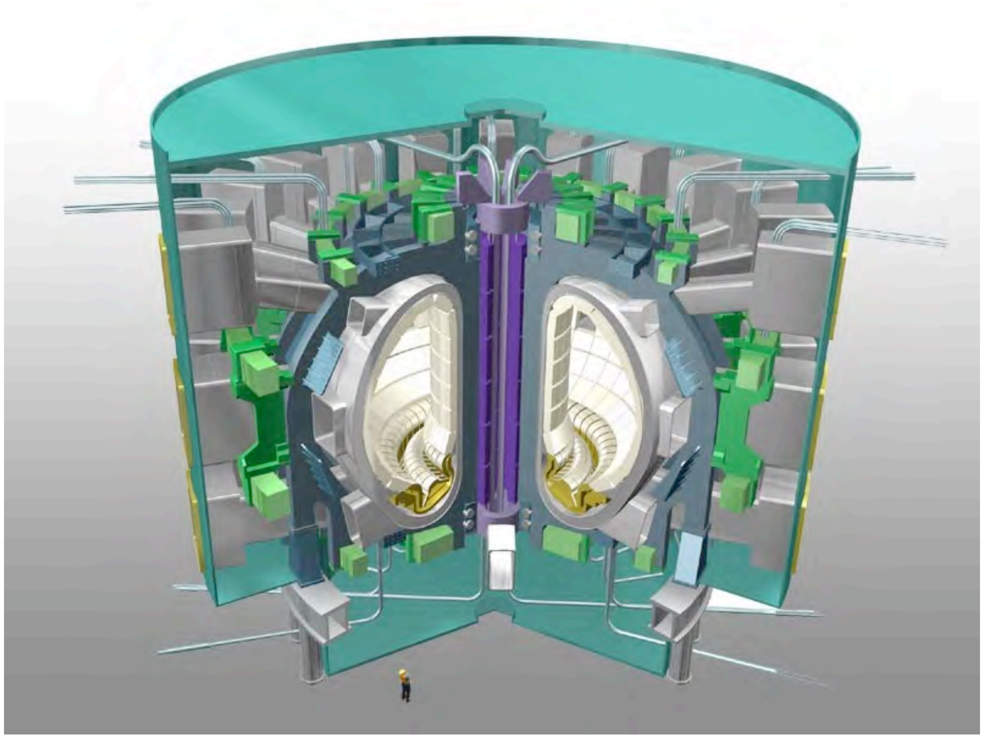
US ITER Project

Providing a Facility for
Burning Plasma Research

Working with the US community
to position the US
for Burning Plasma Research

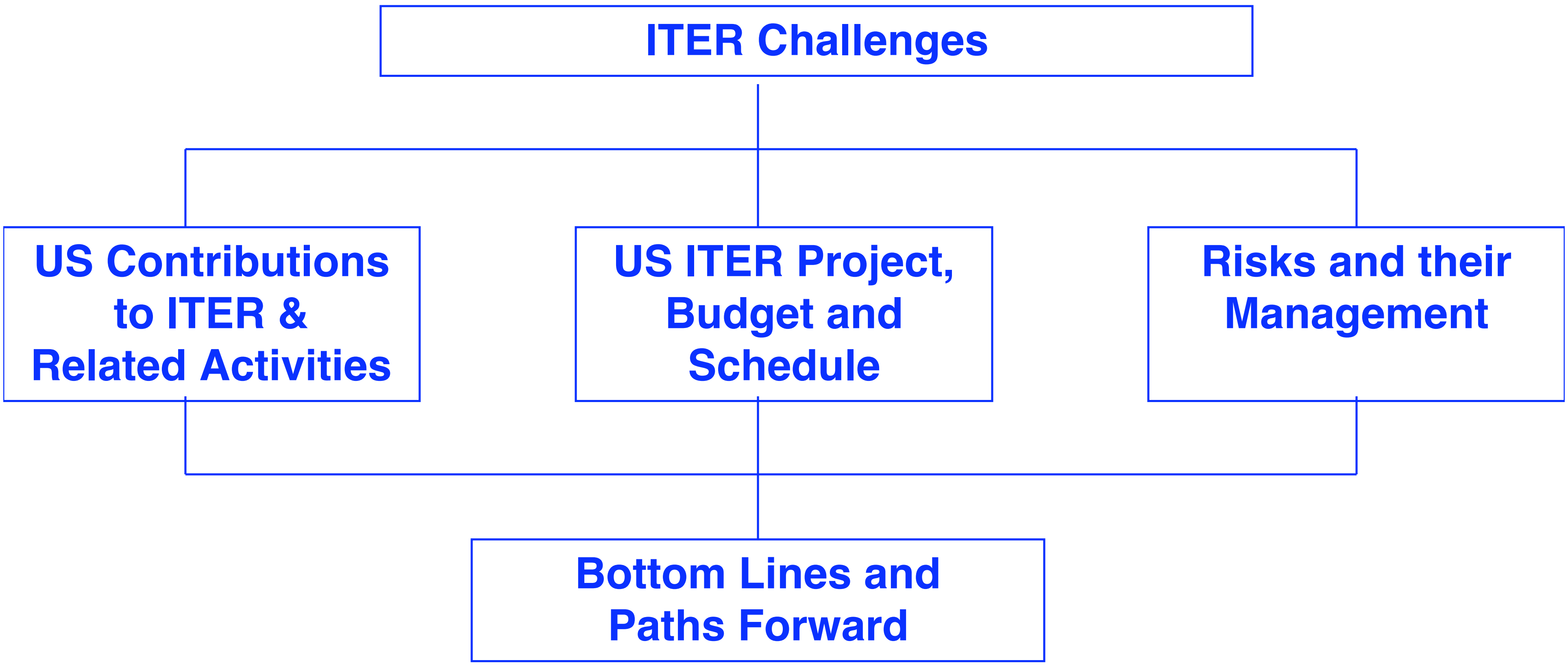


Ned Sauthoff
Project Manager, US ITER Project

APS/DPP meeting
Philadelphia, PA
October 31, 2006

U.S. iter

Structure of the Talk…



Structure of the Talk…

ITER Challenges

US Contributions to ITER & Related Activities

ITER is a unique and complex facility and program

ITER is also a challenging experiment in international collaborative project management

Structure of the Talk…

US Contributions to ITER & Related Activ

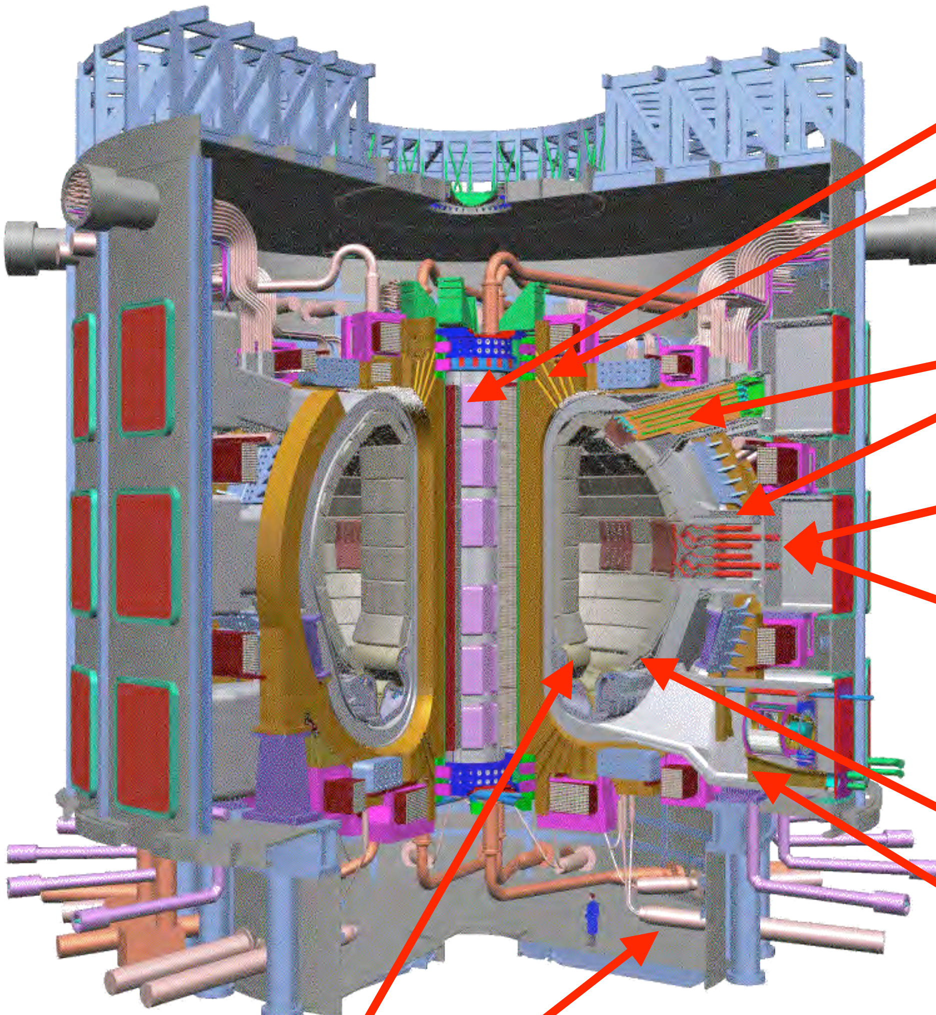
Contributions:

In-kind hardware

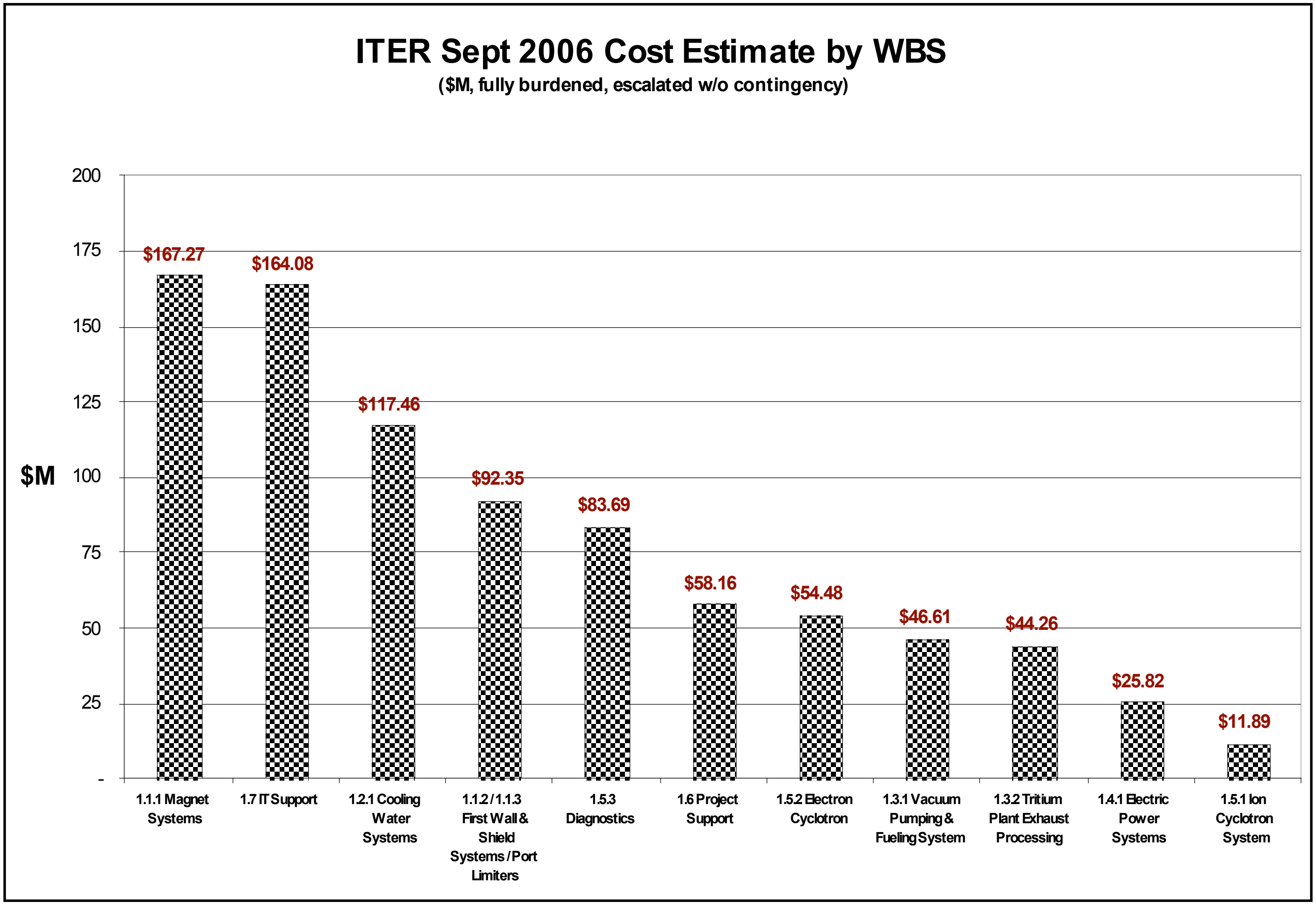
International Organization support
- **staff and infrastructure**
- **cash for assembly/installation/ central procurements**

Bottom Lines and Paths Forward

2006 U.S. “in-kind contribution” hardware scopes



Major Areas of Cost

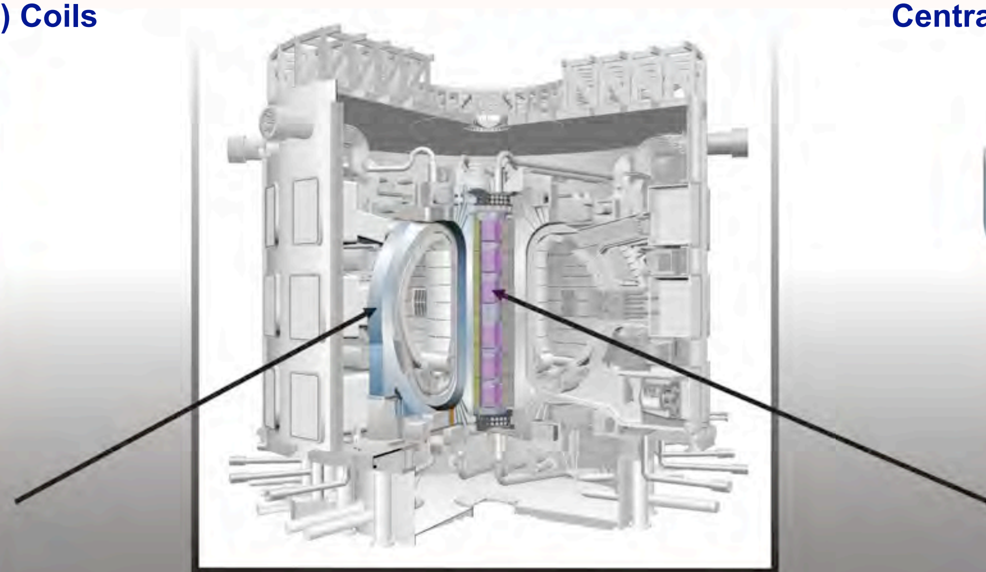


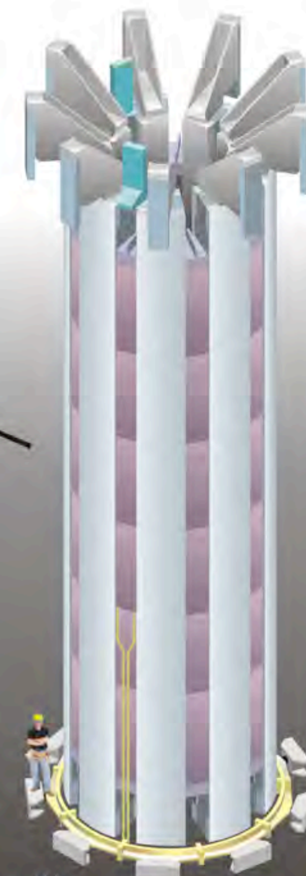
Magnets

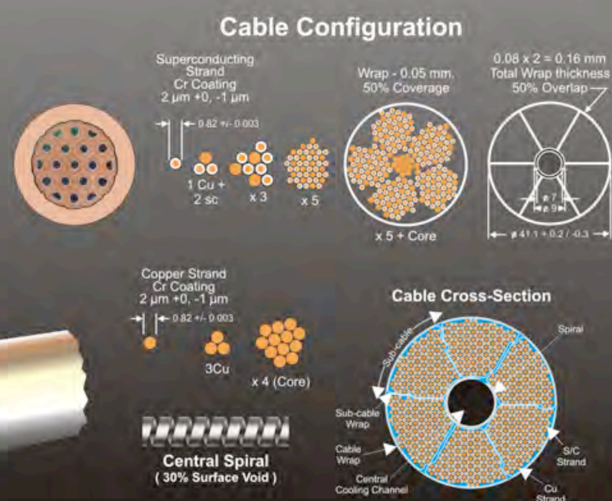
US Magnet Scope

Toroidal Field (TF) Coils

Central Solenoid (CS)



