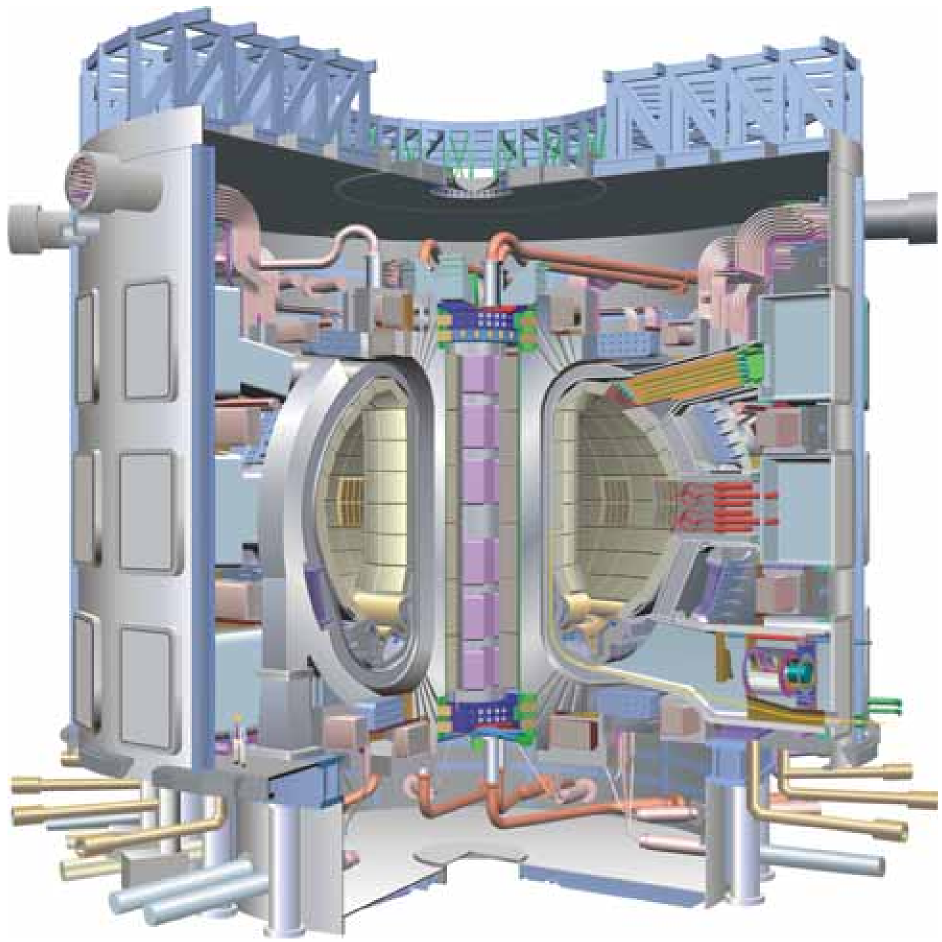
U.S. Contributions to ITER

Exploring Magnetically-Confined
Burning Plasmas
in the Laboratory
with
Early Integration of
Physics and Technology



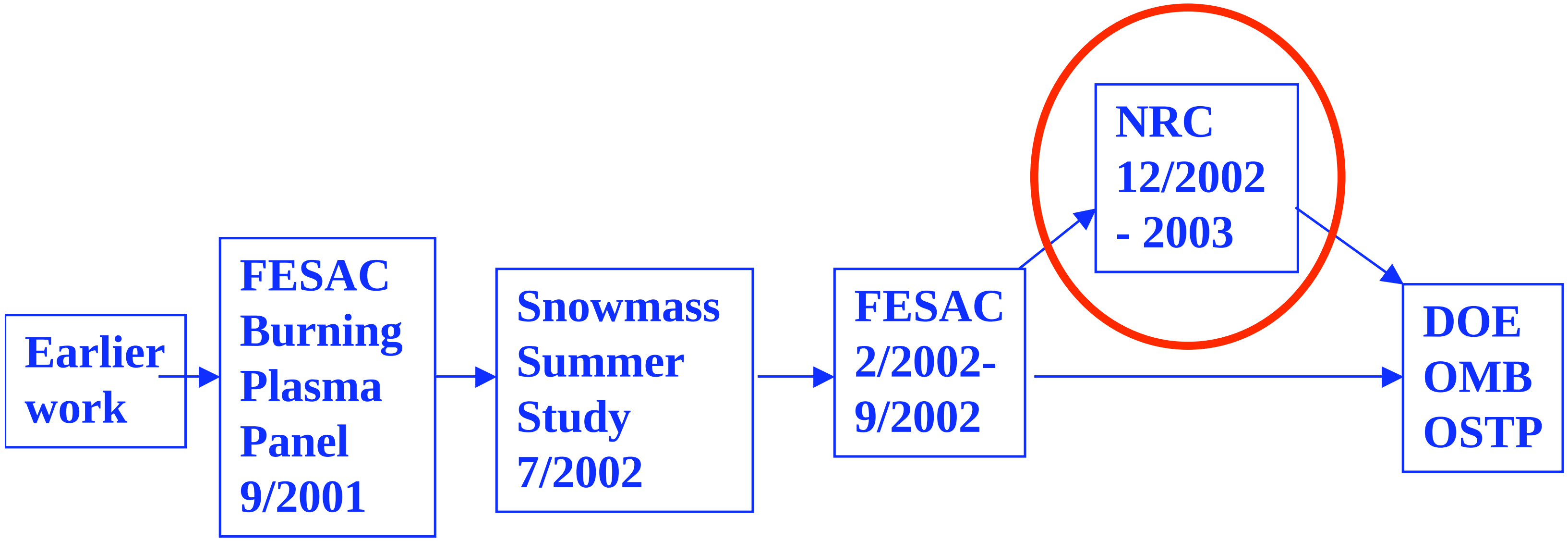
Ned Sauthoff
ISFNT-7
Tokyo, Japan
May 27, 2005

Roadmap

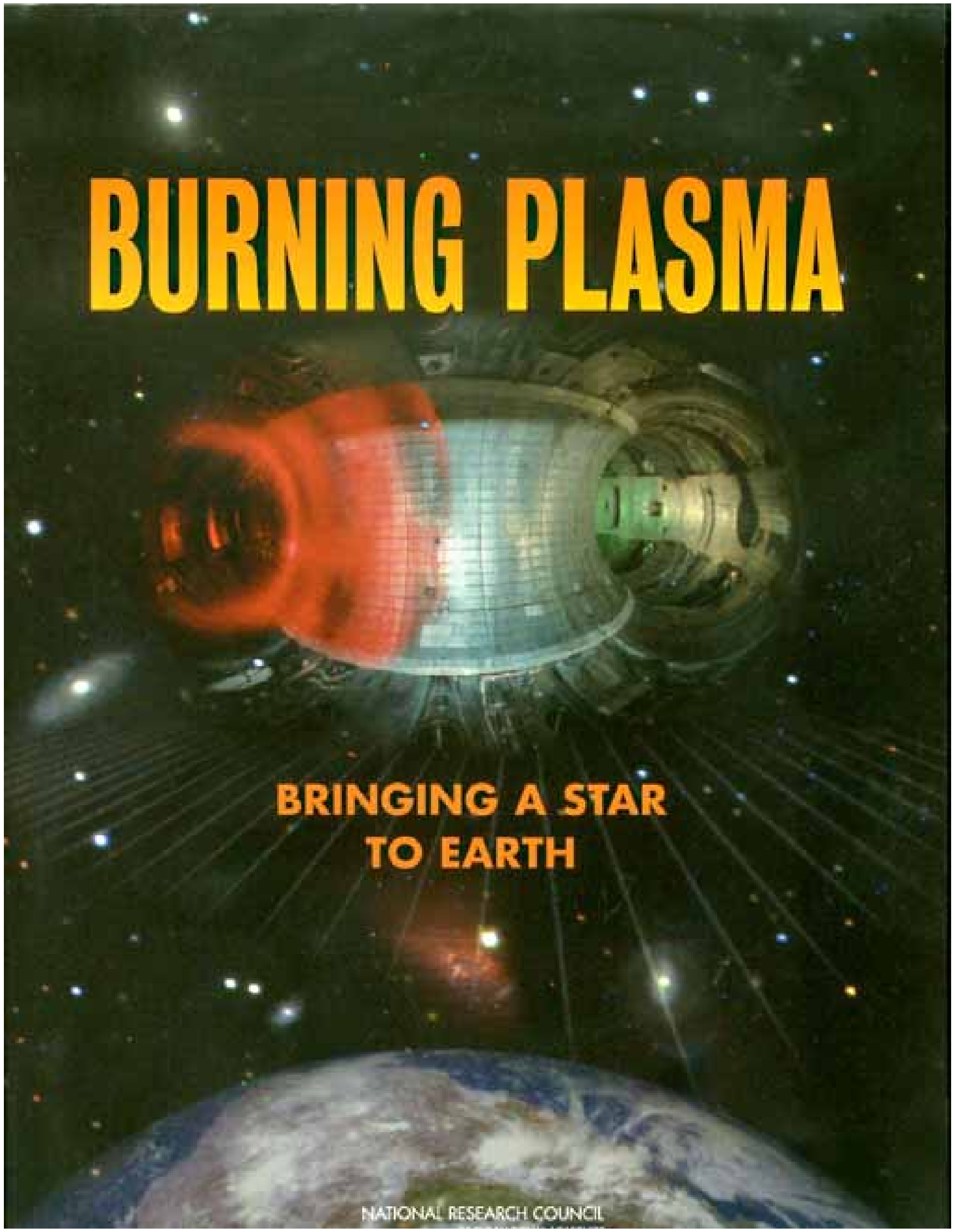
- US path to participation in ITER
- US technical preparations for ITER
- US organizational preparations for ITER

A look to the future

The path to the US decision on Burning Plasmas and participation in ITER negotiations



