Status of the ITER Project

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The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

Synopsis

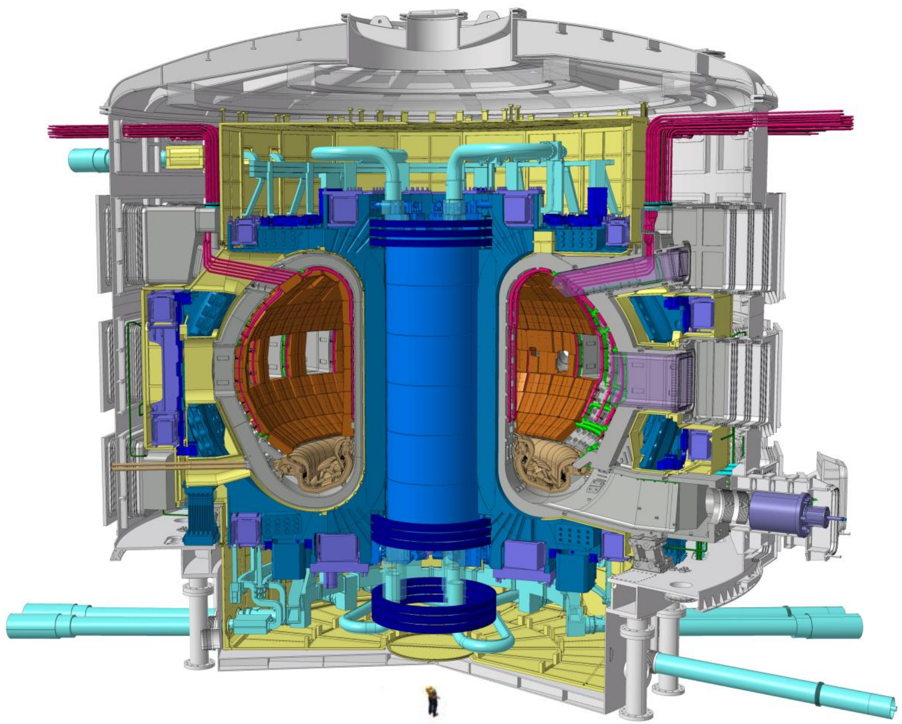
- **The ITER Project**
- **ITER Project status**