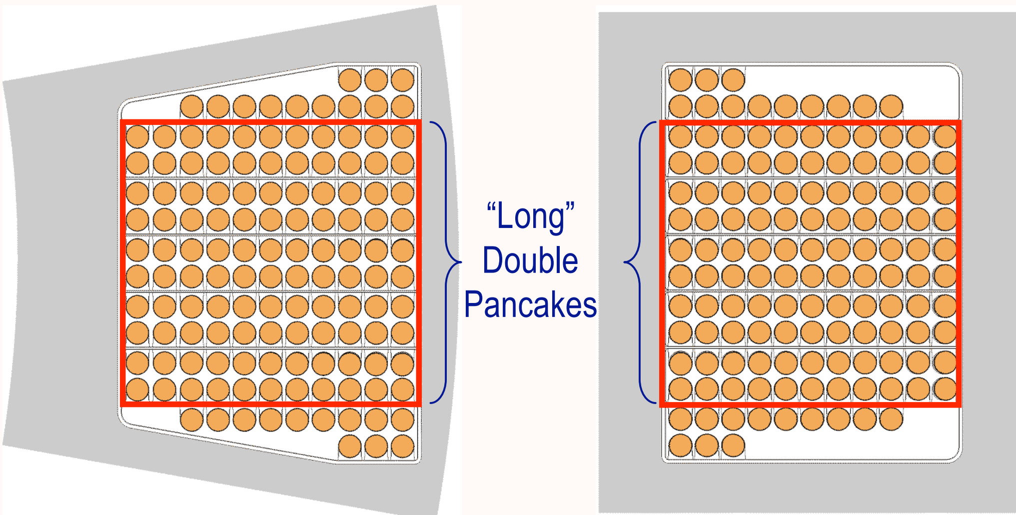


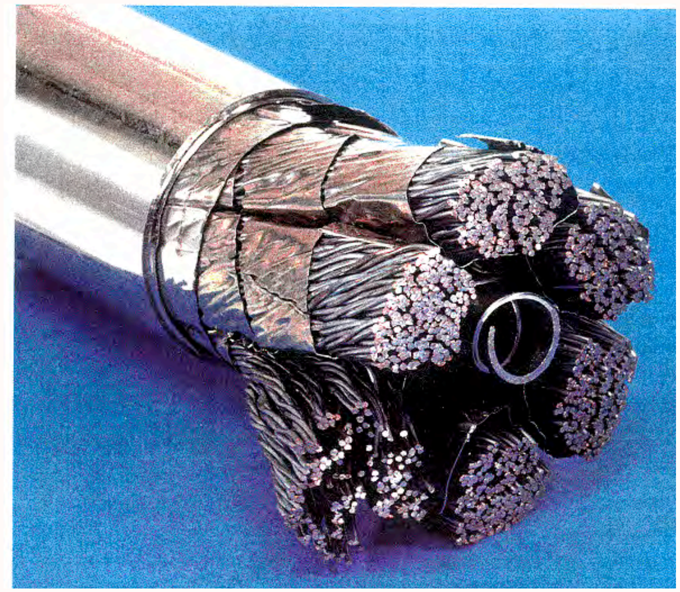


Six of the seven participant teams will provide TF conductor. The US team will fabricate nearly 8 km of TF conductor, including active, dummy, and test samples for qualification.

The U.S. Team will use CS conductor provided by the Japanese Team

TF Conductor Production

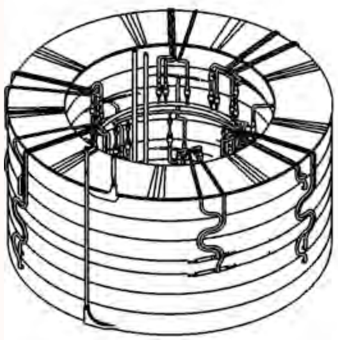


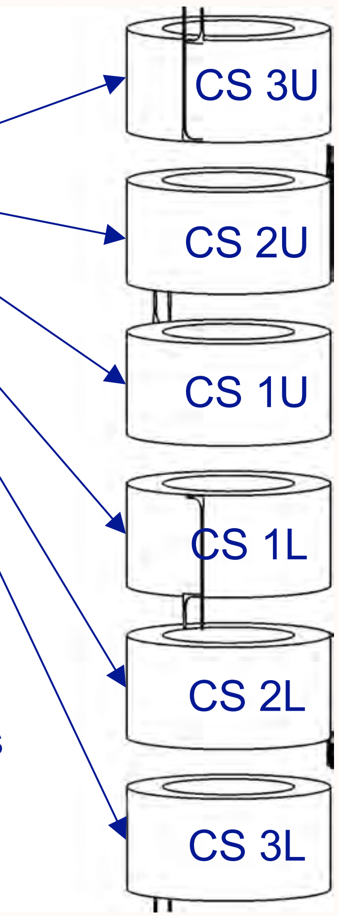


US contributes about 8% of TF conductor

- 9 “long” double-pancake lengths (about 765 m each) + 1 dummy length
- Nearly 7 km of “active” CICC
- Nearly 38 t of Nb_3Sn wire

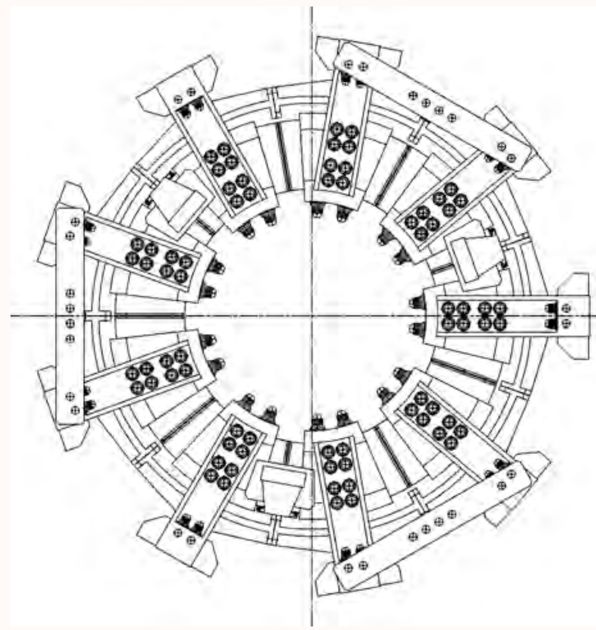
Central Solenoid



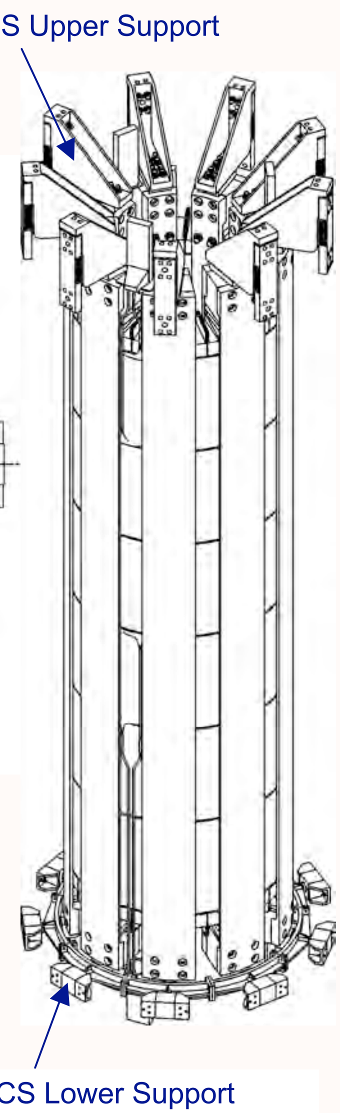


CS Coil Modules

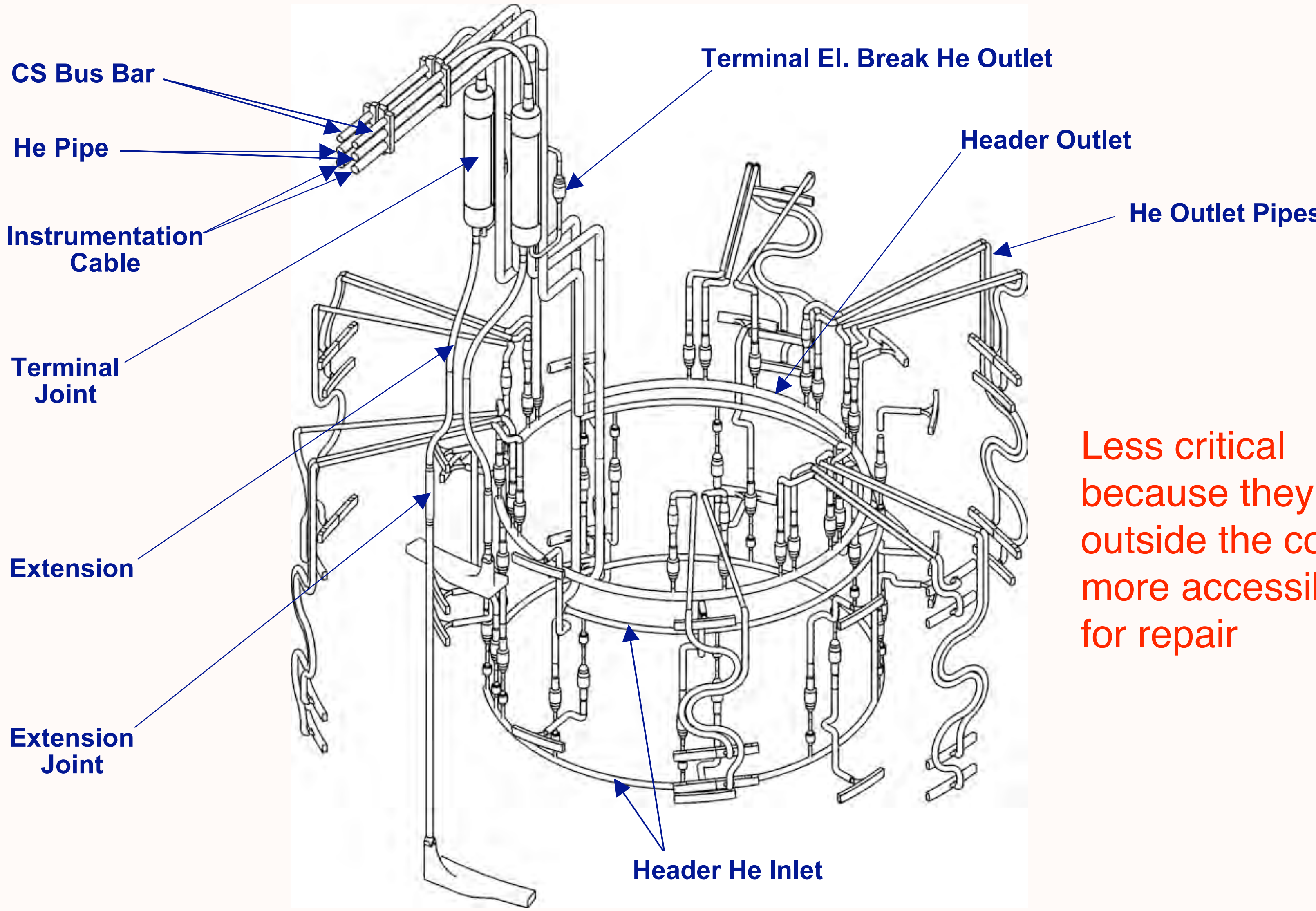
- 6 modules + 1 spare
- All identical
- In-line conductor butt joints between sections



- CS structure positions the assembly and provides axial pre-compression of modules
- Mounts off the TF cases



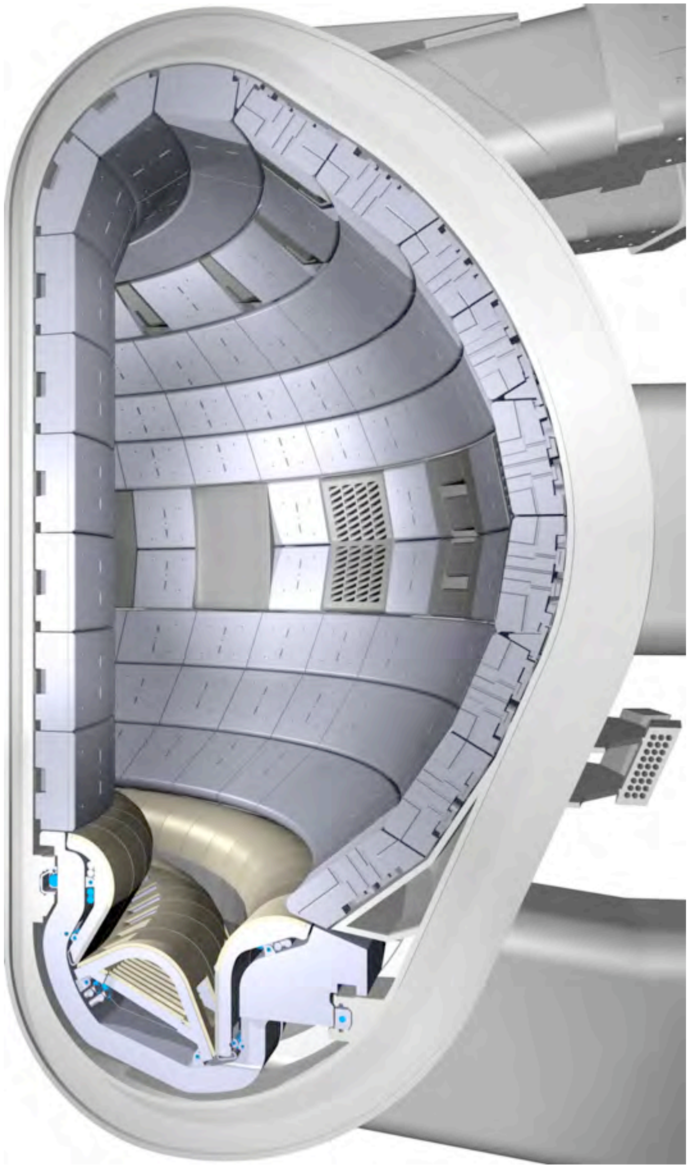
Scope – CS External Piping, Extensions & Joints