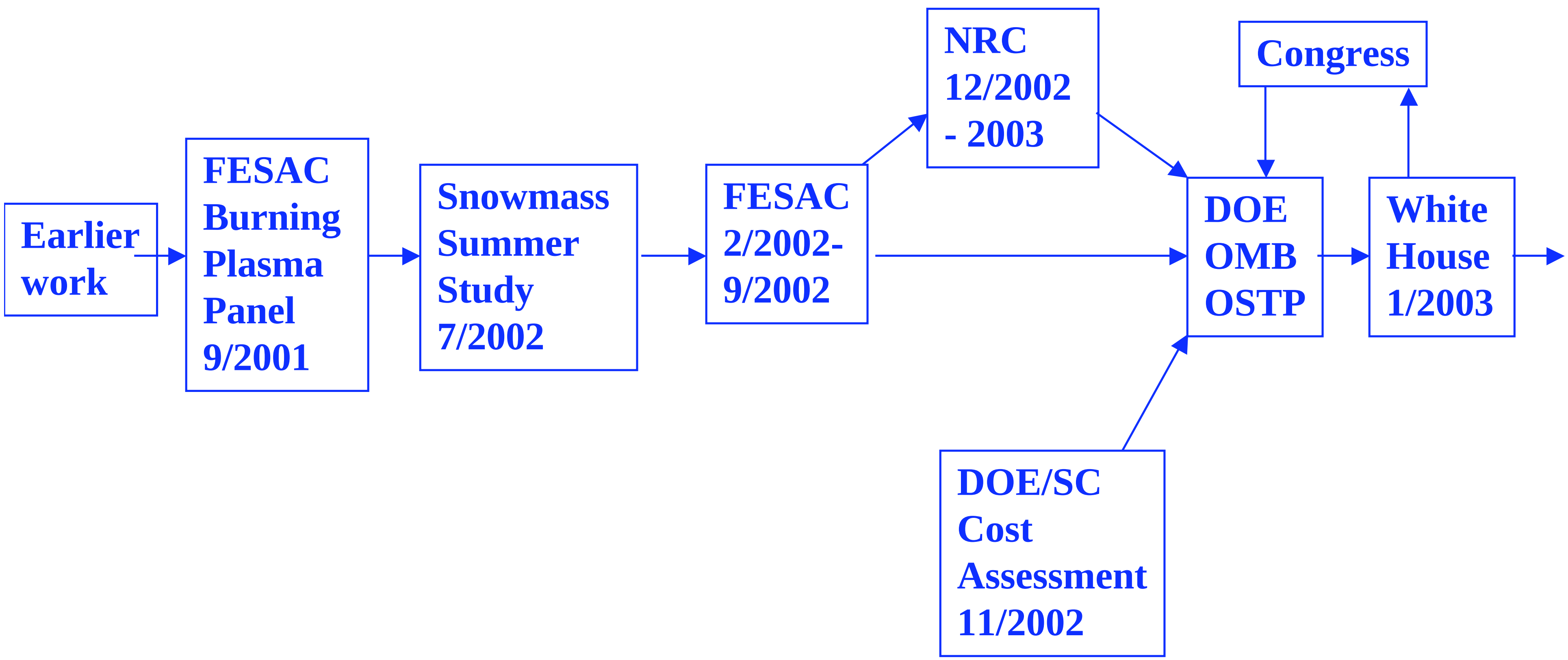
NRC Burning Plasma Report



"The United States should participate in ITER.

If an international agreement to build ITER is reached, fulfilling the U.S. commitment should be the top priority in a balanced fusion science program."

The path to the US decision on Burning Plasmas and participation in ITER negotiations



US decision on joining ITER Negotiations (1/30/03)

"Now is the time to expand our scope and embrace international efforts to realize the promise of fusion energy.

Now it is time to take the next step on the way to having fusion deliver electricity to the grid.

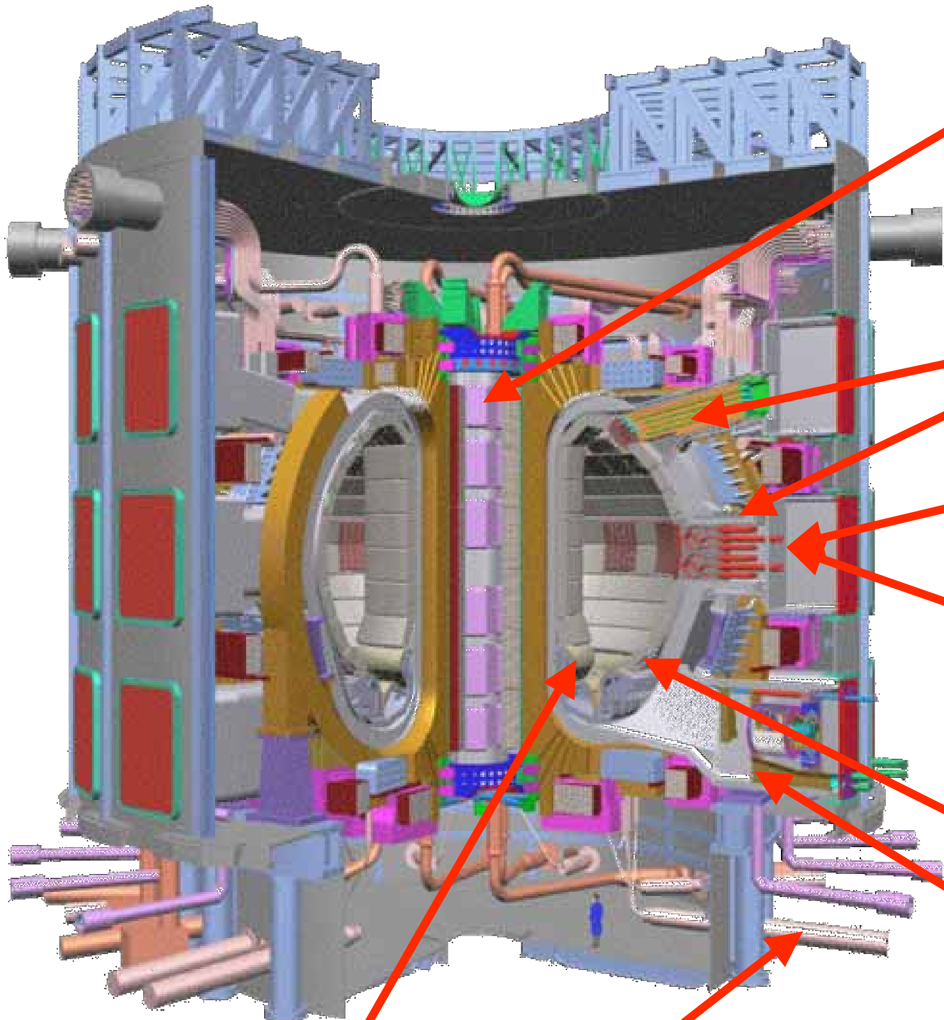
Therefore, I am pleased to announce today, that
President Bush has decided that the United States will join the international negotiations on ITER."

(Energy Secretary Abraham at PPPL)

NSSG Activities

- Management Structure
- Procurement Systems/Methods
- Risk
- Procurement Allocations
- Staffing
- Financial Regulations
- Intellectual Property
- Decommissioning

U.S. provisional “in-kind contribution” scope



4 of 7 Central
Solenoid Modules

Steady-state
power supplies

15% of port-based
diagnostic packages

44% of ICRH antenna +
all transmission lines,
RF-sources, and power supplies

Start-up gyrotrons,
all transmission lines
and power supplies

Blanket/Shield 10%

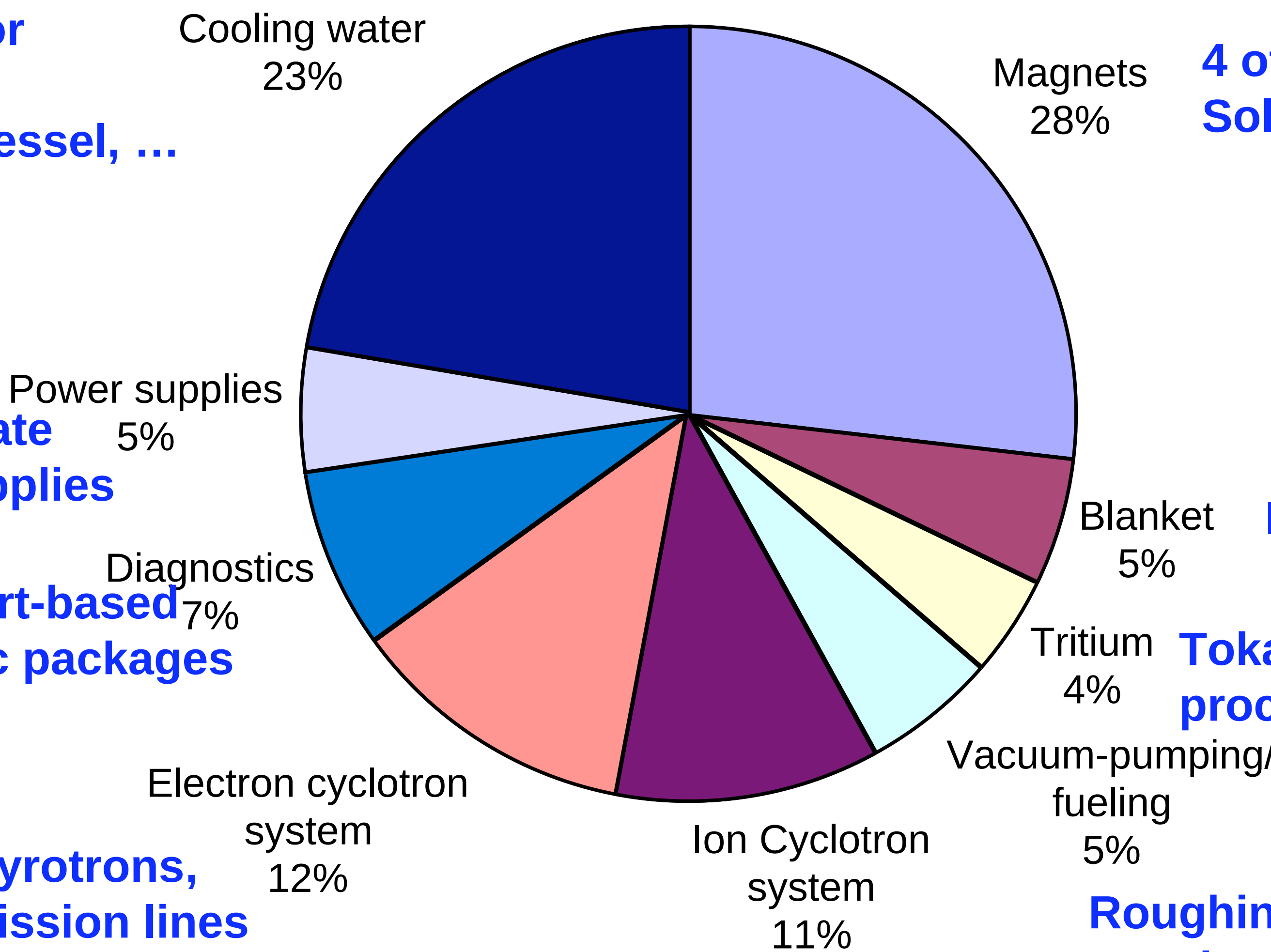
Roughing pumps,
standard components

pellet injector

Cooling for
divertor,
vacuum vessel, …

Tokamak exhaust
processing system

Tentative US in-kind contributions by Value
(total US in-kind contribution ~ 10%)