The ITER Project:
Key Science and Technology

The ITER Mission

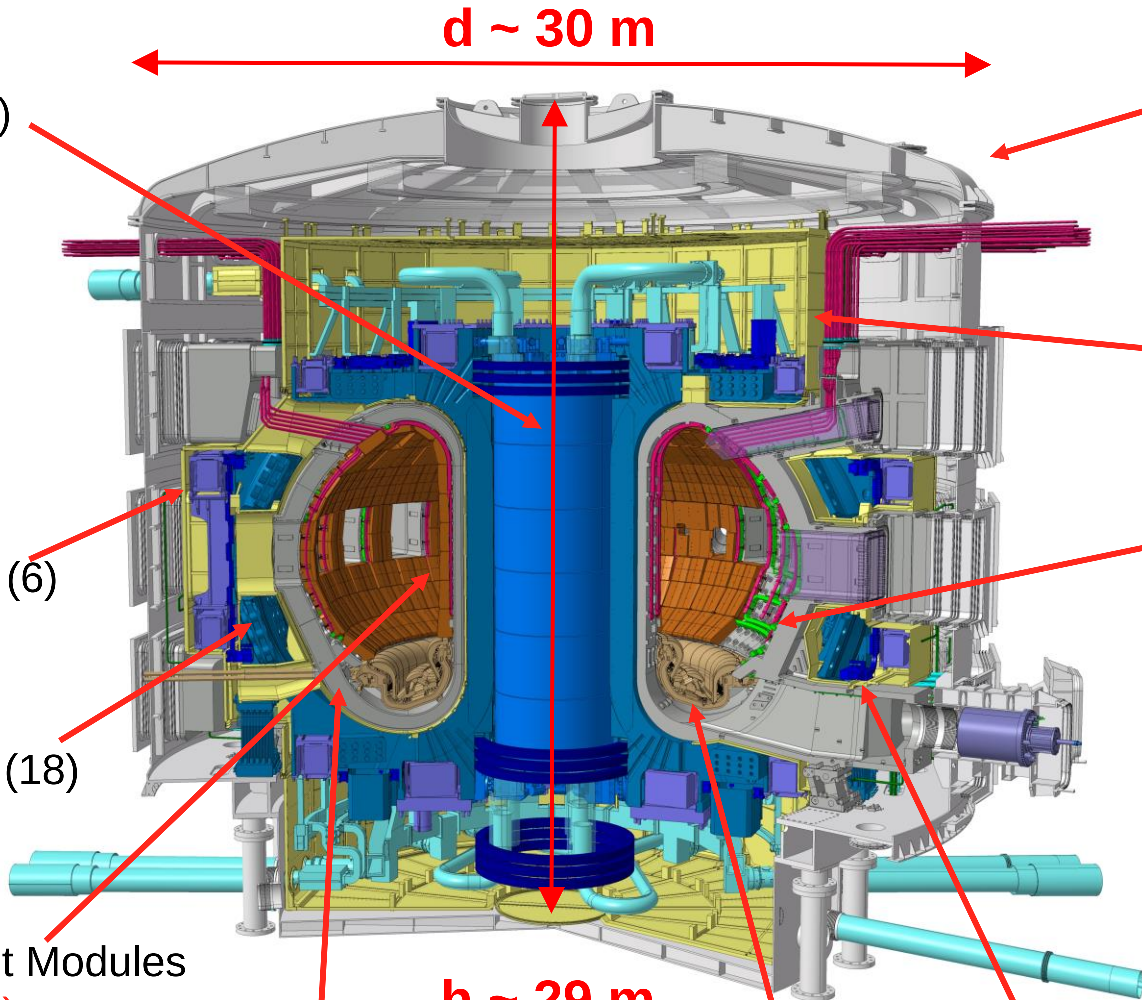
- ITER Program Objective:
  - to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes

- Key Technical Goals:
  - achieve extended burn of a DT plasma with dominant alpha-particle heating (Q ≥ 10, ~500 s)
  - develop steady-state fusion power production as ultimate goal
  - integrate and test all essential fusion power reactor technologies and components
  - demonstrate safety and environmental acceptability of fusion



