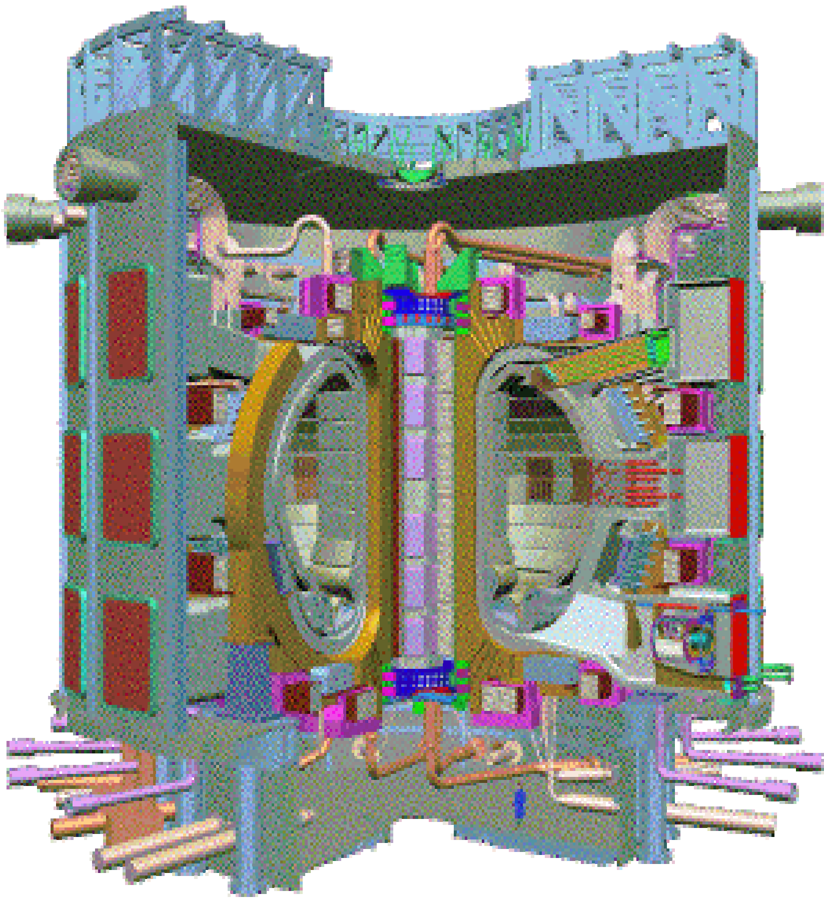
US ITER Project Activities

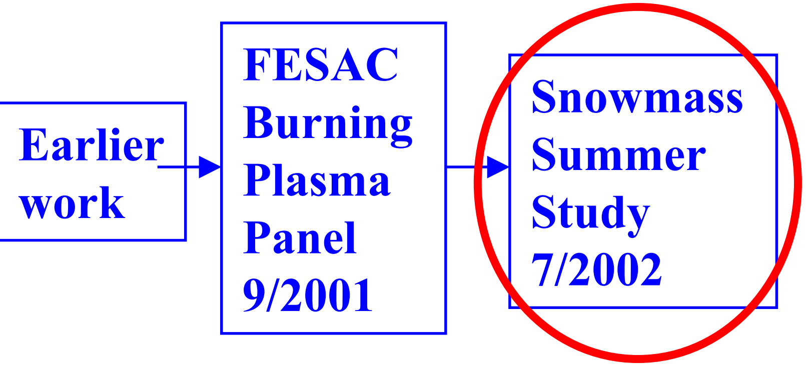
Partnering on ITER for studies of burning plasma science and technology



Ned Sauthoff, Project Manager
U.S. ITER Project Office

16th ANS TOFE
9/16/04

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

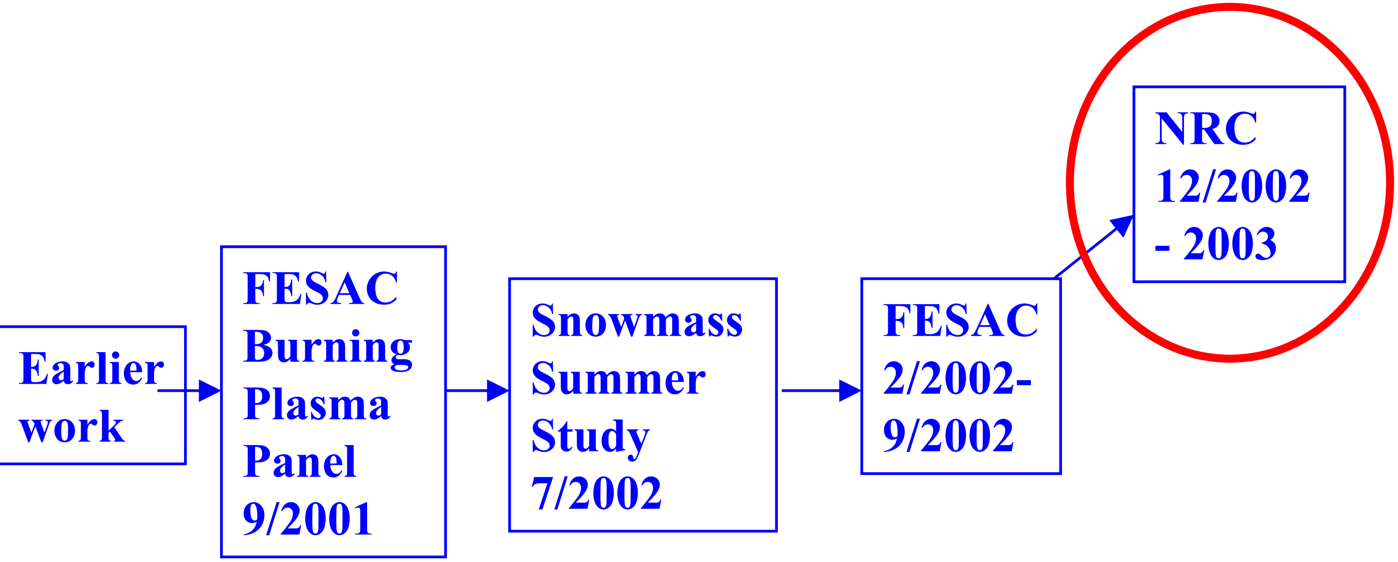


General Observations from Snowmass 2002

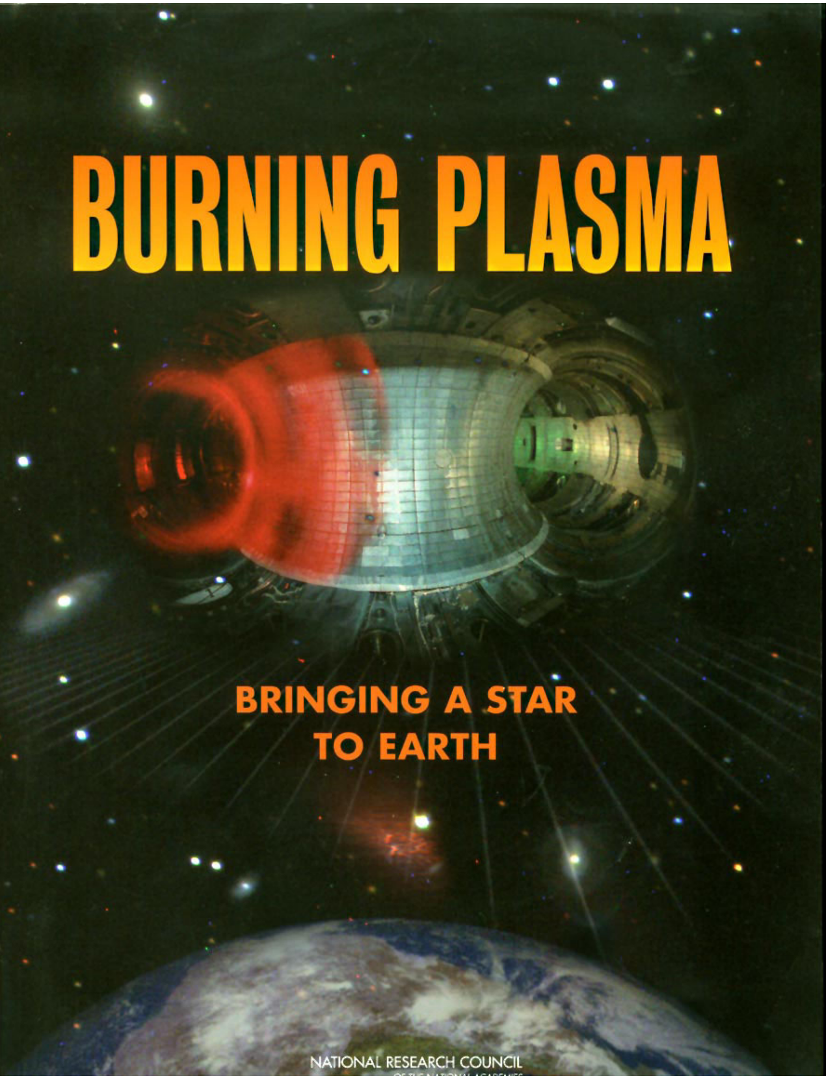
- **Strong sense of excitement and unity in the community for moving forward with a burning plasma step**