Cooling for divertor, vacuum vessel, …

4 of 7 Central Solenoid Modules

Steady-state power supplies

Baffle

15% of port-based diagnostic packages

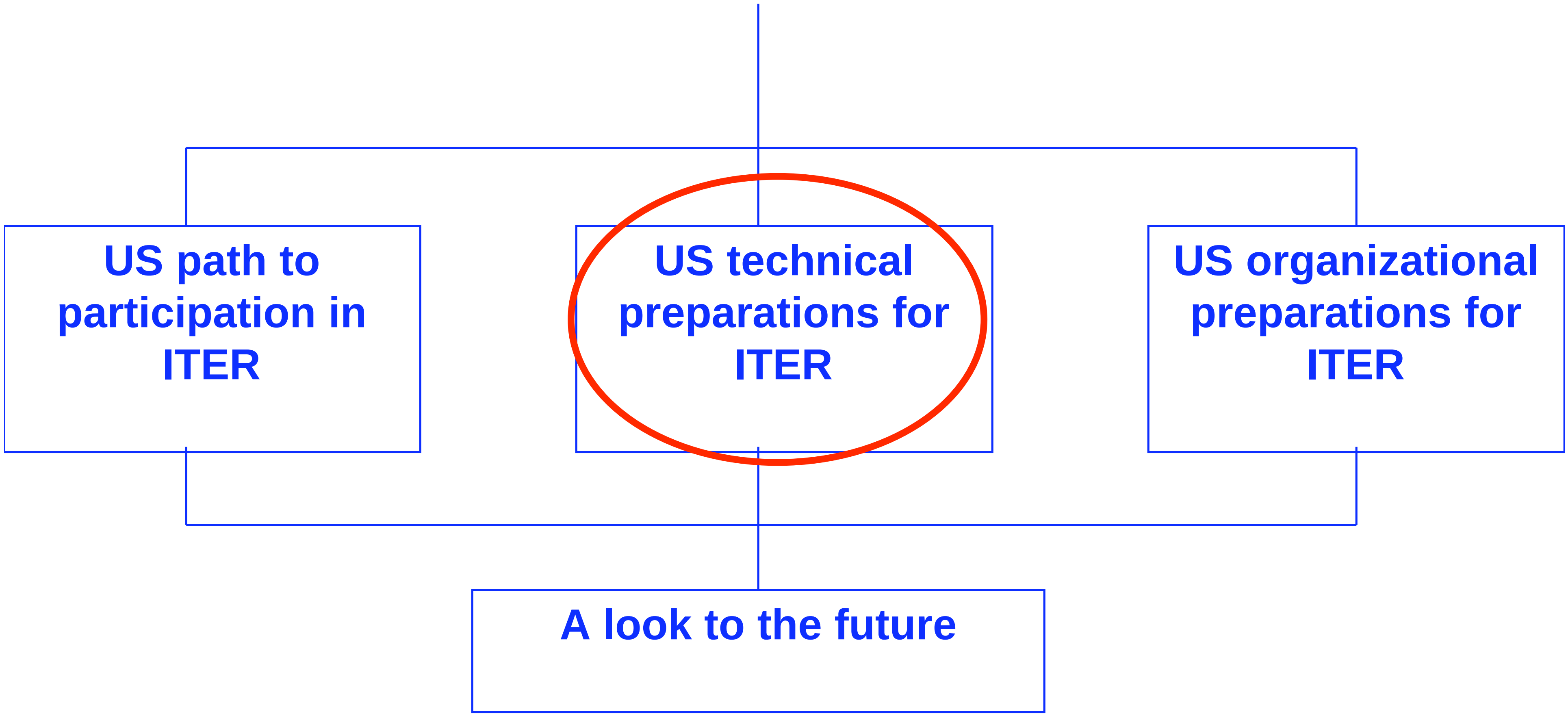
Tokamak exhaust processing system

Start-up gyrotrons, all transmission lines and power supplies

44% of antenna + all transmission lines, RF-sources, and power supplies

Roughing pumps, standard components, pellet injector

Roadmap


US path to participation in ITER
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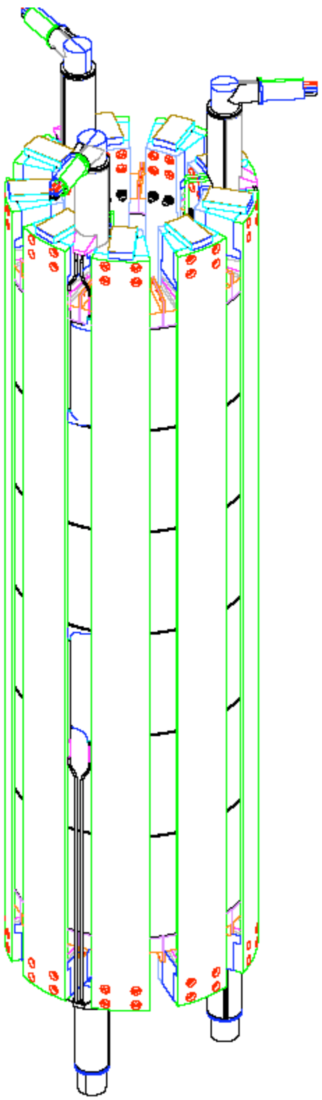
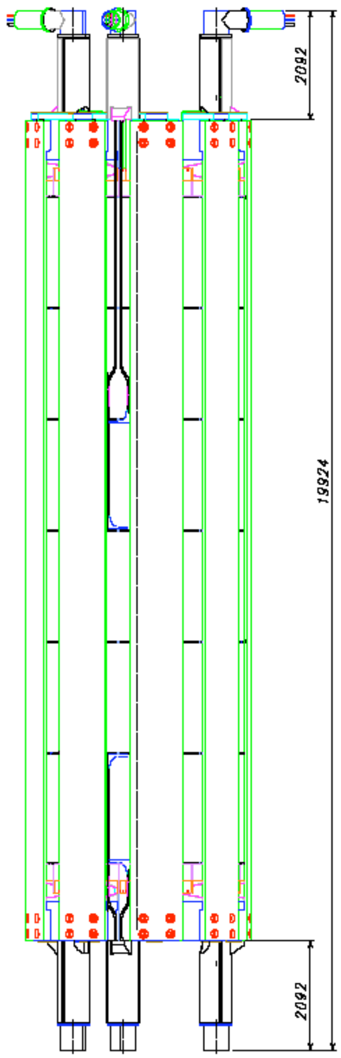
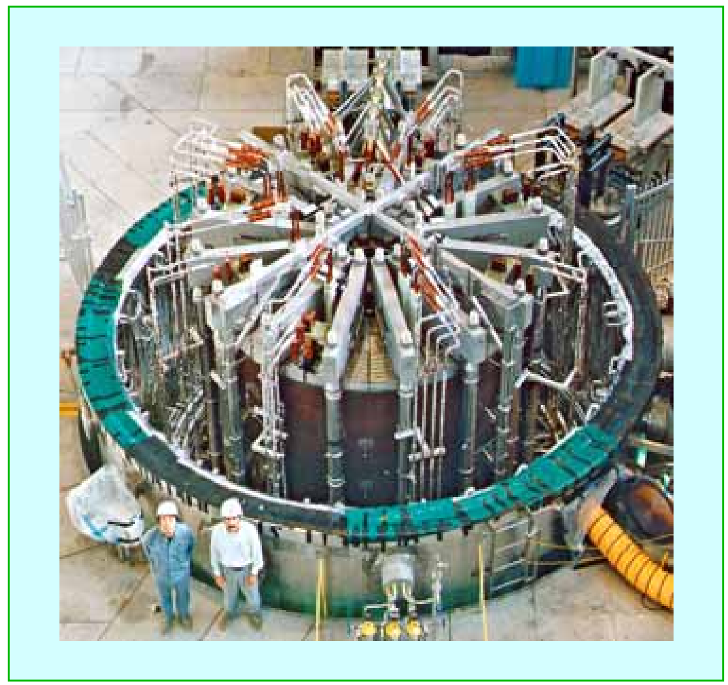
The US is provisionally responsible for 4 of 7 Central Solenoid Modules



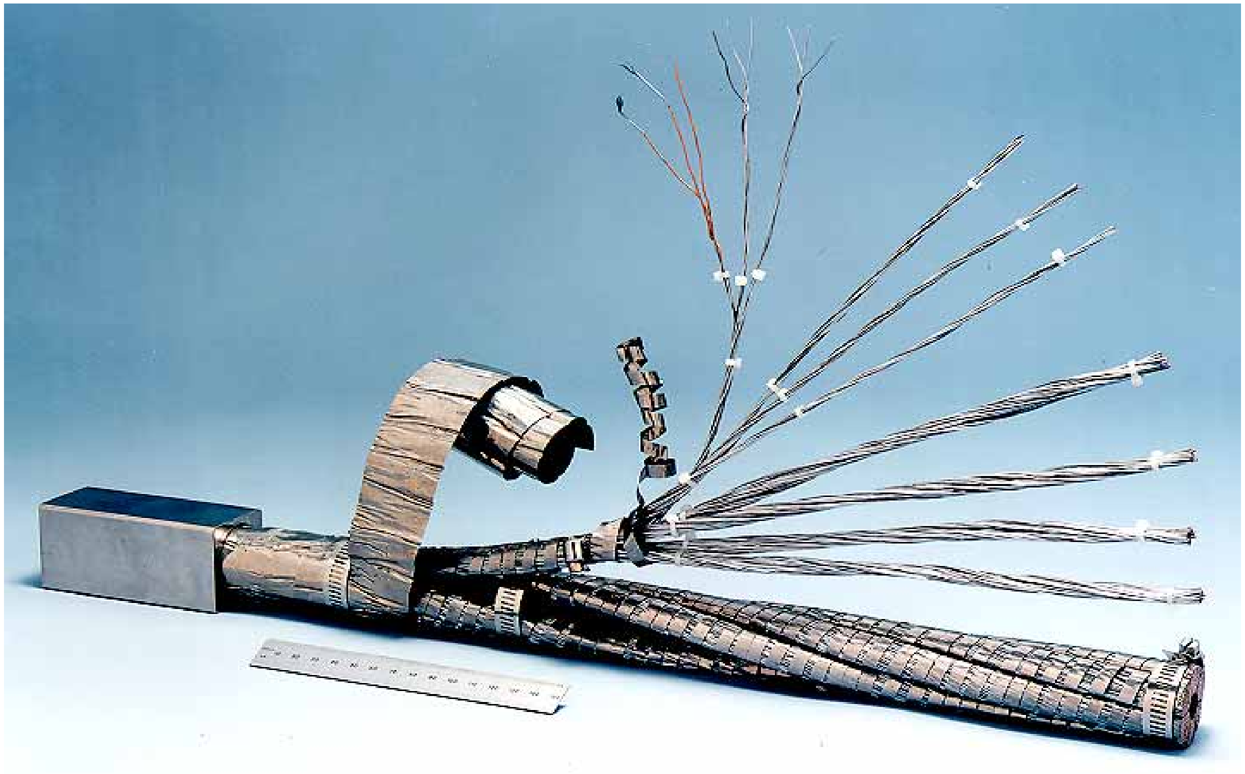


Each Module is slightly larger than the complete CS Model Coil



Central Solenoid Activities

- **Domestic research and development aimed at addressing areas of risk**
  - J_c (current density)
  - Jacket material and impacts
  - Joints
- **Secondees for design and documentation**



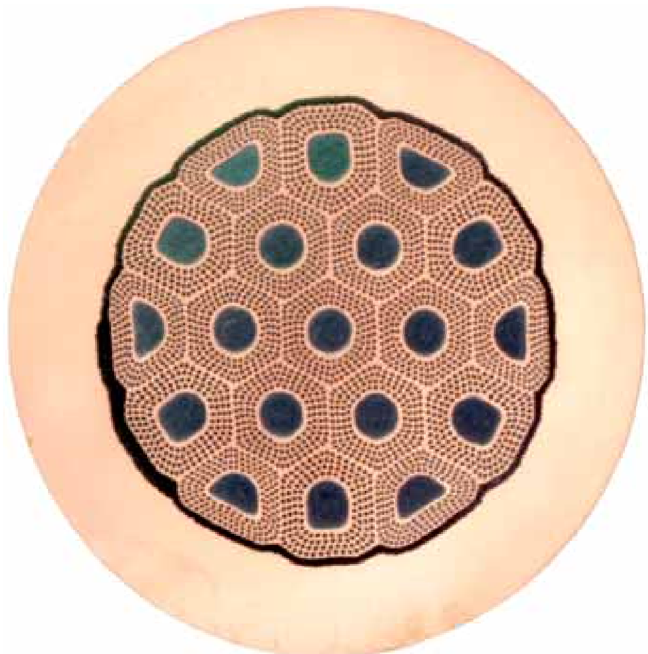
Qualification of industrial suppliers of Nb_3Sn strands with increased value of J_c