ITER tokamak

ITER – Tokamak Core Components

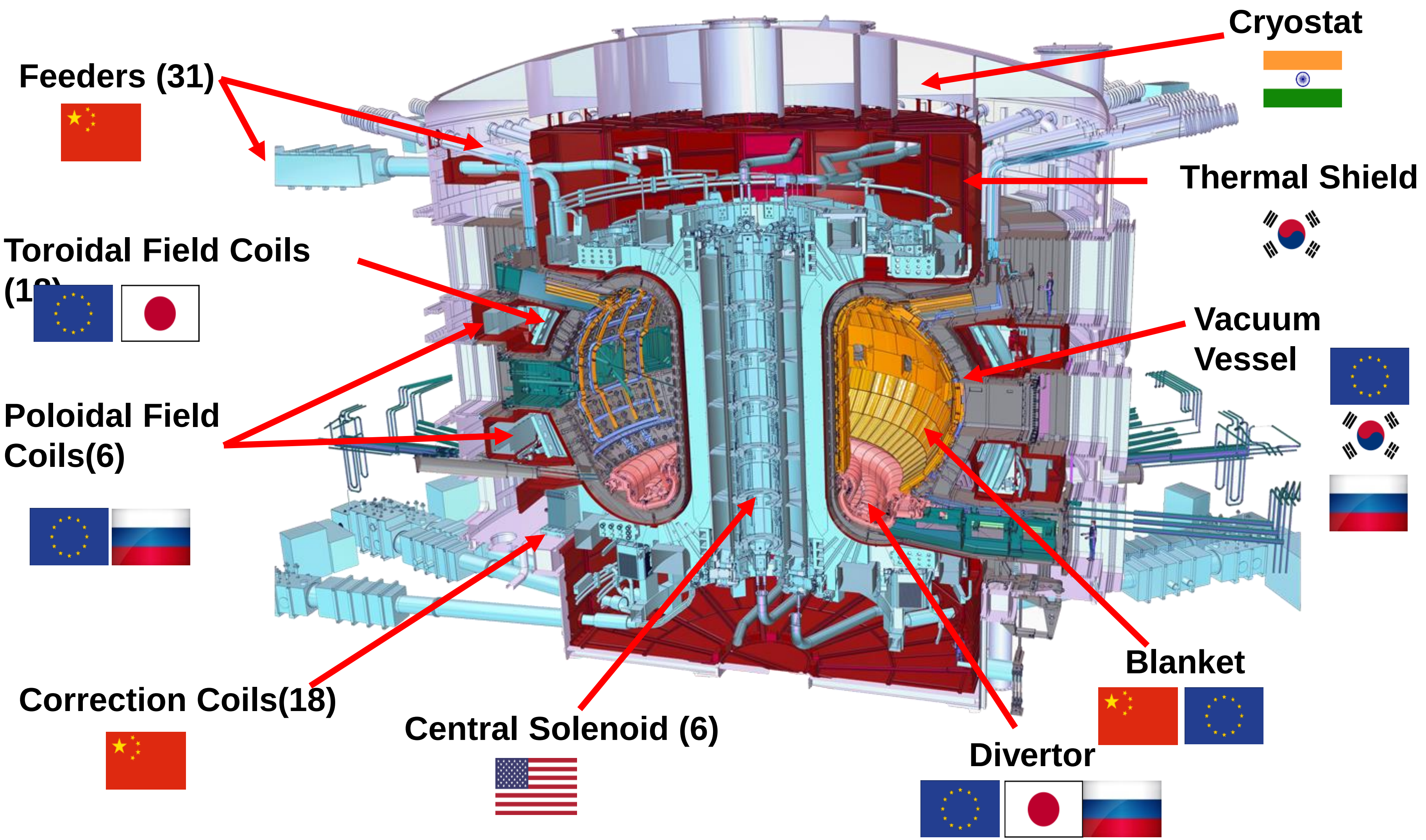


ITER – A Major International Collaboration

- **90% of ITER components will be supplied "in-kind" by the Members through their Domestic Agencies**

- **This approach necessitates the integration of ITER management, design and procurement activities across the globe**

Who manufactures what?

