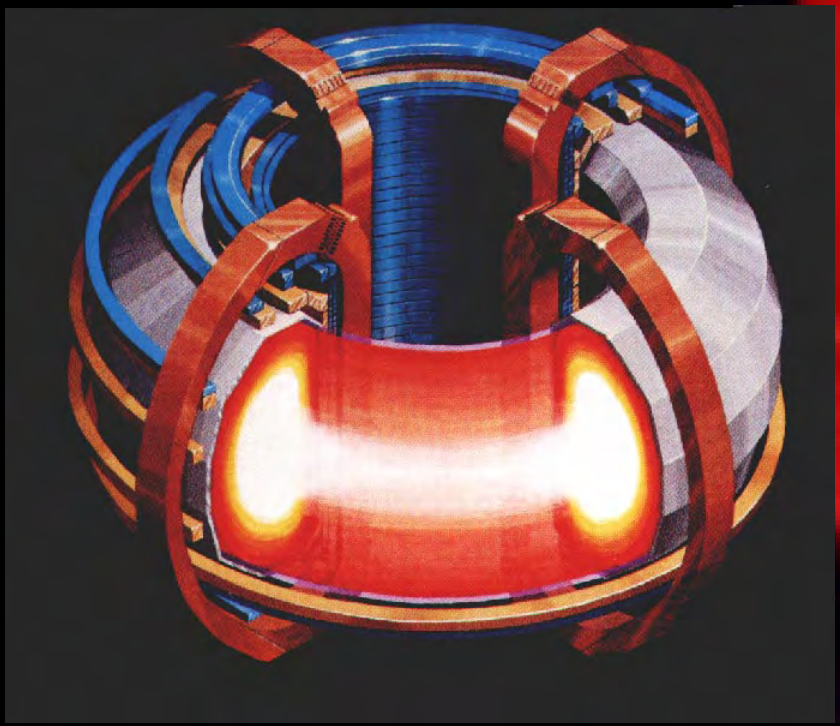
	NAS sub-fields of Plasma Science
Insulation for High τ_E	Multiscale Plasma Transport
Pressure for High $p\tau_E$	Macroscopic Stability
Heat Plasma to 200 million °F	Wave/Particle Interactions
Acceptable Plasma Interaction with Nearby Walls	Plasma/Wall Interactions

Toroidal Confinement





Toroidal Magnetic Confinement of Plasma



Back of the Envelope Fusion Power Plant

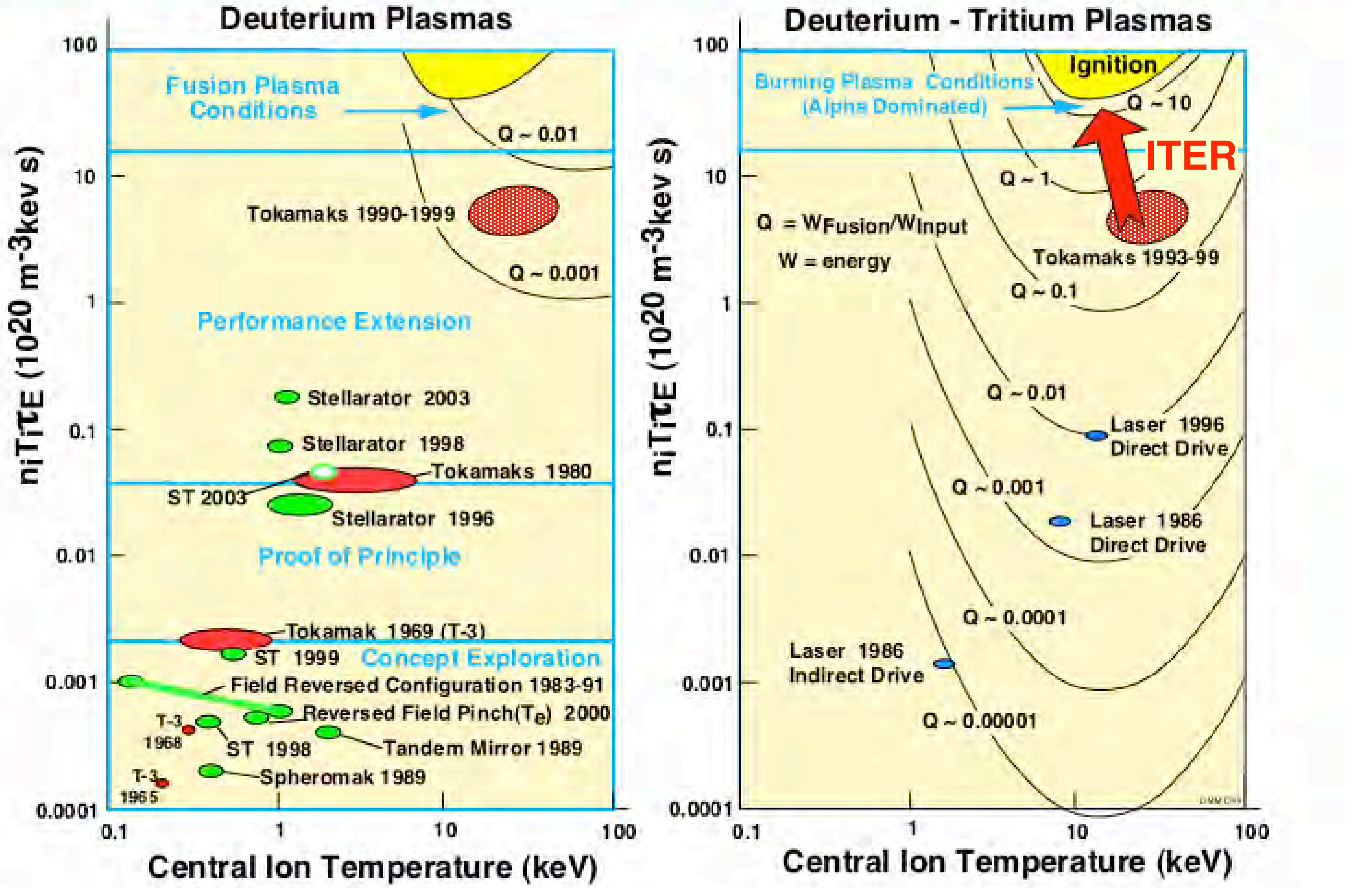
1) Fusion Neutron [14.1 MeV] takes ~ 1 meter in Lithium to produce needed Tritium to close fuel cycle.
   - Sets scale size at $R \sim 1$ meter
     [want to be closer to Mr. Fusion than Hoover Dam in size]

2) Largest Magnetic Field for few meter scale size is ~ 5 Tesla = 50,000 Gauss
   - Pressure is $B^2/2\mu_o$ ~ 10 million Newtons/m^2 ~ 100 atmospheres or 1500 psi
   - Stability Limits are typically ~ 10% magnetic pressure
     so $p \sim 10$ atm in plasma

3) If we need $p\tau_E \sim 10$ atm-sec for $Q \sim 30$ fusion energy gain at $T \sim 200$ million °F
   - $\tau_E \sim 1$ second

4) If $\tau_E \sim 1$ second then heat flux is ~ pR/τ_E
   - Heat Flux ~ 1 MWatt/m^2
   - Insulation "R value" ~ ΔT(°K)/[0.176*Heat Flux] ~ 1000 [or $\chi \sim 1$ m^2/sec]

How Close Are We to Burning Fusion Plasma?



Fusion Research Has Long History of Int'l Collaboration

- **1958: World-wide Declassification of Magnetically Confined Fusion Research at geneva Conference on Peaceful Uses of Atomic Energy:**

  US + USSR + EU begin to share information on Fusion under the IAEA and IEA

- **1960's: Soviets invent the "tokamak" – first to achieve 1 keV temperatures [20 million degrees F]**
- **1970's: Oil Crisis propels major investment in fusion research facilities worldwide & Japan joins as 4th major int'l participant – US uses PLT tokamak to achieve "fusion level" temperatures ~ 7 keV [140 million degrees F]**
- **1980's: Four Large [Q~1 class] Tokamak Experiments built: US – TFTR; USSR – T-10; EU – JET [all aimed at DT tests] and Japan JT-60 [DD only]**

In 1980’s Fusion is Major Area of US/USSR Cooperation

Joint Soviet-United States Statement on the Summit Meeting in Geneva – November 21, 1985

“The two leaders emphasized the potential importance of the work aimed at utilizing controlled thermonuclear fusion for peaceful purposes and, in this connection, advocated the widest practicable development of international cooperation in obtaining this source of energy, which is essentially inexhaustible, for the benefit for all mankind.”

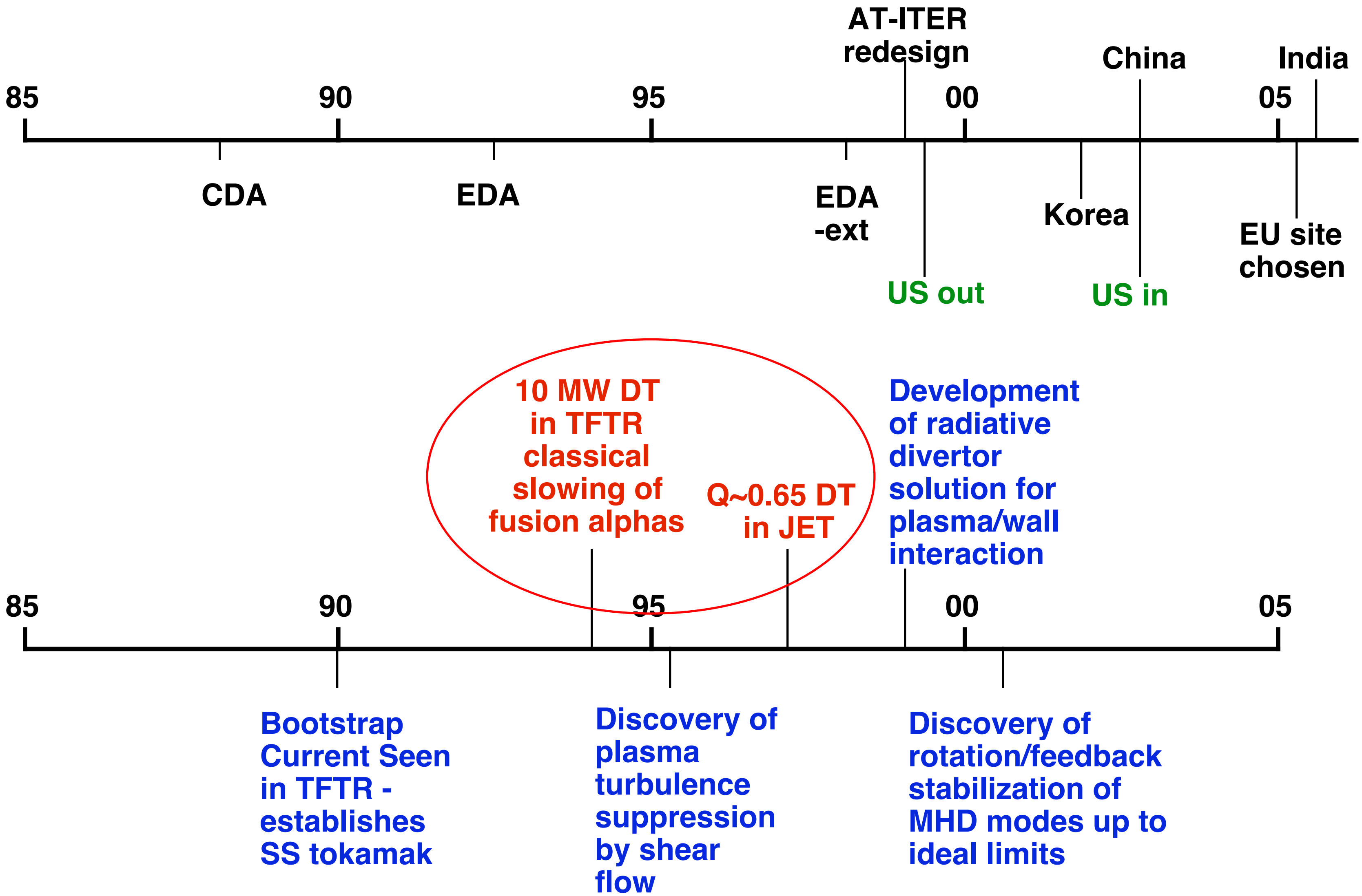
Joint Statement on the Soviet-United States Summit Meeting in Washington – December 10, 1987

“The President and the General Secretary supported further cooperation among scientists of the United States, the Soviet Union and other countries in utilizing controlled thermonuclear fusion for peaceful purposes. They affirmed the intention of the U.S. and the USSR to cooperate with the European Atomic Energy Community (EURATOM) and Japan, under the auspices of the International Atomic Energy Agency, in the quadripartite conceptual design of a fusion test reactor.”