- **In FY04, the US placed contracts for the development and qualification of >100kg of superconducting strand Products are due in May 2005**

- **In FY05, the products will be tested.**

- **In FY06, larger-volume prototypes will be procured.**

- **In FY07, initial production orders could be placed if the IO's specifications are finalized and the procurement packaged agreed.**



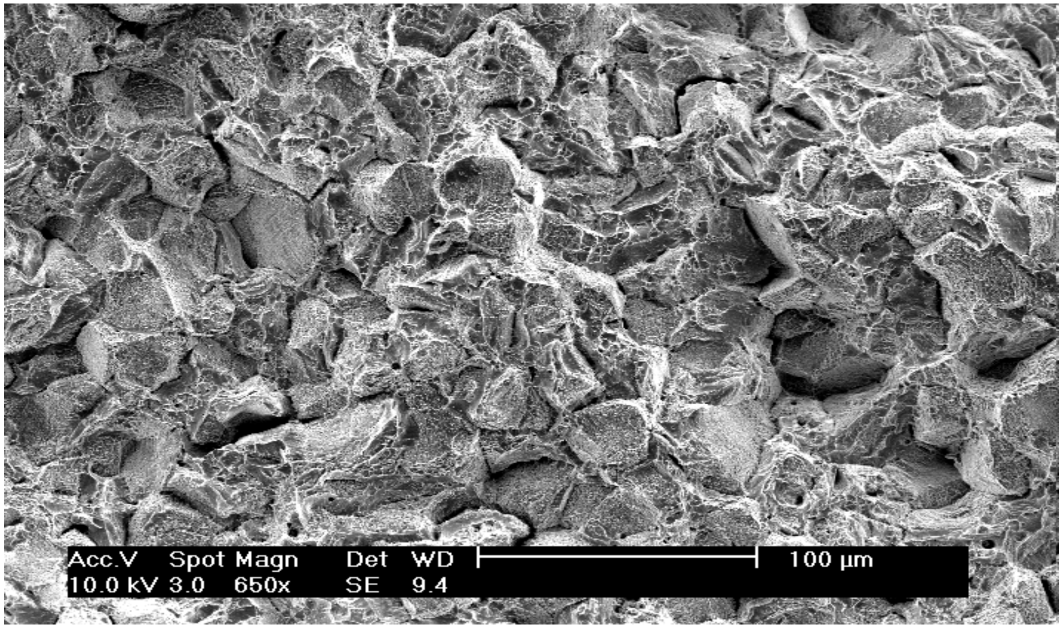
Typical strand layout as proposed by OST. Diameter is ~0.8 mm.

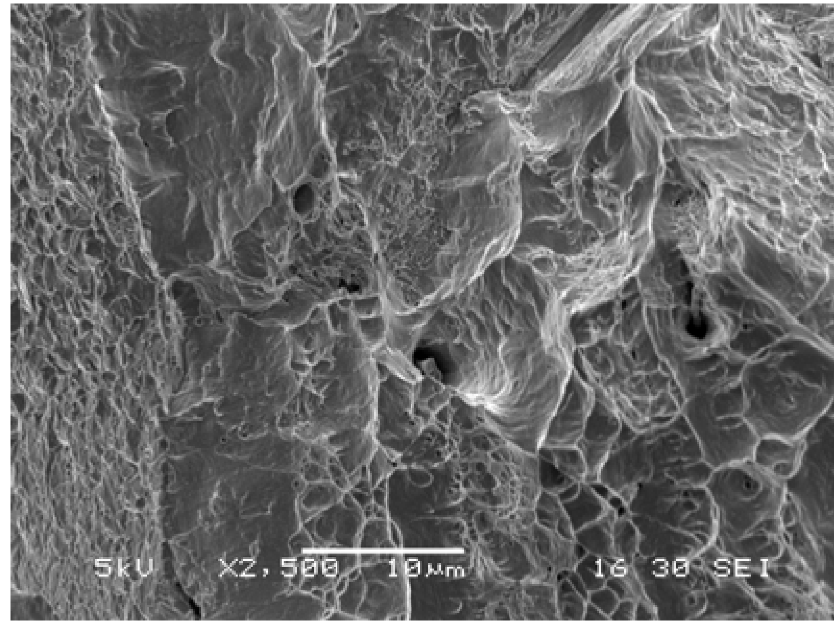
Conductor Performance and Design Criteria

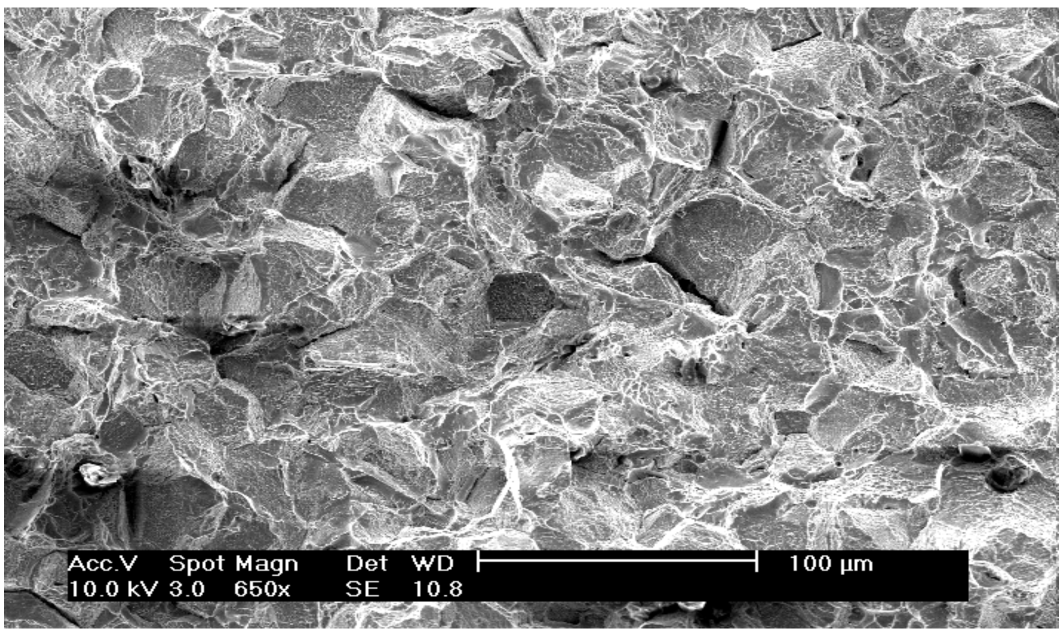
- Both SS- and Ti-jacketed samples are included to help understand effects of expansion-mismatch on conductor performance.

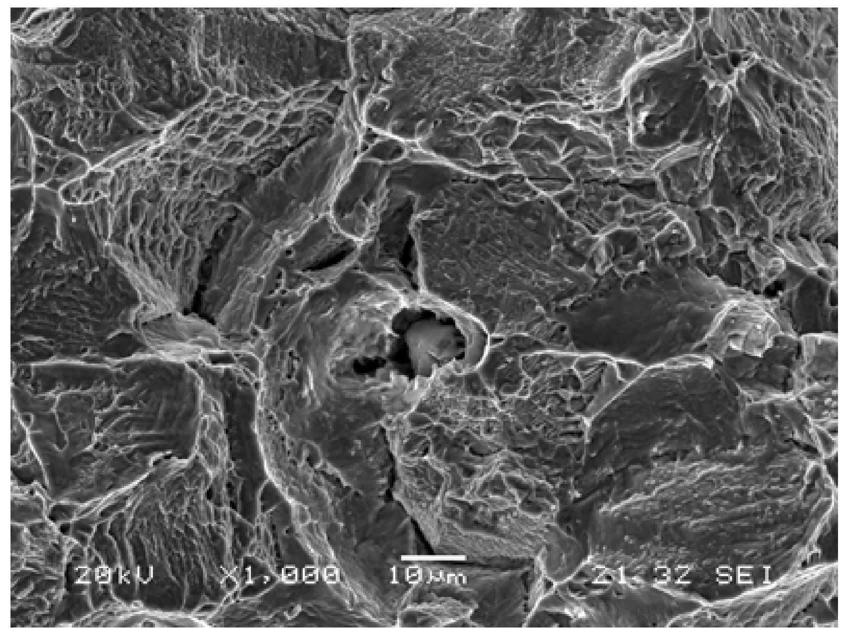
- Cable samples are undergoing testing in the Sultan facility.

Fractographic studies of jacket material to determine mechanisms

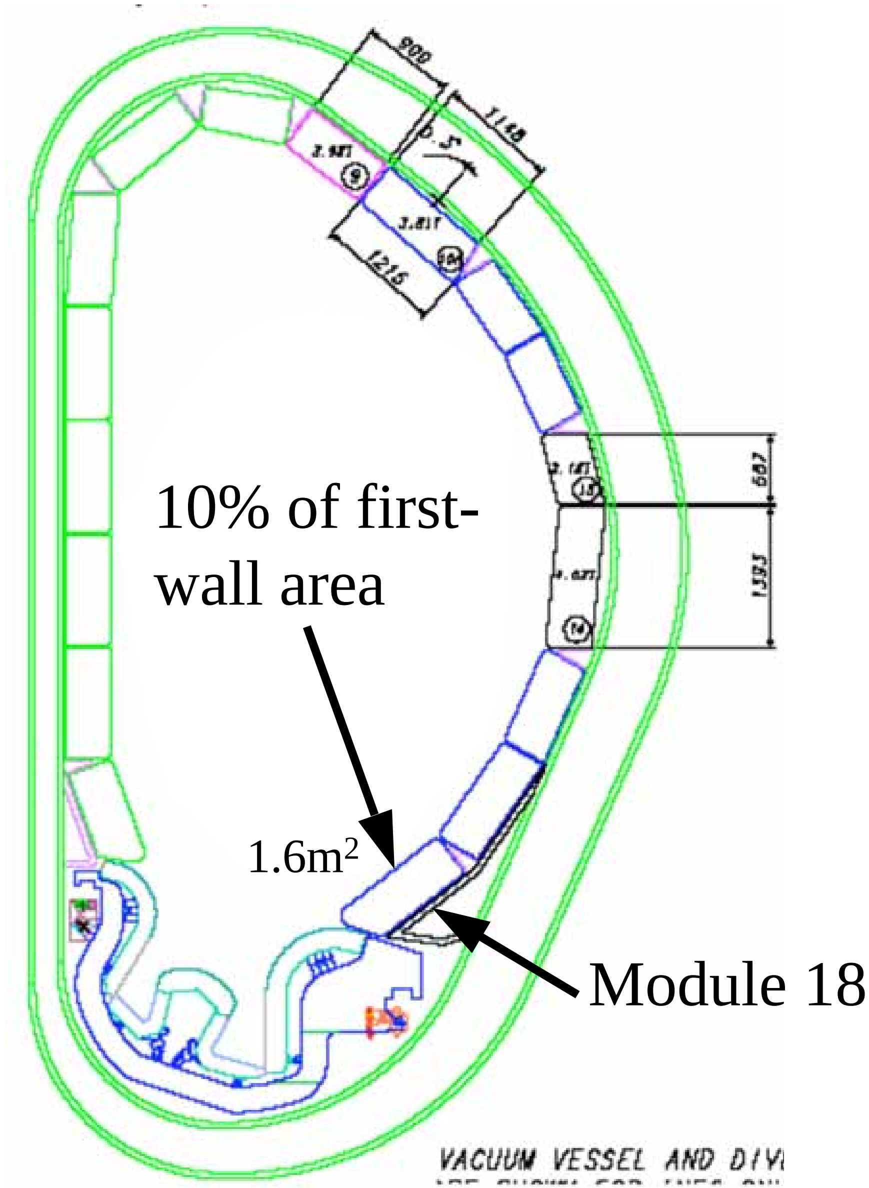








The US is provisionally responsible for all 36 of Module 18 in the First Wall/Shield