Less critical because they're outside the coil, more accessible for repair

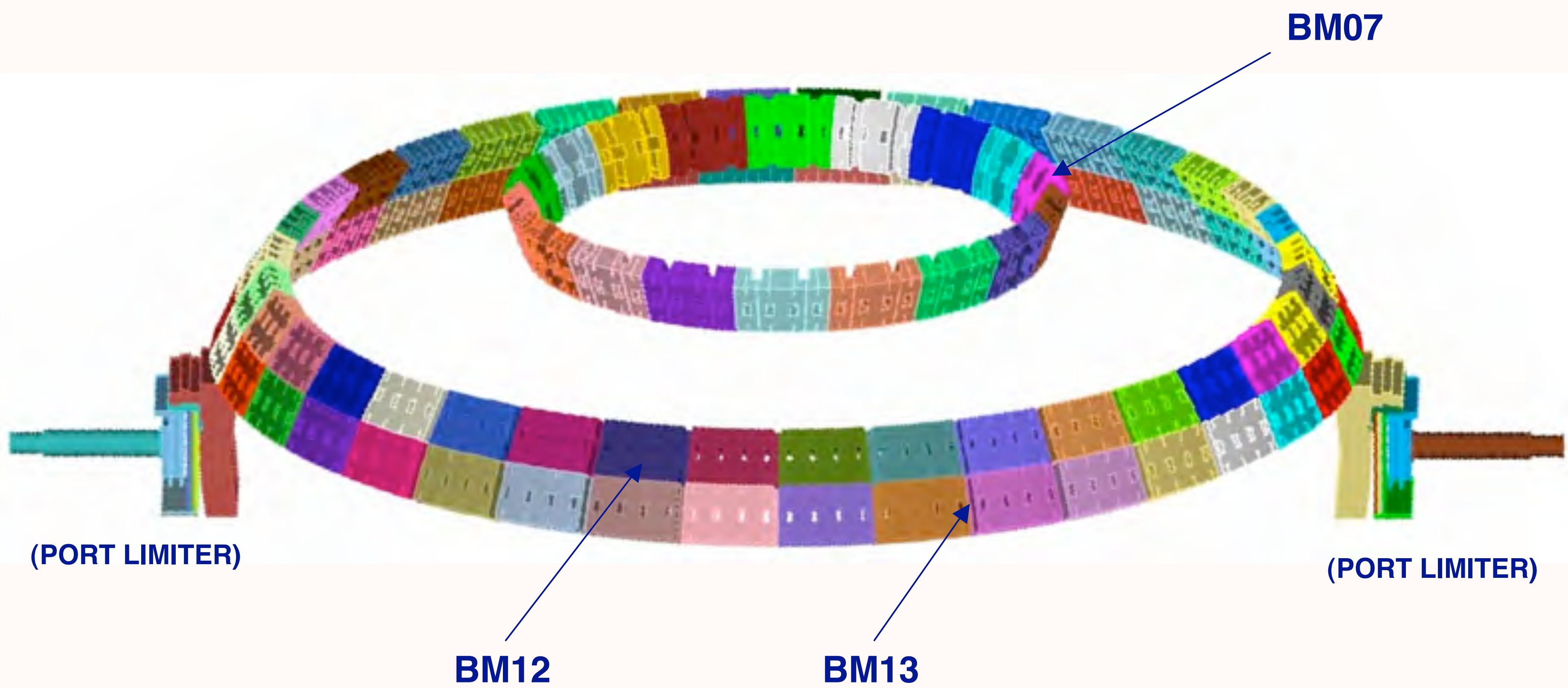
Power-handling

In-vessel structures



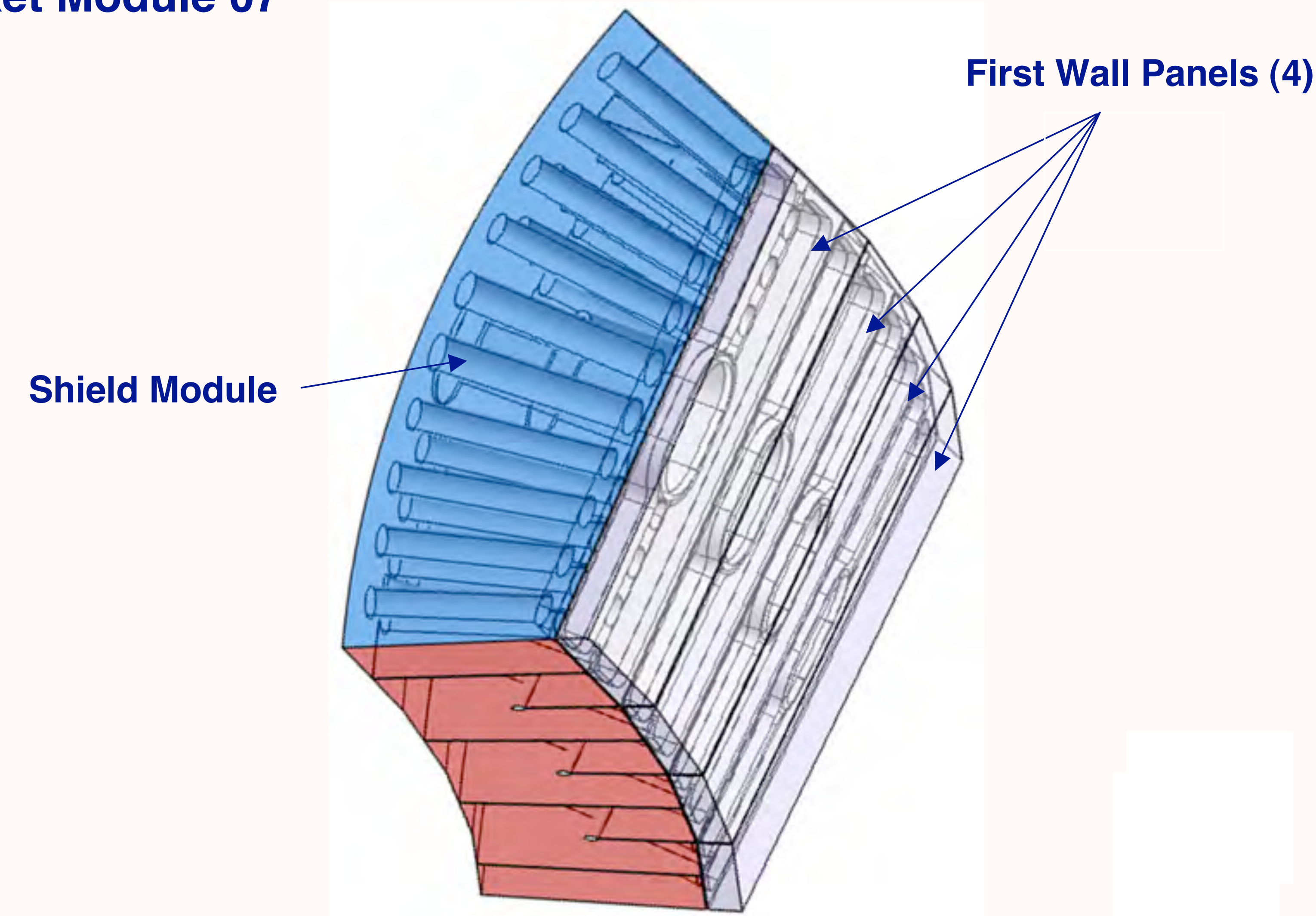
Scope – Blanket Module

Module Allocation



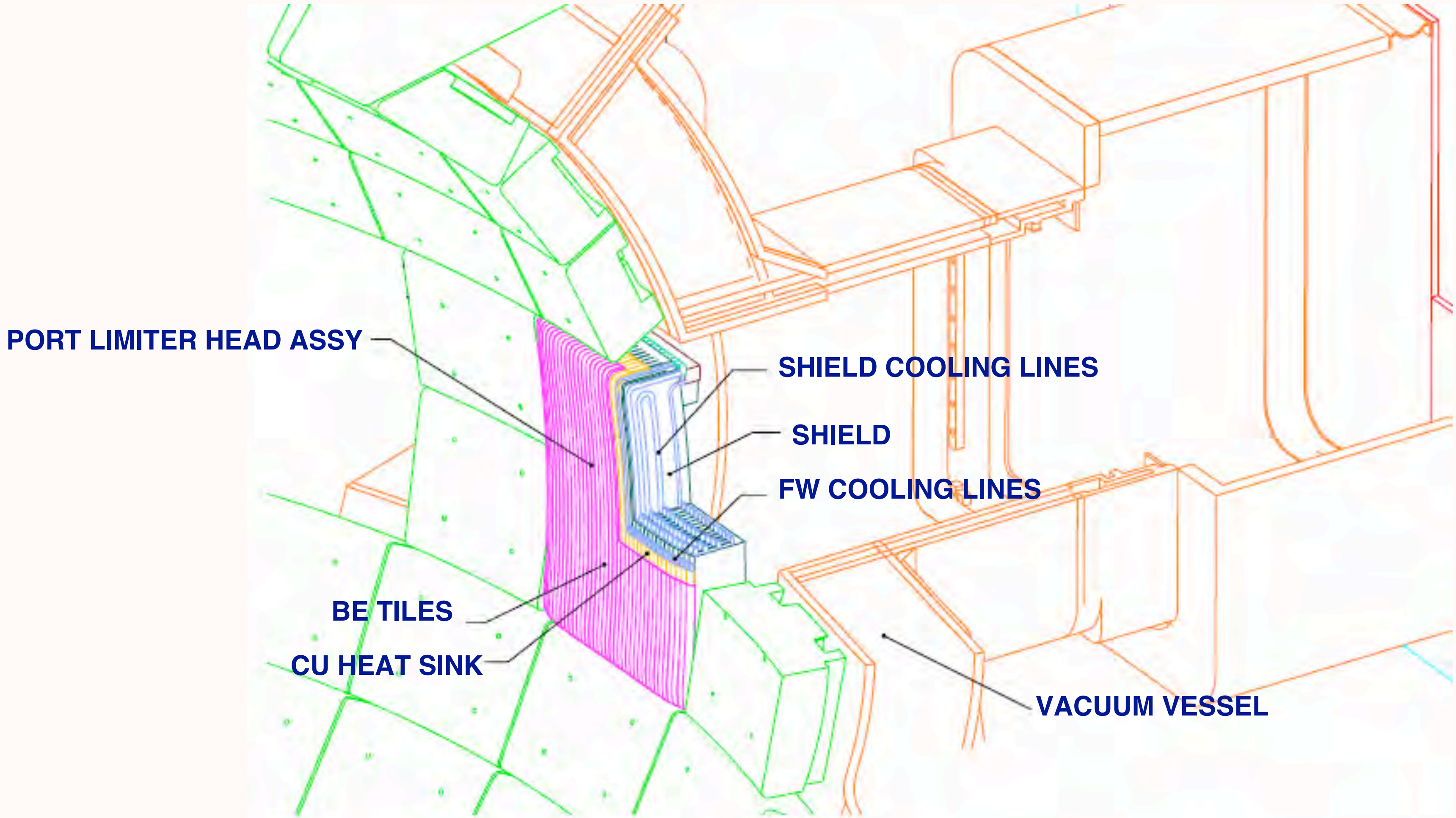
Scope – Blanket Module

Blanket Module 07



Port Limiter

Plasma Facing Head Orientation



Plasma control, heating, current drive

ICH system

The ITER ICH system will deliver 20 MW of power to the plasma for ion heating and for central current drive

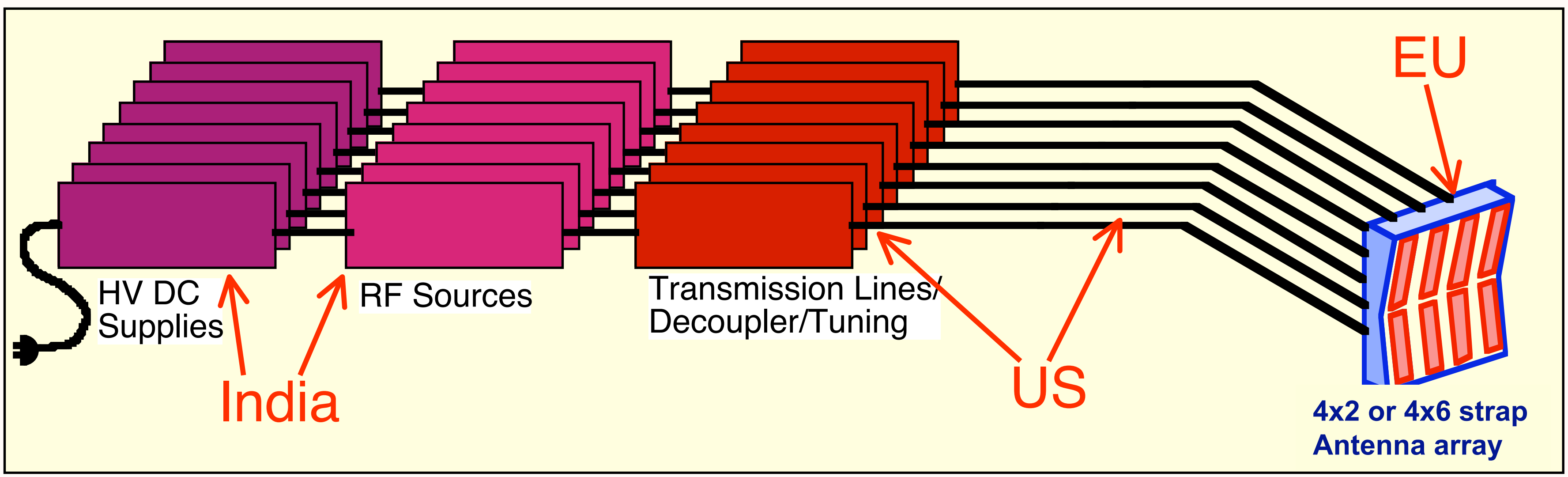
It is:

- One antenna, 8 or 24 current straps
- Eight rf sources, each feeding one set of straps in the antenna
- 40-55 MHz frequency range
- Adjustable phasing between straps for heating or current drive

It can be used for:

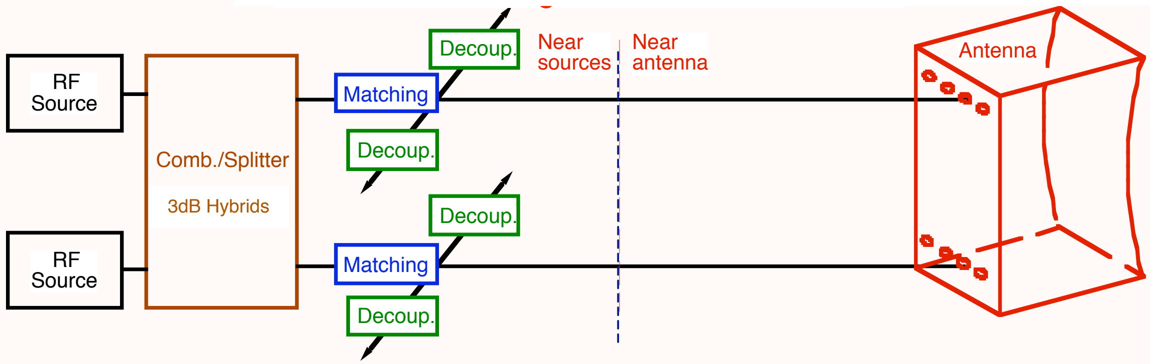
- Tritium ion heating during DT ops
- Minority ion heating with initial H/D ops
- Central current drive for AT ops
- Minority ion current drive at sawtooth inversion radius

ITER ion cyclotron system block diagram



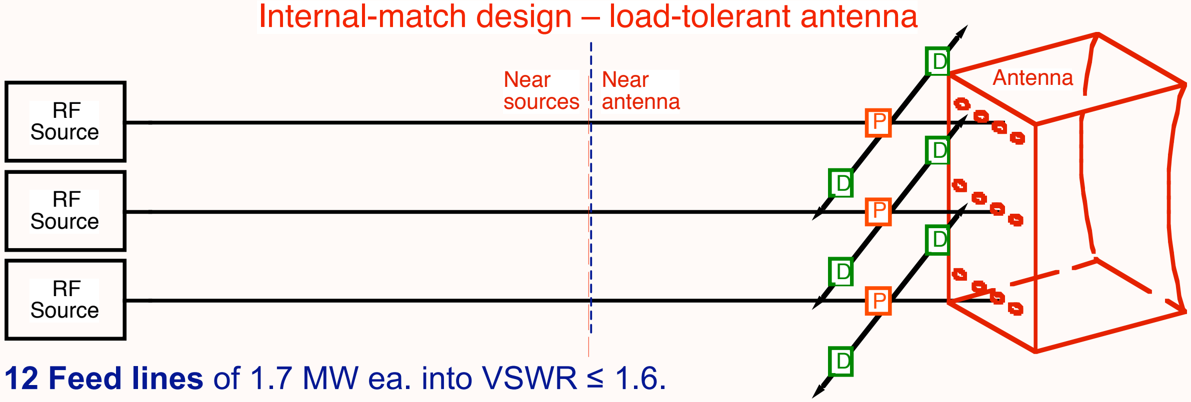
Issue: Matching system depends on antenna, impacts component, quantity details and risk

2001 Internal-match baseline design – load-tolerant antenna



8 Feed lines of 2.5 MW ea. into VSWR ≤ 2.0.
Antenna is load-tolerant with internal matching components (sliding stub-tuned triax).
Risk: 5MW section connects combiner and splitter. 2.5 MW center conductor cooling required. Antenna performance and reliability is now deemed inadequate

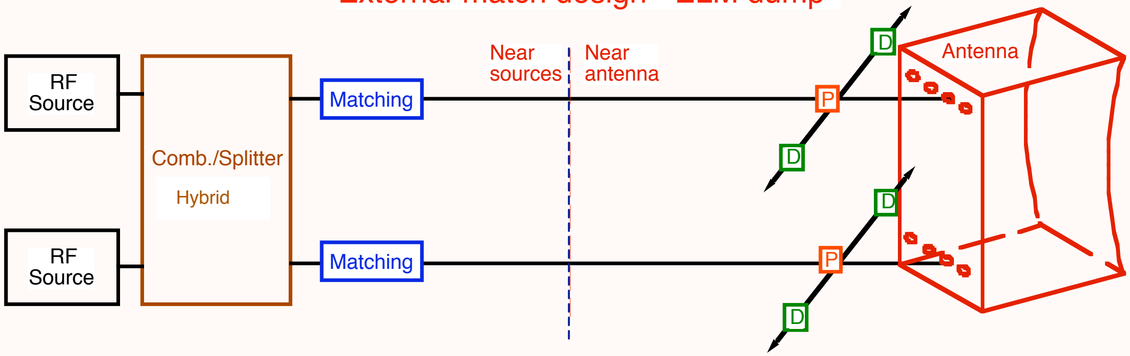
Internal-match design – load-tolerant antenna



12 Feed lines of 1.7 MW ea. into VSWR ≤ 1.6.
Antenna is load-tolerant with internal matching components. Pre-match keeps VSWR ≤ 1.6.
Hybrid not used since it is incompatible with phasing requirements.
Internal tuning similar to JET-EP and Tore Supra load tolerant antennas.
Risk: 12 feed lines increase transmission line & matching cost. Smaller lines still need inner cooling (1.7 MW).