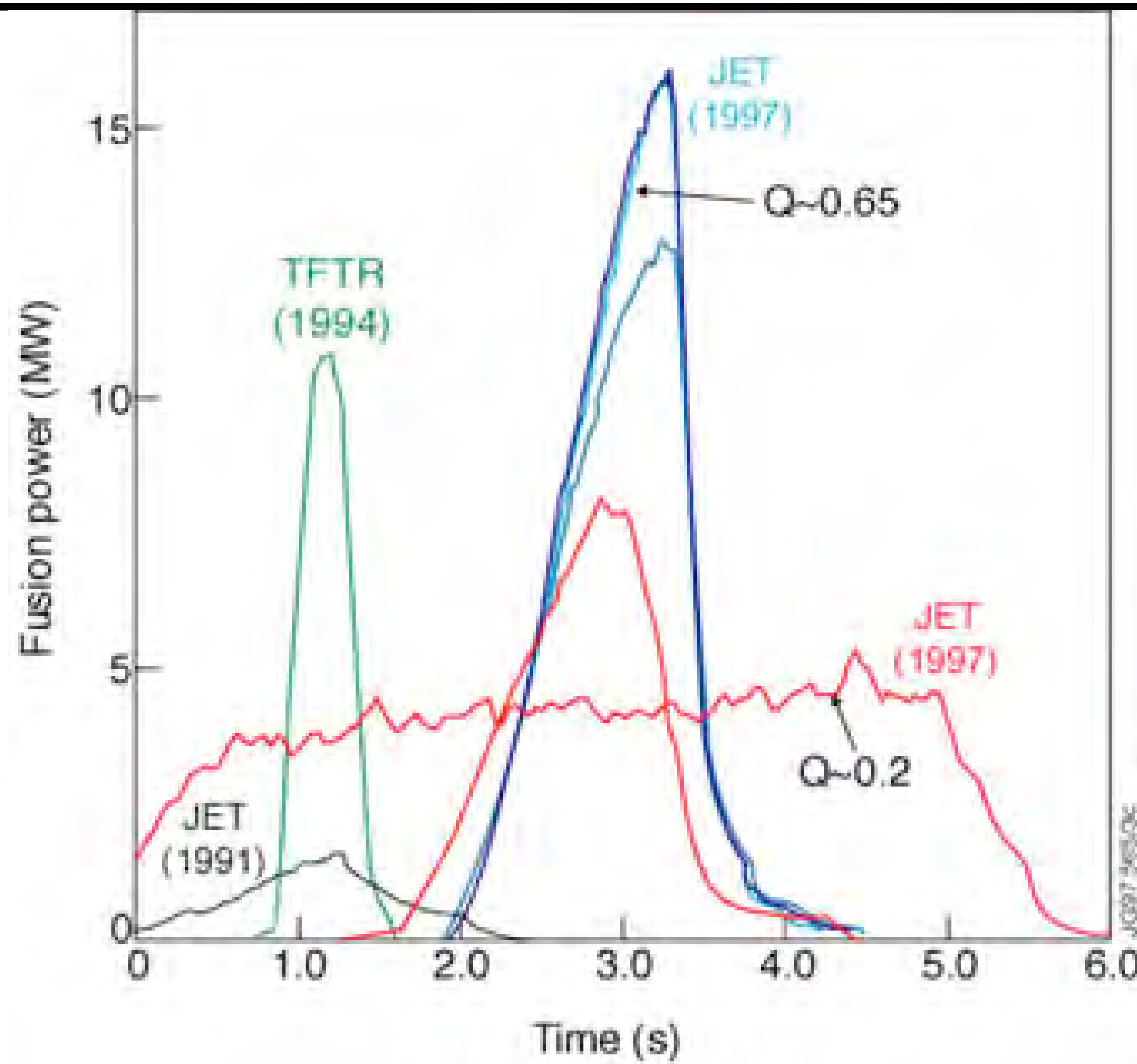
Joint Statement Following the Soviet-United States Summit Meeting in Moscow – June 1, 1988

“The President and the General Secretary noted with pleasure the commencement of work on a conceptual design of an International Thermonuclear Experimental Reactor (ITER), under the auspices of the International Atomic Energy Agency, between scientists and experts from the United States, Soviet Union, European Atomic Energy Community, and Japan. The two leaders noted the significance of this next step toward the development of fusion power as a cheap, environmentally sound, and essentially inexhaustible energy source for the benefit of all mankind.”

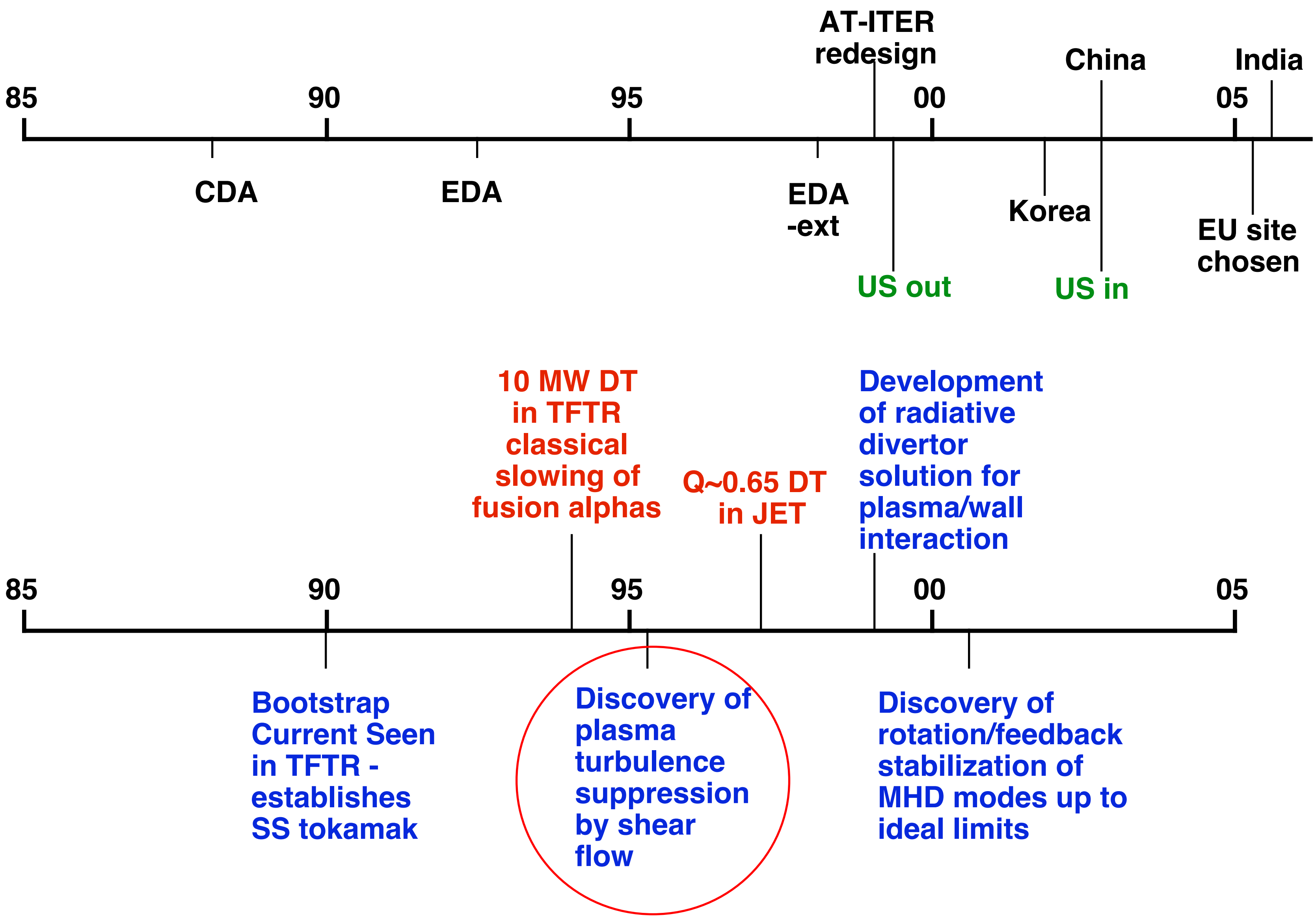
ITER History and Key Fusion Science Advances



DT Fusion Experiments in TFTR and JET Reach ~ 10 MW



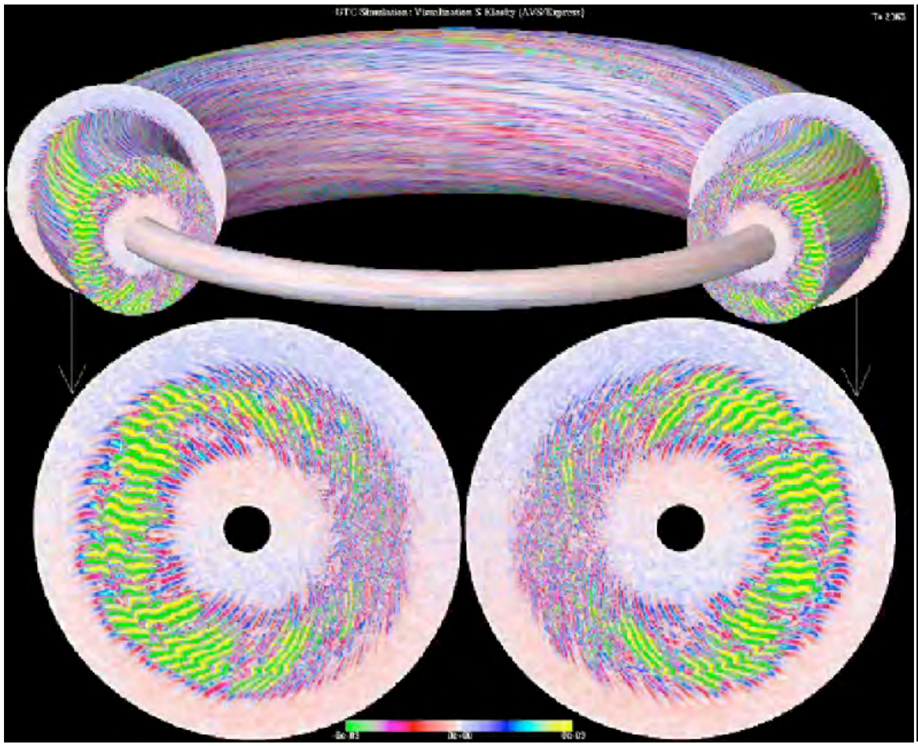
ITER History and Key Fusion Science Advances

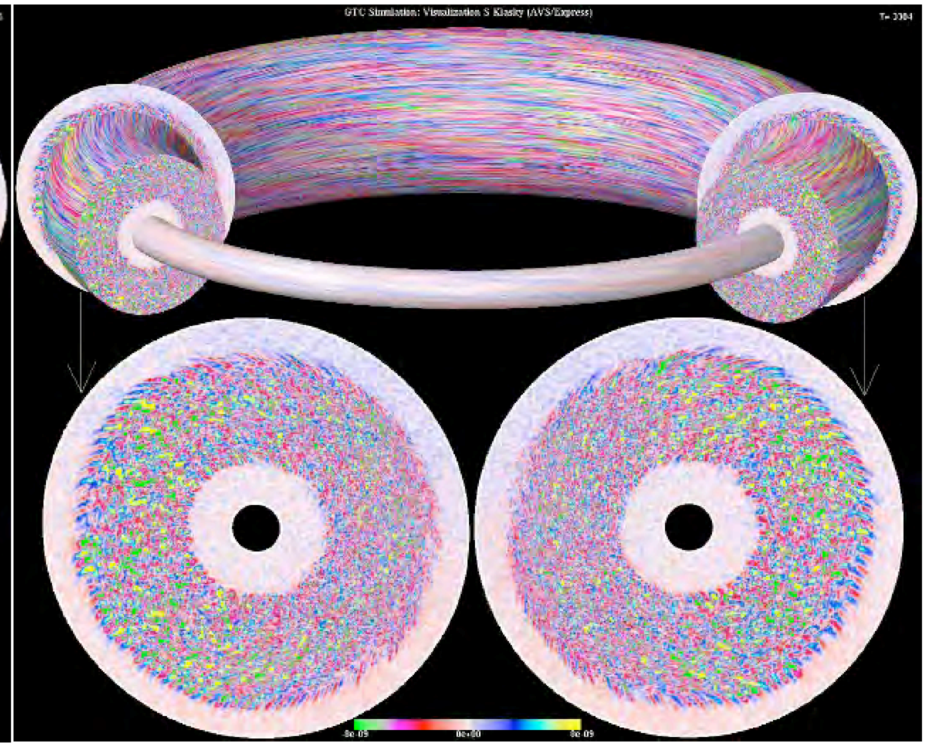


Sheared Rotation Stabilizes Plasma Turbulence

Turbulent Zonal Flows Cause Enhanced Energy Loss in Fusion Plasmas

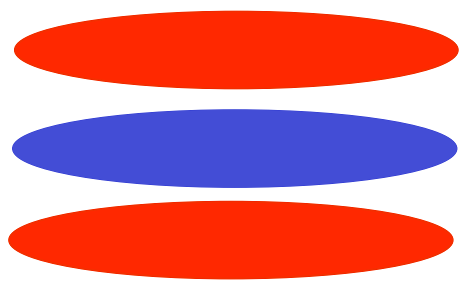
Shear Flow Breaks Up Zonal Flow in Plasma Turbulence and Lead to Major Reduction in Energy Loss Rate





Sheared Flows can Reduce or Suppress Turbulence

Most Dangerous Eddies:
Transport long distances



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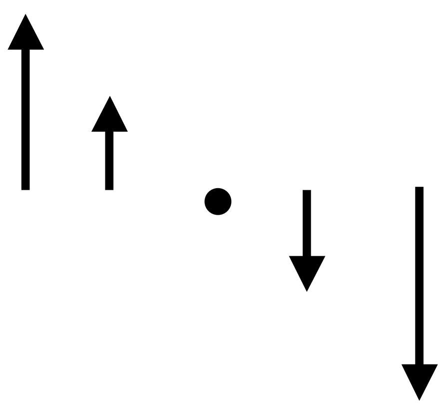
Sheared Flows



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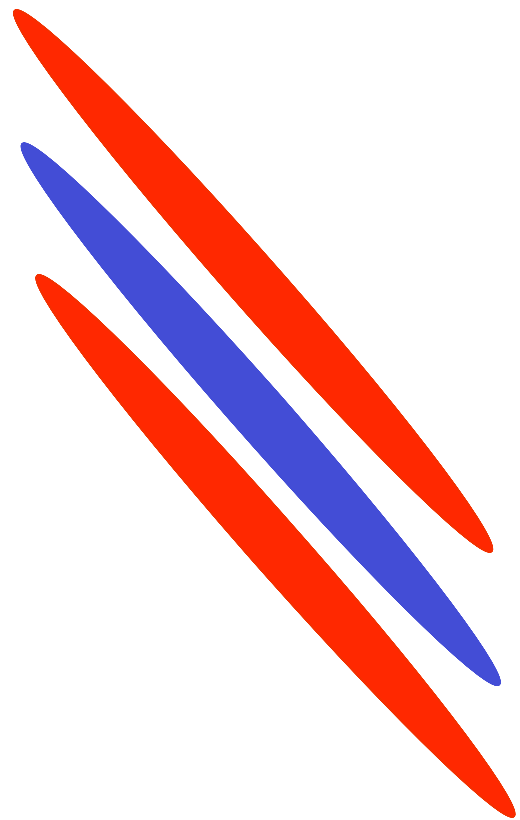
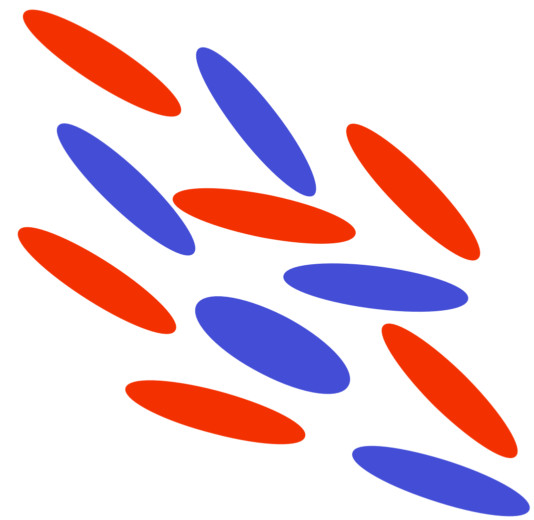
Sheared Eddies
Less effective