- **Design issues:**
  - Electromagnetic forces during disruptions
    - Greater segmentation
    - Better modeling
  - Modifications of the cooling paths by segmentation
  - Viewing slots
  - Ease of remote maintenance

US First Wall Activity

- **Domestic R&D and Design Tasks**
  - Qualification of the FW panel fabrication methods and to establish the NDT method for the FW panel.
  - EM Analysis of modules and dynamic analysis of the key.
  - Detailed design of blanket modules and thermal hydraulic analysis of the shield block and the total blanket system.
  - Development of the welded joint for the first wall leg, suited for cut and re-welding in the Hot Cell
  - Analysis of erosion of the ITER first wall due to plasma impingement
- **Secondees for design**
  - Richard Nygren (Sandia), Tom Lutz/Tina Tanaka (Sandia)

Areas of commonality motivate an integrated approach…

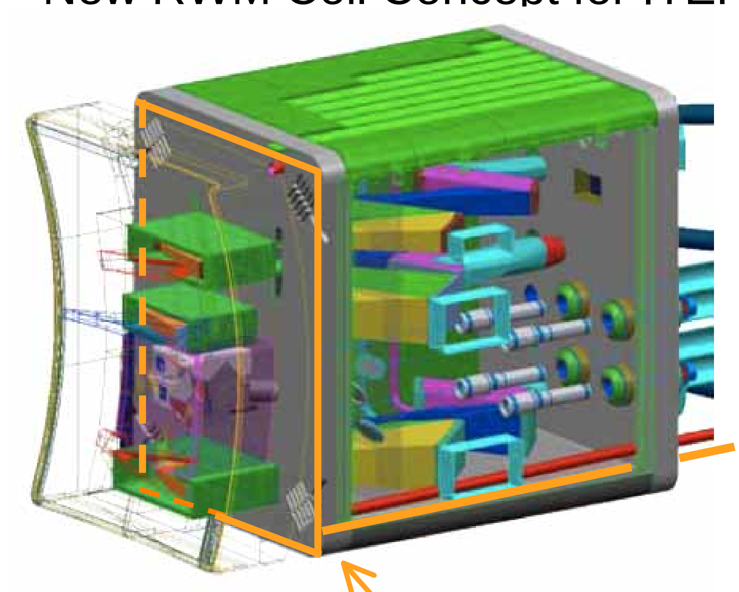
- **Several ITER systems share issues:**
  - Shield/blanket
  - Ion cyclotron antenna
  - Electron cyclotron launcher
  - Diagnostic port plugs
  - Test blanket modules

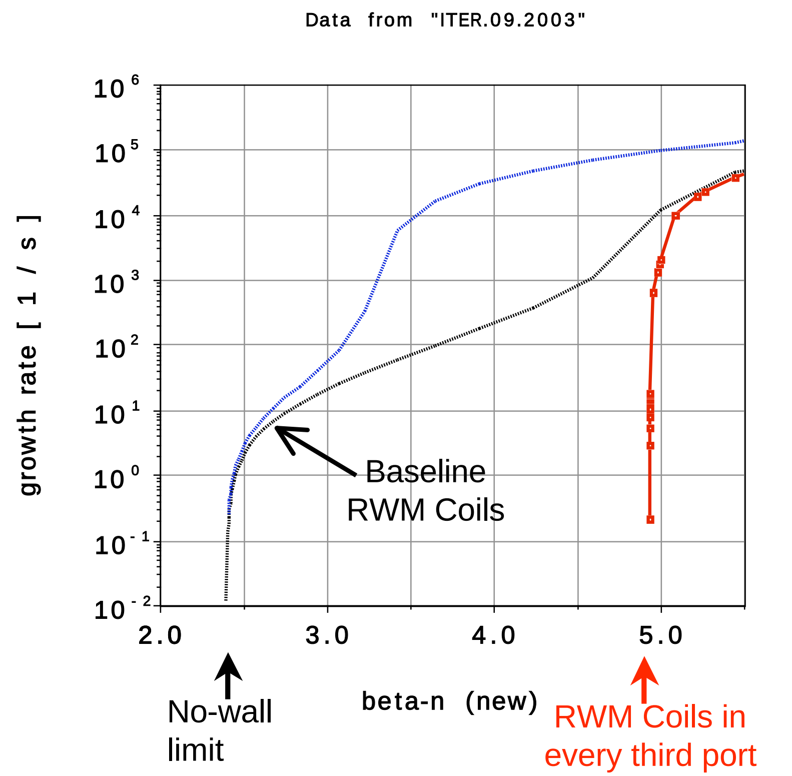
- **Issues**
  - Plasma-facing materials and structures
  - Surface-power handling
  - Forces from disruptions, …
  - Neutron shielding
  - Volume-power handling / power extraction

- **Commonality motivates shared integrated approaches**
  - 3-D neutronics analyses, and integration with CAD
  - Thermohydraulics
  - Plasma-facing structures, materials and fabrication technologies

Port plug studies also explore opportunities for improved plasma performance by internal RWM Feedback Coils to increase ITER's β-limit

New RWM Coil Concept for ITER



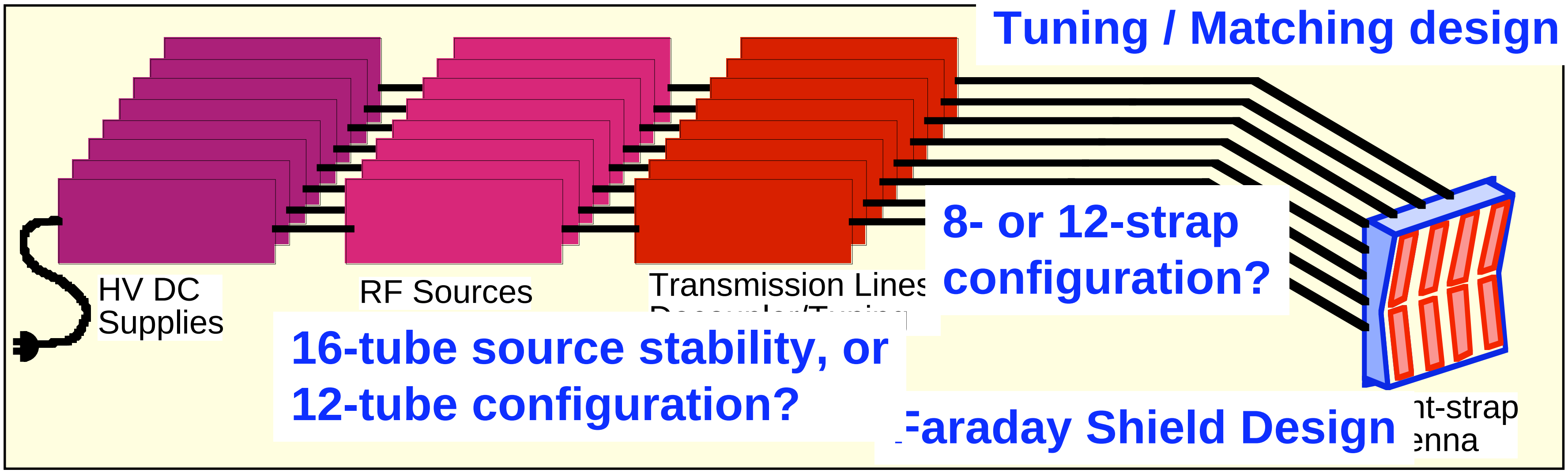


- Baseline RWM coils located outside TF coils

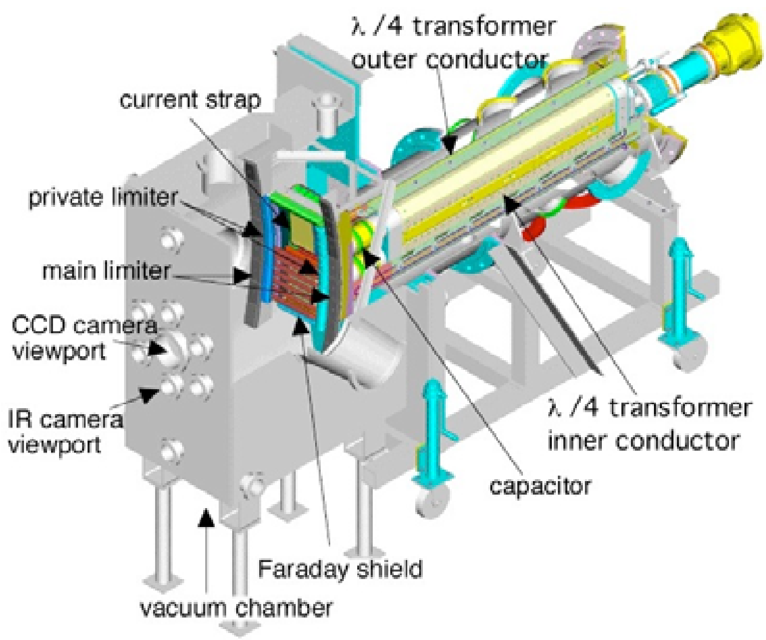
- **RWM coils might be located on port shield plugs inside the vacuum vessel.**