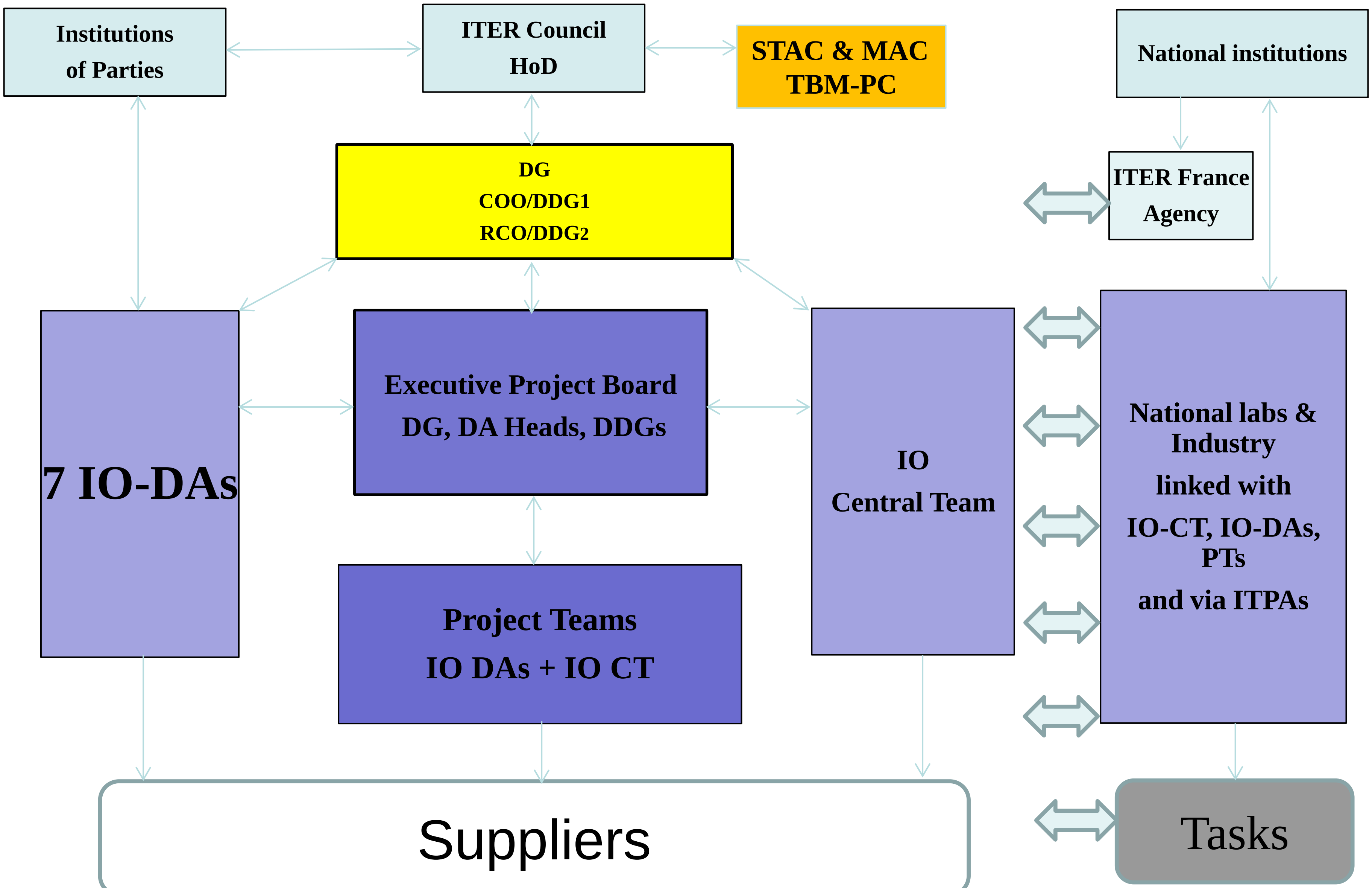


ITER Project Status

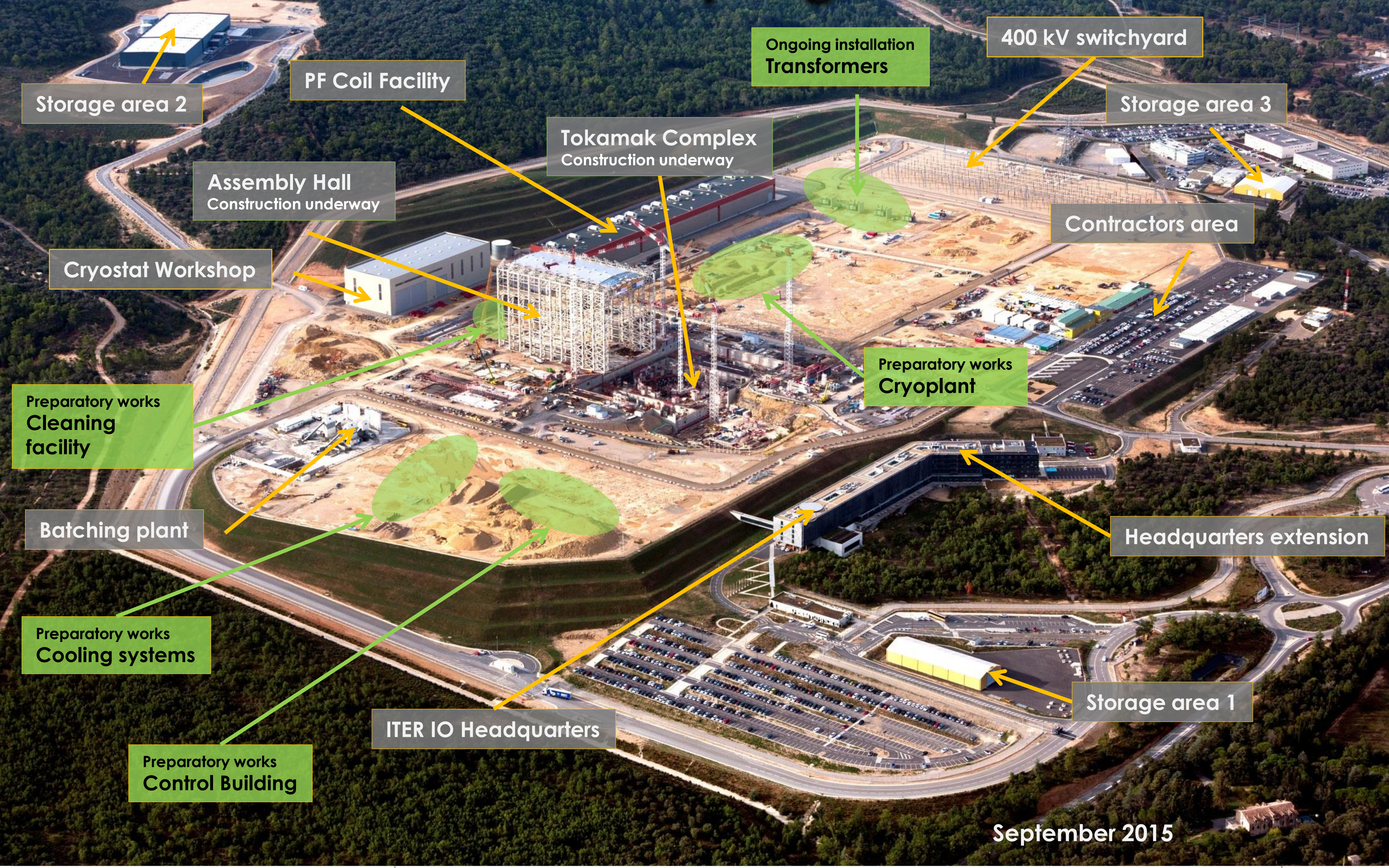
DG Bigot: 7-Point Action Plan

1. The DG is given full authority to take all technical decisions for the best interest of the project; he will benefit from:
2. A overall simplified Project-oriented organization characterized by a profound integration of the DAs and the CT for all decisions on technical matters of the Project;
3. An Executive Project Board (EPB) empowered to take the needed decisions in due time for an effective global project management;
4. A cost effective "Central" Reserve Fund under his control to cover specific operations for the best interest of the project decided by the EPB;
5. Tight coordination of the activities of CT and DA staff jointly in charge of specific equipments or tasks through the creation of Project Teams;
6. Implementation within the entire organization (CT+DAs) of powerful coordinated tools for establishing a nuclear project culture fulfilling the best world standards;
7. New staff regulations for an improved efficiency and cost effectiveness.