- **Overwhelming consensus that**
  - Burning plasmas are opportunities for good science and technology --- exploration and discovery
  - Tokamaks are ready to proceed --
    the science-technology basis is sufficient
  - Other toroidal configurations (ICCs) would benefit from a burning tokamak plasma
  - The base program and the ICC elements play critical roles

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

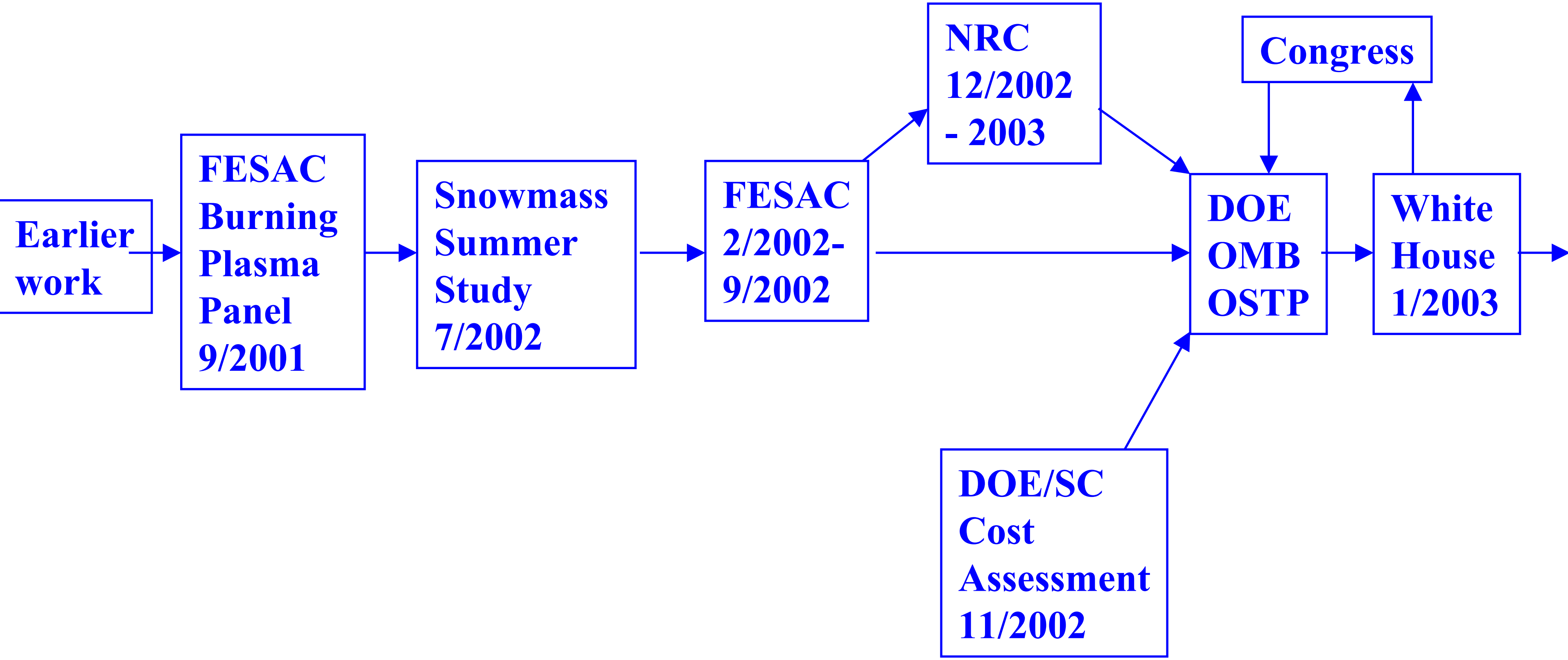


NRC: "Burning Plasma: Bringing a Star to Earth"



- "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.

…

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

(Energy Secretary Abraham at PPPL)

DOE/SC Facilities Plan (11/03): ITER #1

"ITER is an international collaboration to build the first fusion science experiment capable of producing a self-sustaining fusion reaction, called a 'burning plasma.'

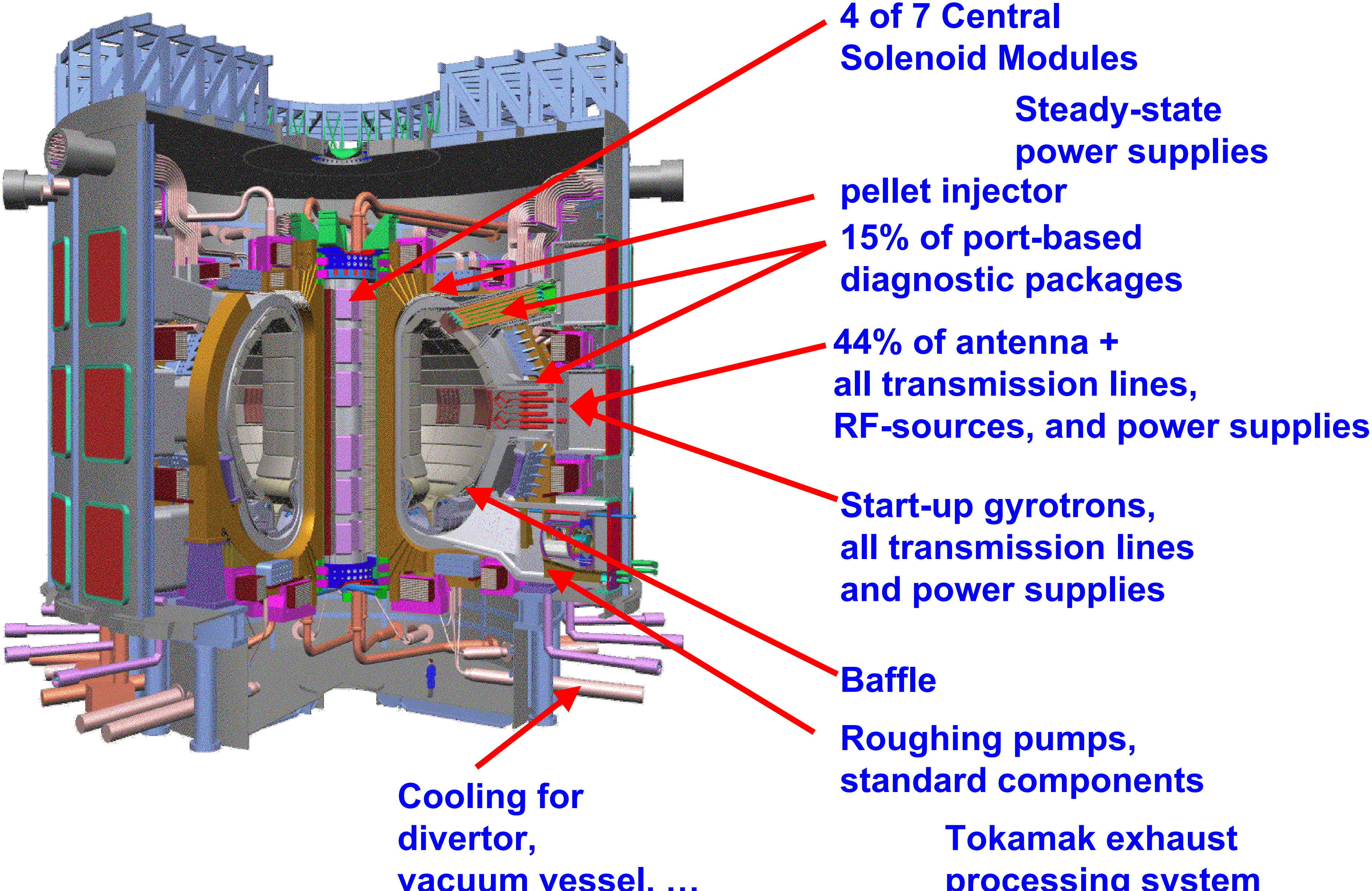
It is the next essential and critical step on the path toward demonstrating the scientific and technological feasibility of fusion energy."