Closer RWM coils would have large stabilizing effect on n=1

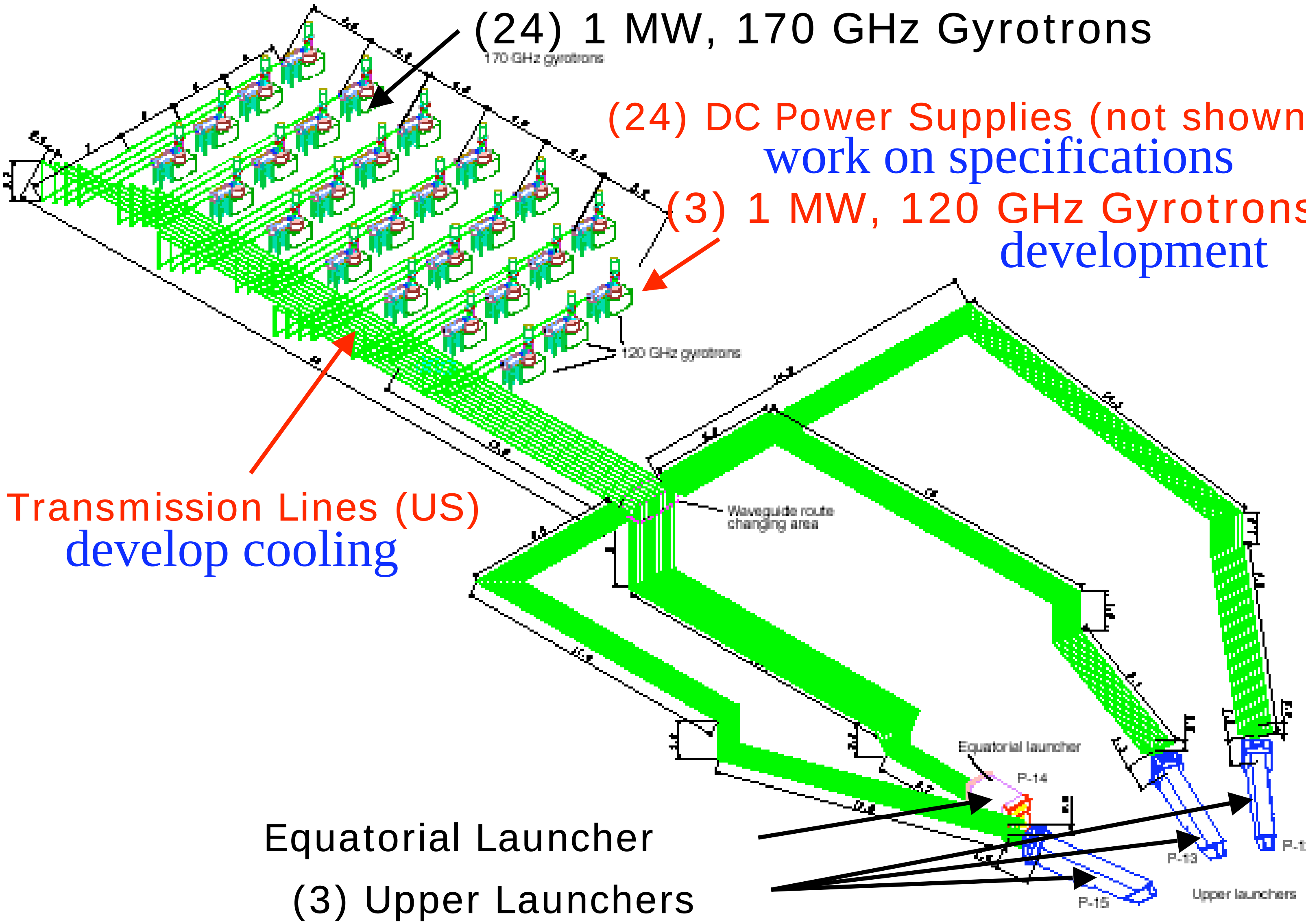
Overview of the ITER IC system



ITER ion cyclotron system block diagram



Electron Cyclotron System Configuration



(24) 1 MW, 170 GHz Gyrotrons

(24) DC Power Supplies (not shown) (US)
work on specifications

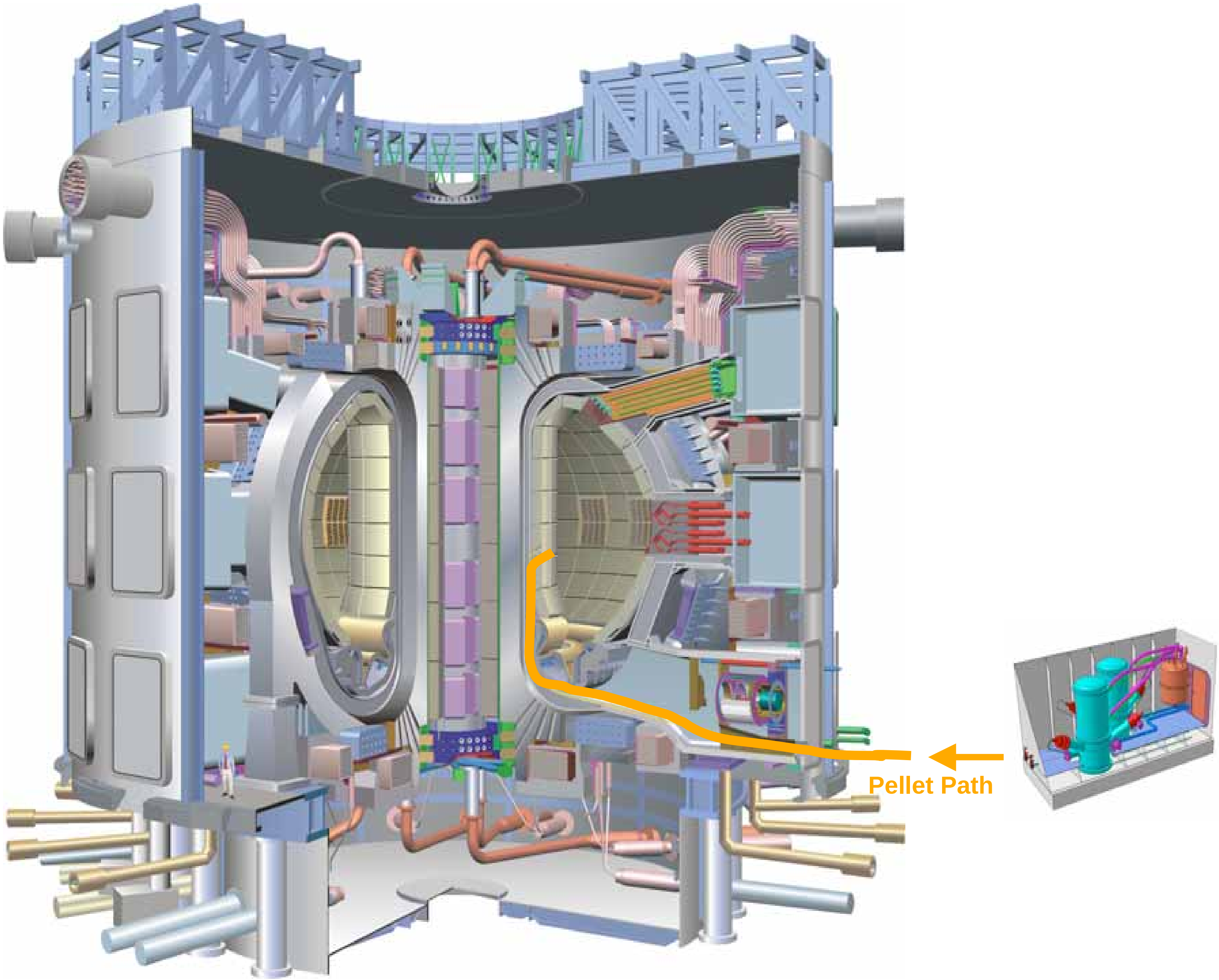
(3) 1 MW, 120 GHz Gyrotrons (US)
development

Transmission Lines (US)
develop cooling

Equatorial Launcher

(3) Upper Launchers

High Field Side Pellet-Launch being developed



Overview of ITER Tritium Plant

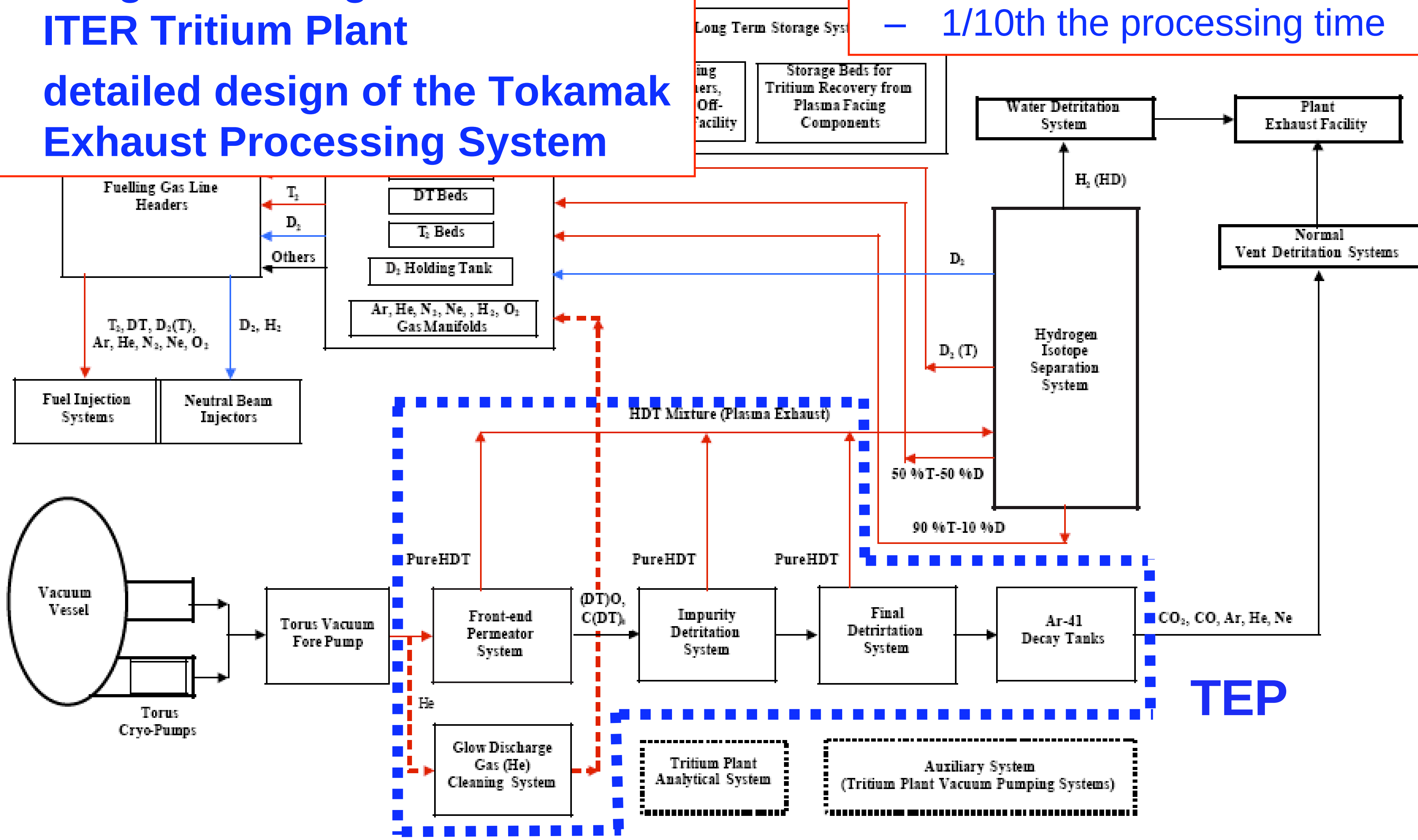
FY05-06 activities

- **integrated design of the overall ITER Tritium Plant**
- **detailed design of the Tokamak Exhaust Processing System**