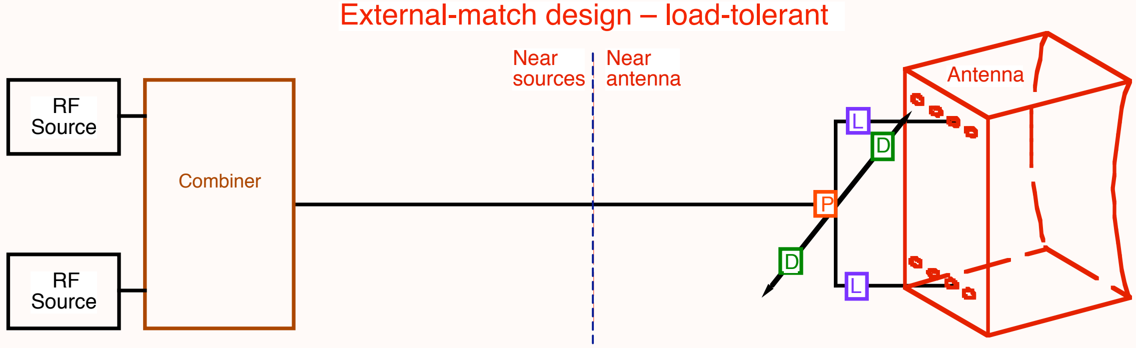
Issue: Matching system depends on antenna, impacts component, quantity details and risk

External-match design -ELM dump



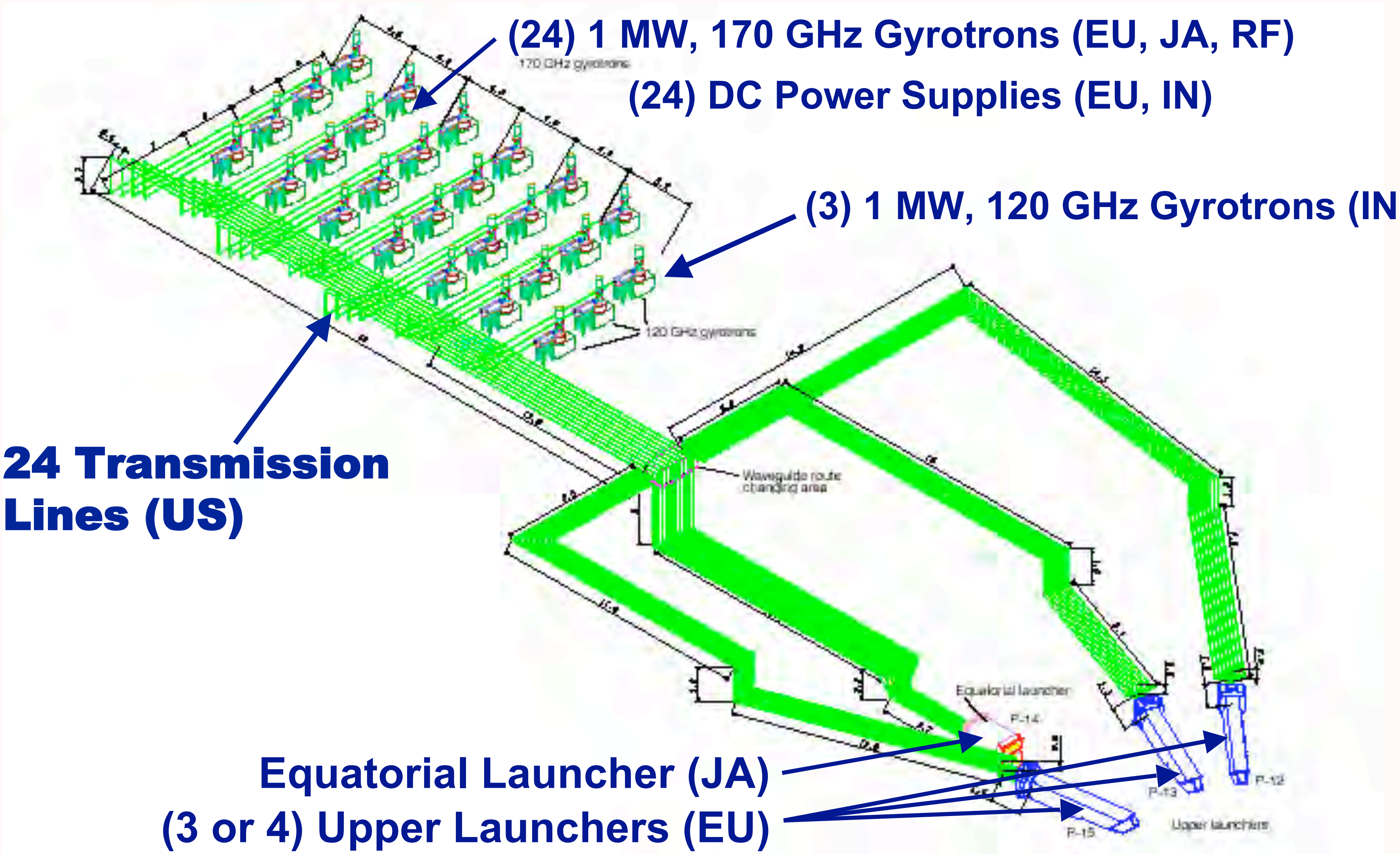
8 Feed lines of 2.5 MW ea. into VSWR ≤ 1.3.
Antenna not load-tolerant, simple design with no moving parts. Pre-match keeps VSWR ≤ 1.6.
Reflected power (plasma load variations) absorbed in dump resistors, not available for plasma heating.
Rearrangement of baseline components with minor changes
Risk: Some loss of power/performance during ELMs. Lowest risk option for transmission line and matching

External-match design – load-tolerant



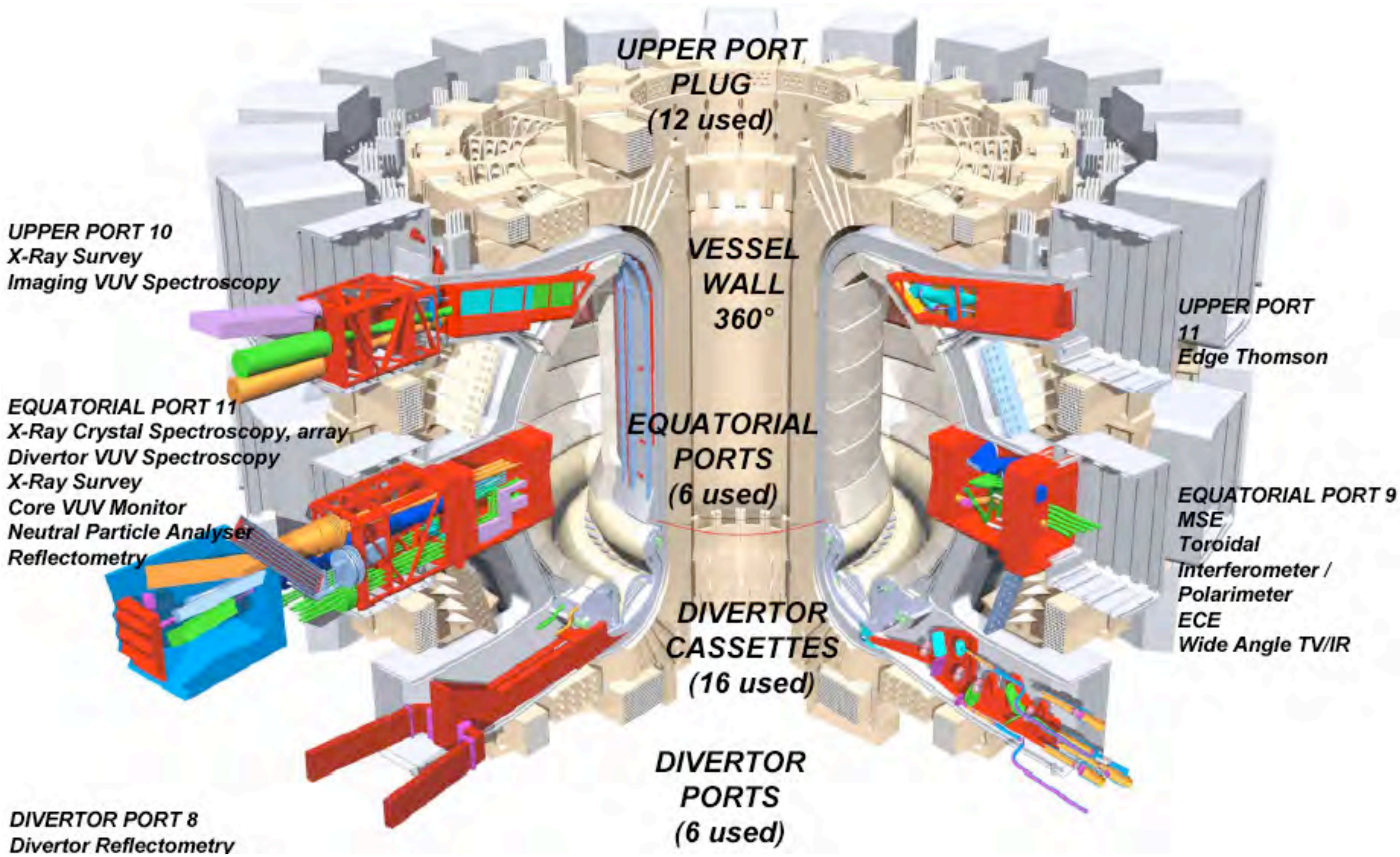
4 Feed lines of 5 MW ea. into VSWR ≤ 1.6.
Antenna load tolerant with no moving parts, but requires significant external components near antenna.
Pre-match keeps VSWR ≤ 1.6. May need additional tuning components near antenna.
Tuning architecture to be tested on JET A2 antenna
Risk: Extended length of high power line (5 MW). More matching components required.

ECH&CD Transmission Lines



Diagnostic instrumentation

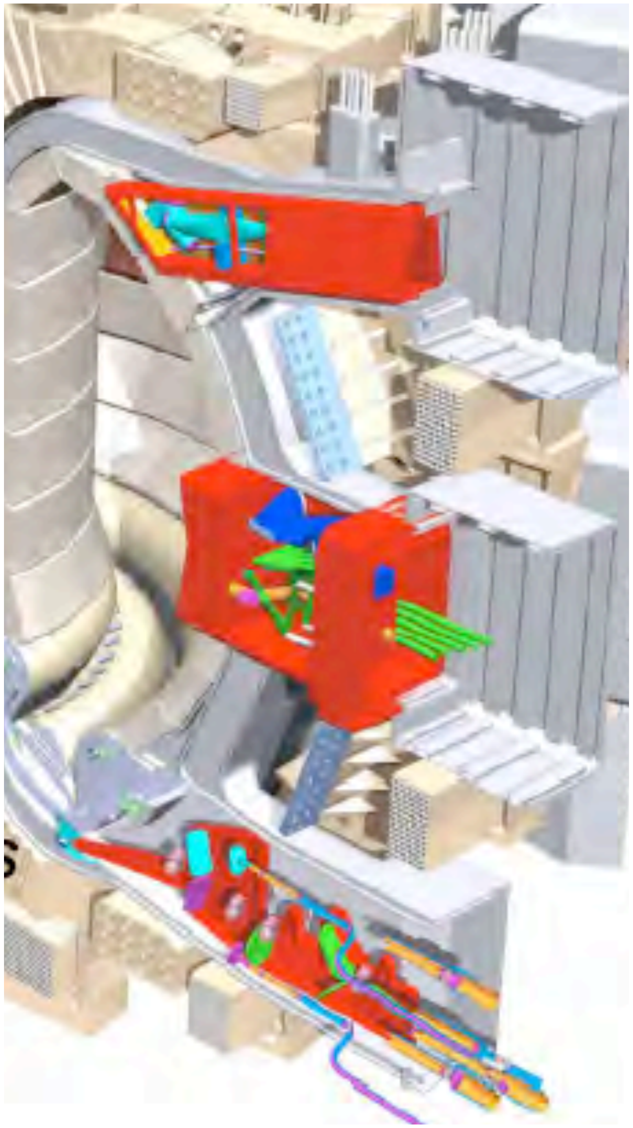
Instrumentation is key to science on ITER



A Significant (16%) Diagnostic Role in ITER Supports a Strong Research Presence

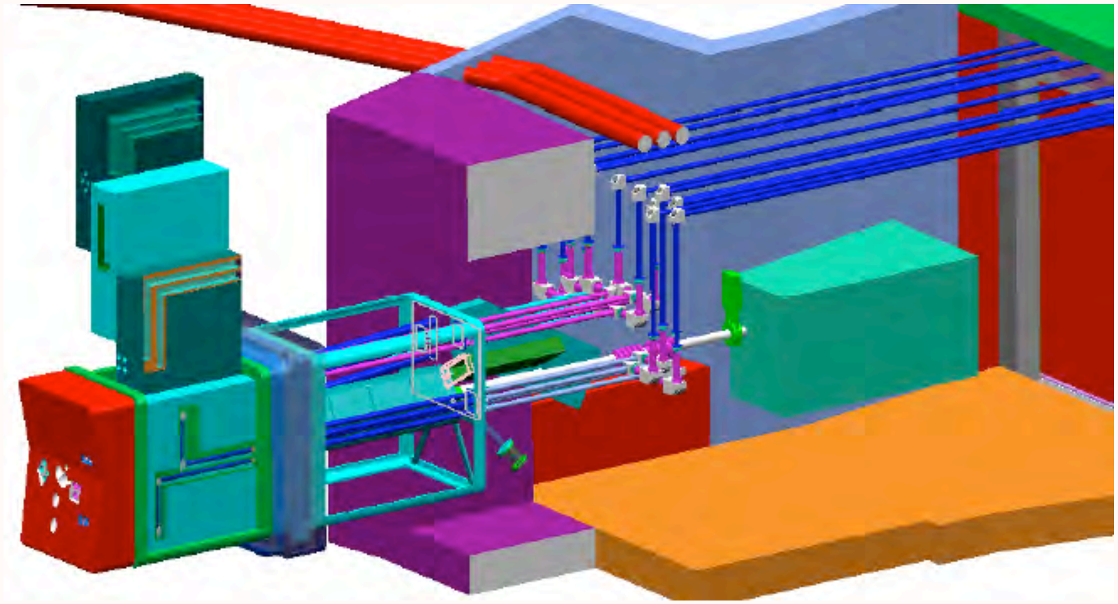
- **Seven Diagnostic Systems**
  - Motional Stark effect polarimeter
  - 6 visible/IR cameras in upper ports
  - Low-field-side reflectometer
  - Electron cyclotron emission
  - Tangential interferometer/polarimeter
  - Divertor interferometer
  - Residual gas analyzer

- **Five Diagnostic Port Plug Structures**
  - 2 upper plugs
  - 2 equatorial plugs
  - 1 lower plug structure



Instrumentation Example Reflectometer

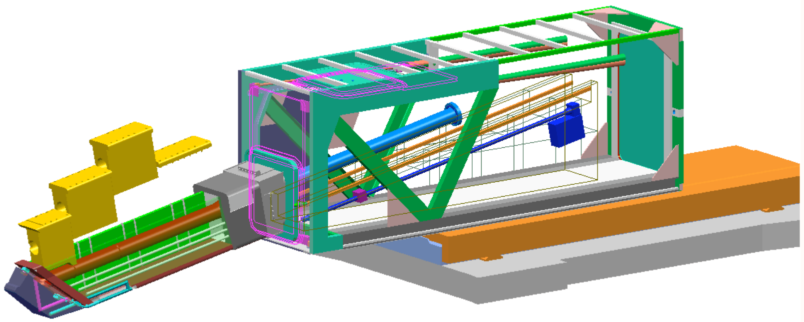
- Designed to measure density profiles with high time resolution and density fluctuations.