Scope of the ITER Transitional Arrangements*

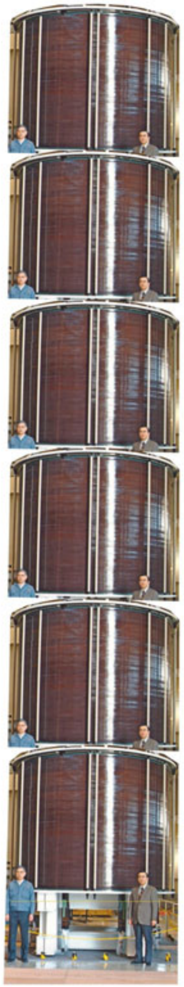
- "Joint technical preparations directed
  at maintaining the coherence and integrity of the ITER design and
  at preparing for an efficient start of ITER construction"

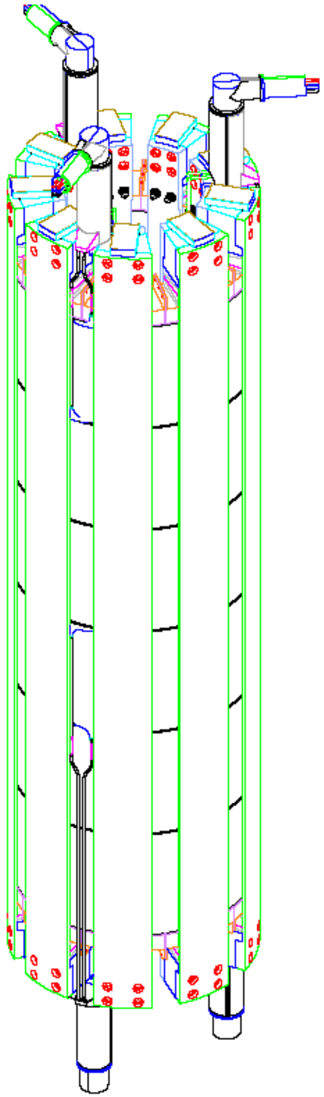
- "Organisational preparations directed
  at enabling the ITER Legal Entity to enter into effective operation
  with least possible delay following the entry into force of the ITER
  Joint Implementation Agreement"

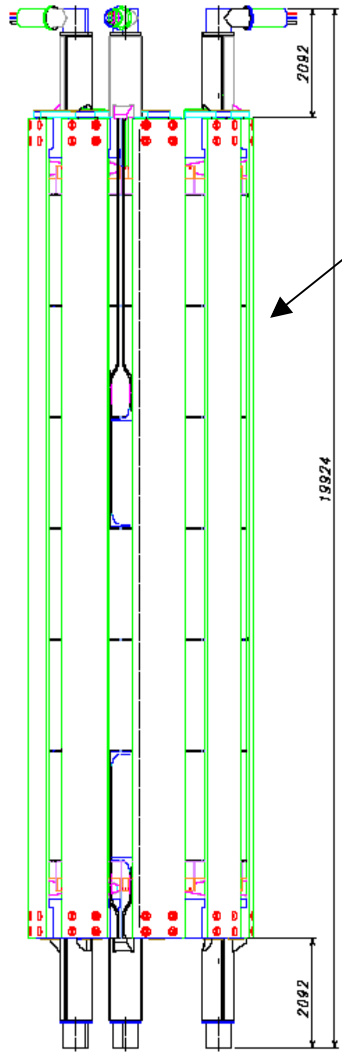
US In-kind Contributions to ITER



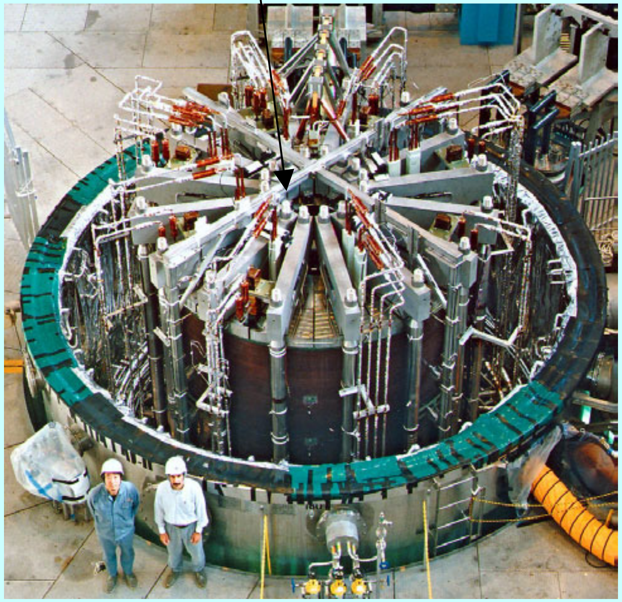
CS Coil is Composed of 6 Pancake Wound Modules



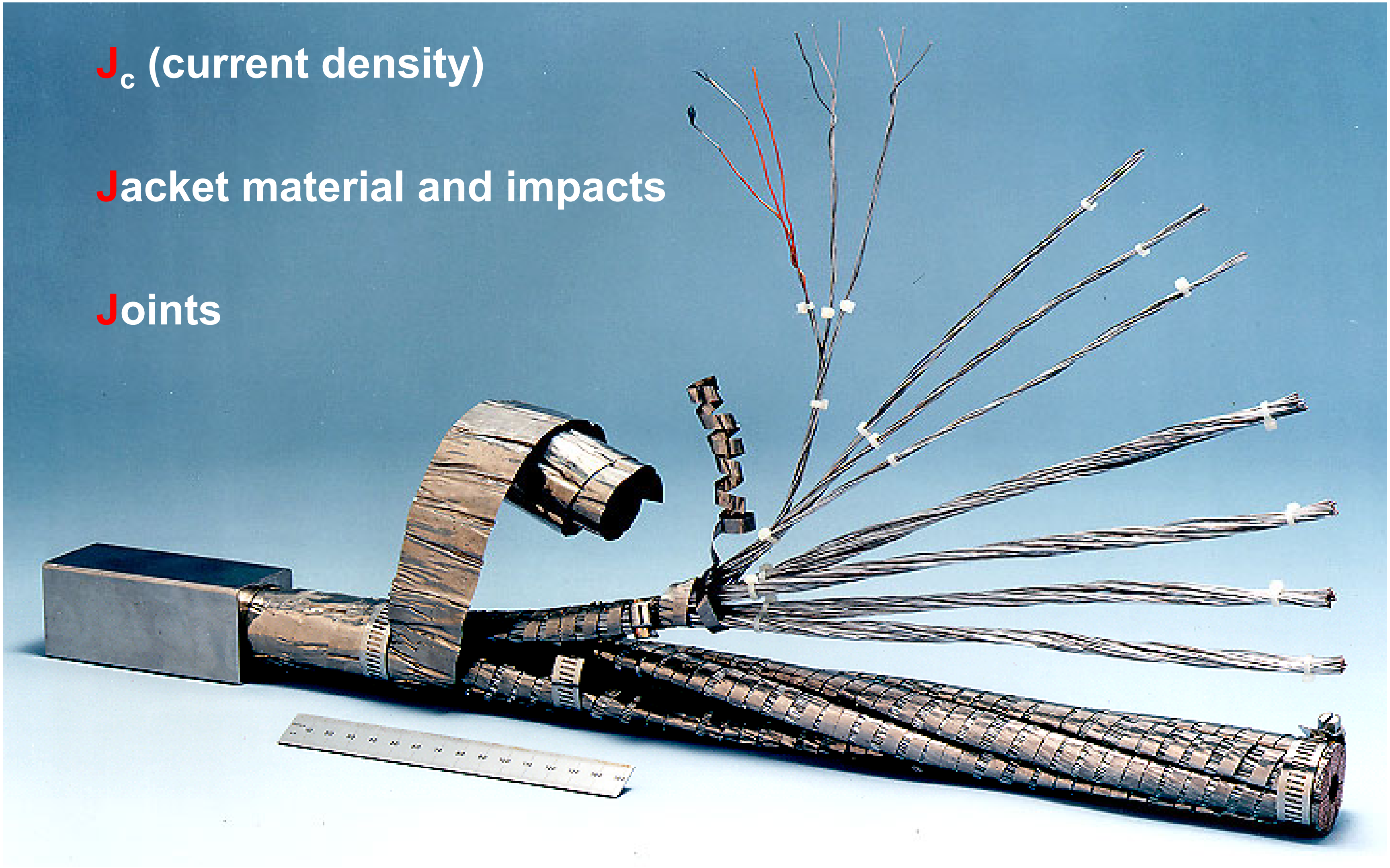




Each **Module** is slightly larger than the complete **CS Model Coil**



Central Solenoid Conductor



J_c (current density)

Jacket material and impacts

Joints

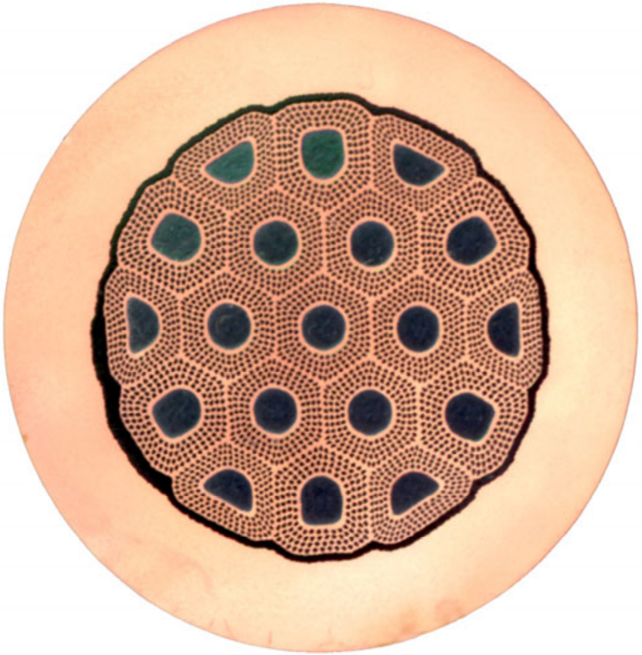
Mitigating the CS Magnet Technical Risks