Overall ITER Project Organization

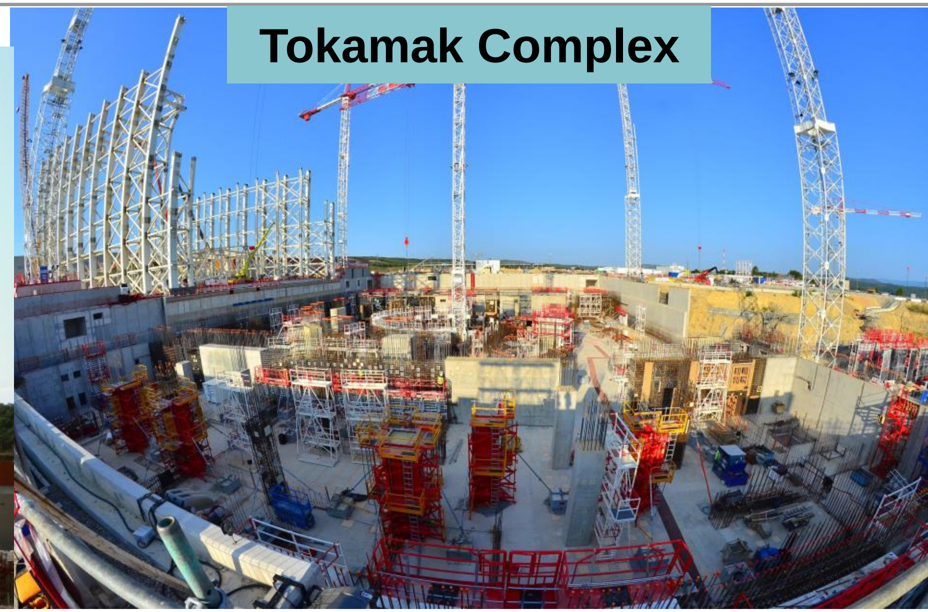


Worksite progress



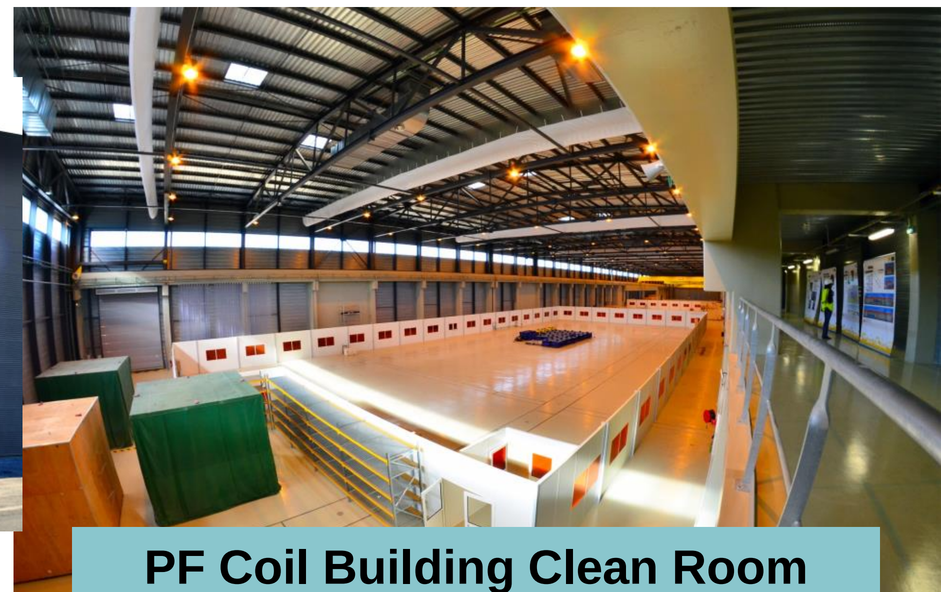
Construction Status at St-Paul-lez-Durance

Assembly Hall Roof Lift



Tokamak Complex

Large Storage Facility



PF Coil Building Clean Room

Delivery of Large Components

Exceptional Transport Rehearsal

Drain Tank Delivery

First Component Installation: 400 keV Transformers

Large Drain Tank Transport

Tokamak Complex

Resting on 493 anti-seismic bearings, the 1.5-metre-thick Tokamak Complex basemat will support 400,000 metric tons of buildings, equipment and machinery. This « B2 slab » was finalized on 27 August 2014; B1+L1 wall and Bioshield construction is underway.

Manufacturing progress

China

China is responsible for the procurement of 14 poloidal field AC/DC converter units that will provide reliable, controlled DC power to the ITER poloidal field magnetic coils. In February 2015, a prototype converter unit was successfully tested, opening the way to future batch production.