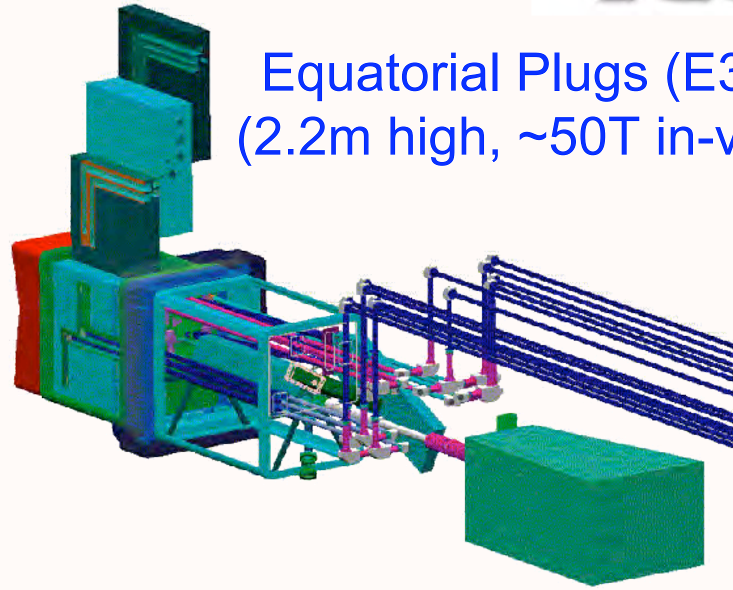
- Instrumentation packages consist of
  - Front-end components embedded in port plug
    - mirrors, waveguides/horns, shutters, calibration sources
  - Ex-cryostat components some of which are far removed
    - fiber optics, transmission lines, sources, detectors

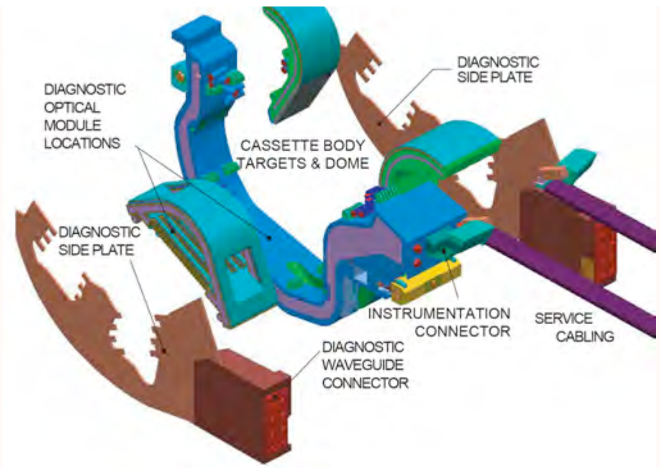
Scope - US Port Plugs

Upper Plugs (U5, U17)
(4.5m long, ~25T in-vessel)



Equatorial Plugs (E3, E9)
(2.2m high, ~50T in-vessel)



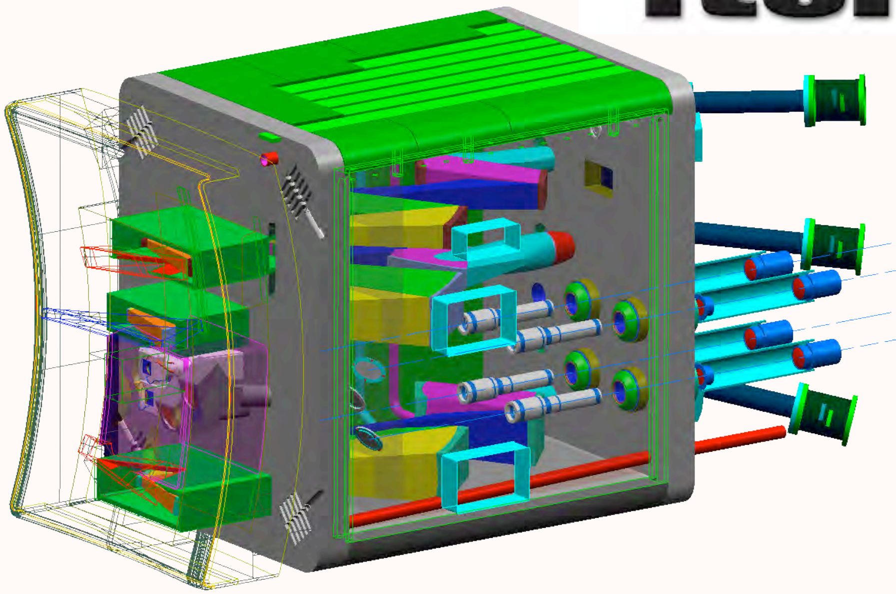


Divertor Side Panels
and Back Boxes (L8)

Plugs provide

- Vacuum seal, radiation shielding
- Cooling water and support for blanket shield modules
- Support and access for diagnostics

Scope - Integration of Diagnostics into Plugs



- Diagnostics from other parties need to be integrated into plug E3
  - 2 visible/IR camera views (EU)
  - 2 edge CXRS views (RF)
  - 2 H_α arrays (RF)
  - X-ray crystal views (IN?)

- The division of integration design responsibility between the IT and the parties has not been fully negotiated.

Preparations Leading to Major Diagnostic Design Effort for US Diagnostic Systems

- **Over the next 6-9 months, USIPO will be assisting the ITER Organization to prepare procurement documents to more clearly define the US diagnostic scope.**
  - First award for major design of a US system presently scheduled for early FY08.
- **A number of “assessment studies” were recently launched to re-engage US diagnostic experts.**
  - Resulting performance assessments and revised cost estimates will help guide procurement arrangements.
- **Core engineering team will assist US diagnostic designers to integrate instrument front-ends into the plugs.**

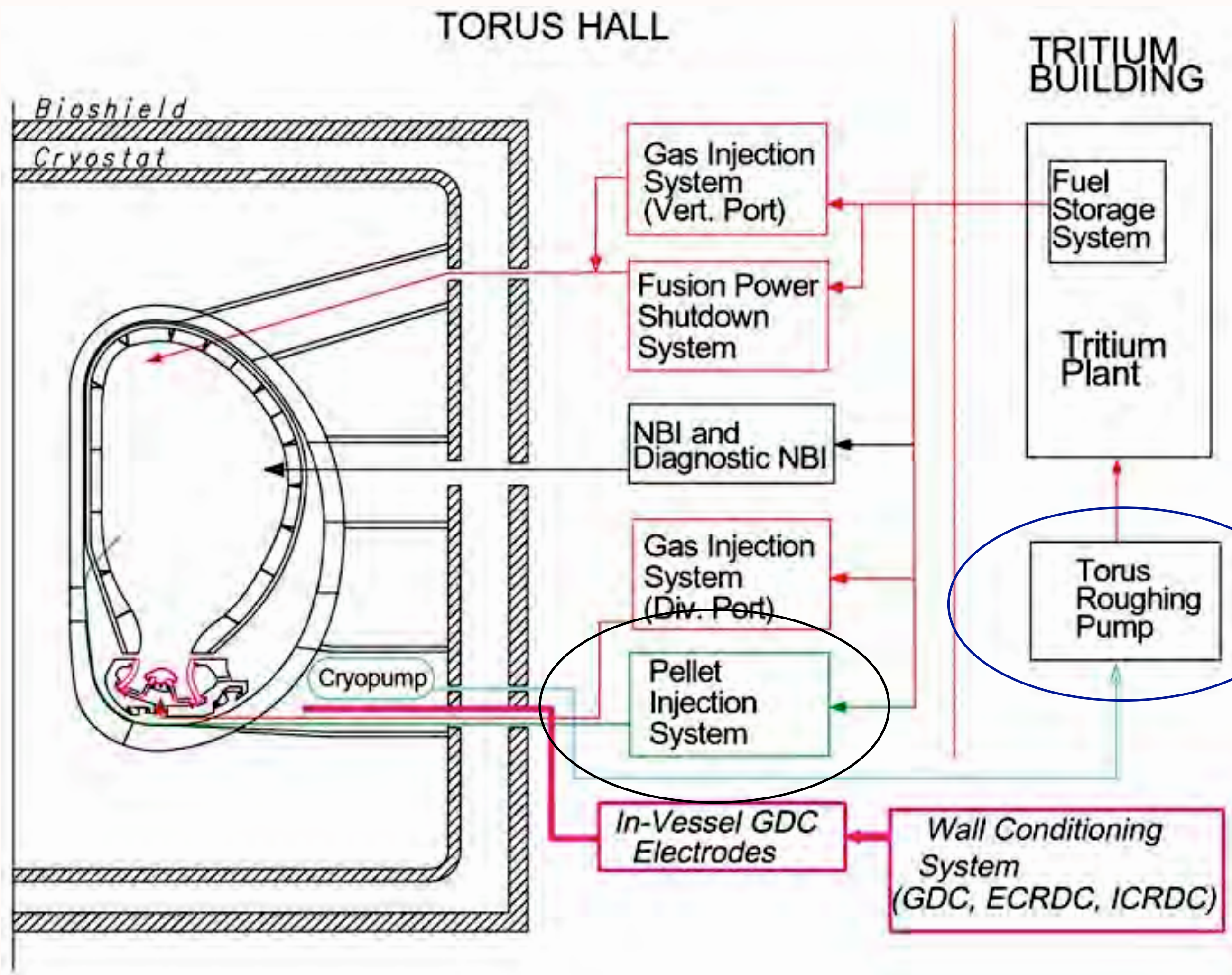
Ongoing Studies Assess Reference Designs for US Systems

Diagnostic Package	Task Summary	Institution(s)
Upper Visible/IR Camera	assess optical design, central tube concept	LLNL
LFS Reflectometer	determine optimum frequency bands and polarizations	UCLA
MSE	assess usefulness of |B| determination	NOVA
MSE	performance simulation of conventional polarimetry approach	PPPL
MSE	optimization of optical design	LLNL
ECE	investigate non-thermal issues, use of oblique view	PPPL
ECE	review reference design	U. Texas-U. Md-MIT
Divertor Interferometer	develop conceptual design	GA-UCLA
RGA	develop conceptual design	ORNL
Tang. Interfer./Polarimeter	optimize reference design	UCLA-GA
First Mirror R&D	model erosion/deposition on 1st mirrors	ANL
Neutronics Analysis	benchmark neutronics models for plug integration using ATILLA	UCLA-PPPL

- **Focus on identification of ‘front-end’ configurations**
- **Upcoming meetings provide opportunity for broader input**
  - USBPO Workshop 6 - 8 February 2007 at General Atomics.
  - ITPA Diagnostics TG Meeting 26 - 30 March 2007 at PPPL.

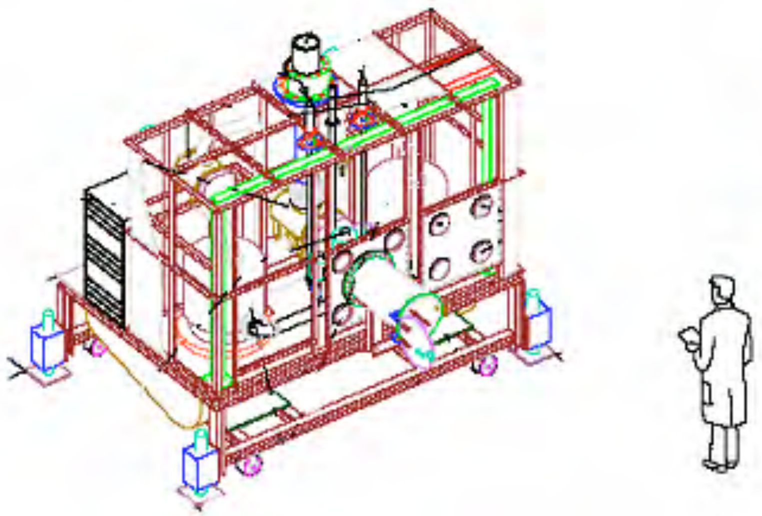
Fuelling and exhaust processing

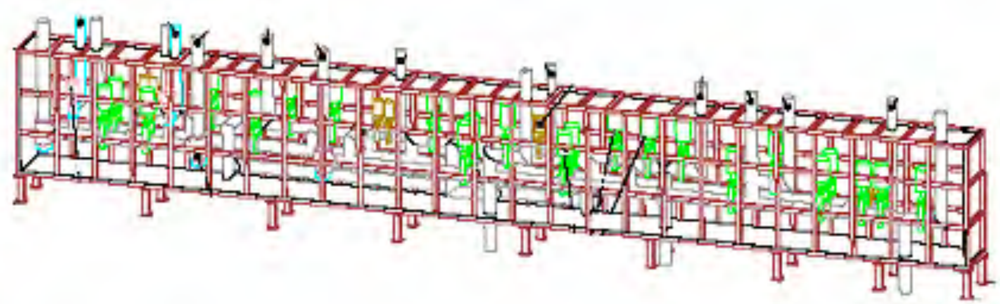
ITER Pumping and Fueling Systems



ITER Roughing Pump Sets

- **Roughing pump sets - 4 identical pump assemblies**
  Piston pumps, Blowers, mounted in glove box assembly with associated valves, instrumentation and controls





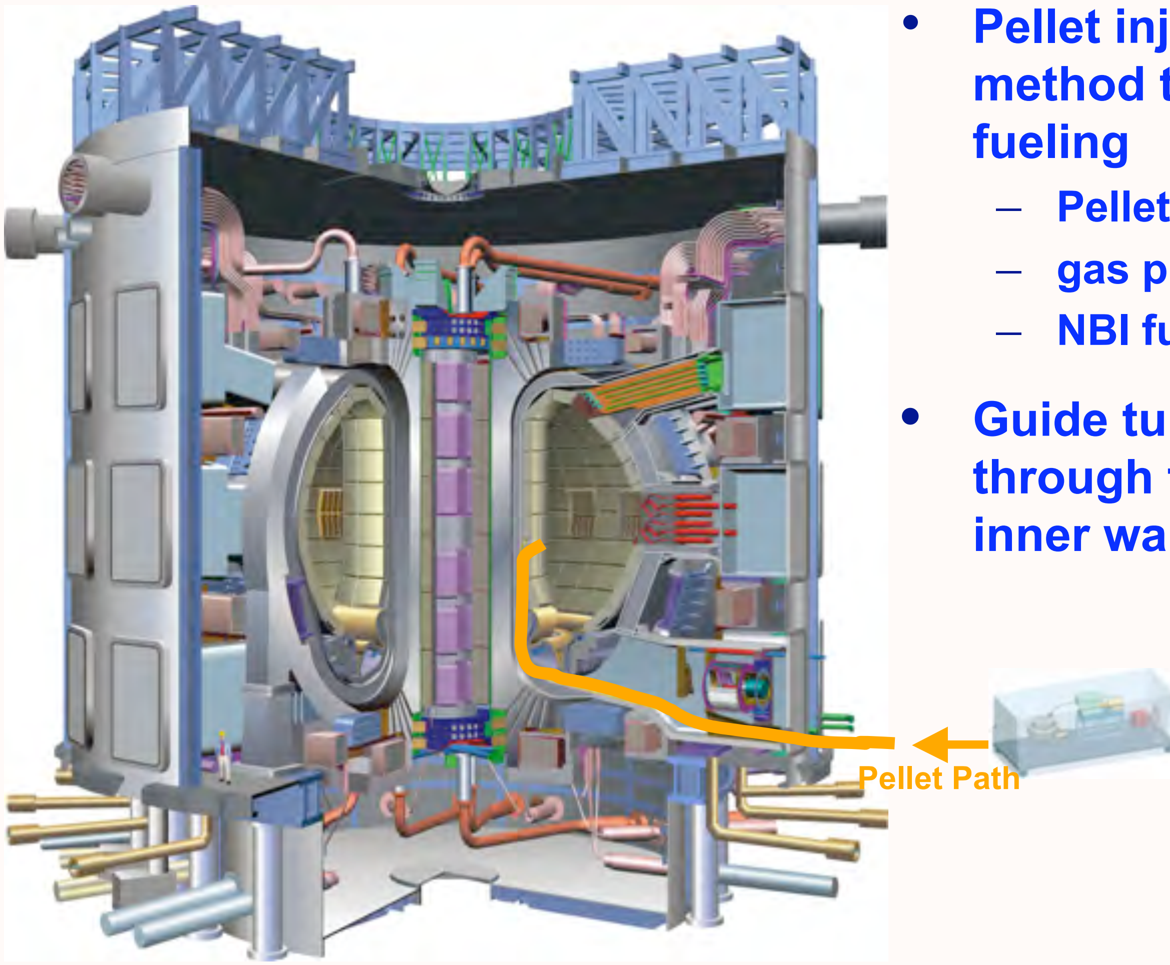
Roughing Pump Set Assembly

Change Over Valve Box Assembly

ITER Vacuum Standard Components

- **Standard components consists of**
  - **ICRF vacuum system - 64 getter pumps and 32 valves**
  - **ECH vacuum system - 130 sputter ion pumps, 10 TMPs, 10 dry pumps & 220 valves**
  - **Guard and service vacuum system - 86 cryo pumps, 2 dry pumps and 1738 valves**

Pellet Injector



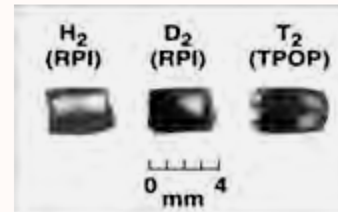
- Pellet injection the only known method to achieve efficient core T_2 fueling
  - Pellets ~90% efficient
  - gas puffing < 1% efficient
  - NBI fueling negligible
- Guide tubes bring the pellets through the divertor ports to the inner wall.