Risks/Issues	Tasks and Secondee Assignments
Strand performance and supply	✔ Qualification of industrial suppliers of Nb3Sn strands with increased Jc
Conductor performance and temperature margin	✔ Conductor performance and design criteria (transverse load effects)
Fatigue life of Conductor Jacket	• Jacket Materials characterization ✔ CS jacket weld defect assessment
Failures of Butt-joints	• Joint Development and Tests (butt-type and lap-type)
Integrated performance of the CS	• Mechanical Characterization of CS modules, pre-compression structure and support structure
Incomplete CS design and procurement specifications	✔ Secondees: Completion of CS Specifications and Procurement Package
Stresses in the high-field regions of CS Modules	✔ Stress analysis of the helium inlet regions

✔ Indicates an approved task or secondee-assignment

Qualification of industrial suppliers of Nb3Sn strands with increased value of Jc (ITA 11-18)

- A Request For Proposal (RFP) was issued in May to 4 US strand vendors for the development and qualification of >100kg of superconducting strand meeting a US-proposed CS specification.

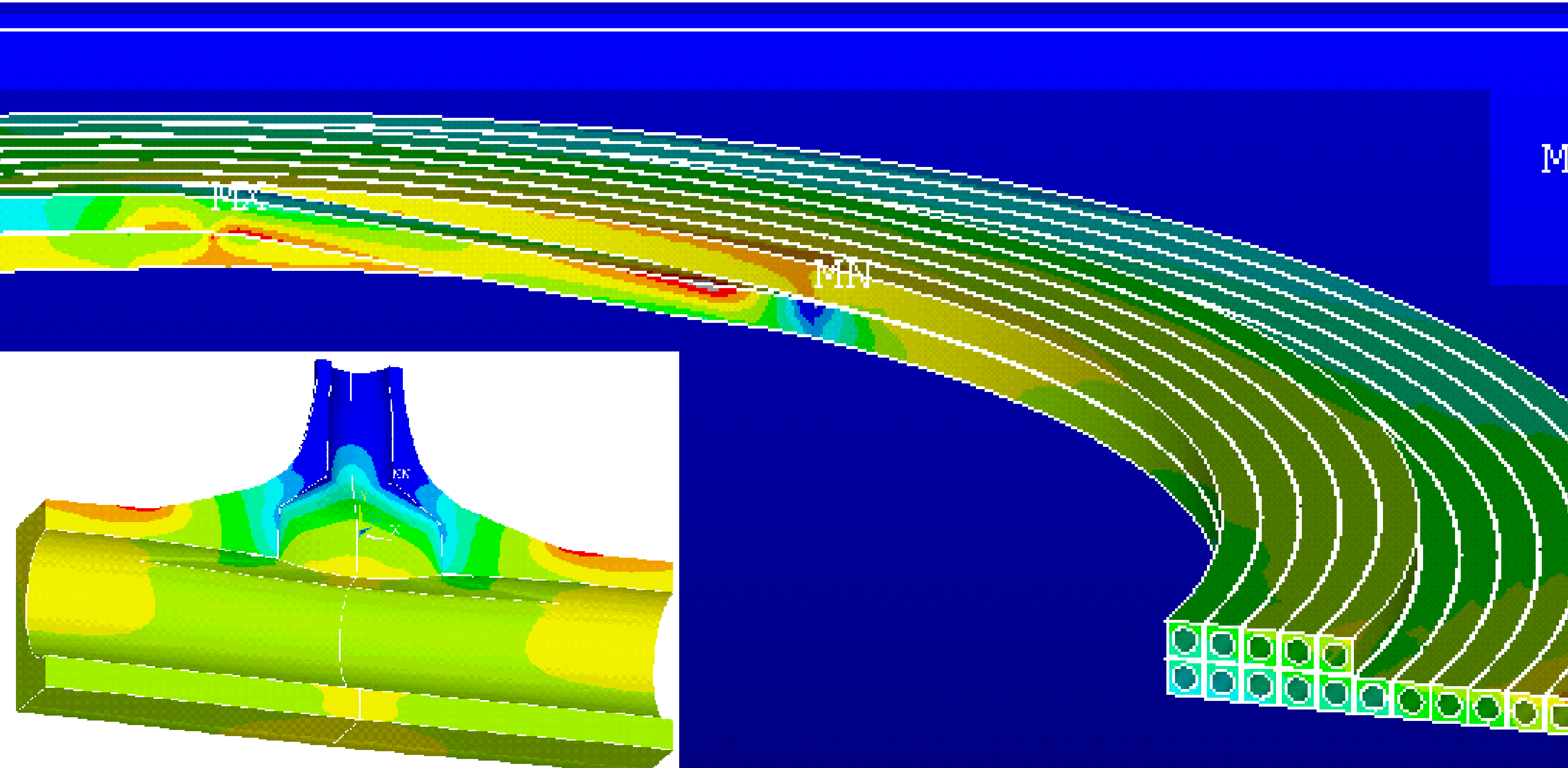


Typical strand layout as proposed by OST. Diameter is ~0.8 mm.

Stress Analysis of Helium Inlet Regions (ITA 11-20)

A preliminary analysis using a non-asymmetric 3D ANSYS model of the CS winding pack has been carried out to assess the stress in the helium inlet region.

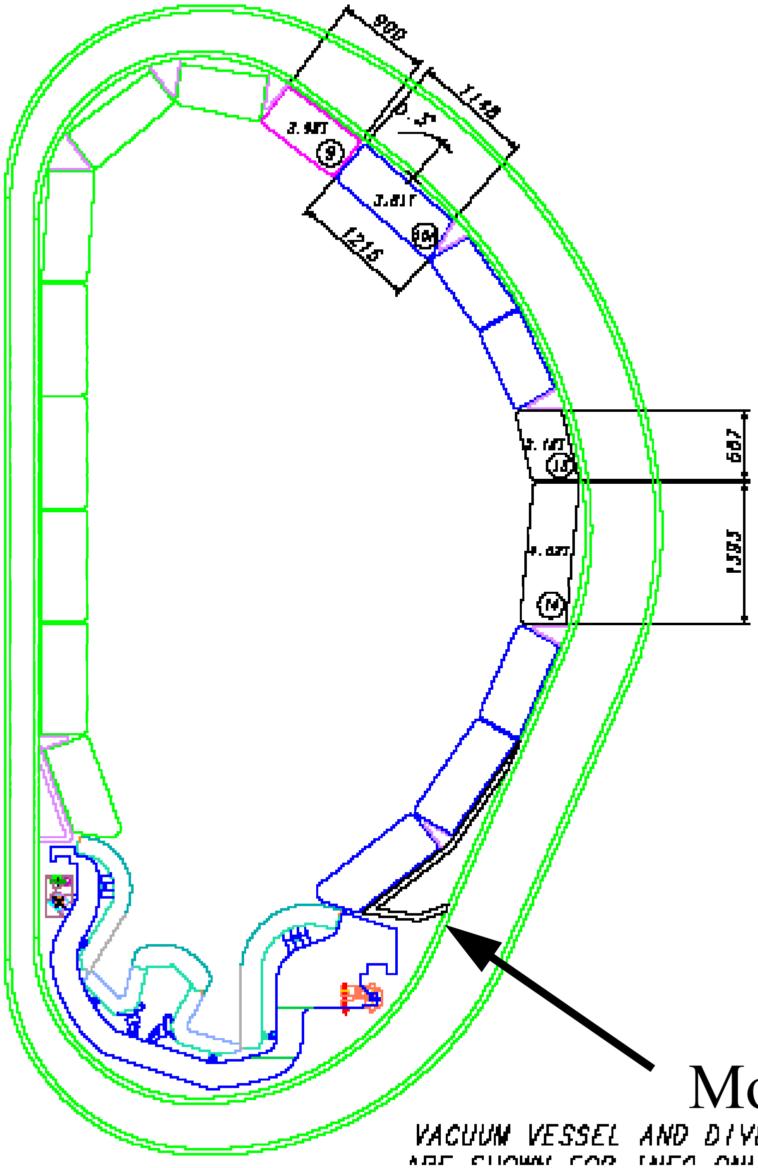
Suggestions for redesign of the welded helium inlet have been made to lower the stress concentration in this area



Conductor Performance and Design Criteria (ITA 11-22)

- Sub-size jacketed CICC samples are undergoing testing in the Sultan facility. Both SS and Ti jacketed samples are included to help understand effects on conductor performance.
- The adequacy of the present conductor design and cost/performance ratios for design alternatives have been evaluated.
- A higher performance conductor design has been recommended and the result has been used to specify the strand for the development contracts.