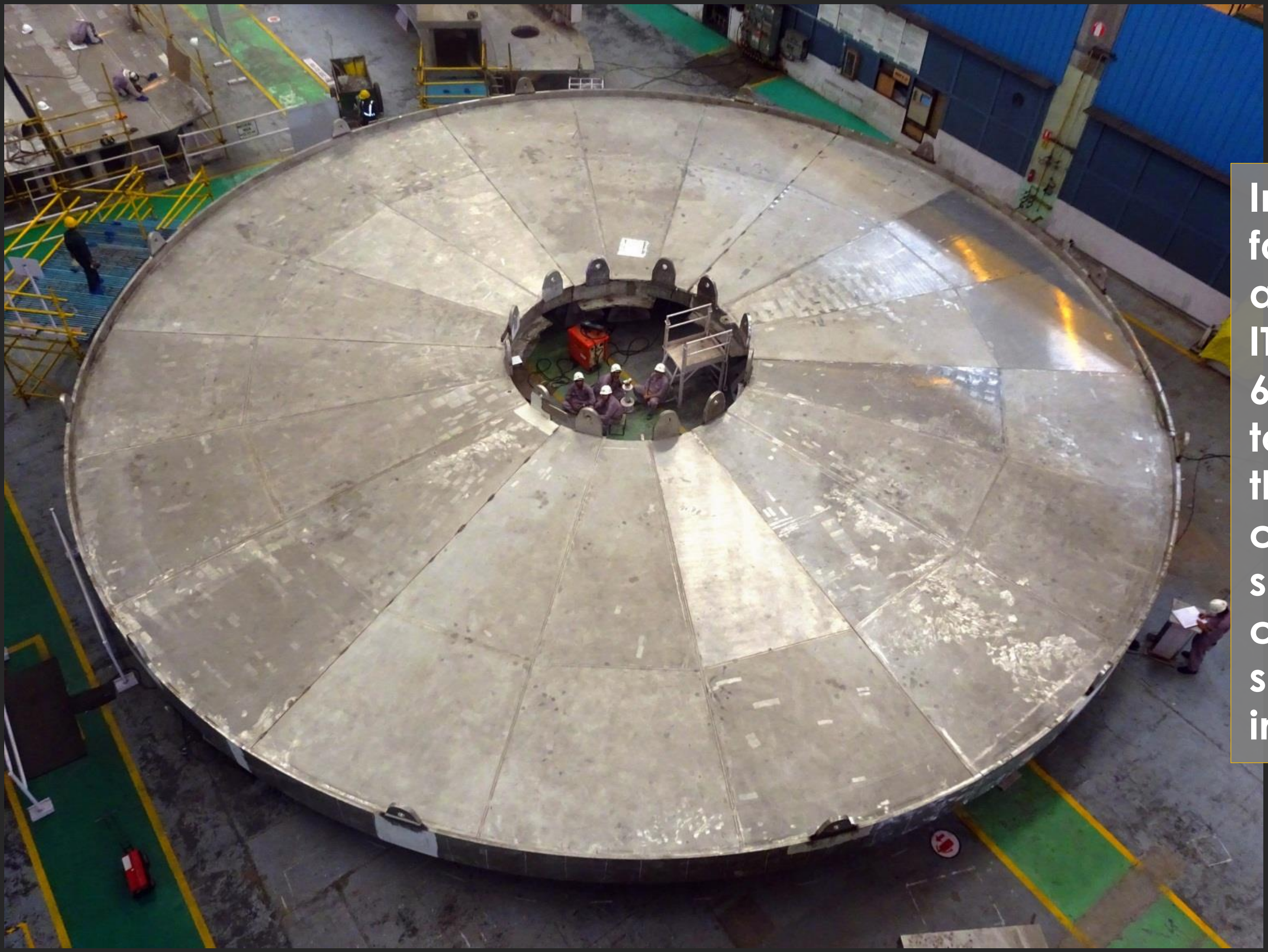
Manufacturing progress

Europe

Europe is responsible for delivering remote handling systems for the divertor, the neutral beam system, in-vessel viewing and metrology, and the cask transfer system for activated components—in all, about EUR 250 million of investment. At the Divertor Test Platform facility hosted by the VTT Technical Research Centre in Finland, the final demonstration of the divertor cassette remote handling system was carried out in February 2015.