Pellet Injector Design

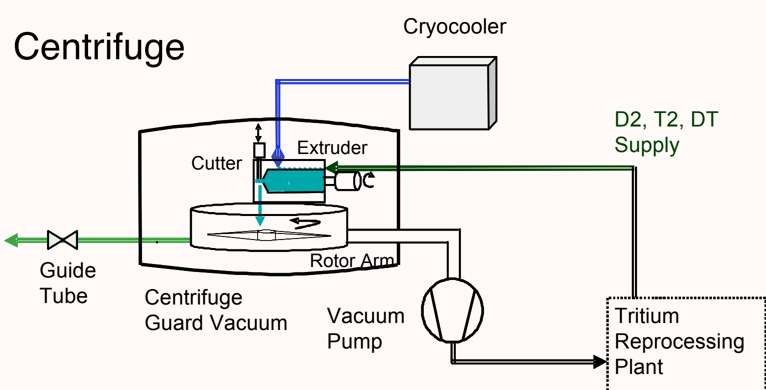
Two concepts are available for ITER pellet acceleration

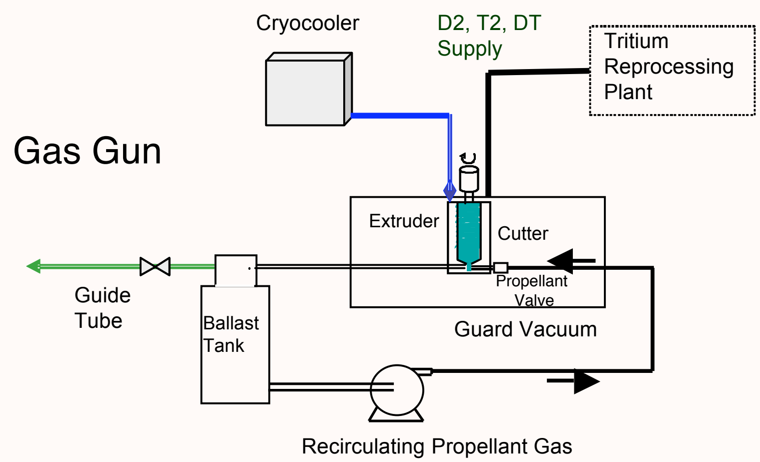
- **ITER baseline design assumes a centrifuge accelerator**
  - Low (~10%) recirculating gas from accelerator
  - Existing designs do not meet the needed reliability
  - Significant development needed to meet the ITER reliability requirements

- **Gas gun technology may be a better choice**
  - High reliability has been demonstrated for slow pellets
  - Propellant gas valve can be optimized for low gas usage
  - A recirculating propellant gas system can be employed to minimize impact on the tritium plant

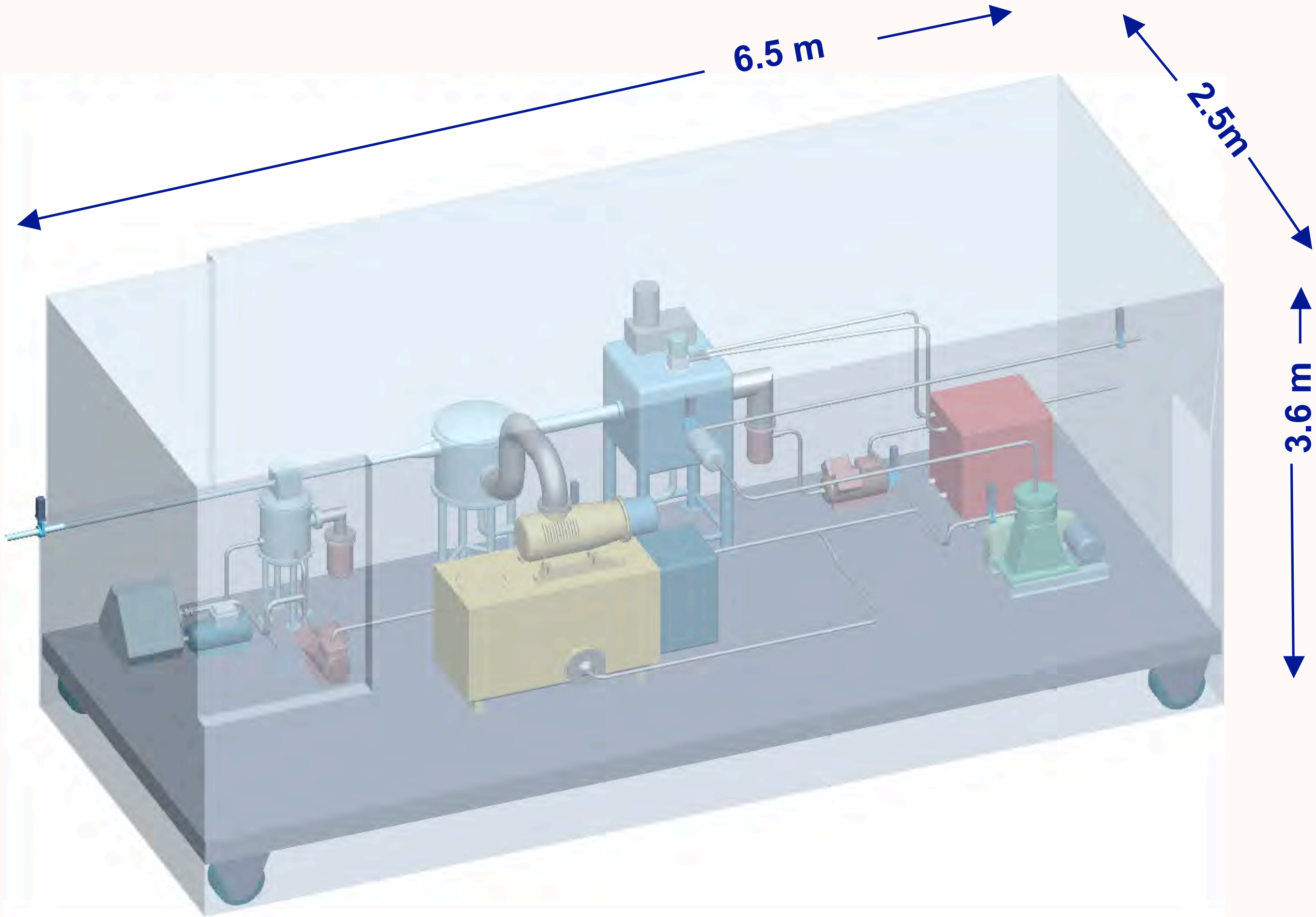


Hydrogen, Deuterium and Tritium Pellets



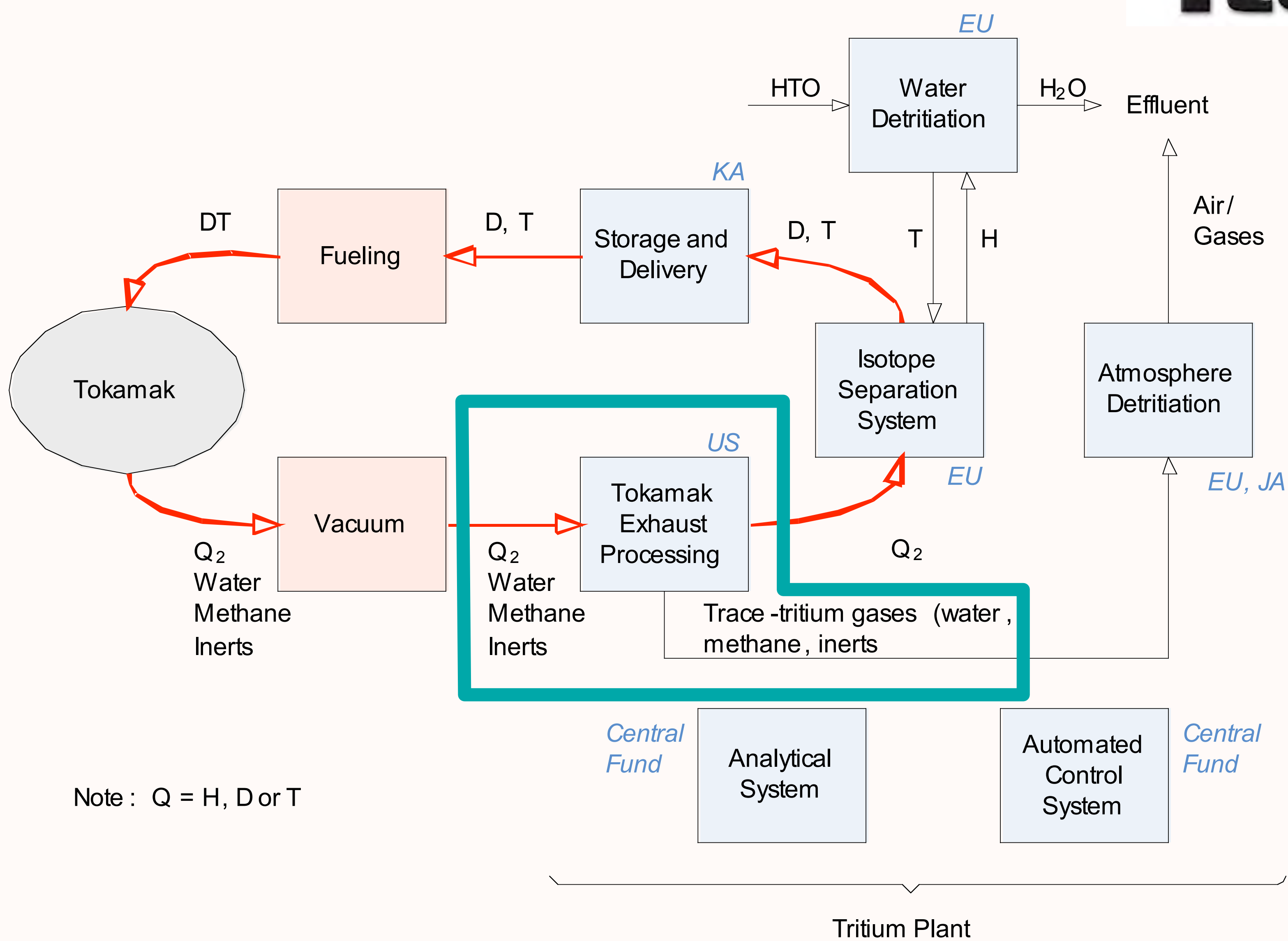


ITER Gas Gun Pellet Injection System Conceptual Design

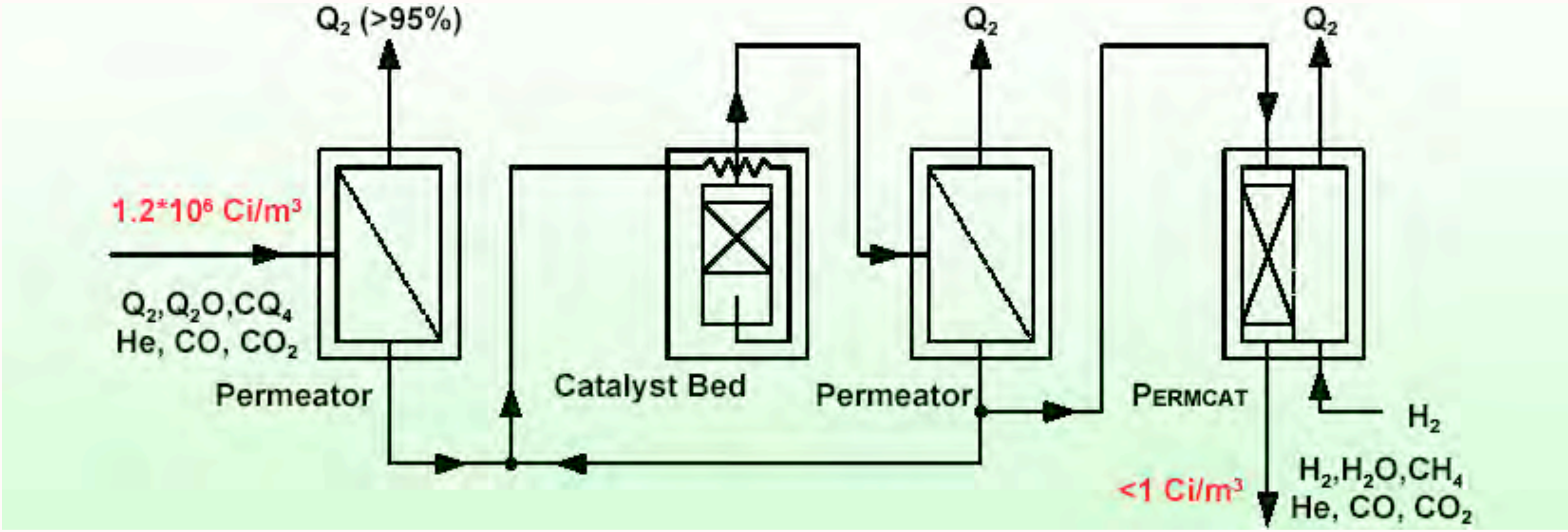


Cask layout from P. Fogarty, ORNL

Tritium Processing System

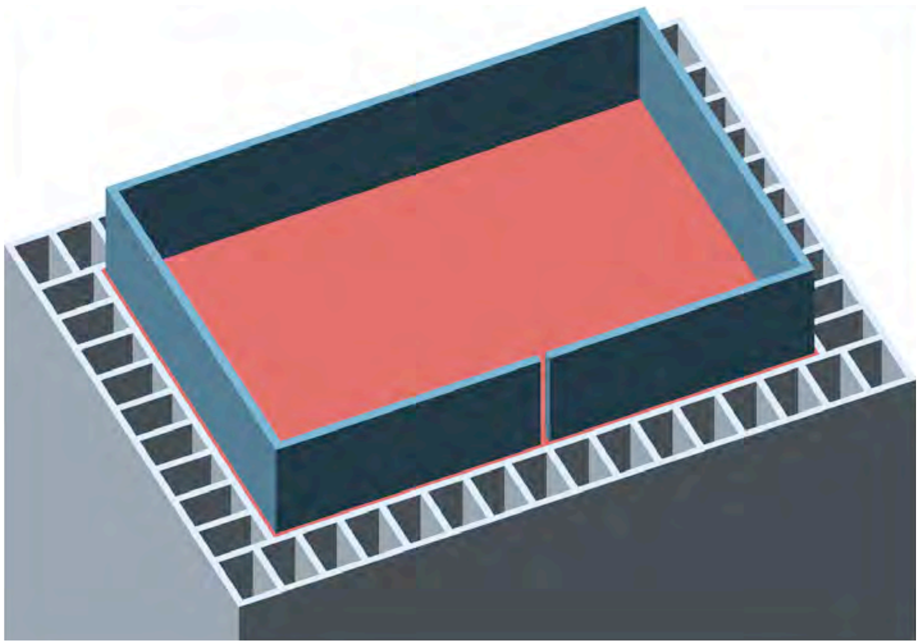


Steps of the Tokamak Exhaust Processing

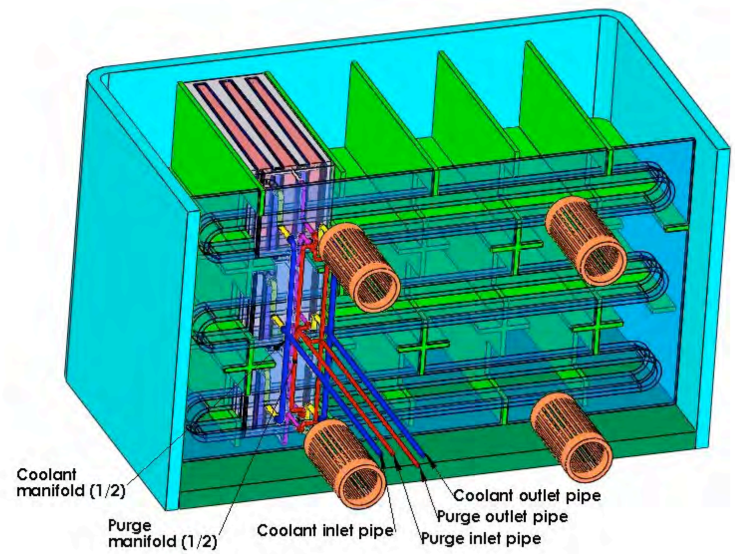


- Battery of front-end permeators (first process step)
- Cracking or conversion reactions (impurity processing, second process step)
- Counter current isotopic swamping (final clean-up, third process step)

Tritium-breeding: Test Blanket Modules
(Outside the ITER Construction Project and US ITER Project)