ITER FW/Shield Design



Module 18

Module 18 of the FW/Shield

- 36 modules around torus
- Shield module weight 3.6 Tonnes (316 LNIG steel)
- PFC area 1.6m^2
- PFC weight 0.8Tonnes (Cu+316)
- 10% of the first wall area
- 45 cm thick (PFC +shield)

US ITER First Wall Tasks

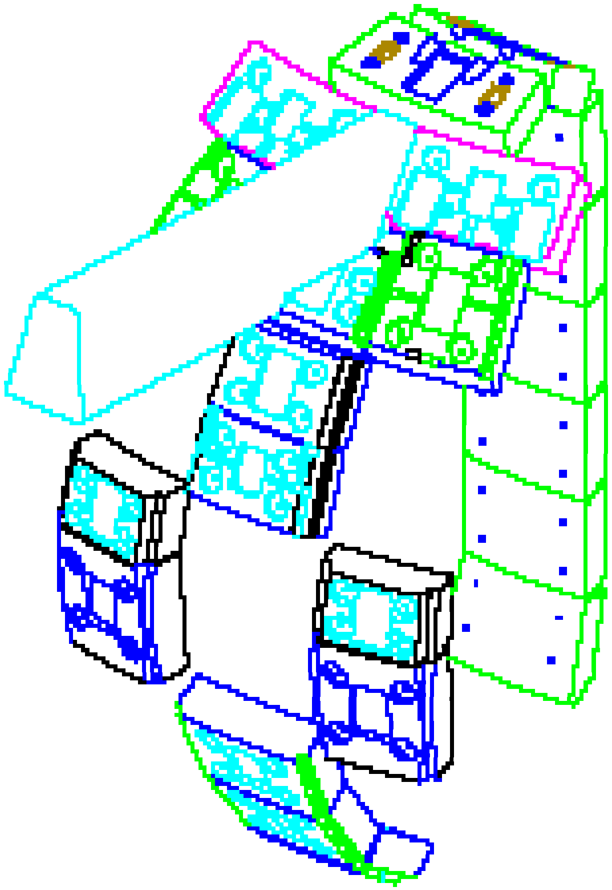
Development of the welded joint for the first wall leg, suited for cut and re-welding in the Hot Cell

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.

Analysis of erosion of the ITER first wall due to plasma impingement

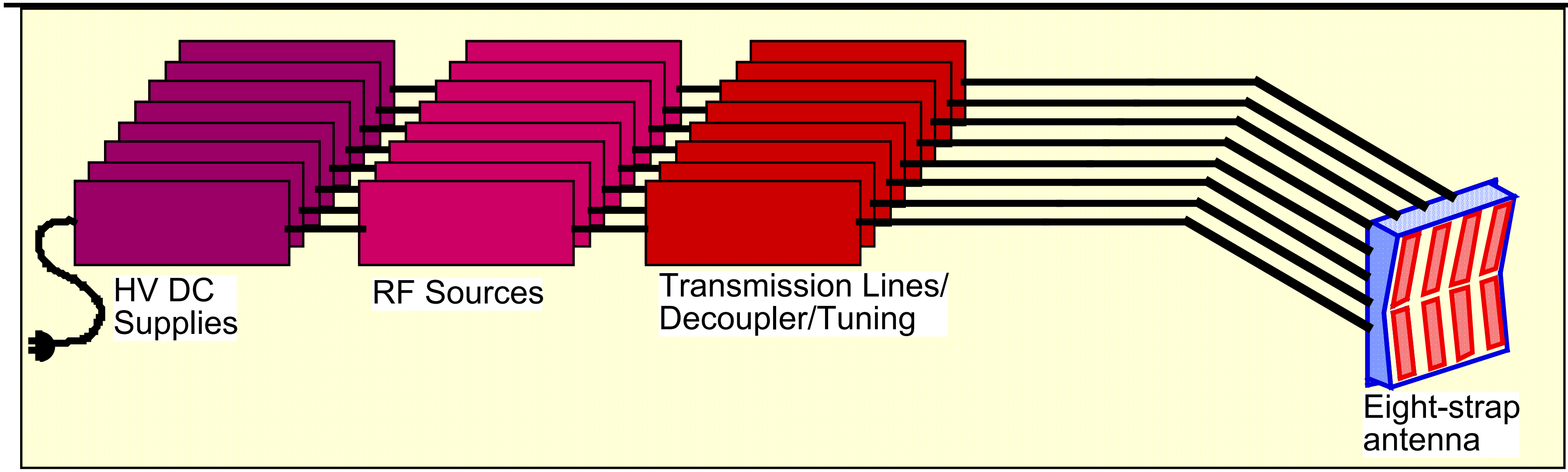


What are the major risks to be managed? Why now?

- **Design incomplete**

- **Manufacturing processes unspecified**
  - module forged with machined coolant holes or cast
  - Be/Cu joint made at 850 or 950 C with or without a Ti layer HIP or braze
  - Cu to SS joint made at 1050 C by HIP or braze.

Overview of the ITER IC system



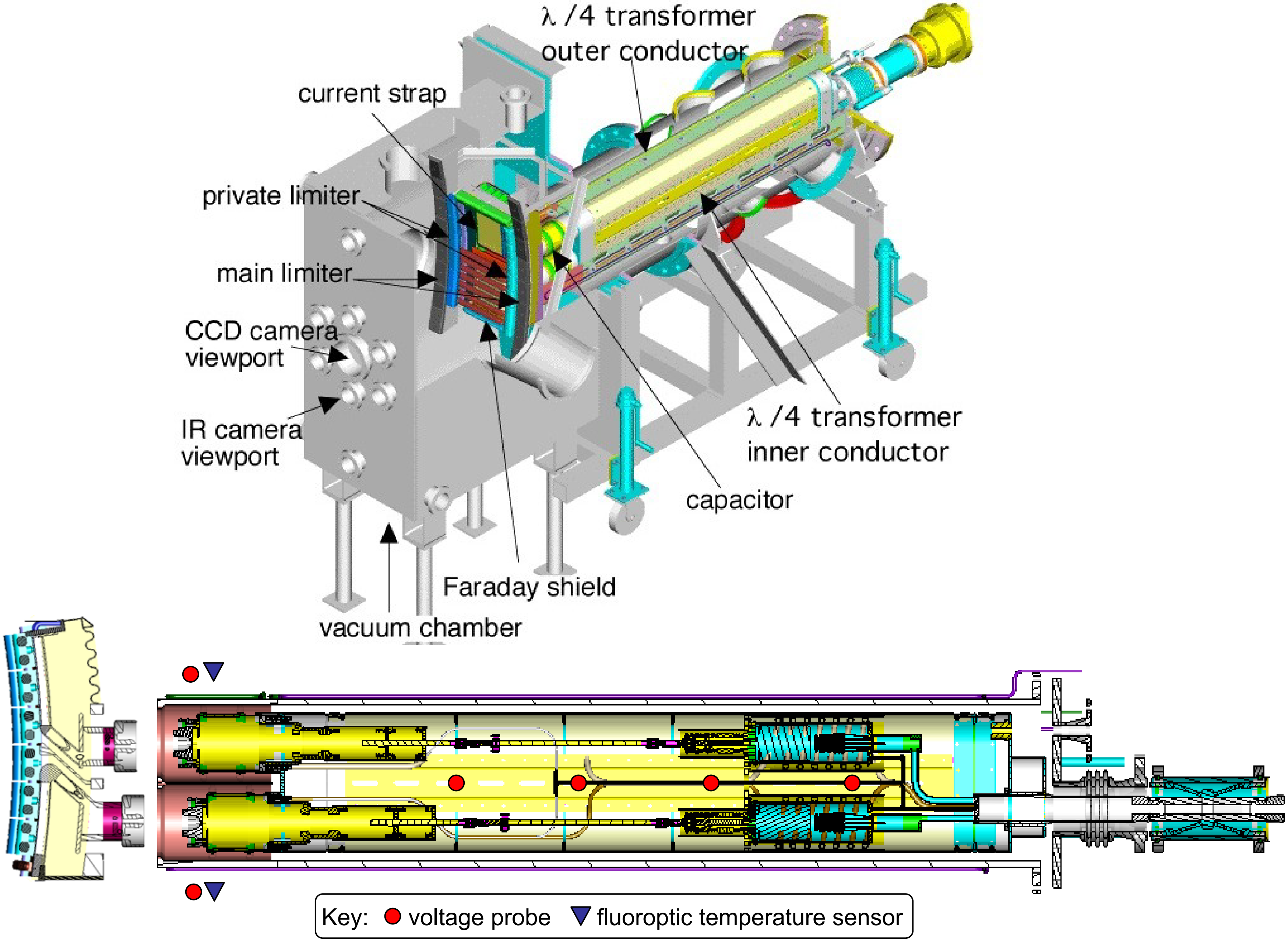
ITER ion cyclotron system block diagram

What it is:

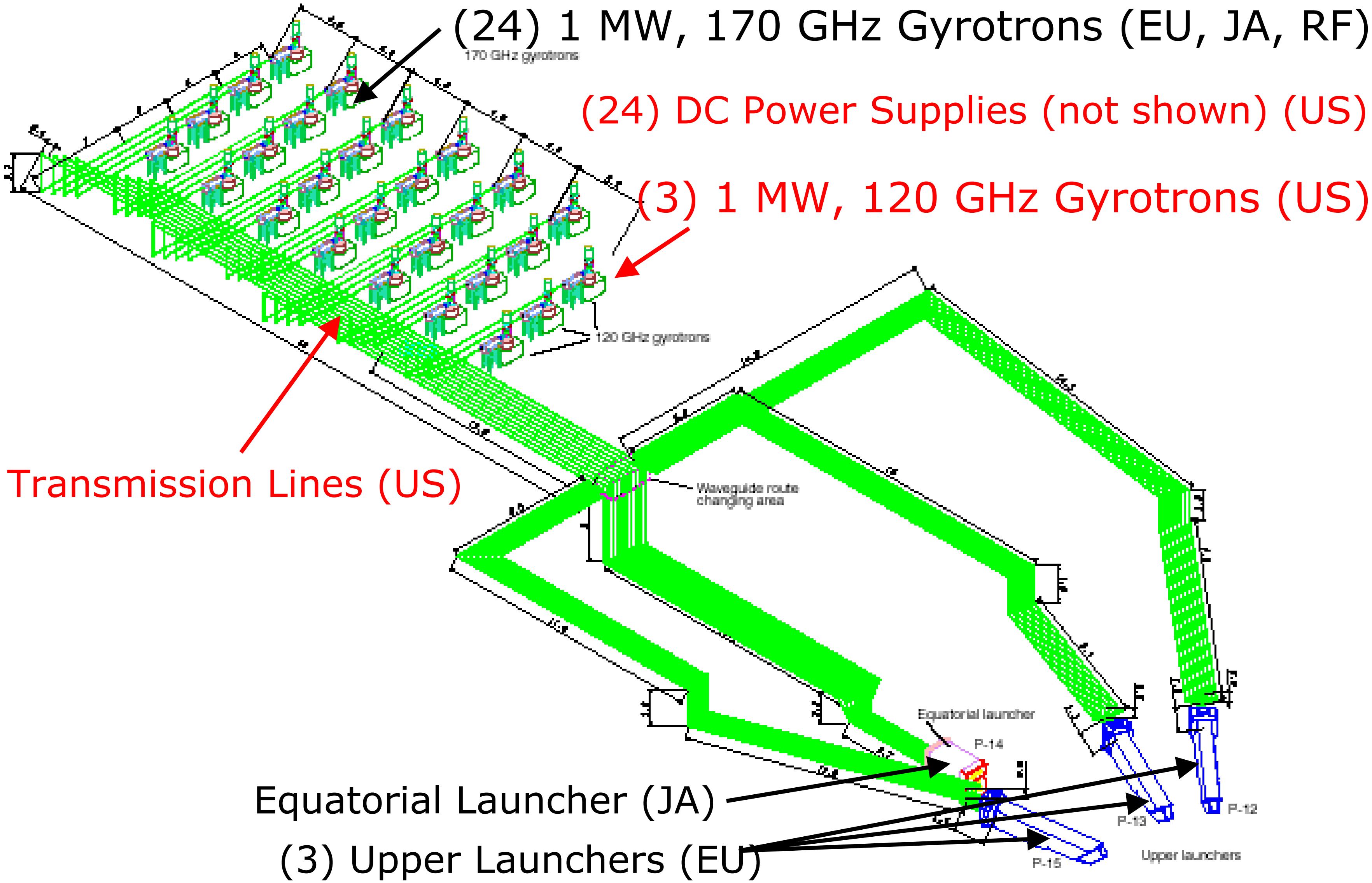
- One antenna, eight current straps
- Eight rf sources, each feeding one strap in the antenna
- 35-65 MHz
- 20 MW total power to the plasma
- Variable phasing between straps

What it can be used for:

- Tritium ion heating during DT ops.
- Minority ion heating during initial ops.
- Current drive near center for AT operation
- Minority ion current drive at sawtooth inversion radius

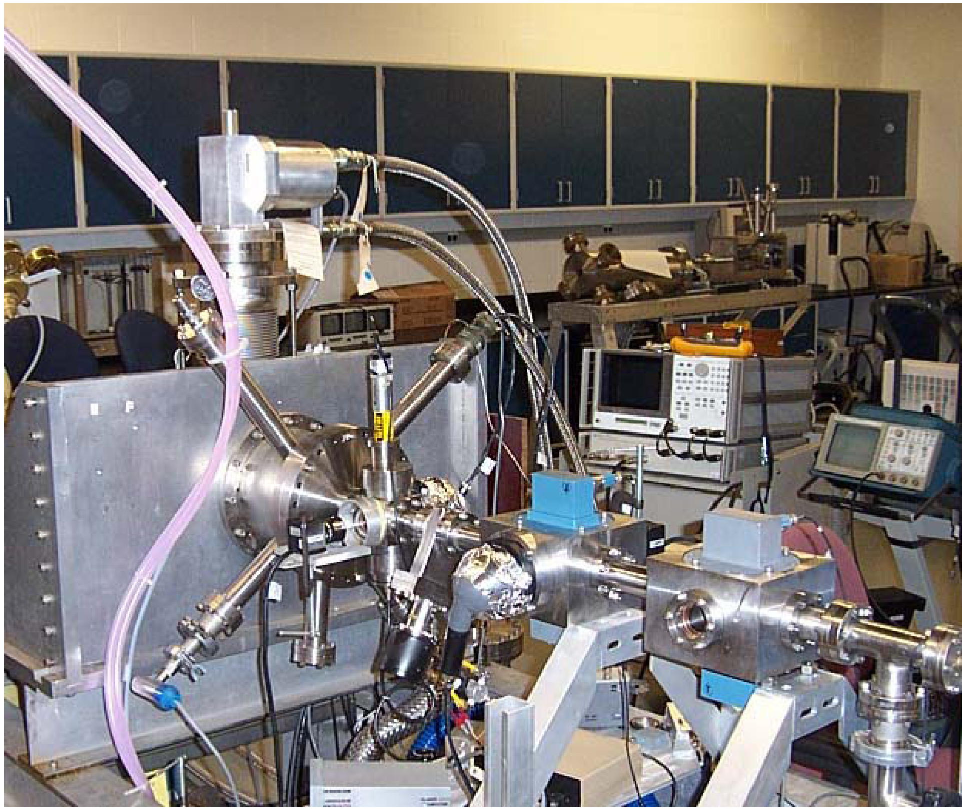

λ /4 transformer
outer conductor
current strap
private limiter
main limiter
CCD camera
viewport
IR camera
viewport
λ /4 transformer
inner conductor
capacitor
Faraday shield
vacuum chamber
Key: voltage probe fluoroptic temperature sensor