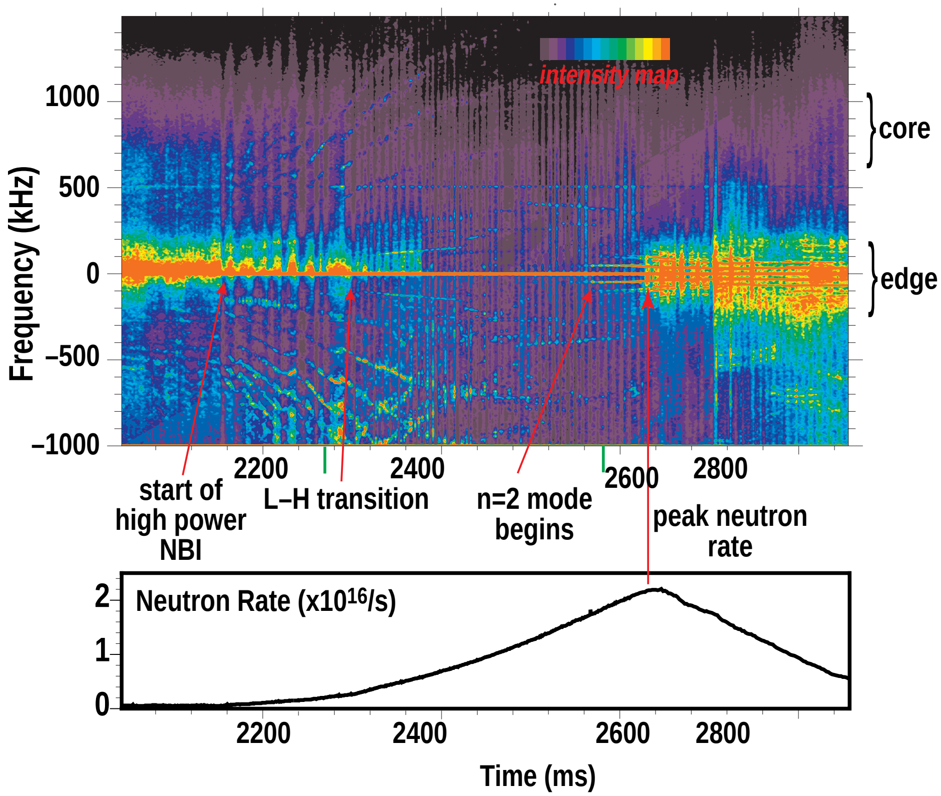
Eventually break up



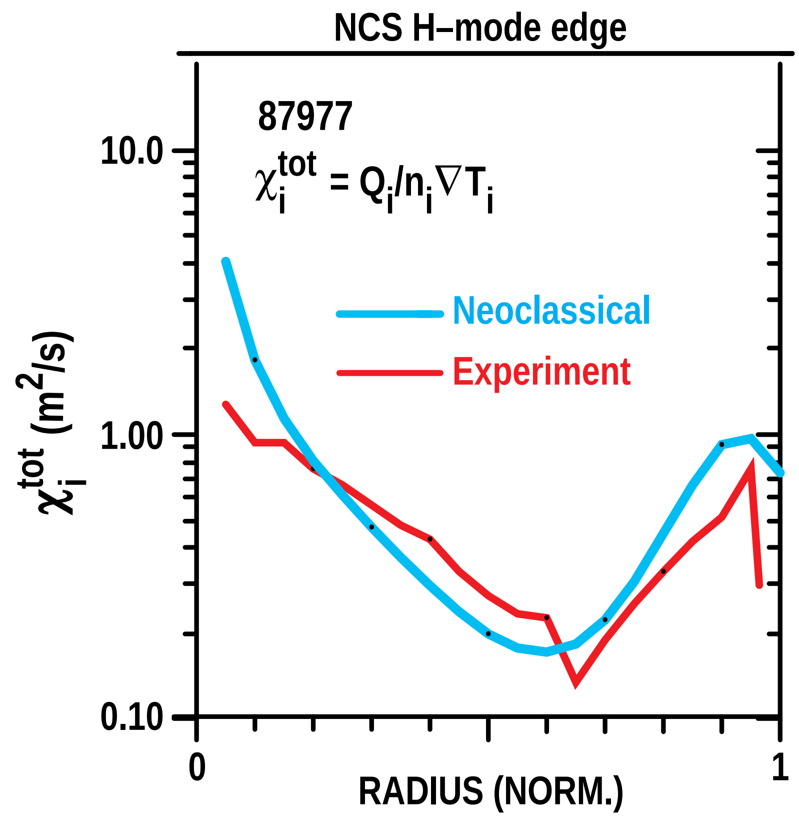
$$\omega_{E\times B} \equiv \nabla v_{E\times B} \sim \gamma$$

MAJOR DISCOVERY OF THE 1990's: ION TURBULENCE CAN BE ELIMINATED

- Color contour map of fluctuation intensity as function of time from FIR scattering data
  - Higher frequencies correspond to core, low to edge



- Total ion thermal diffusivity at time of peak performance
  - H = 4.5 W = 4.2 MJ
    β = 6.7% β_N = 4.0



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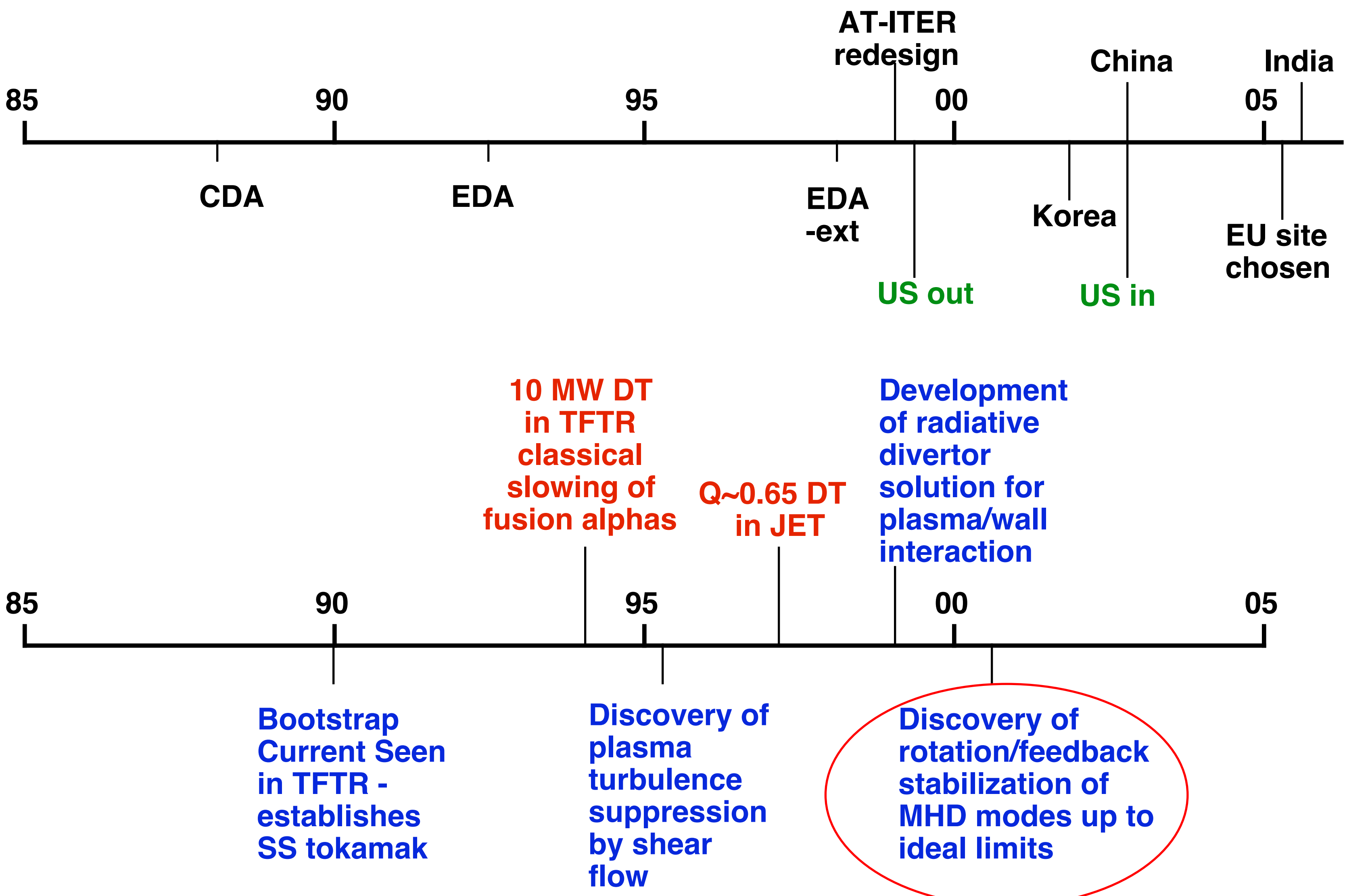
ITER History and Key Fusion Science Advances



GENERAL ATOMICS

News Release

For Release JULY 2, 2001

"SPINNING" FUSION ENERGY SOURCE IMPROVES PROSPECTS FOR POWER APPLICATIONS

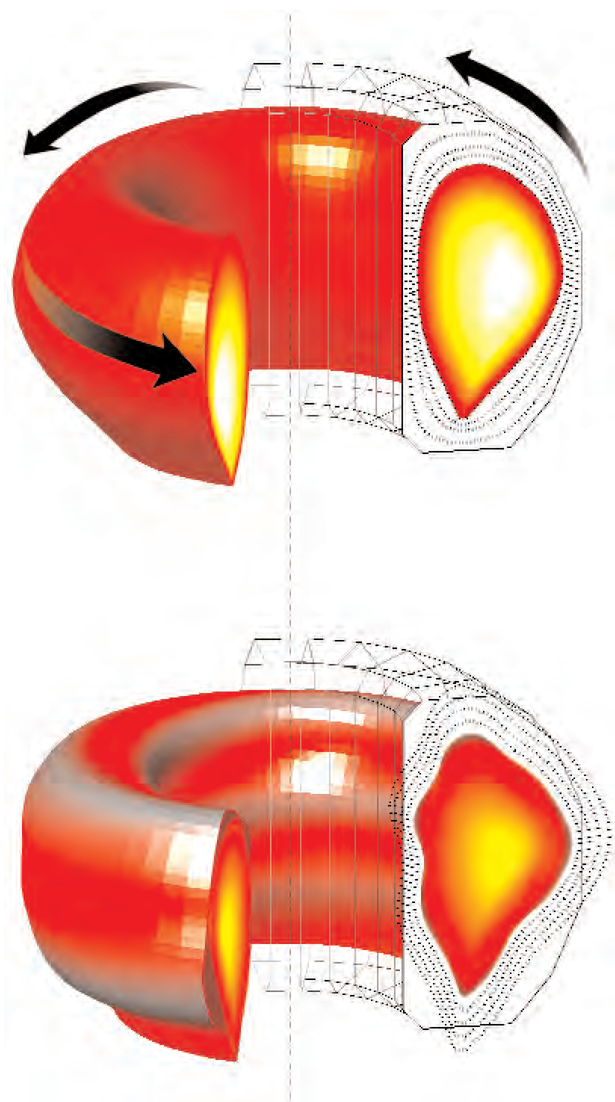
The DIII–D National Fusion Facility Announces Major Advance For Fusion Energy Research

San Diego, CA – July 2, 2001 — Researchers at the U. S. Department of Energy funded DIII–D National Fusion Facility at General Atomics, the largest fusion energy experiment in the United States, have nearly doubled the usual limits on pressure in a fusion energy device by spinning the hot, fusion fuel very rapidly. A significant scientific advance in understanding the pressure limit in fusion energy devices made these higher limits possible. These results are an important step towards controlled fusion power production that is feasible, economical, and attractive.

Fusion, the combining of two small atomic nuclei to form a heavier nucleus, is the vast energy source that powers the sun and the stars. Scientists worldwide are striving to harness the fusion process. As stated in the recently released U. S. National Energy Policy: "Fusion — the energy source of the sun — has the long-range potential to serve as an abundant and clean source of energy. The basic fuels, deuterium (a heavy form of hydrogen) and lithium, are abundantly available to all nations for thousands of years." Fusion power will have no smog or greenhouse gas emissions to pollute air, ground, or water.

The fusion process requires extraordinarily high temperatures in the fusion fuel to produce useful amounts of energy. The DIII–D fusion energy device uses strong magnetic fields to contain the very hot (200 million degrees) fusion fuel (called a "plasma") inside a 15-foot diameter donut-shaped metal reaction chamber. This tokamak magnetic field configuration is presently the most successful fusion system being investigated by scientists worldwide. At these very high temperatures, all atoms are separated into their constituent nuclei and electrons forming an electrically conducting, high pressure plasma similar to the plasma inside a fluorescent light bulb or neon sign, but thousands of times hotter.