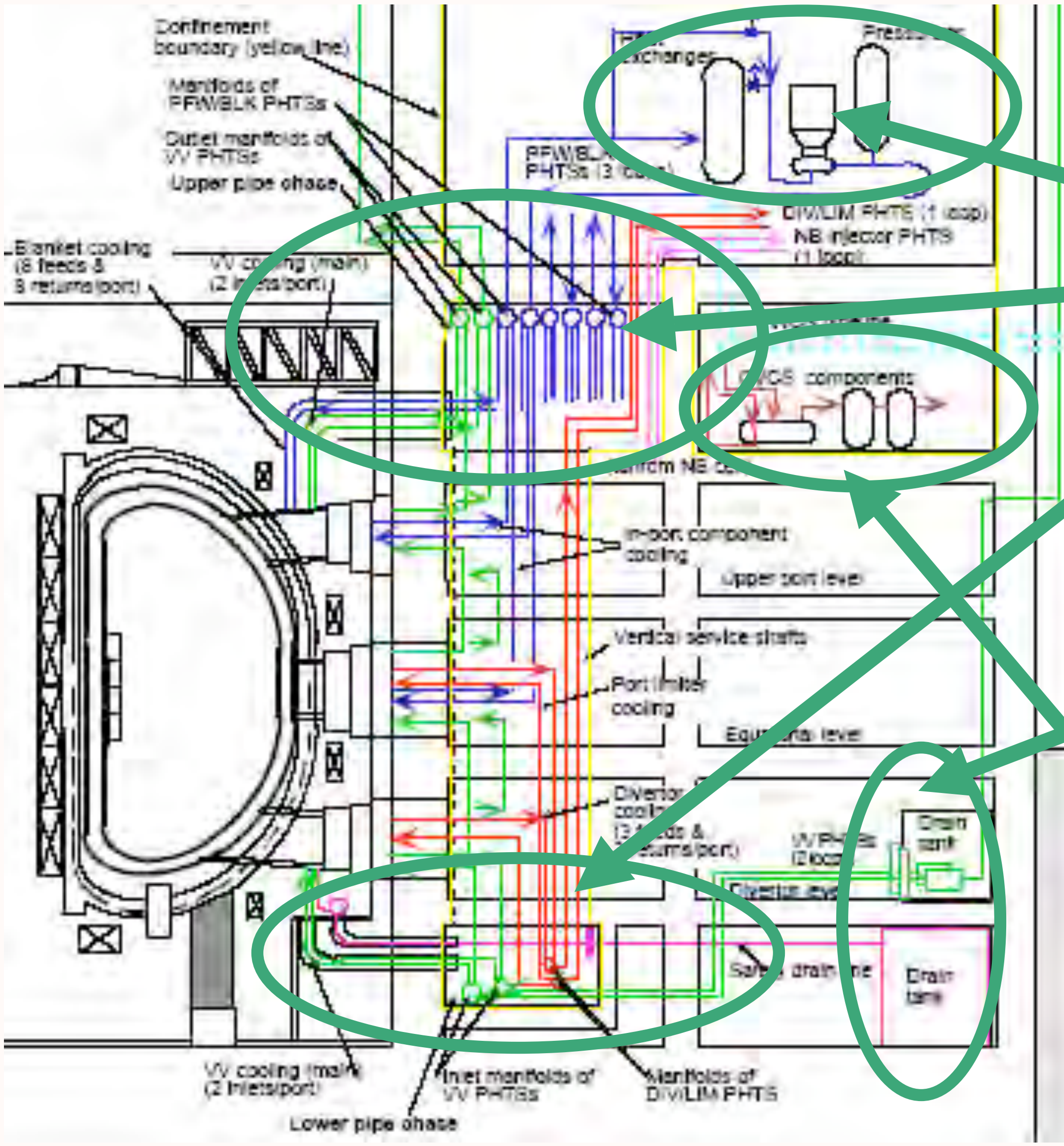
Dual Coolant Lead- Lithium TBM



Schematic view of solid breeder thermomechanics unit cell test articles housed inside helium-cooled pebble bed box

Cooling Water

Seven sub-systems distributed throughout Tokamak building



Primary Heat Transfer:

- Vault
- Upper Pipe Chase
- Roof
- Lower Pipe Chase

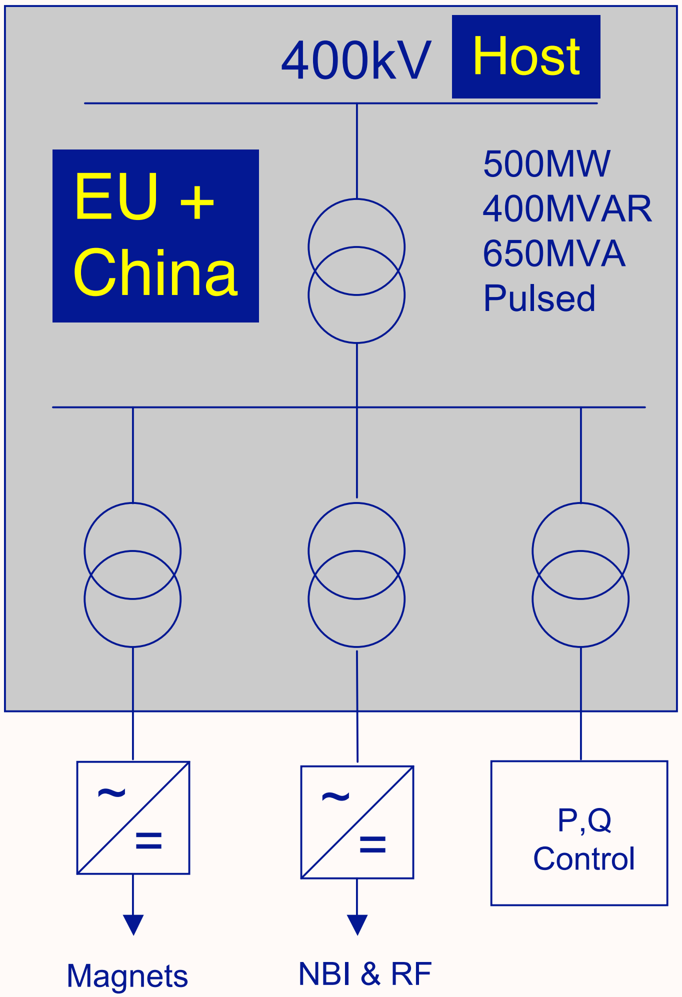
Support Systems:

- Draining and Refilling (WBS1.2.1.6)
- Chemical and Volume Control System (WBS1.2.1.5)
- Drying (WBS1.2.1.7)