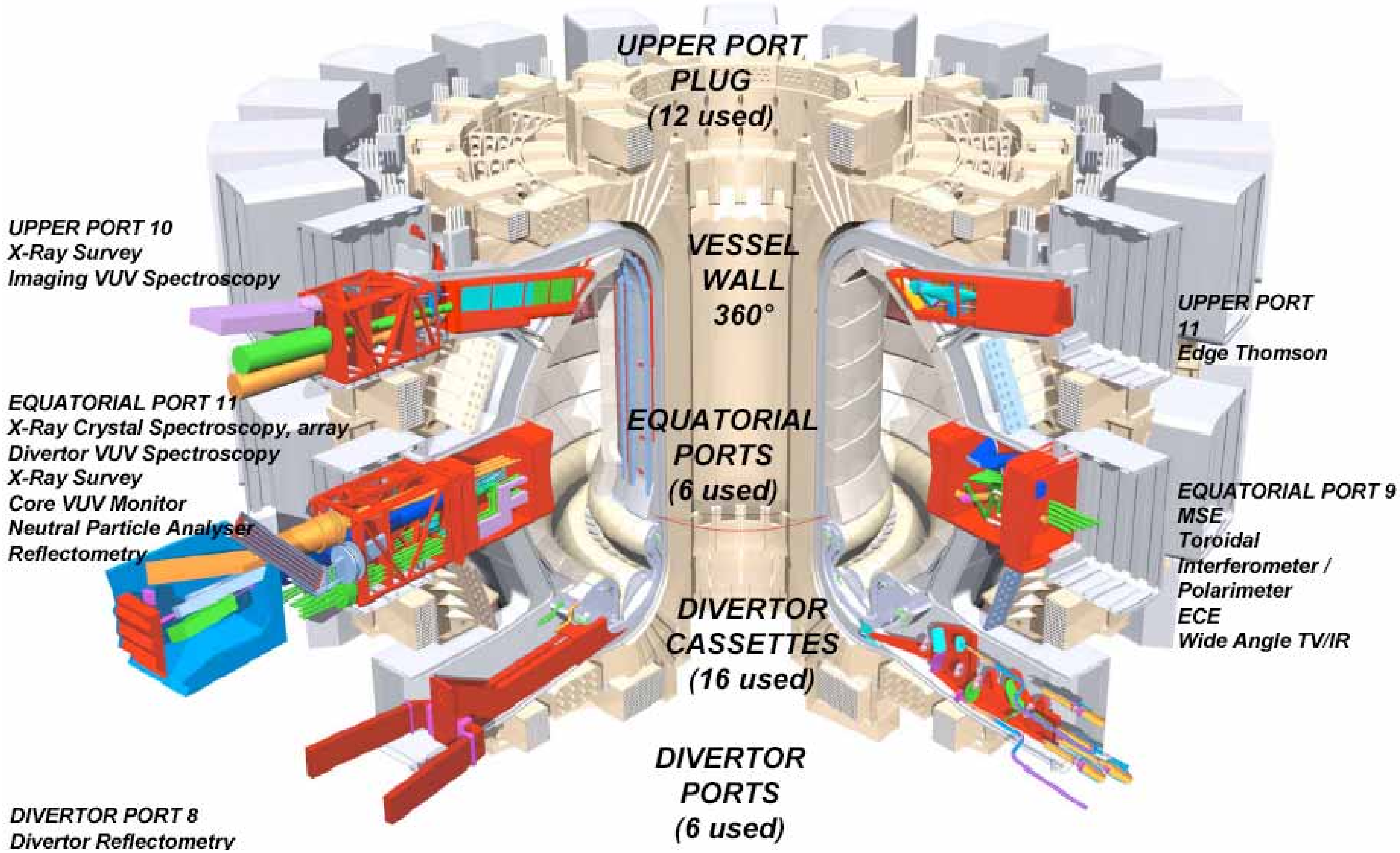
– 10x's flowrate

– 10x's inventory (initial ITER charge of tritium ~1000 gm, expensive, and ~5% of available supply)

– 1/10th the processing time



The US is expected to provide 2 Midplane-ports, 2 Upper-Ports, and 1 Divertor-port



Diagnostics activities

- **Diagnostic Working Group**
  - Completed its recommendation on packaging of diagnostic allocations
  - Port-based allocation was accepted by the International Team/Participant Team Leaders

- **Port-Plug Task Force**
  - Developing approaches to the design and integration of port-plugs

- **Diagnostic Design**
  - Specifications of the diagnostic
  - Integrated design of the instrument
  - Component selection
  - Integration in the Port-Plug

Test Blanket Module Program

- **Objective:**
  - Develop the technology necessary to address the critical “tritium supply” issue
  - First integrated experiments on breeding blanket and first wall components and materials in a fusion environment

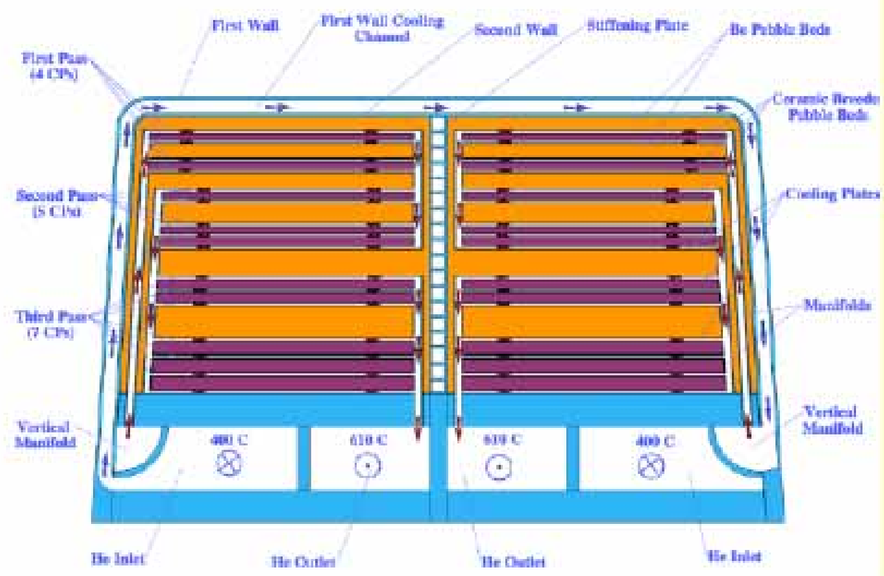
- **US approaches, via joint research with other parties:**
  - A helium-cooled solid breeder concept with ferritic steel structure and beryllium neutron multiplier, but without an independent TBM
  - A Dual-Coolant Pb-Li liquid breeder blanket concept with self-cooled LiPb breeding zone and flow channel inserts (FCIs) as MHD and thermal insulator

- **Activities:**
  - TBM designs, analysis, and design description documents
  - Simulations of PbLi MHD flow in complex geometries with flow channel inserts (experiments being developed)
  - Simulations and experiments on packed particle bed (ceramic and metallic) thermomechanical response and physical properties
  - Planning for medium-term mockup fabrication and testing with international community

Helium-Cooled Solid Breeder Blanket and First Walls Concepts

Idea of "Solid Breeder" concepts –
Tritium produced in immobile lithium ceramic and removed by diffusion into purge gas flow

- ❑ **First wall / structure / multiplier /breeder all cooled with helium**
- ❑ **Beryllium multiplier and lithium ceramic breeder in separate particle beds separated by cooling plates**
- ❑ **Temperature window of the ceramic breeder and beryllium for the release of tritium is** a **key issue for solid breeder blanket.**



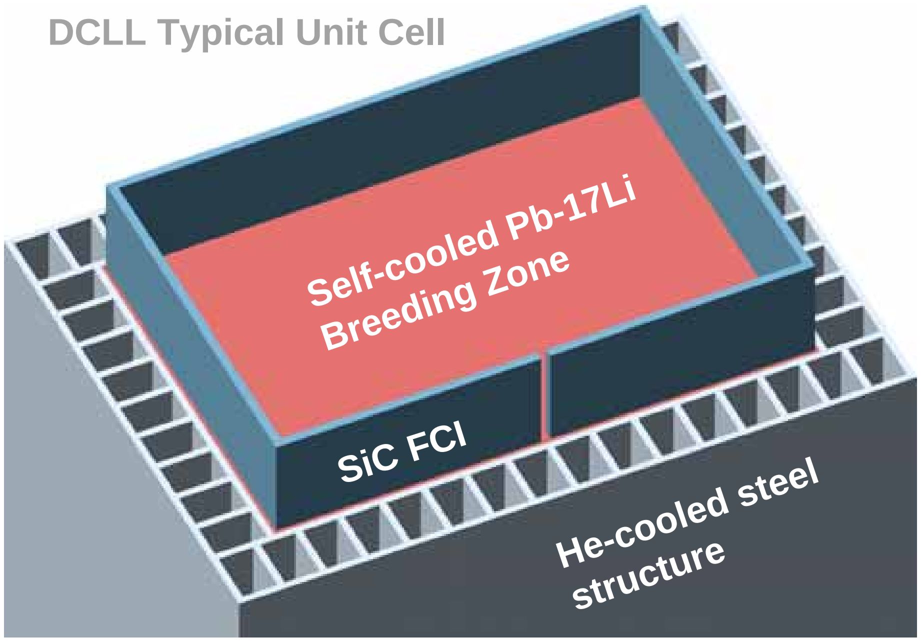
Schematic view of generic US ARIES-CS MFE/IFE solid breeder blanket showing layers of solid ceramic breeder, beryllium multiplier and cooling structures and manifolds

- ❖ **Thermomechanical behavior of breeder and beryllium particle beds under temperature and stress (and irradiation) loading affects the thermal contact with cooled structure and impacts blanket performance**
- ❖ **Nuclear performance and geometry is highly coupled and must be balanced for tritium production and temperature control**

Dual Coolant Lead-Lithium (DCLL) FW/Blanket Concept

Idea of "Dual Coolant" concept –
Push towards higher performance with present generation materials

- **First wall and ferritic steel structure cooled with helium**
- **Breeding zone is self-cooled Pb-17Li**
- **Structure and Breeding zone separated by SiCf/SiC composite *flow channel inserts (FCIs)* that**
  - **Provide thermal insulation to decouple Pb-17Li bulk flow temperature from ferritic steel wall**
  - **Provide electrical insulation to reduce MHD pressure drop in the flowing breeding**



Pb-17Li exit temperature can be significantly higher than the operating temperature of the steel structure ⇒ High Efficiency