(continued on next page)

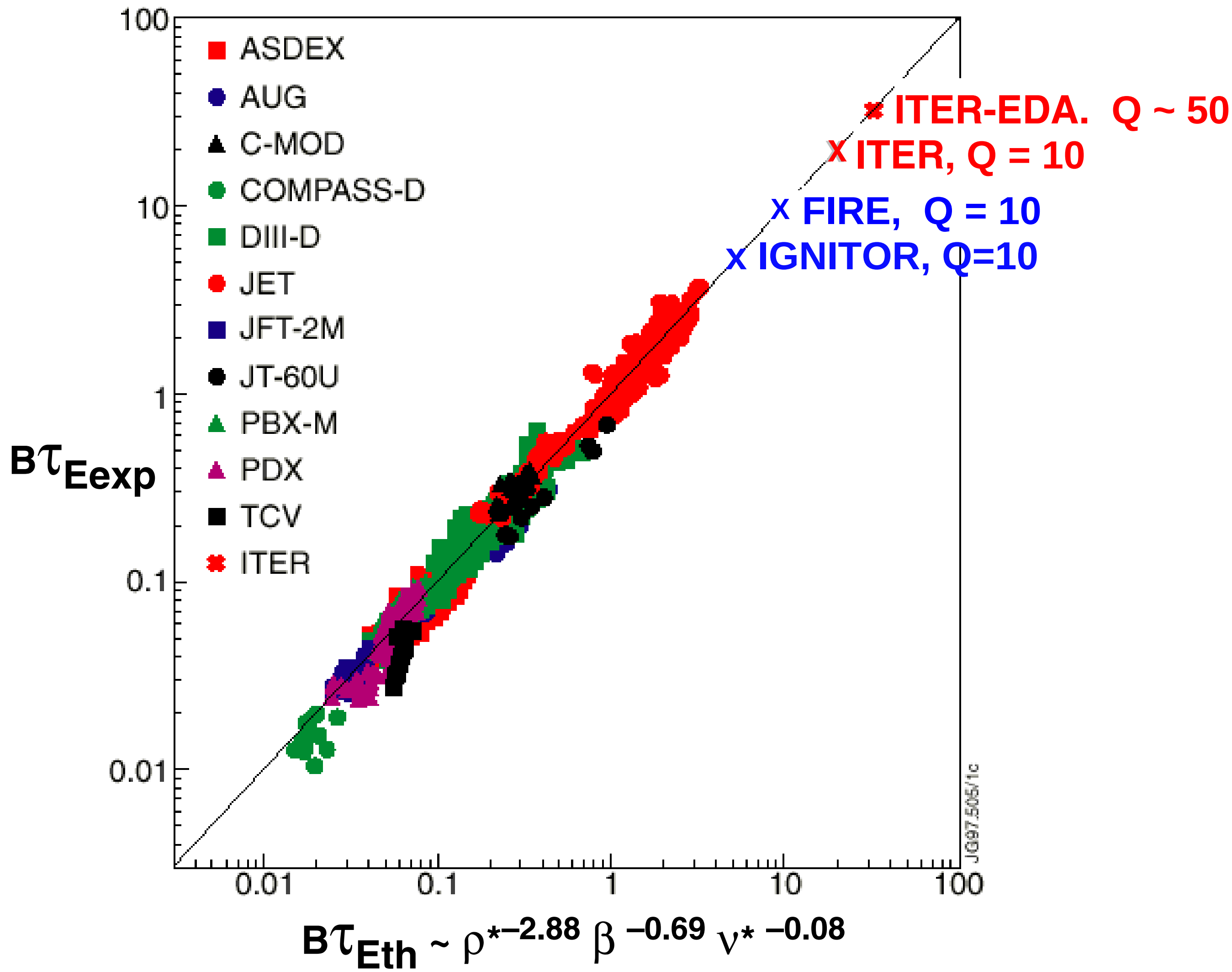


***SPINNING PLASMA* stabilizes the plasma surface allowing improved performance.** *When stable, the plasma in the DIII–D tokamak is a tear-drop shaped donut inside a metal chamber as shown in the upper cutaway figure. When unstable, the plasma surface distorts as shown in the lower figure (exaggerated about 10 times). Control magnet coils (not shown) push back on these distortions, keeping the surface smooth, allowing the plasma to continue spinning rapidly (in the direction of the arrow) and to remain stable to higher pressure.*

Modest Confinement Extrapolation Needed for BP

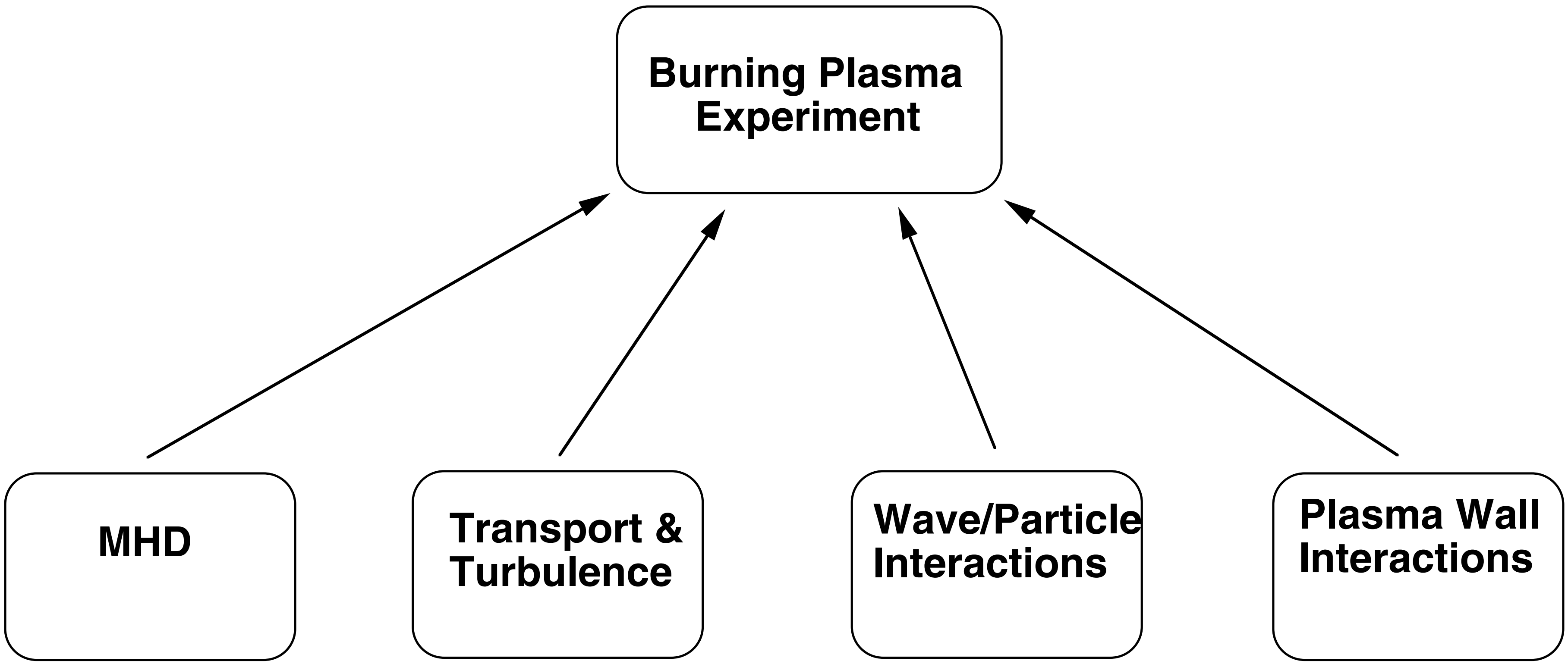
Dimensionless Parameters
$\omega_c \tau = B\,\tau$ $\rho^* = \rho/\mathbf{a}$ $\nu^* = \nu_c/\nu_b$ β

Similarity Parameter
$B\,R^{5/4}$



Kadomtsev, 1975

Major Advances & Discoveries of 90's Lay Foundation for Next Step Burning Plasma Experiments



MHD

- q-profile control and measurement
- steady-state, bootstrap equilibria
- active mode control of kink & tearing

Transport & Turbulence

- shear-flow turbulence suppression
- gyro-kinetic theory based models
- extensive data-base models on transport using dimensionless scaling

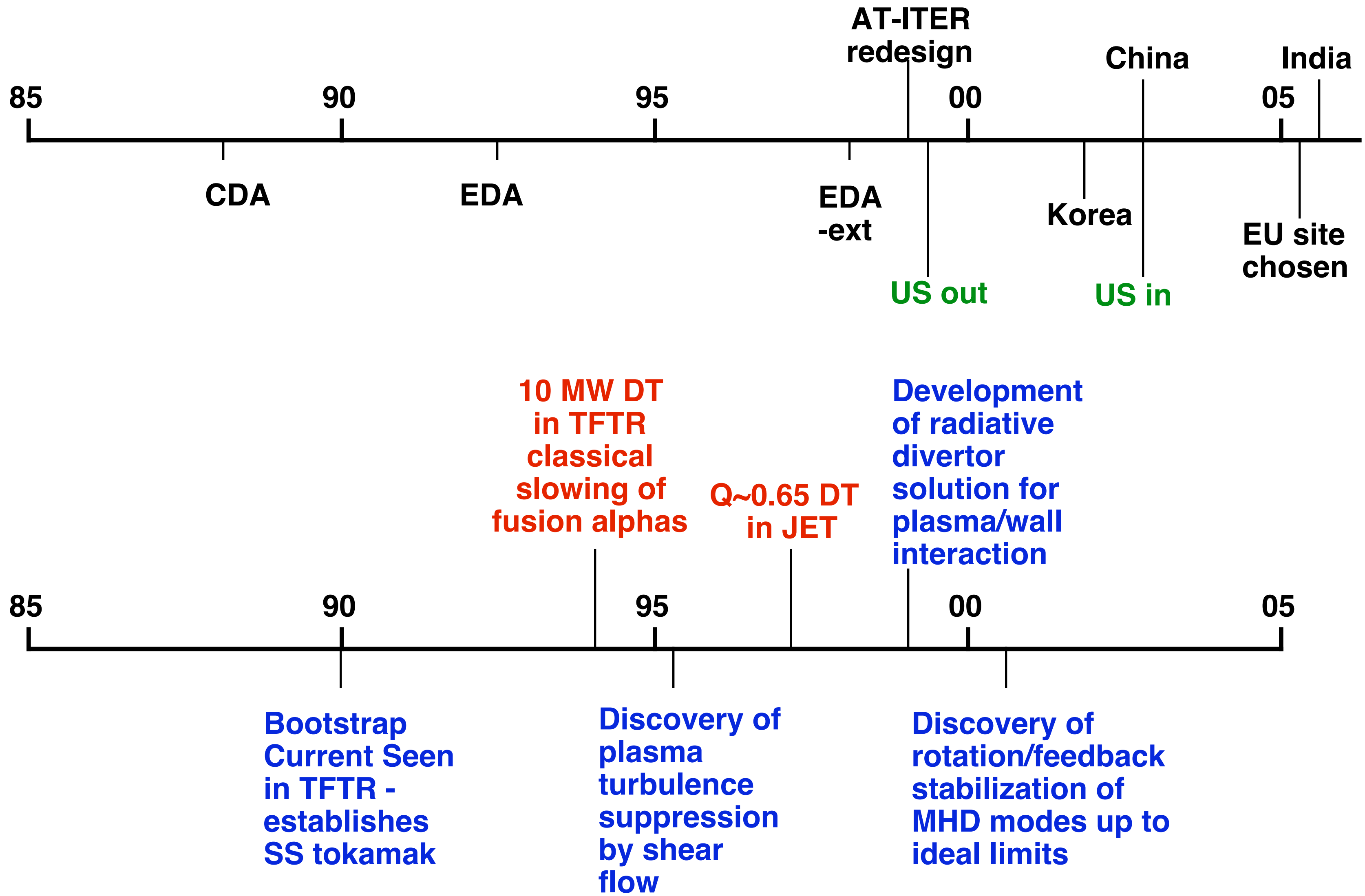
Wave/Particle Interactions

- alpha heating in DT found to be classical for $Q \leq 1$
- "standard model" of Alfvén Eigenmodes
- LHCD & ECCD used for near SS & mode control

Plasma Wall Interactions

- detached divertor demonstrated
- large scale models developed
- high heat-flux metallic technology developed

ITER HISTORY AND KEY FUSION SCIENCE ADVANCES



"I am pleased to announce today, that President Bush has decided that the United States will join the international negotiations on ITER."

Secretary of Energy Spencer Abraham
30 January 2003

…we know that this experiment is a crucial element in the path forward to satisfying global energy demand.

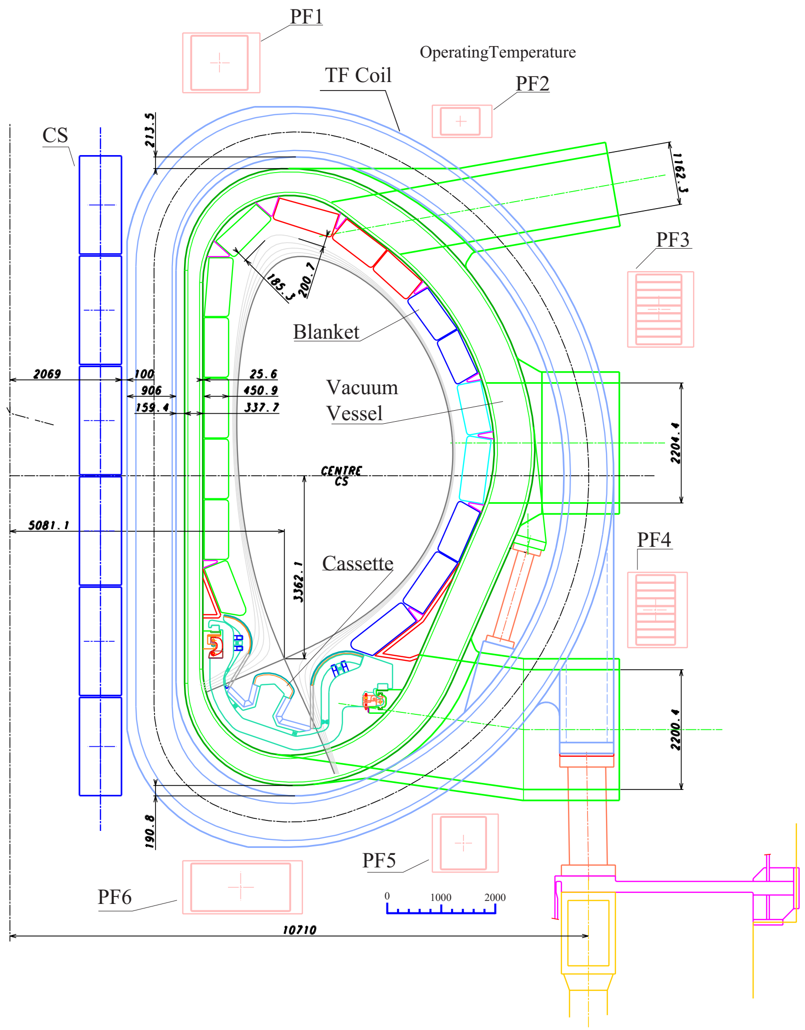
President Bush has faith in American science. And he knows the huge energy challenges for the United States and for the world that fusion science seeks to tackle.