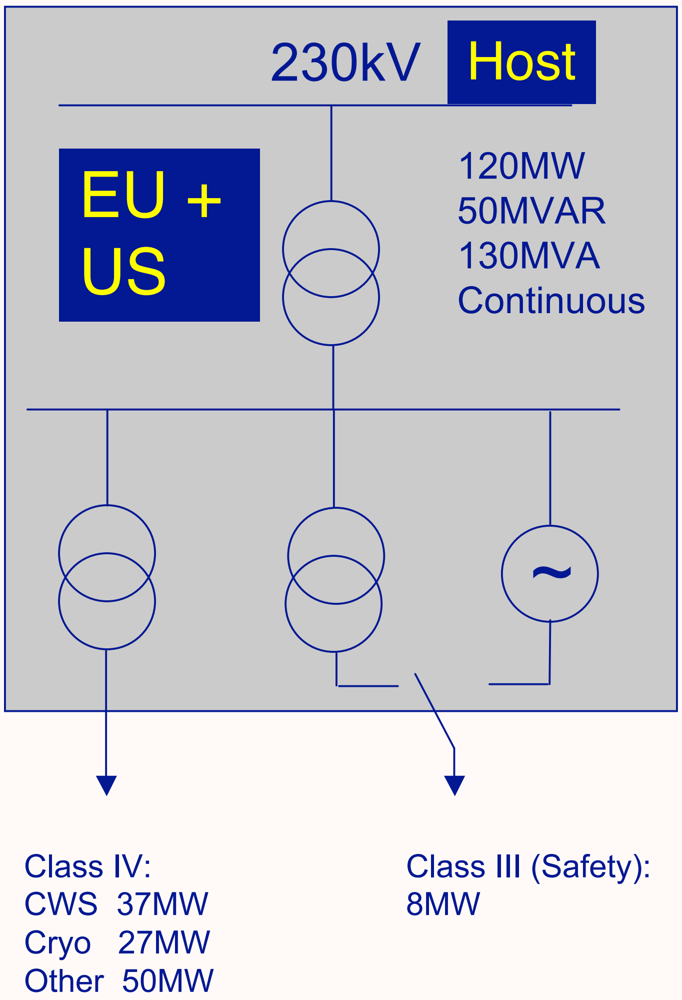
Steady-state Electric Power

ITER AC Power Systems: Generic Site

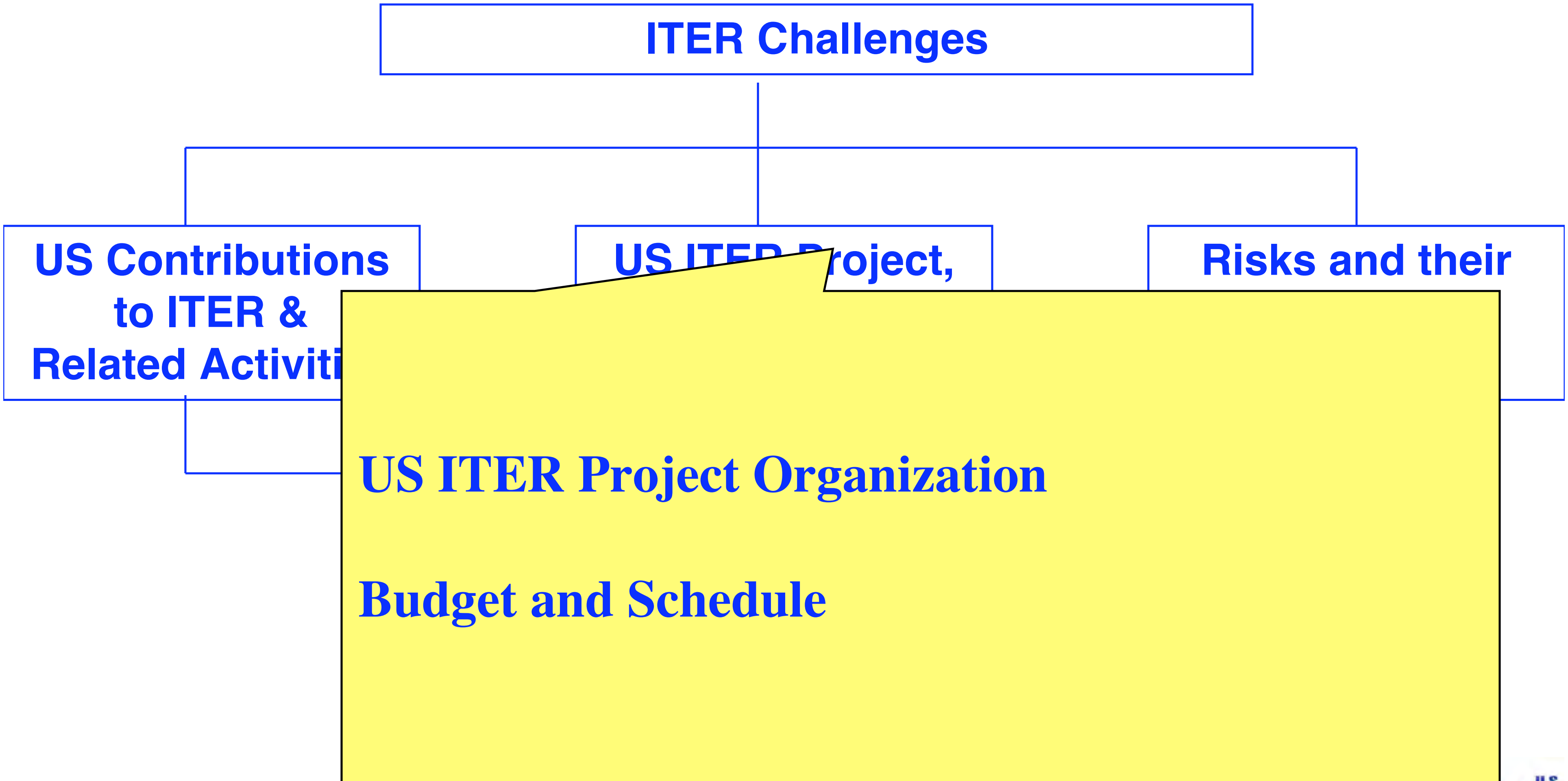
Pulsed Power Electric Network



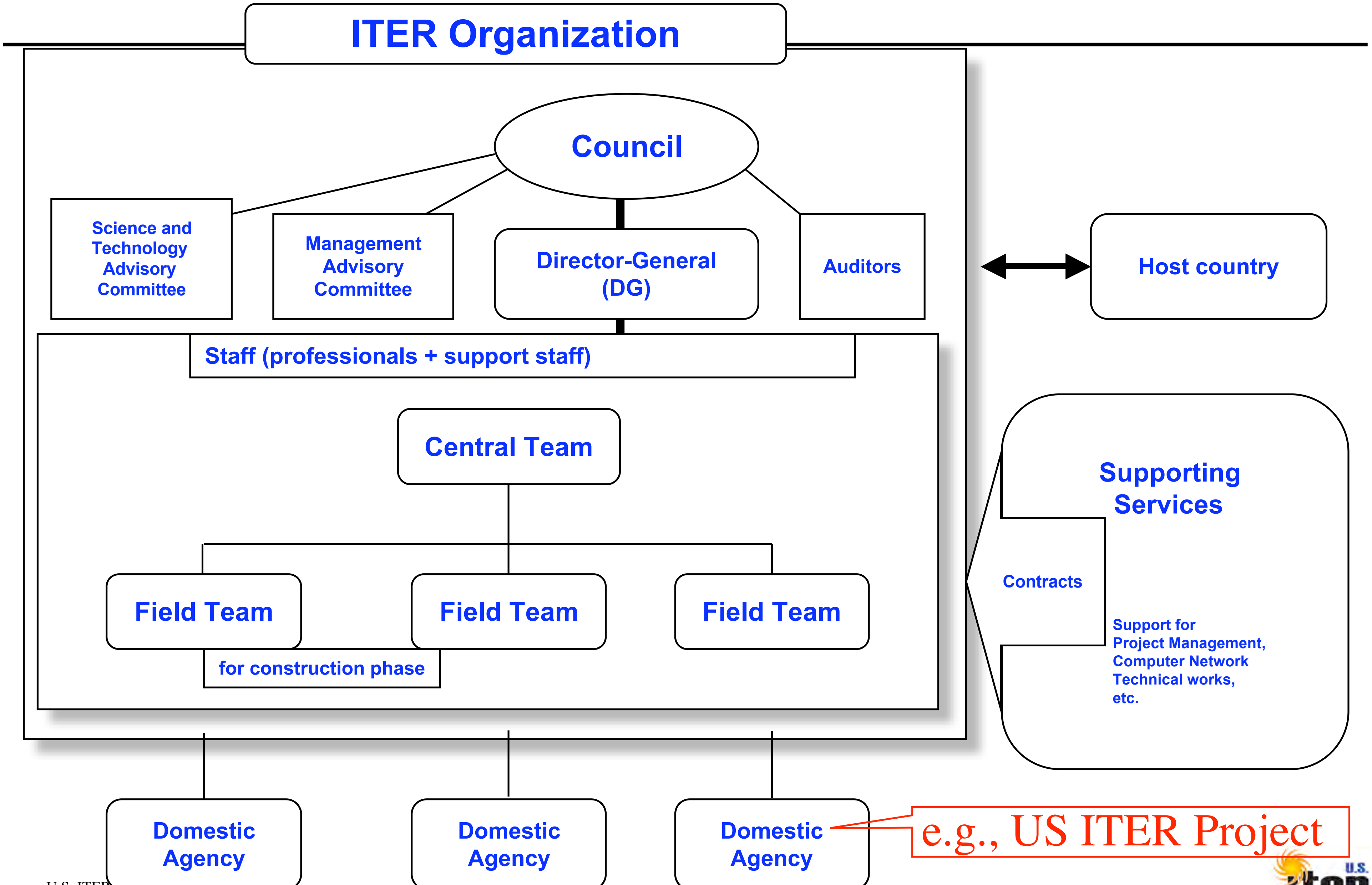
Steady State Electric Power Network



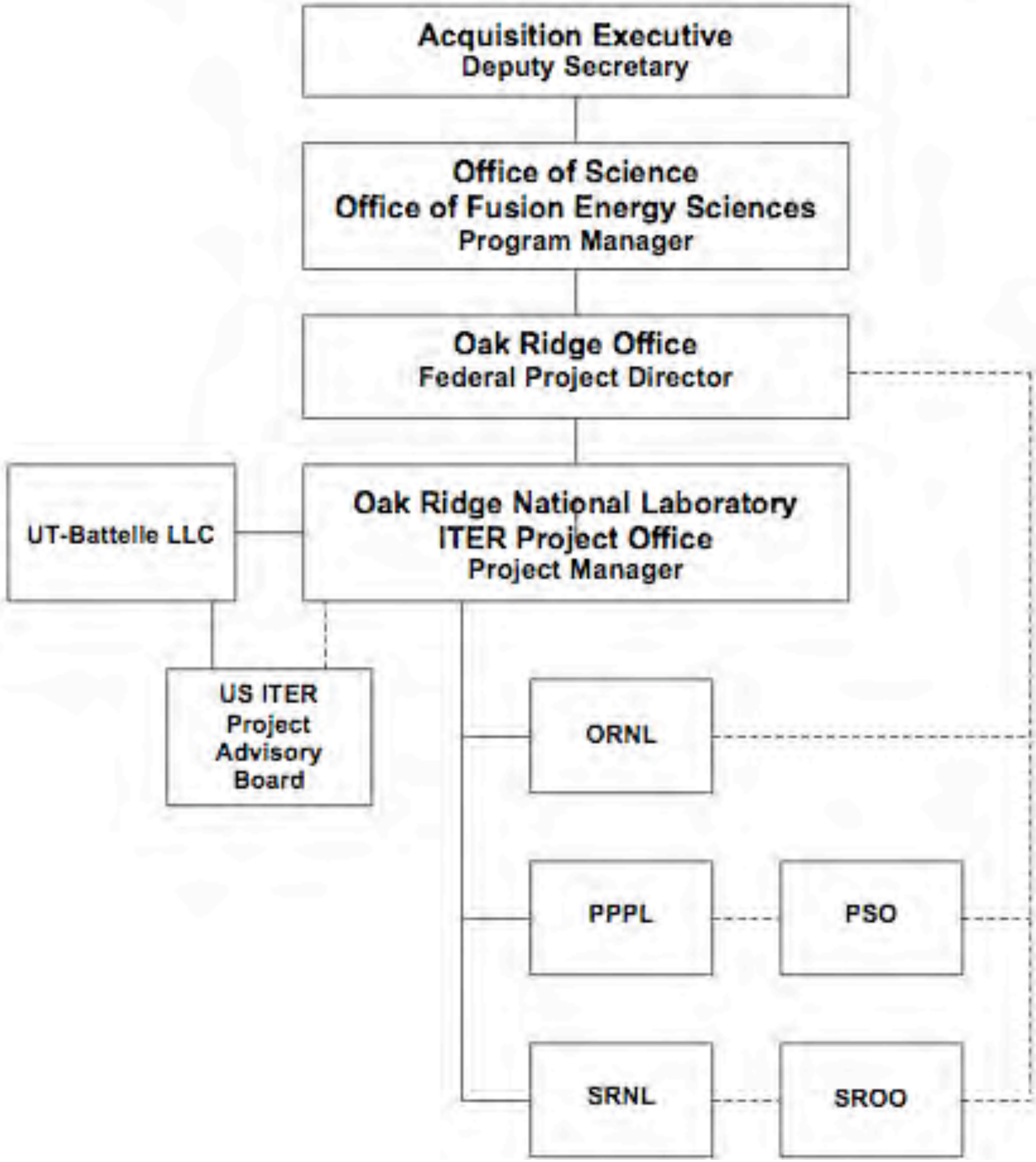
Structure of the Talk…



Highest Level Management Structure



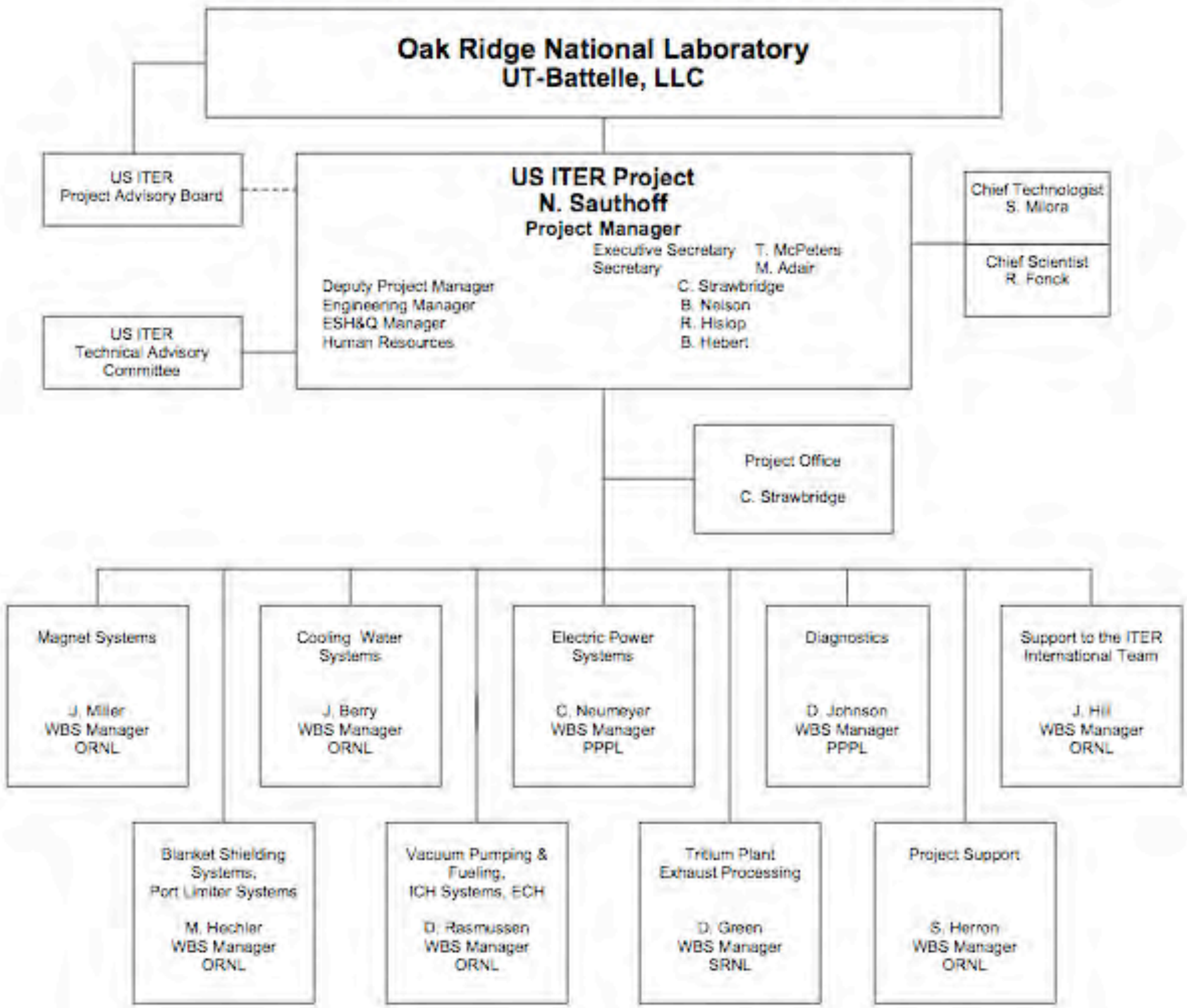
The US ITER Project Office (US IPO) is established



Legend:

LLC	Limited Liability Company
ORO	Oak Ridge Office
PSO	Princeton Site Office
ORNL	Oak Ridge National Laboratory
PPPL	Princeton Plasma Physics Laboratory
SRNL	Savannah River National Laboratory
SROO	Savannah River Operations Office

The US IPO management team has been fully staffed, with all seven WBS Managers now on board”



Support of the International Team

- **Cash, as part of “Staff and Infrastructure”**
- **Domestic Staff support of the IT**
  - Design and facilitation of systems with US-scope
  - Project management expert support
- **Candidates to fill “Urgent Positions”**

IT-selected US Secondee Candidates and Visiting Researchers

DDG/Tokamak:	Gary Johnson (ORNL)
Buildings:	Jerry Sovka (ATI)
Diagnostics/in-vessel [VR]:	Doug Loesser (PPPL)
Fusion Nuclear Safety:	Dennis Baker (SRNL)
IC H&CD [VR]:	Richard Goulding (ORNL)
IC H&CD:	Joe Tooker (General Atomics)
Magnets [VR]:	Nicolai Martovetsky (LLNL)
Magnets:	Remy Gallix (General Atomics)
Planning:	Larry Lew (High Bridge)
QA:	Ken Sowder (INL)
Site & Facility:	Paul Holik (ORNL)
Vacuum Vessel:	Chang Jun (PPPL)

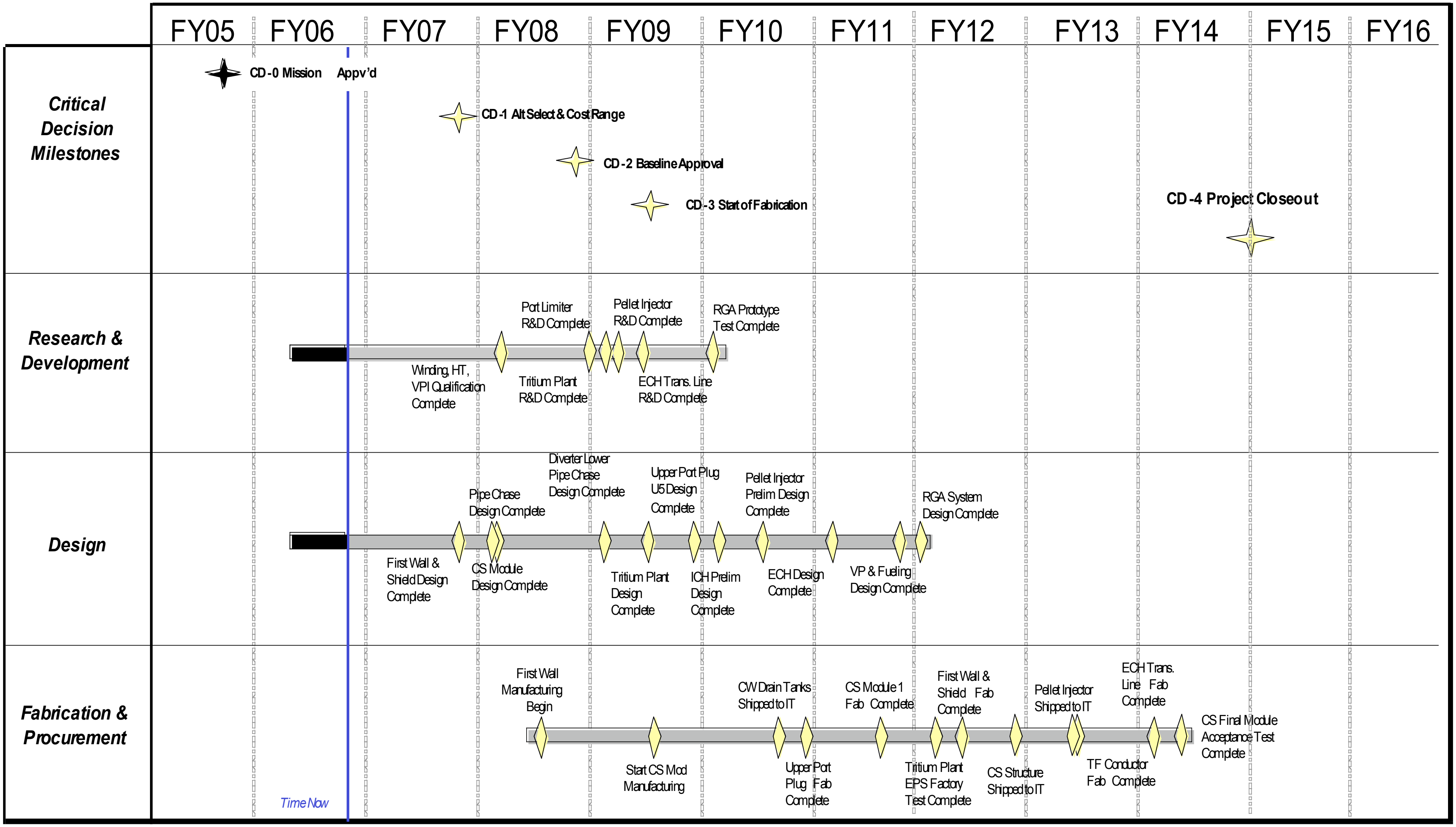
Future IT/IO staff selections

- **Now posted in the US:**
  - Diagnostics Engineer
  - Diagnostic Physicist
  - Superconductor Engineer
  - Coil Designer
- **Expected soon:**
  - ~50 additional positions in physics, technical, administrative, and project management areas

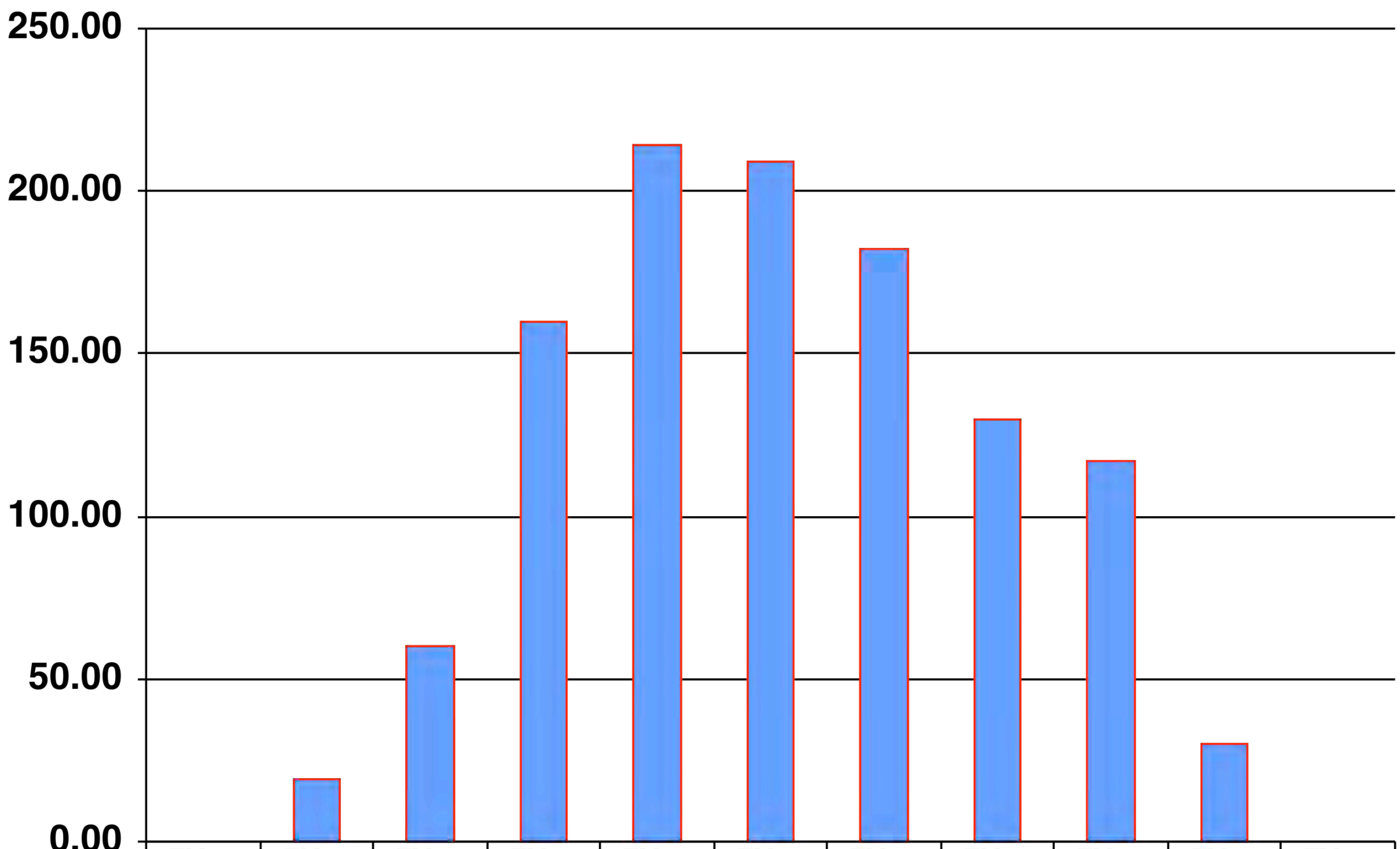
International Design Review

- **To enable US domestic project progress, the US seeks a revised baseline for the US scope by Summer 2007**
- **Schedule for the Design Review**
  - Now: Preparation, submission and prioritization of “issues;” development of design approaches/solutions
  - Winter 2006/7: International Team Design Review meeting
  - Winter/Spring 2007: International Team, Working Groups and Participant Teams update the design and schedule
  - Spring/Summer 2007: revised Design Baseline
  - ??? 2007: Council-approved Design Baseline

US ITER Preliminary Schedule



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



	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Budget request	0.00	19.32	60.00	160.00	214.50	209.32	181.96	130.00	116.90	30.00	0.00

Structure of the Talk…

ITER Challenges

US Contributions to ITER Related Act

US ITER Project,

Risks and their Management

Major Risks

Risk Mitigation Actions

- IT support/joint work
- participation in the design review

Major Risks and Issues

- **Uncertainties about International "need dates" for US components**
- **Uncertainties about contents and availabilities of Internationally-provided component specifications and requirements**
  - Design Baseline
  - Procurement Agreements (technical and management aspects for US procurements)
  - Codes, standards, and Host regulations
- **Uncertainties about drivers of US cost linked to other parties**
  - Sub-components from other parties
  - Responsibilities for costs related to regulatory requirements imposed by the Host

Summary assessment and path forward

- **A strong international ITER Organization is key to ITER success**
  - the central ITER team is growing in strength, improving its ability to perform necessary system integration and project leadership

- **The US Domestic Agency senior management is assembled, is building it team and tools, and is developing its FY2007 Work Plans**

- **US Near-term Activities focus on:**
  - Completing R&D, design, and re-baselining of the US scope
    - Positioning for updated scope, and firmer cost and schedule estimates by the end of 2007
    - Supporting the International Team with secondees, on-site experts, and domestic work
  - Enabling the US scientific and technology communities to participate in the upcoming ITER Design Review to make ITER as good a research tool as it can be….