Roadmap

US path to participation in ITER

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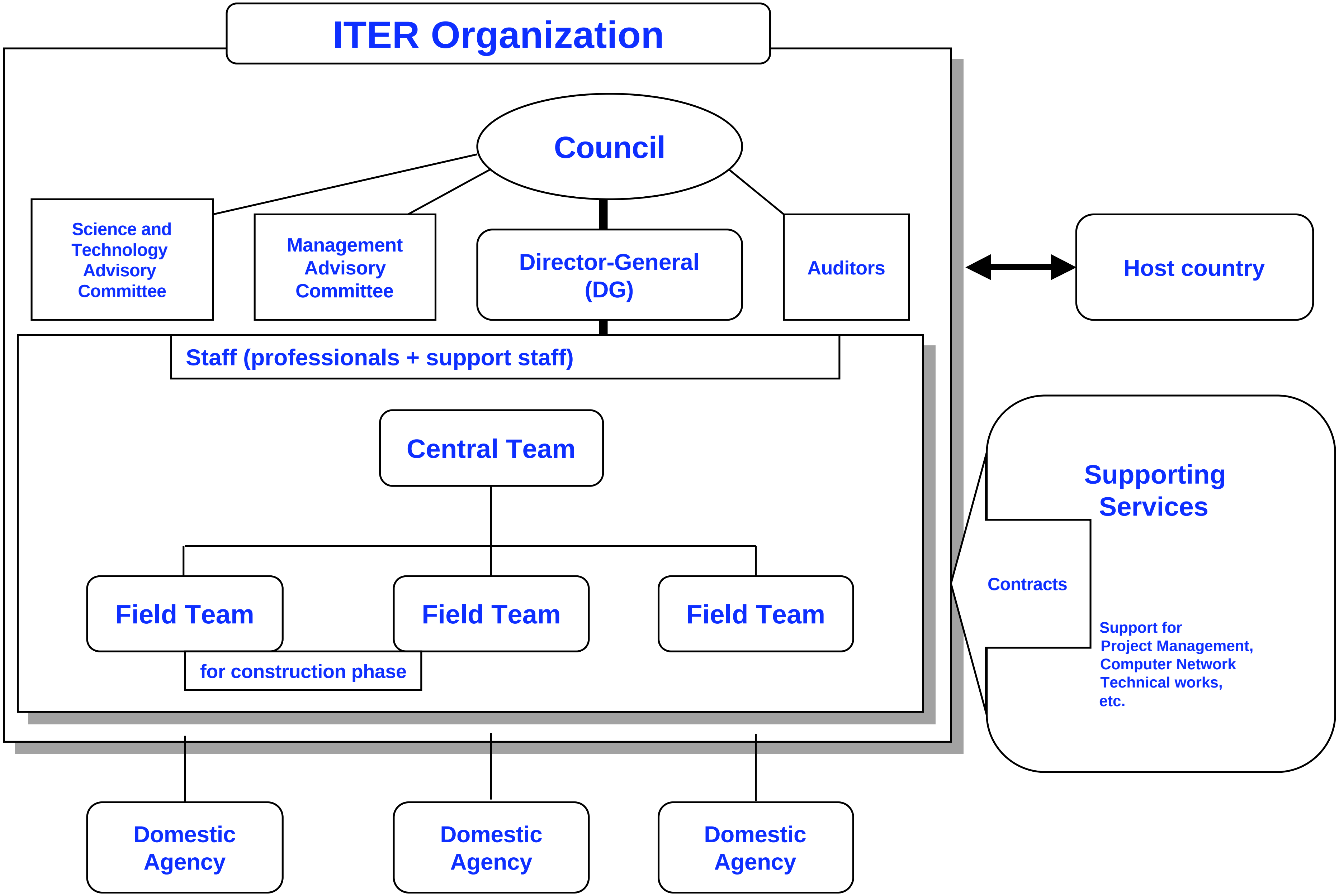
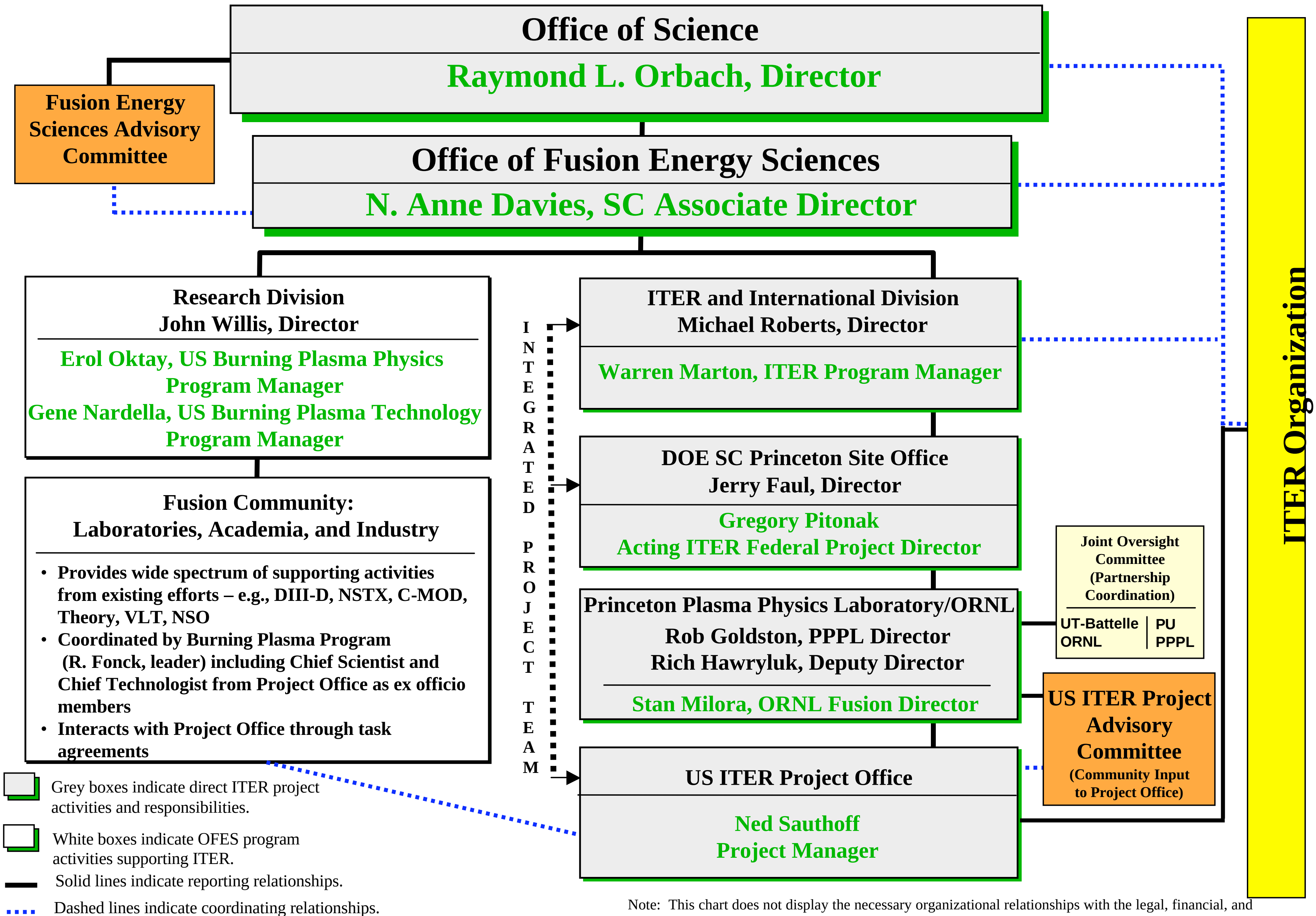
A look to the future

Management Structure considered during international discussions of the Negotiator's Standing Sub-Group



Management Structure for the US ITER Project and Program

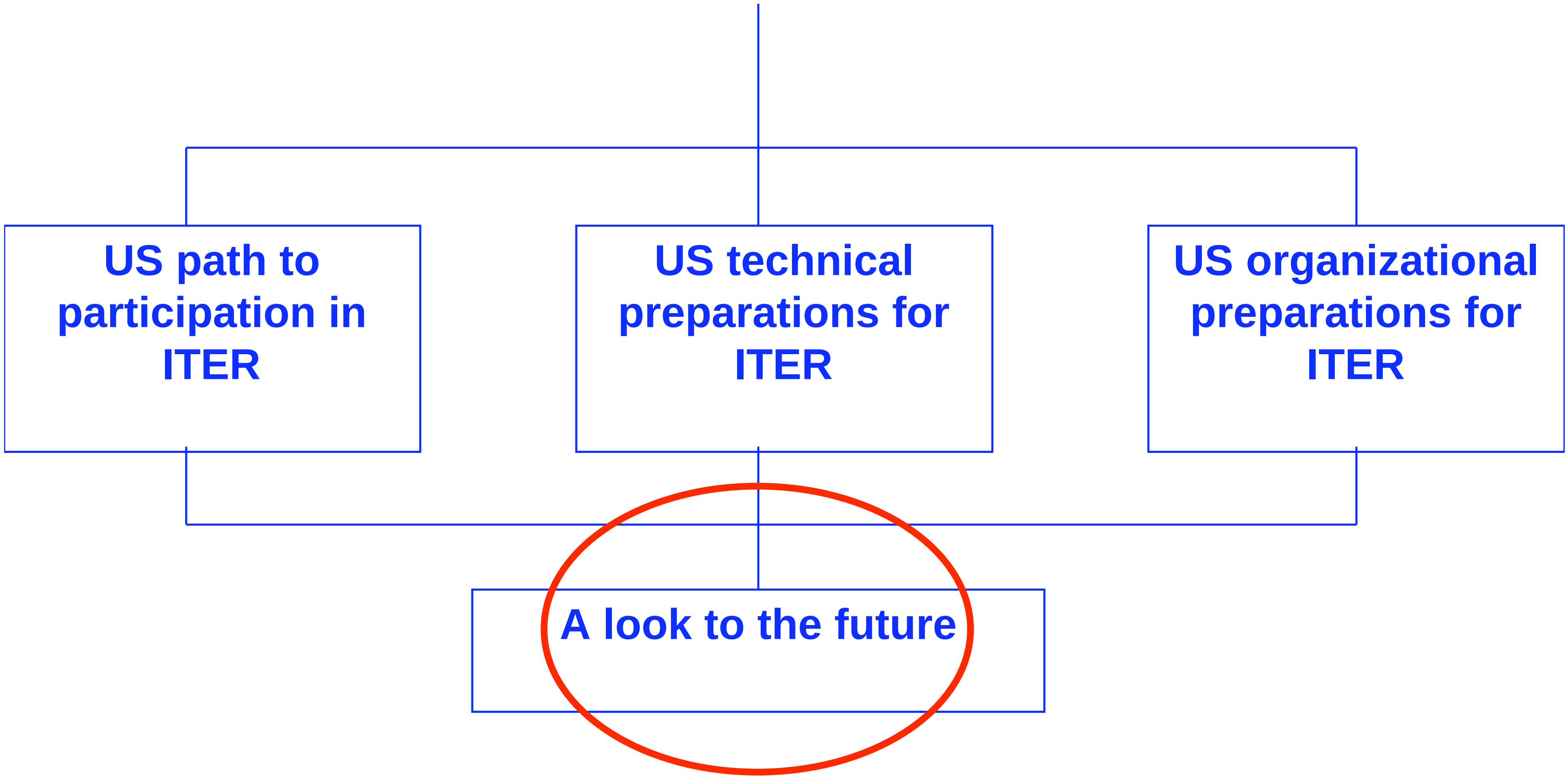


Note: This chart does not display the necessary organizational relationships with the legal, financial, and construction management offices within DOE.

FY2006 President's Budget Request ($000)
Funding Profile for US ITER Project

Fiscal Year	Total Estimated Costs (TEC)	Other Project Costs (OPC)	Total Project Costs (TPC)
2006	~~46,000~~ 16,100	3,500	~~49,500~~ 19,600
2007	130,000	16,000	* 146,000
2008	182,000	18,800	200,800
2009	191,000	16,500	207,500
2010	189,000	10,300	199,300
2011	151,000	9,300	160,300
2012	120,000	6,200	126,200
2013	29,000	3,400	32,400
Total	1,038,000	84,000	1,122,000

Roadmap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Following the site-decision, innovative arrangements will be needed

- Procurement systems, including in-kind contributions, cash-contributions and change management
- Resource management, including change-management
- Staffing by secondees, direct employees of the international organization, and contracts
- Effective distributed project management the integrates the activities of the parties
- Engaging the world's industrial base for roles in management, fabrication, assembly/installation, and operations
- Engaging the worldwide fusion research community to see ITER as an opportunity

The Bottom Line….

- **Scientific and technological assessments have affirmed**
  – the significance of burning plasma science and technology
  – the readiness of the tokamak as a vehicle for the study of toroidal magnetically-confined self-heated plasmas.

- **The world fusion community is striving to start the construction to enable burning plasma research.**

- **ITER's integrated physics and technology research,**
  including fusion nuclear technology research,
  will maximize our overall progress toward fusion energy.