And let me tell you, he is not one for taking baby steps when leaps are called for.

By the time our young children reach middle age, fusion may begin to deliver energy independence and energy abundance to all nations rich and poor. Fusion is a promise for the future we must not ignore.

But let me be clear, our decision to join ITER in no way means a lesser role for the fusion programs we undertake here at home. It is imperative that we maintain and enhance our strong domestic research program … at the universities and at our other labs.

The ITER Design: Poloidal Elevation



	ITER
Major radius	6.2 m
Minor radius	2.0 m
Plasma current	15 MA
Toroidal magnetic field	5.3T
Elongation / triangularity	1.85 / 0.49
Fusion power amplification	≥ 10
Fusion power	~400 MW
Plasma burn duration	~400 s

ITER parameters in Q = 10 reference inductive scenario

ITER Design Goals

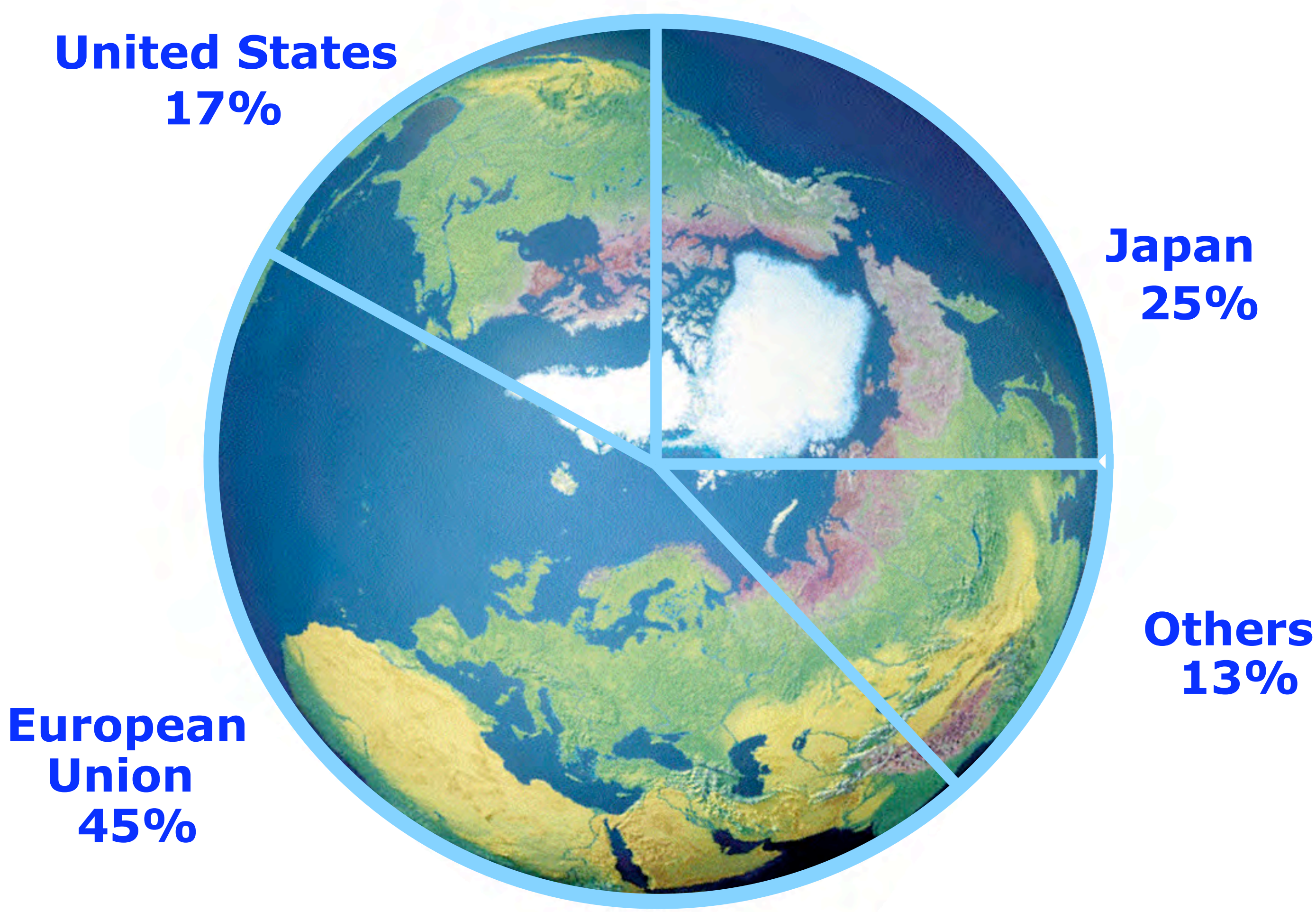
Physics:

- ITER is designed to produce a plasma dominated by α-particle heating
- produce a significant fusion power amplification factor ($Q \geq 10$) in long-pulse operation
- aim to achieve steady-state operation of a tokamak ($Q = 5$)
- retain the possibility of exploring ‘controlled ignition’ ($Q \geq 30$)

Technology:

- demonstrate integrated operation of technologies for a fusion power plant
- test components required for a fusion power plant
- test concepts for a tritium breeding module

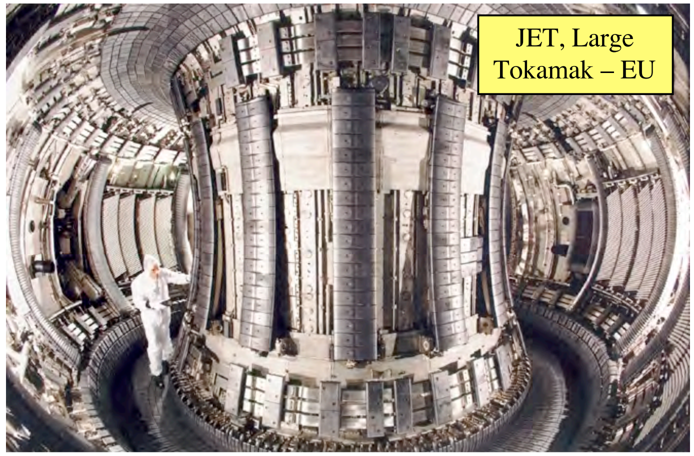
The U.S. is about 1/6 of the World Magnetic Fusion Effort



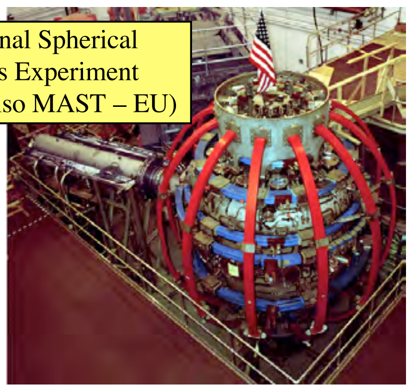
US: $260M/yr
World: ~$1.5B/yr
(FY 2005)

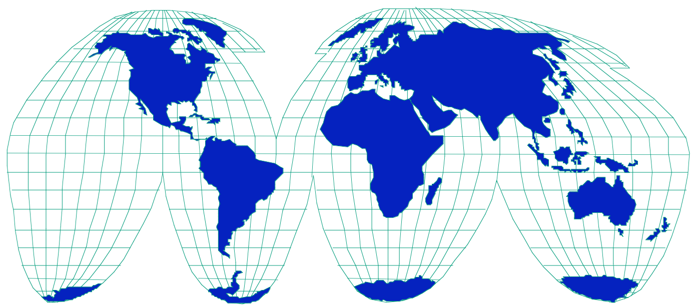
Magnetic Fusion Research is a Worldwide Activity: Optimizing the Configuration for Fusion


C-Mod, Tokamak MIT

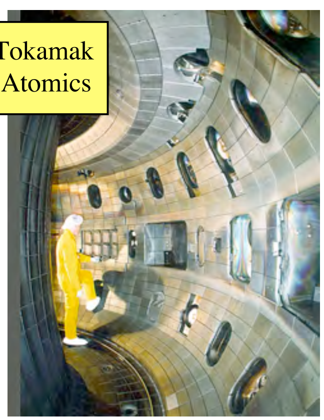

JET, Large Tokamak – EU

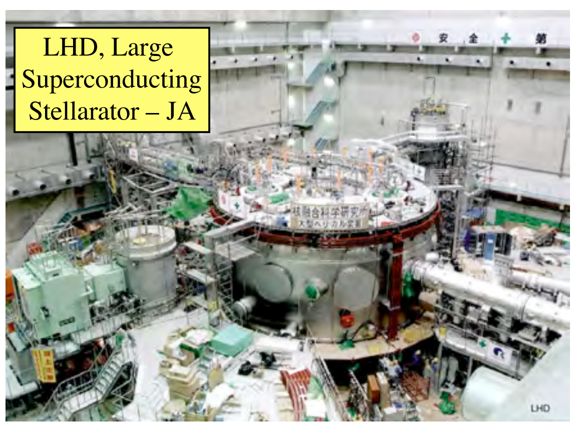

W7-X, Large Superconducting Stellarator – EU

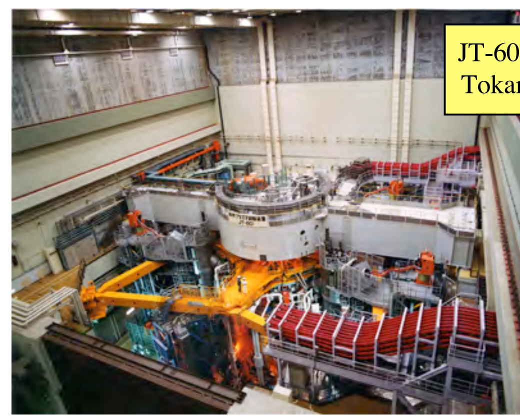

National Spherical Torus Experiment PPPL (also MAST – EU)




KSTAR, EAST, SST-1 Superconducting Tokamaks, – Korea, China, India


DIII-D, Tokamak General Atomics


LHD, Large Superconducting Stellarator – JA

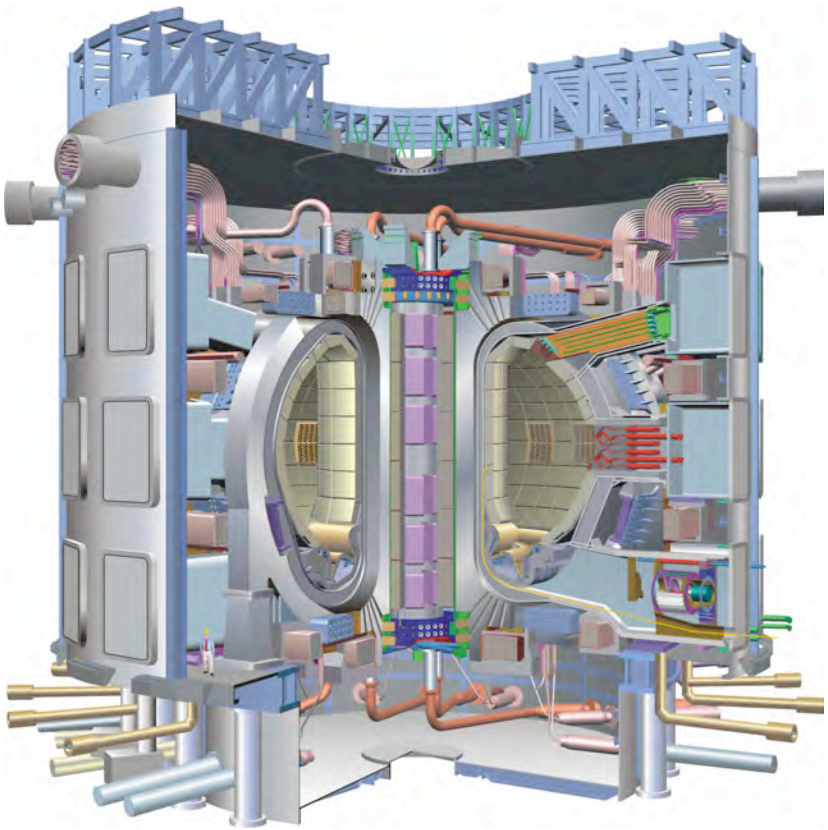

JT-60U, Large Tokamak– JA

ITER Partners:

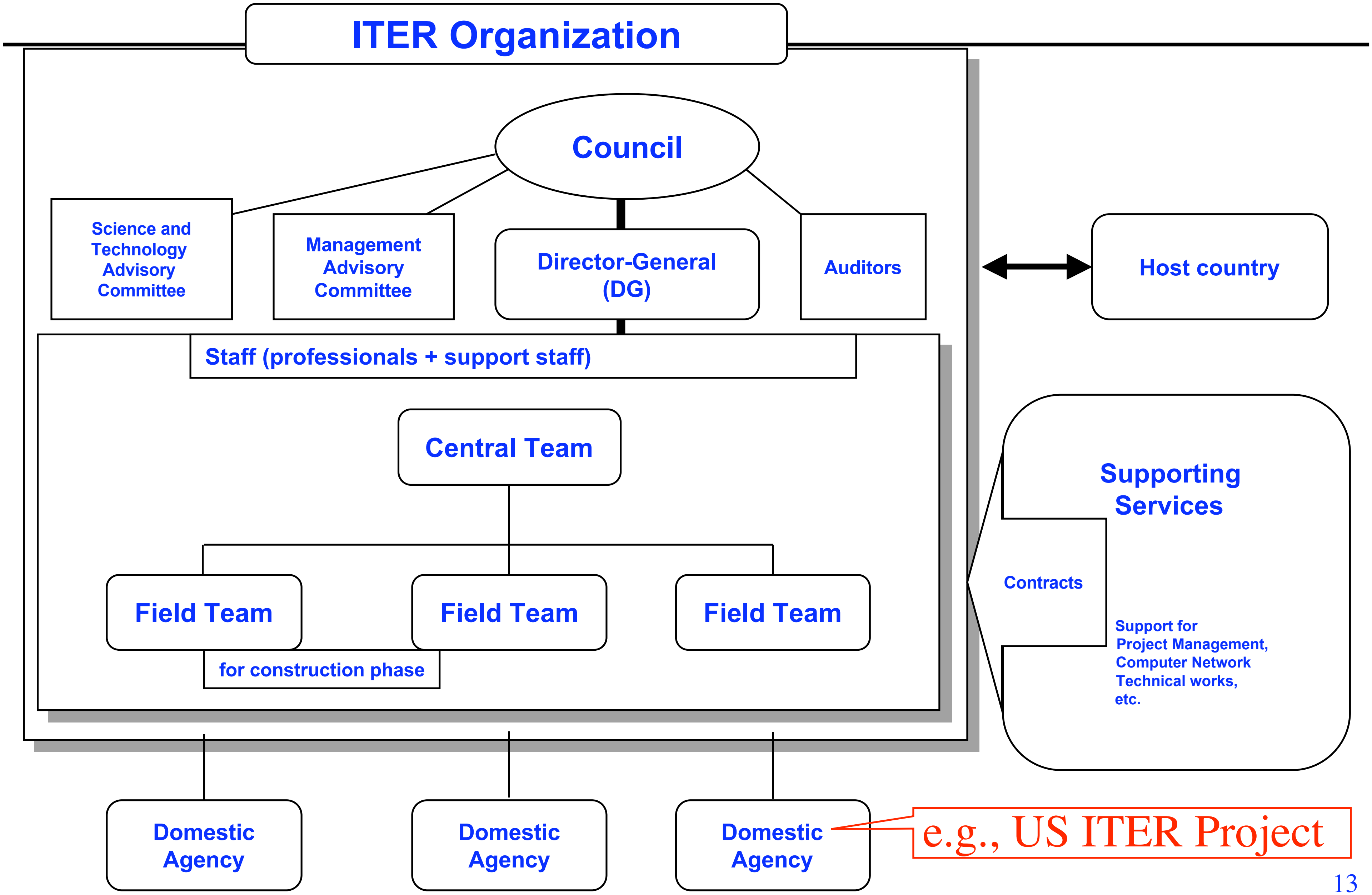
China, Europe, India, Japan, Russia, South Korea, U.S.

- **The site and Director General have been selected:**
  - Cadarache, France, near Aix-en-Provence.
  - Kaname Ikeda; JA Ambassador to Croatia, former head of JA Space Agency, nuclear engineer with experience in large-scale international projects

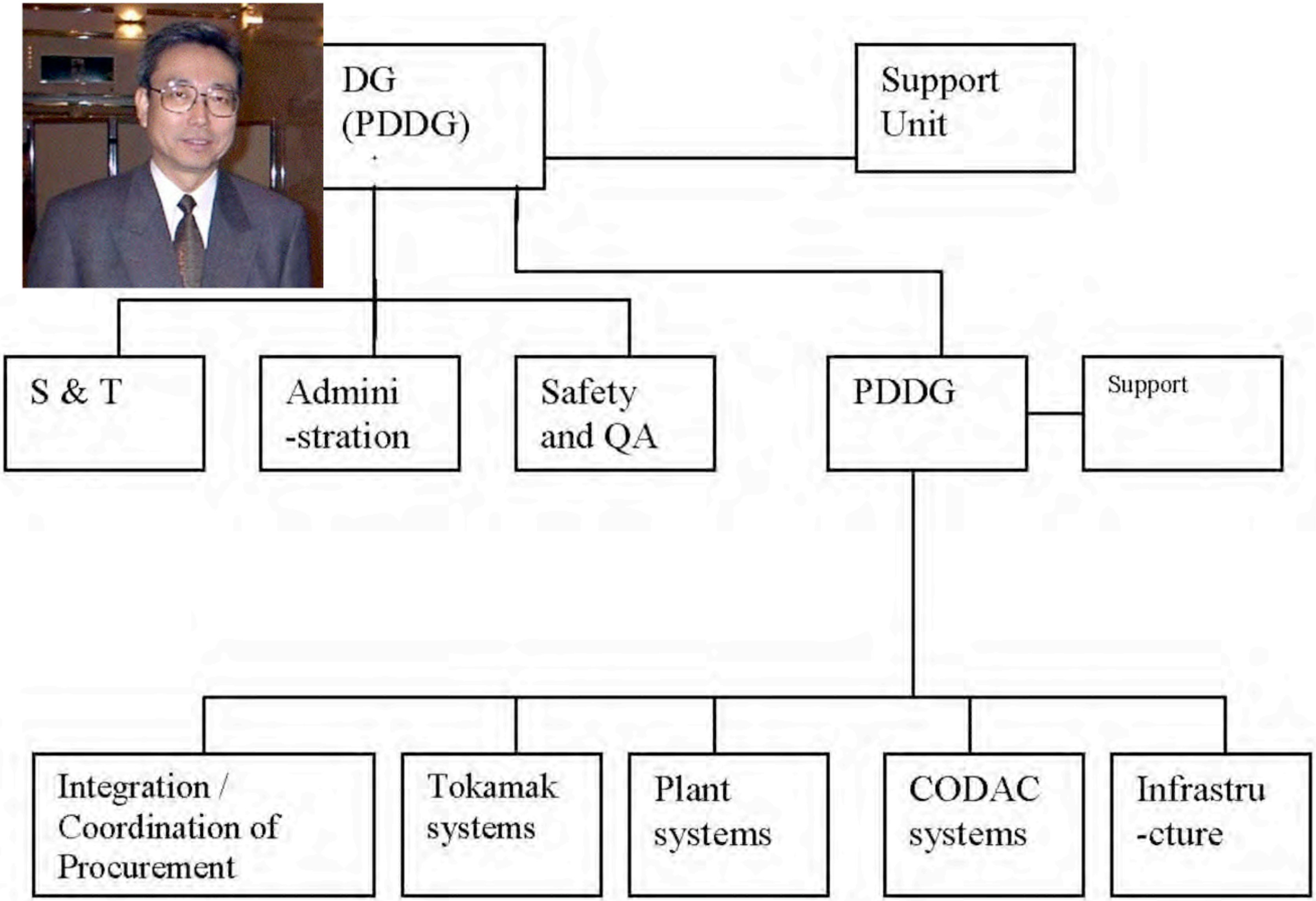
- **The finances are agreed:**
  - Europe pays 45.4% – spending 10 of these % in Japan (!).
  - Each of the other six pays 9.1%.
  - Europe pays for 1/2 of "broader approach" additional fusion facilities in Japan, valued at 16% of ITER.
  - More than 1/2 of the world in ITER.



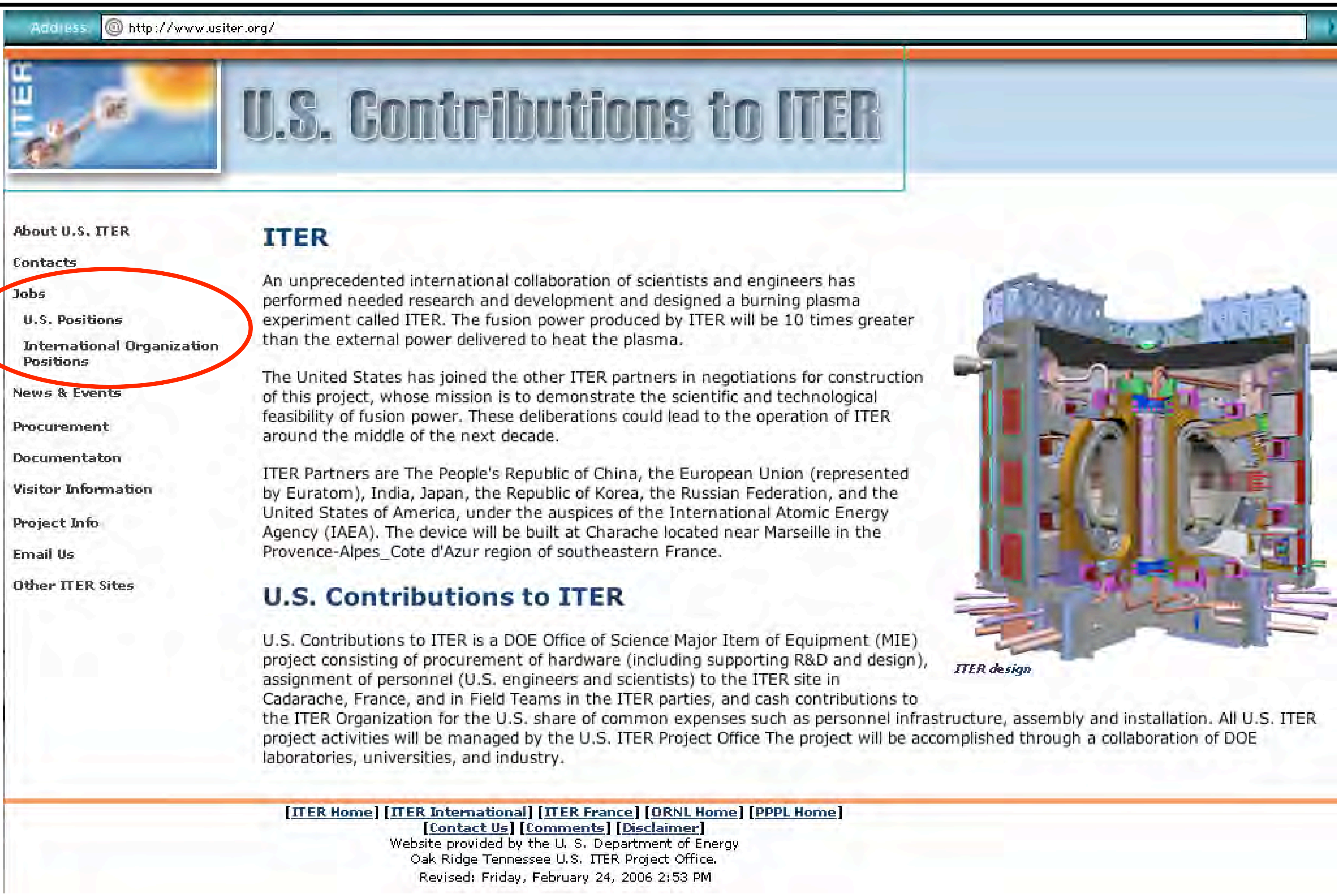
Highest Level Management Structure



Director General's ITER Organization Structure
for purpose of soliciting candidates for DDG positions



US ITER Web Site (www.usiter.org)



Address http://www.usiter.org/

U.S. Contributions to ITER

About U.S. ITER

Contacts

Jobs

U.S. Positions

International Organization Positions

News & Events

Procurement

Documentaton

Visitor Information

Project Info

Email Us

Other ITER Sites

ITER

An unprecedented international collaboration of scientists and engineers has performed needed research and development and designed a burning plasma experiment called ITER. The fusion power produced by ITER will be 10 times greater than the external power delivered to heat the plasma.

The United States has joined the other ITER partners in negotiations for construction of this project, whose mission is to demonstrate the scientific and technological feasibility of fusion power. These deliberations could lead to the operation of ITER around the middle of the next decade.

ITER Partners are The People's Republic of China, the European Union (represented by Euratom), India, Japan, the Republic of Korea, the Russian Federation, and the United States of America, under the auspices of the International Atomic Energy Agency (IAEA). The device will be built at Carache located near Marseille in the Provence-Alpes_Cote d'Azur region of southeastern France.

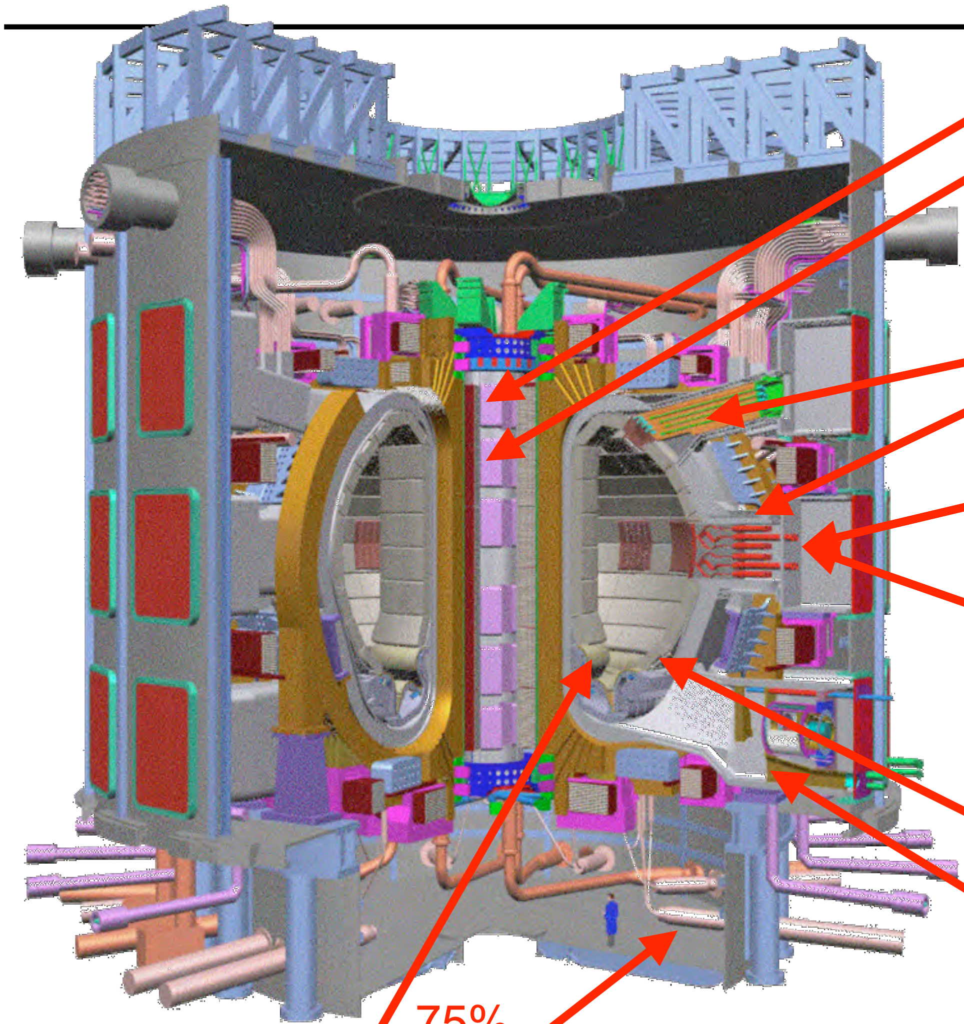
ITER design

U.S. Contributions to ITER

U.S. Contributions to ITER is a DOE Office of Science Major Item of Equipment (MIE) project consisting of procurement of hardware (including supporting R&D and design), assignment of personnel (U.S. engineers and scientists) to the ITER site in Cadarache, France, and in Field Teams in the ITER parties, and cash contributions to the ITER Organization for the U.S. share of common expenses such as personnel infrastructure, assembly and installation. All U.S. ITER project activities will be managed by the U.S. ITER Project Office The project will be accomplished through a collaboration of DOE laboratories, universities, and industry.