ECH System / Allocations

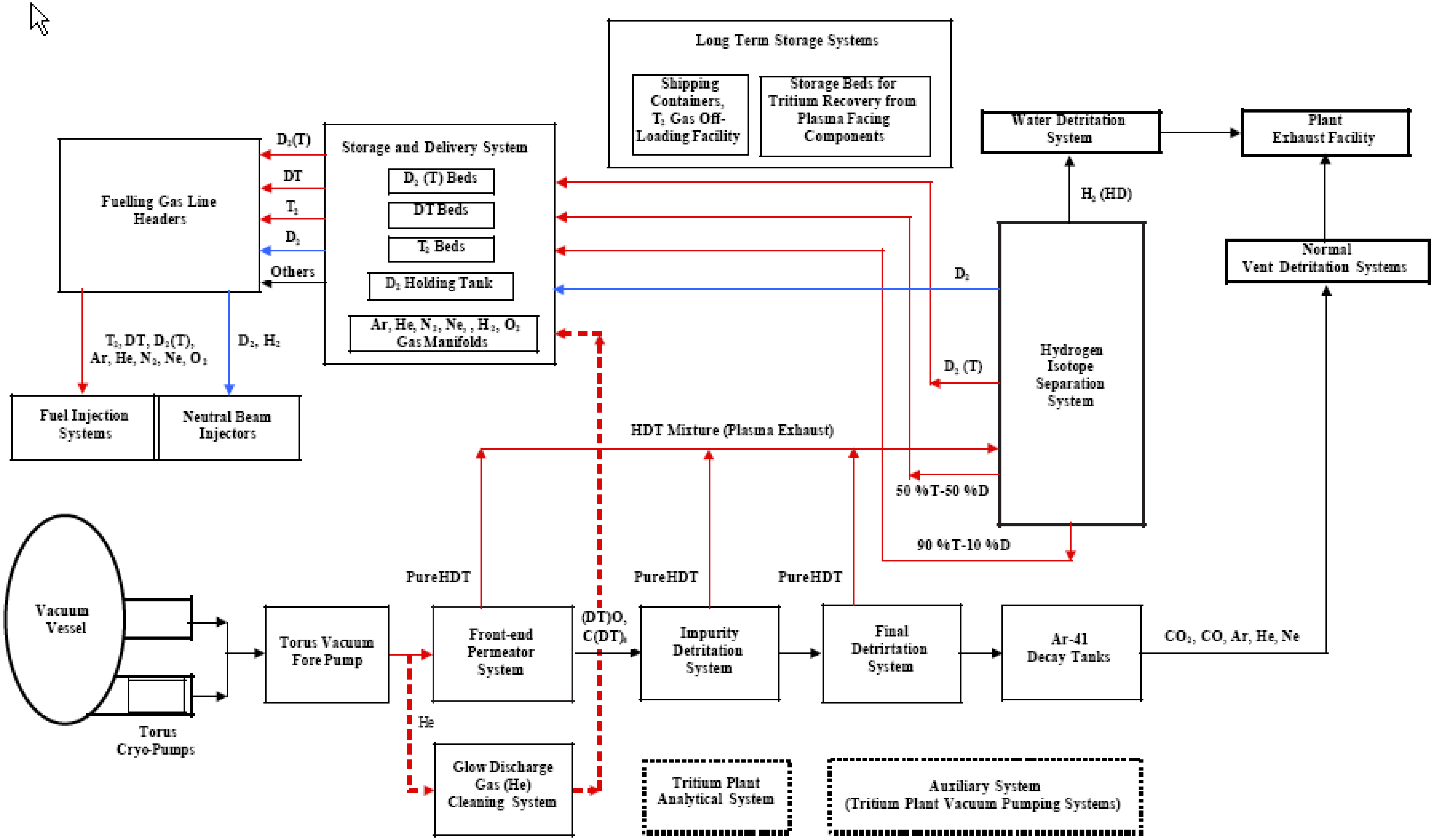


Pellet Injection and Pumping: R&D is starting

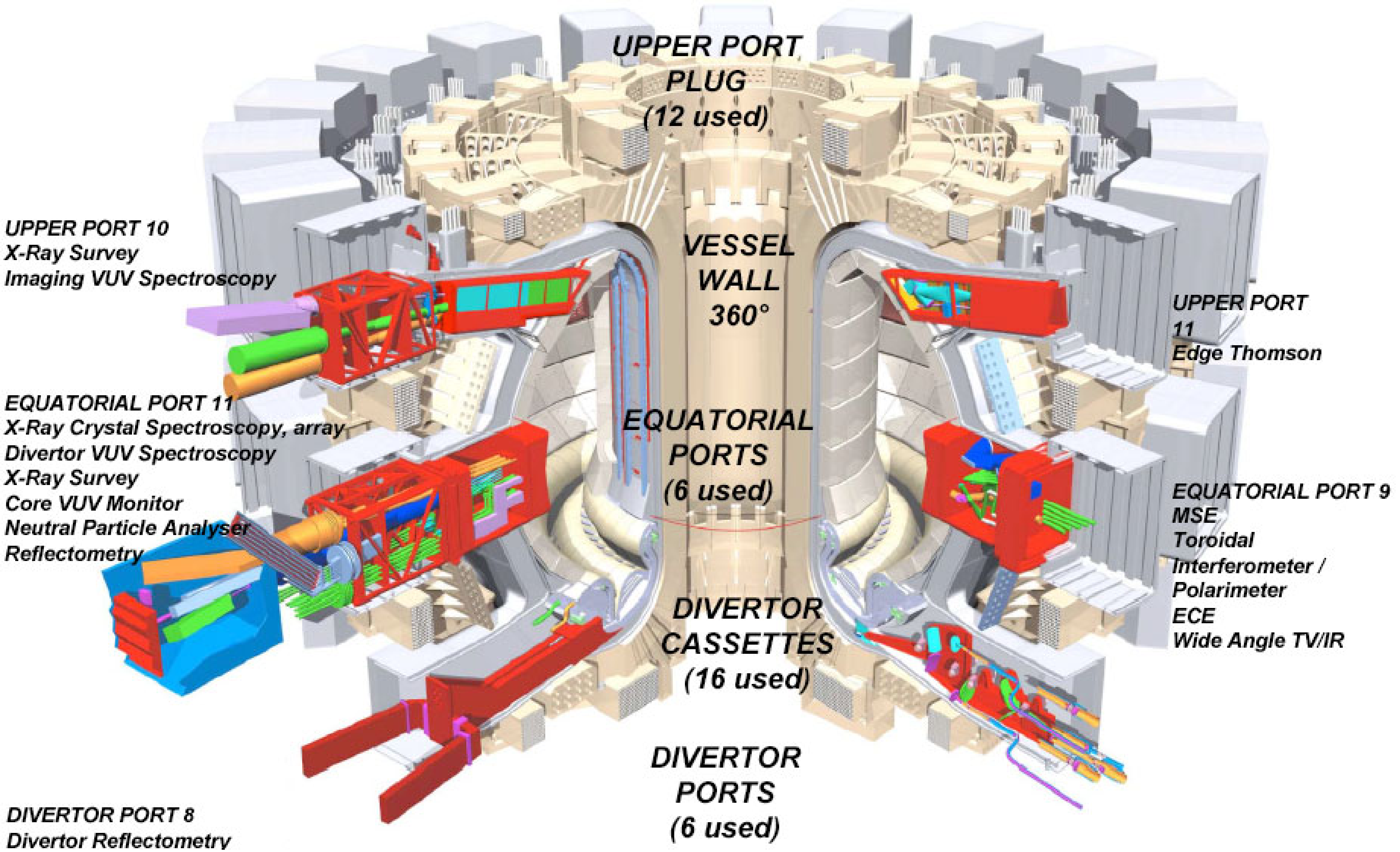
- **US starting R&D work for ITER Pellet Injection System**
  - significant R&D to meet throughput and reliability needs
  - pressing issues have been identified with IT
  - ORNL test of ITER guide tube mockup is underway