[ITER Home] [ITER International] [ITER France] [ORNL Home] [PPPL Home]
[Contact Us] [Comments] [Disclaimer]
Website provided by the U. S. Department of Energy
Oak Ridge Tennessee U.S. ITER Project Office.
Revised: Friday, February 24, 2006 2:53 PM

N-12 (2005) Revised U.S. “in-kind contribution” scopes



to JA

7 ~~4~~ of 7 Central Solenoid windings

~~4 of 7 Central Solenoid conductor~~

8% of Toroidal Field conductor

15% of port-based diagnostics

to EU

~~44% of ICRH antenna +~~

all Ion Cycl. transmission lines,

~~IC sources, and power supplies~~

to IN

~~Start-up gyrotrons,~~

to IN

all Elec. Cyclo. Trans. Lines

~~and power supplies~~

to IN

Blanket/Shield ~~10%~~ 20%, limiters

Roughing pumps,
standard components

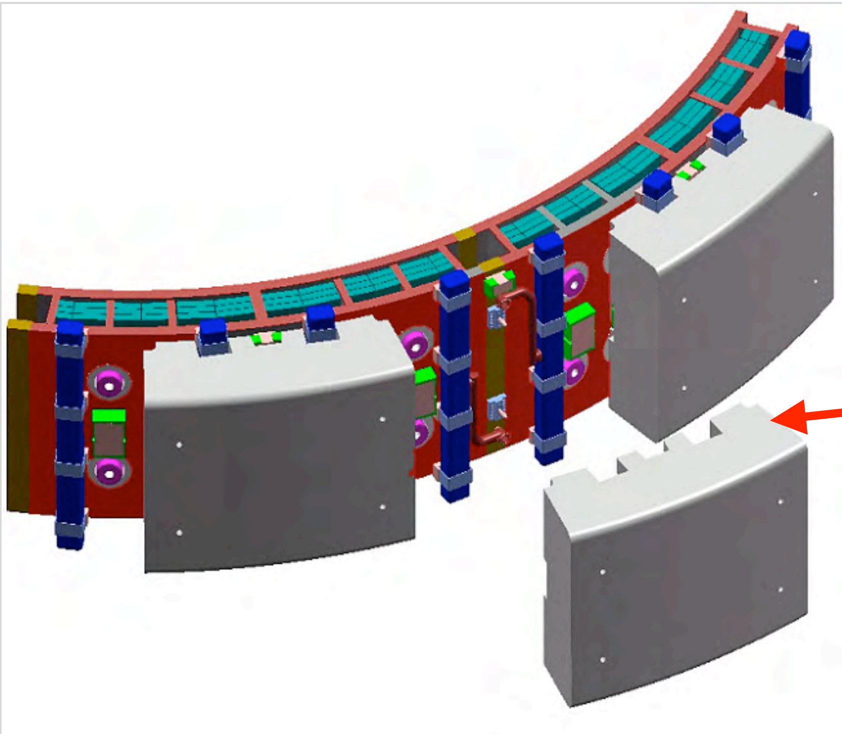
pellet injector

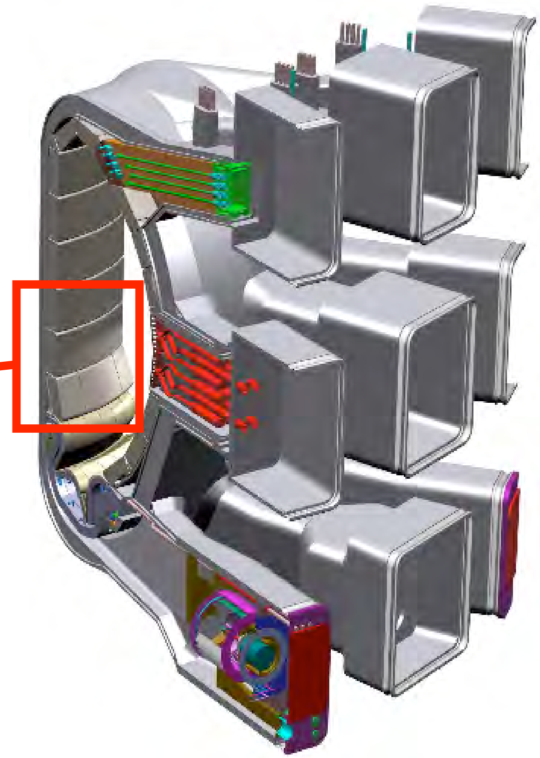
75%
~~78%~~ Cooling for
divertor,
vacuum vessel, …

Steady-state
power supplies

Tokamak exhaust
processing system

First Wall / Blanket/Shield

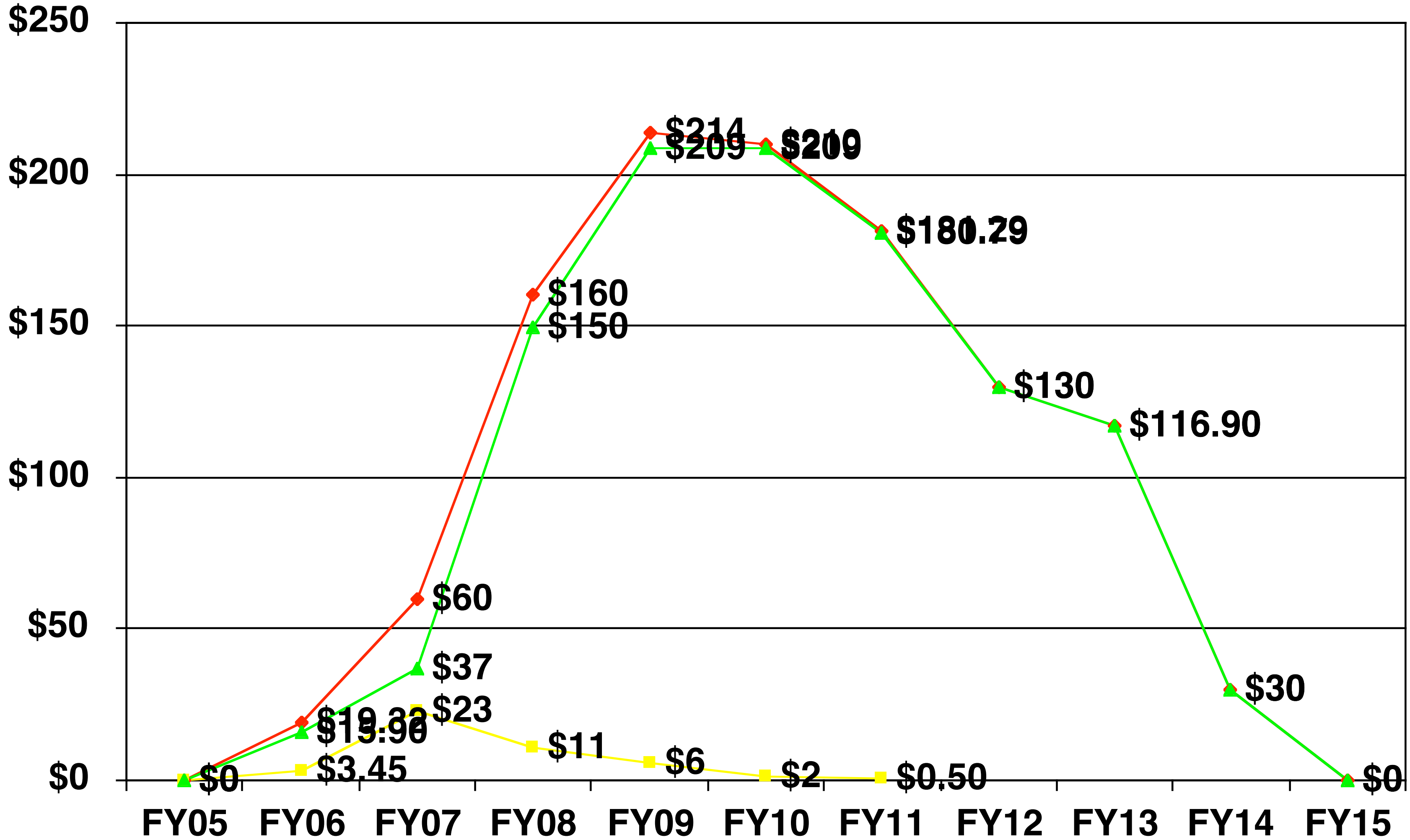


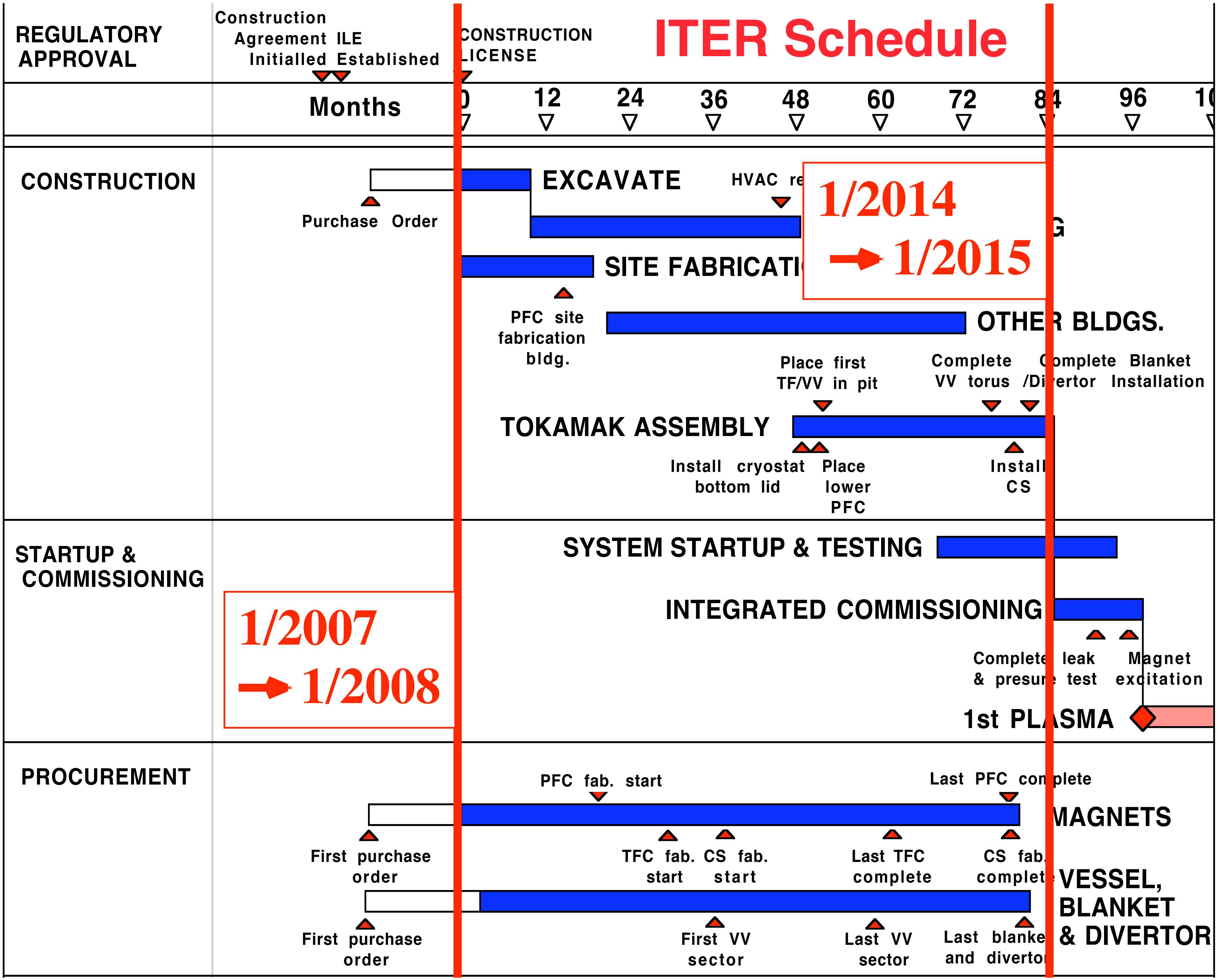


- **2003: US provides 10% of the area of First Wall / Blanket / Shield modules**
  - Issue: significant R&D spread over only small amount of fabrication

- **2005: US provides 20% of the area of First Wall / Blanket / Shield modules**
  - Advantage: Spreads R&D over larger fabrication base