Overview of ITER Tritium Plant



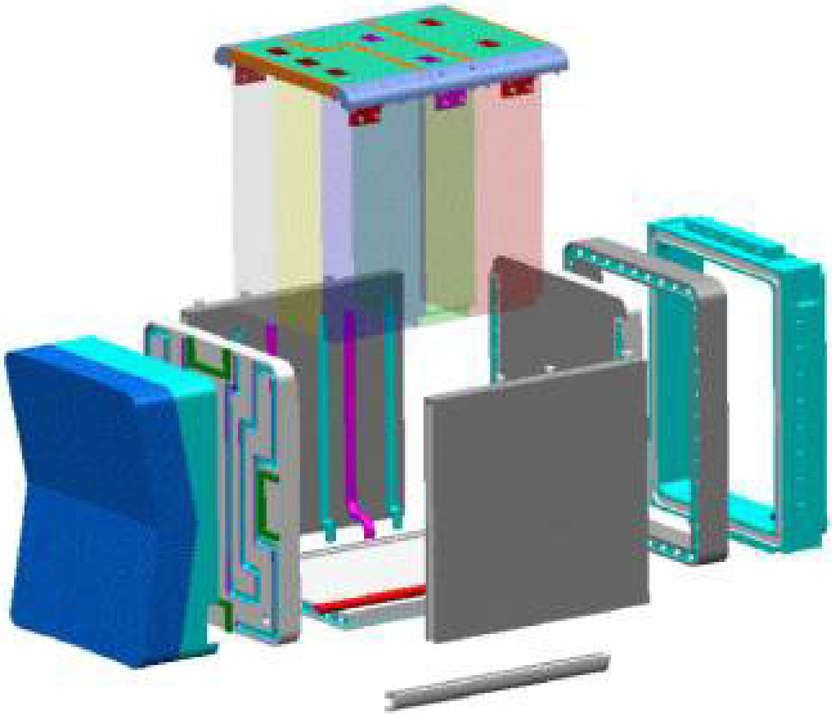
ITER diagnostics landscape



Overview of tentative US in-kind contributions: Diagnostics

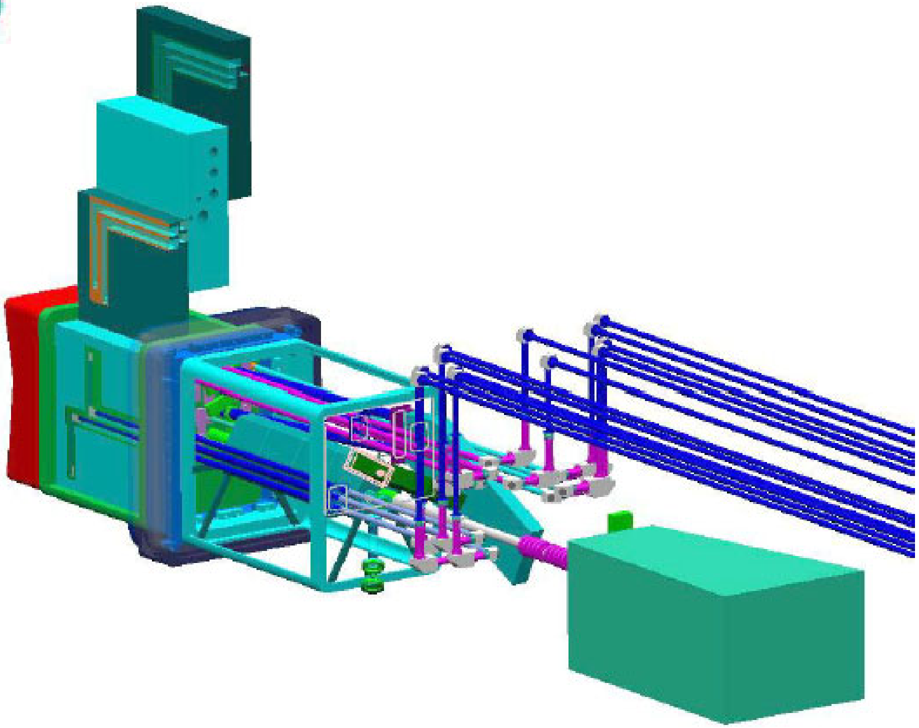
System	Subsystem	US Percentage
Diagnostics	Visible/IR Cameras (upper)	1.8%
	Reflectometer (main plasma – LFS)	2.5%
	MSE	2.4%
	ECE (main plasma)	4.6%
	Interferometer (divertor)	2.5%
	RGA	2.1%
TOTAL		16%

US ITER Tasks: Diagnostics



Contribute to a Port Engineering Task Force.

Support the ITER IT in the writing of procurement specifications for diagnostic port-based procurement packages.



US ITER Tasks:
Other

- **Safety (D. Petti/INEEL)**
  - ✔ Support and analysis for the latest fusion versions of computer codes MELCOR and ATHENA
  - ✔ Magnet safety
  - – Dust Characterization including mobilization and transport

- **Materials (S. Zinkle/ORNL)**
  - ✔ Support of materials activity

- **Test Blanket Working Group (Abdou)**

Physics Tasks requested by the International Team Leader [need clearer specifications and integration with ITPA]

- **Magnets and PFCs (power and particle-handling, including tritium inventory):**
  - How disruptions/VDEs which may affect the ITER design.
  - Characterization of thermal energy load during disruption
  - Model development of halo current width during VDEs based on experiments
  - Simulations of VDEs in ITER with 3D MHD code
  - Disruption mitigation by noble gas injection
  - Oxygen baking experiment, which could be possible during spring 2005 at D III-D and is under discussion at GA, may be one of the possible tasks.
- **Heating and Current-drive and advanced control:**
  - ITER Plasma Integrated Model for ITER for Control
  - Feasibility study of ITER SS scenarios with high confinement, NBCD, ECCD, LHCD, ICCD and fueling by pellet injection.
  - RF launchers
  - Validation of enhanced confinement models and application to ITER.
  - Development of Steady State Scenarios in ITER
  - RWM in Steady State Scenario in ITER
  - Evaluation of Fast Particle Confinement of ITER
- **Diagnostics:**
  - Specific diagnostic design tasks, including updating procurement packages [activities related to the diagnostics for which the US is responsible]

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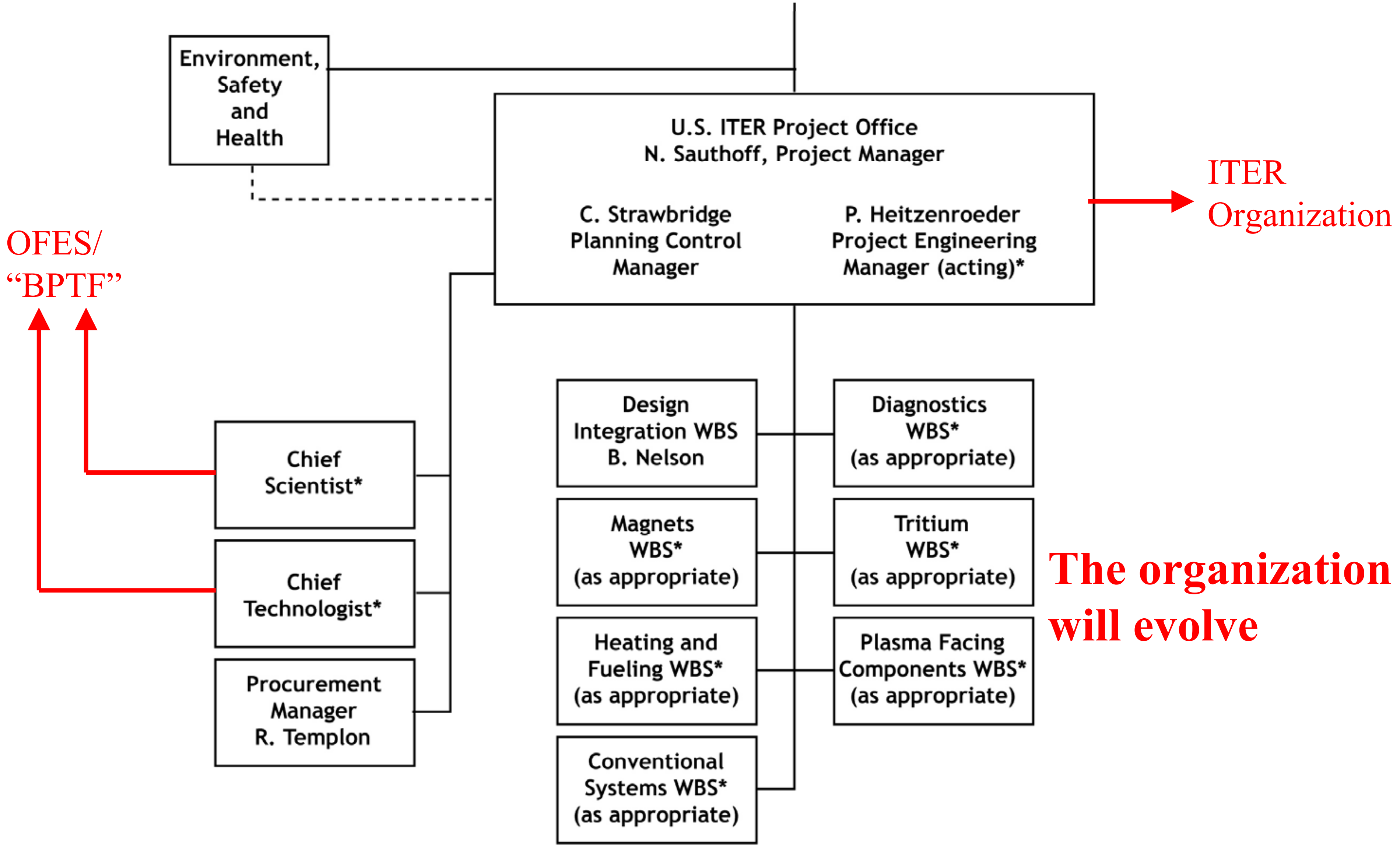
Overview of NSSG-Groups

Area	US emphasis
• Management Structure	*effectiveness*
• Staffing	*accessibility*
• Procurement Systems/Methods	*in-kind/in-cash; changes*
• Procurement Allocations	*project success and US interests*
• Resource Management Regulations	*visibility and changes*
• Risk	*recognition and management*
• Intellectual Property	*benefits and protection*
• Decommissioning	*amount and timing of the funds*

U.S. ITER Project Office



** National search will be conducted to assure best qualified individual is available to the project.*

FY04 US Secondees/Visiting Experts (~3 FTEs)

- **The present ITER international team consists of 69 persons:**
  31 from Europe,
  21 from Japan,
  13 from Russia,
  3 from the US, and
  1 from China,

- **US “Secondees”:**
  - Magnets [Naka, Japan]
    - Nicolai Martovetsky (LLNL) and Philip Michael (MIT)
  - First Wall/Blanket [Garching, Germany]
    - Dr. Richard Nygren (Sandia) and Mr. Thomas Lutz (Sandia)
  - Ion Cyclotron [Garching, Germany]
    - David Swain (ORNL) and Richard Goulding (ORNL)
  - Port Plugs/diagnostics [Garching, Germany]
    - Douglas Loesser (PPPL)

Bottom-Line…

- **The US ITER Activity is focused on ITER success**

- **“Joint technical preparations directed at maintaining the coherence and integrity of the ITER design and at preparing for an efficient start of ITER construction”**
  - The US VLT and US-ITER-project are engaged in focused R&D and design activities in areas of US in-kind contribution and key project enablers
  - US emphasis is on risk mitigation via R&D, design, cost-estimation, and innovative procurement

- **“Organisational preparations directed at enabling the ITER Legal Entity to enter into effective operation with least possible delay following the entry into force of the ITER Joint Implementation Agreement”**
  - The US is developing its domestic Project Plans, including drafting processes for open team-building
  - The US has offered to participate in refinement of the ITER Organization’s Project Management Plan, Risk Mitigation Plan, codes and standards, ….