US ITER Budget Profile ($M), summing to $1.122B




ITER Schedule
REGULATORY APPROVAL
Construction Agreement Initialled
ILE Established
CONSTRUCTION LICENSE
Months
0 12 24 36 48 60 72 84 96
CONSTRUCTION
EXCAVATE
Purchase Order
HVAC
1/2014 → 1/2015
SITE FABRICATI
PFC site fabrication bldg.
OTHER BLDGS.
Place first TF/VV in pit
Complete VV torus
Complete Blanket /Divertor Installation
TOKAMAK ASSEMBLY
Install cryostat bottom lid
Place lower PFC
Install CS
STARTUP & COMMISSIONING
SYSTEM STARTUP & TESTING
INTEGRATED COMMISSIONING
1/2007 → 1/2008
Complete leak & presure test
Magnet excitation
1st PLASMA
PROCUREMENT
PFC fab. start
Last PFC complete
MAGNETS
First purchase order
TFC fab. start
CS fab. start
Last TFC complete
CS fab. complete
VESSEL, BLANKET & DIVERTOR
First purchase order
First VV sector
Last VV sector
Last blanket and divertor

Next Steps Prior to Signing

- April 1, Principals' meeting in Tokyo whereby Heads of Delegation, Ray Orbach for US, will meet to resolve any remaining issues, then confirm text and call negotiations complete
  - also to be addressed are the Principal Deputy Director General Nominee and main management structure
- April 1-late May, Domestic reviews of all texts
- May 24, Ministerial meeting in Brussels

  All Documents 'initialed' and texts fixed
- US will submit text in early June to Congress for 120 day review, available for public review

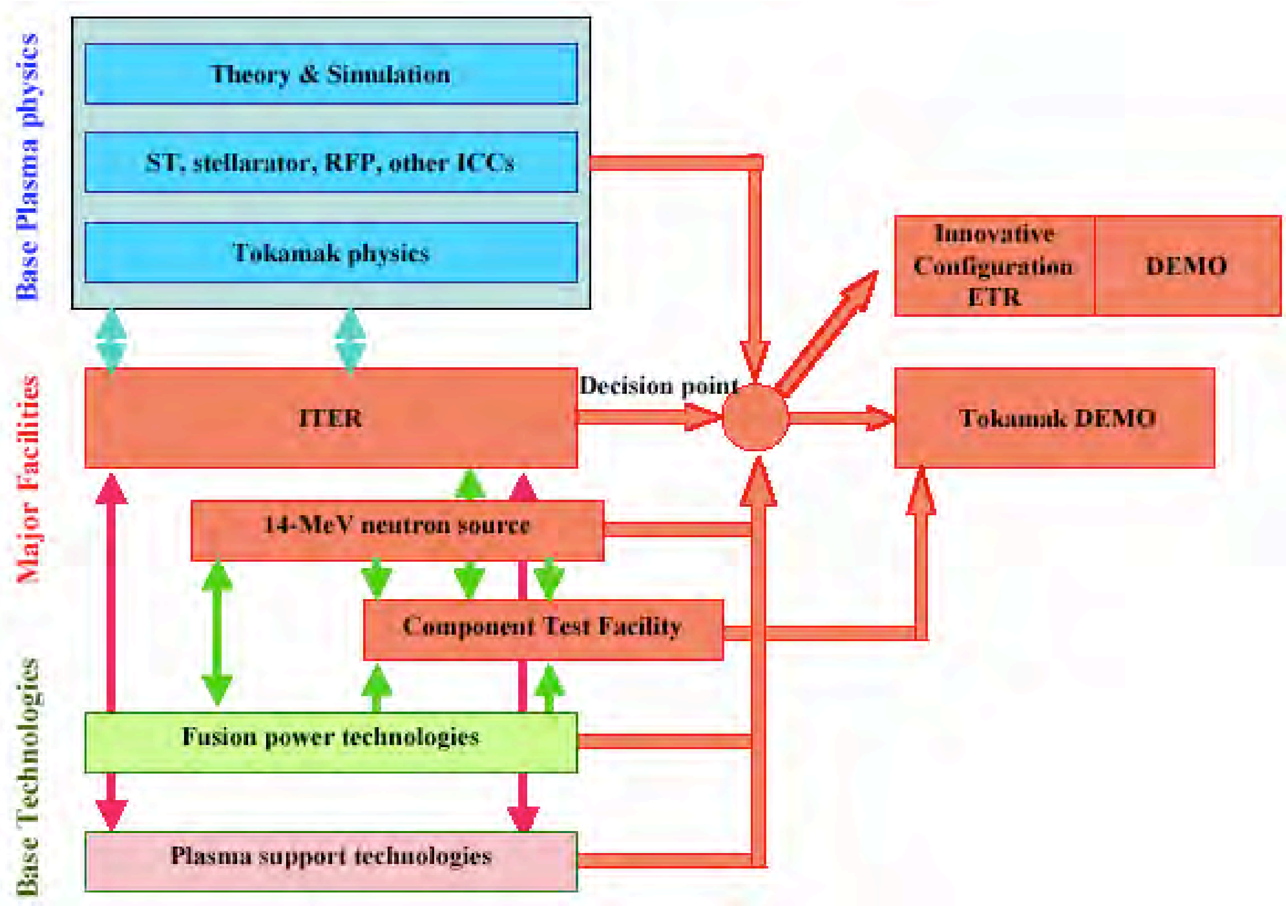
Signing and Ratification

- Next step is prepare for signing, a formal commitment of Executive Branch(es).
  - Seek inter-agency authorization for the US to sign
- Signing would be as early as end of 2006.
- Final step is Entry into Force, i.e. ratify and accept agreements, expected in early 2007.
- One of signed documents would be Provisional Applications allowing ITER Org. to start functioning at signing, before Entry into Force, except for P&I.
- P&I requires ratification by Legislatures (other 6) and action by President (for US)

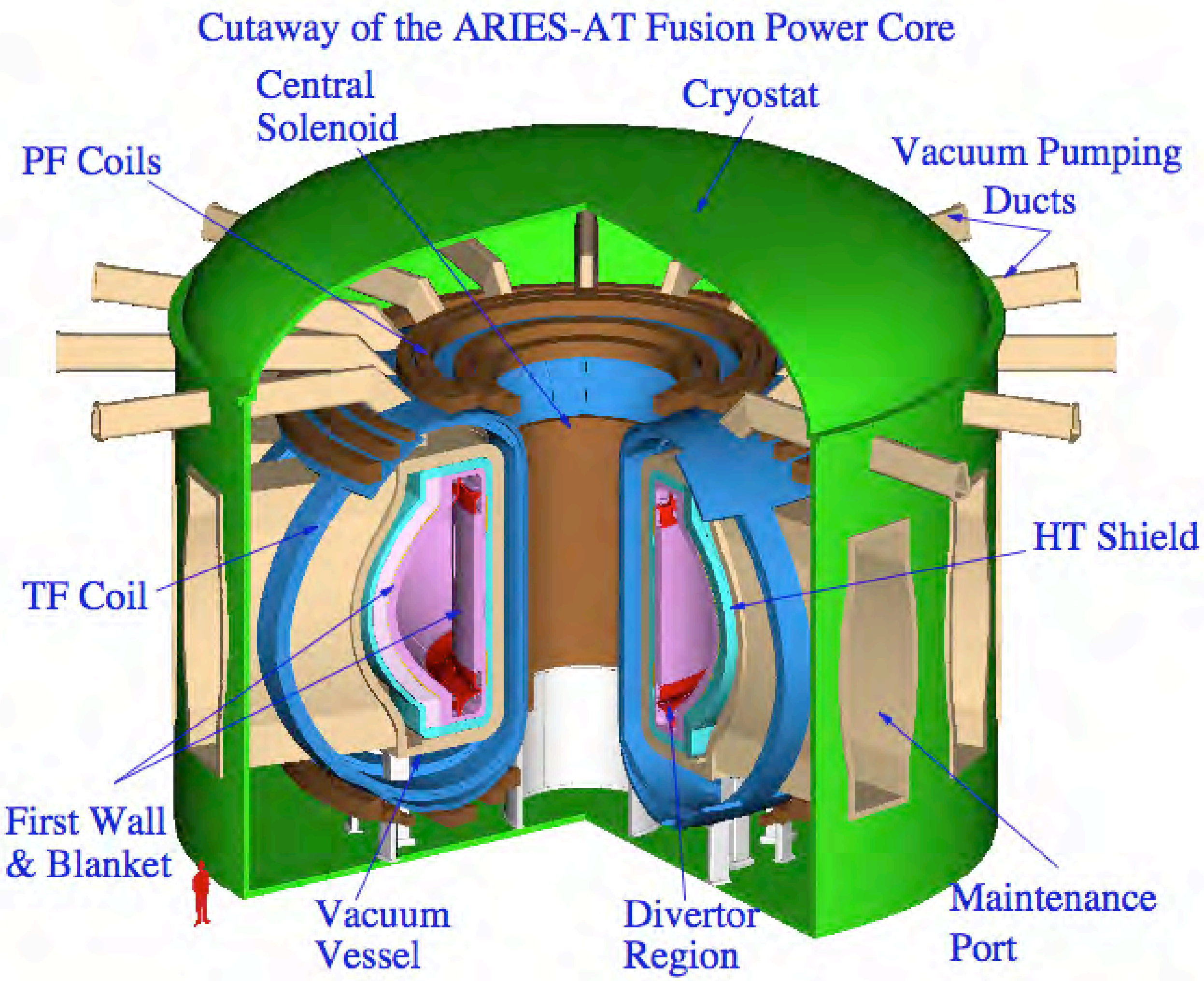
ITER Based Fusion Development Path

An international tokamak research program centered around ITER and including these national performance-extension devices has the highest chance of success in exploring burning plasma physics in steady-state.

- ITER will provide valuable data on integration of power-plant relevant plasma support technologies.
- Assuming successful outcome (demonstration of high-performance AT burning plasma), an ITER-based development path would lead to the shortest development time to a demonstration power plant.



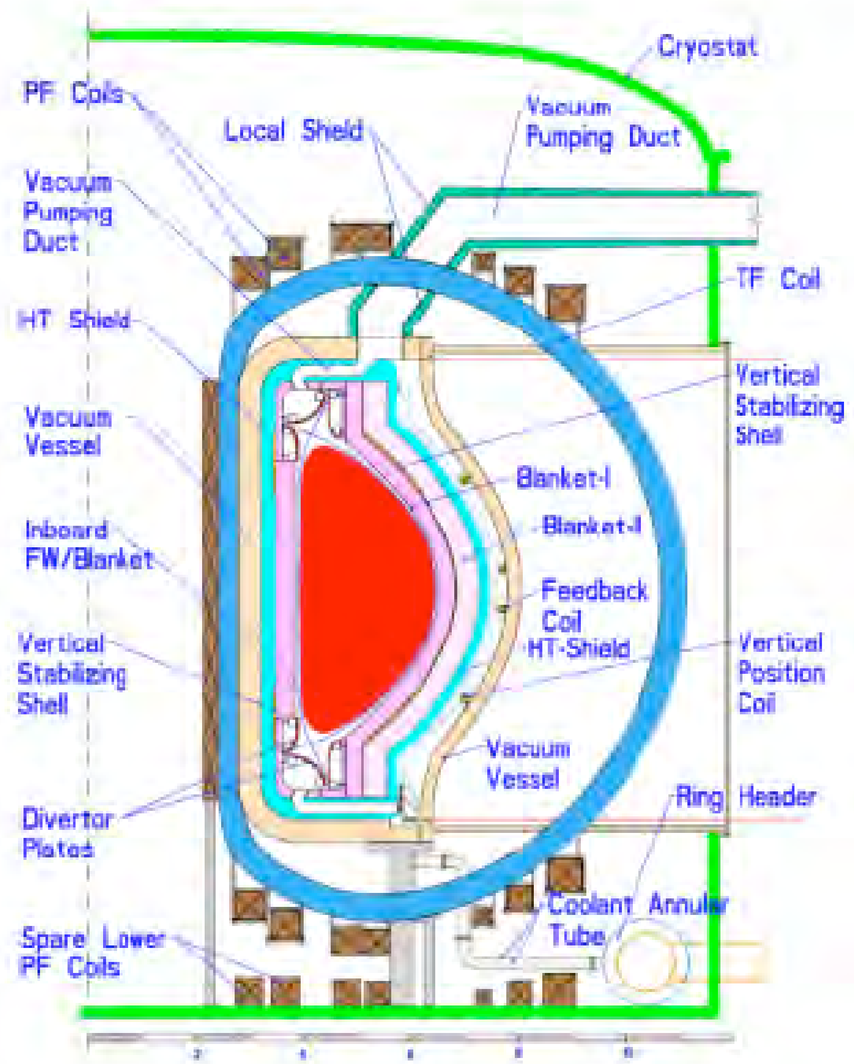
ARIES-AT IS PRESENT US TARGET FOR COMMERCIAL FUSION



ARIES-AT IS PRESENT US TARGET FOR COMMERCIAL FUSION

Table 1: Major Parameters of ARIES-AT

Plasma aspect ratio	4.0
Major toroidal radius (m)	5.2
Plasma minor radius (m)	1.3
Plasma elongation, κ_x	2.2
Plasma triangularity, δ_x	0.84
Toroidal β_N	5.4*
Toroidal β	9.2 %
Electron density (10^{20} /m^3)	2.3
Greenwald Density (10^{20} /m^3)	2.4
ITER-98H scaling multiplier	1.4
Plasma current (MA)	13
CD power to plasma (MW)	36
On-axis toroidal field (T)	6.0
Peak field at TF coil (T)	11.4
Thermal cycle efficiency	59%
Average neutron load (MW/m^2)	3.3
Fusion power (MW)	1,755
Recirculating power fraction	14%
Net plant efficiency	51%
Cost of electricity (c/kWh)	5



CONCLUDING REMARKS

- DRAMATIC PROGRESS IN 1990'S HAS ESTABLISHED A SOUND BASIS FOR EXPLORATION OF THE 'BURNING' FUSION PLASMA REGIME.
- US WORKING WITH INTERNATIONAL COMMUNITY IS NOW READY TO BUILD THE WORLDS FIRST MAGNETICALLY CONFINED BURNING FUSION PLASMA EXPERIMENT: ITER
- ITER SUCCESS WOULD REPRESENT FOR FUSION ENERGY THE SAME MILESTONE AS THE FIRST NUCLEAR CHAIN REACTION BY FERMI UNDER THE UNIVERSITY OF CHICAGO STADIUM IN 1942 WAS FOR FISSION ENERGY.