Manufacturing progress

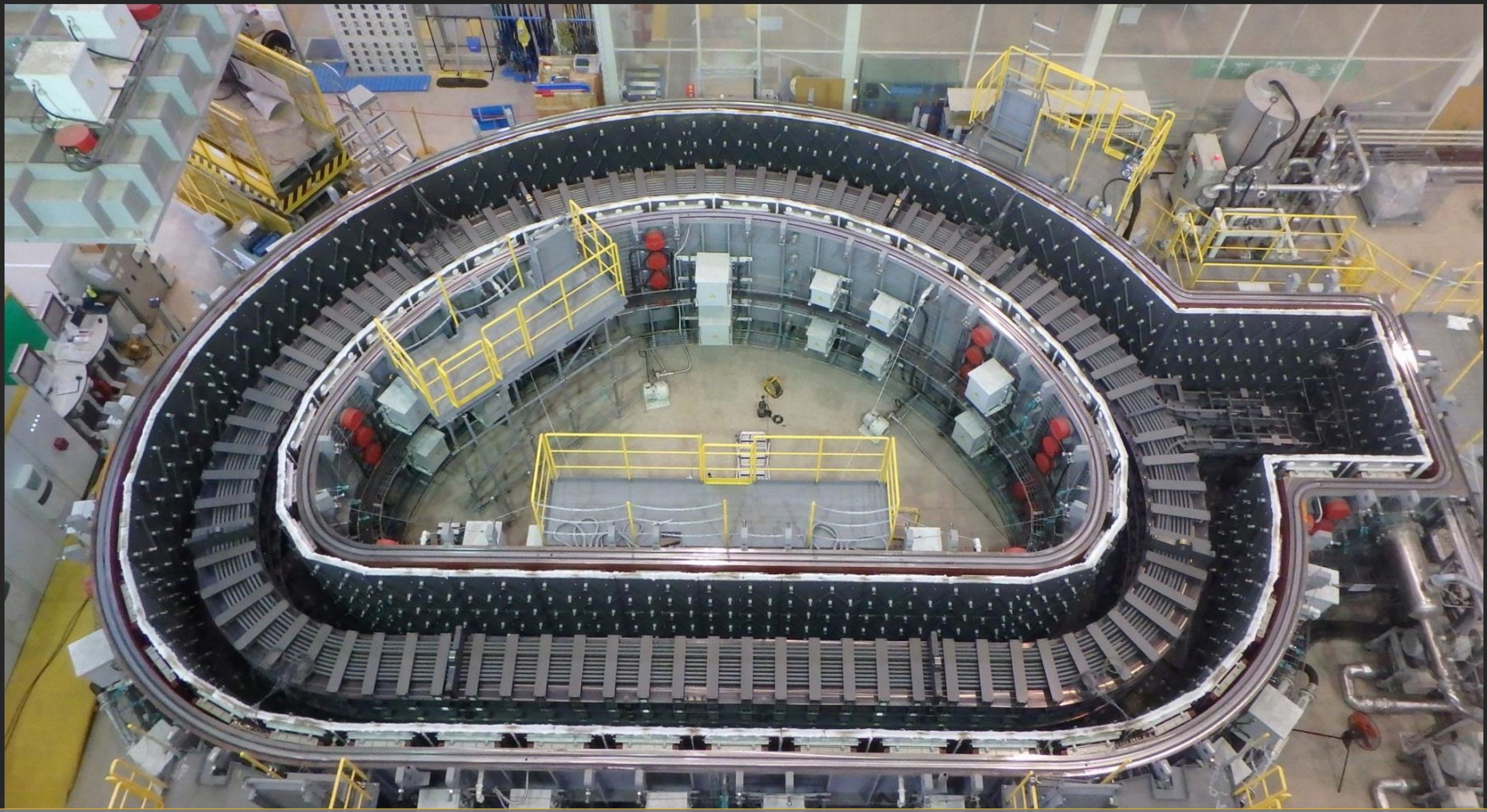
India



India is responsible for the fabrication and the assembly of the 30 x 30 m. ITER cryostat. Pictured, six 60° base plates are temporarily assembled at the factory in order to check tolerances prior to shipment to ITER. The first cryostat elements are scheduled to arrive at ITER in November 2015.

Manufacturing progress

Japan



Japan is manufacturing half of the 18 giant toroidal field coils needed for ITER. Here, the D-shaped pancake windings are heat treated at 650 ° C for 100 hours to react tin and niobium to form the superconducting compound niobium-tin.

Manufacturing progress

Korea

In Korea, where two of nine vacuum vessel sectors are under construction, welding is carried out on the upper section of an inner shell—only a small piece of the full component...

Manufacturing progress

Russia

Russia completes its share of toroidal field conductor in June 2015. The milestone marks the end of a five-year campaign to manufacture 28 production lengths (more than 120 tons of material).

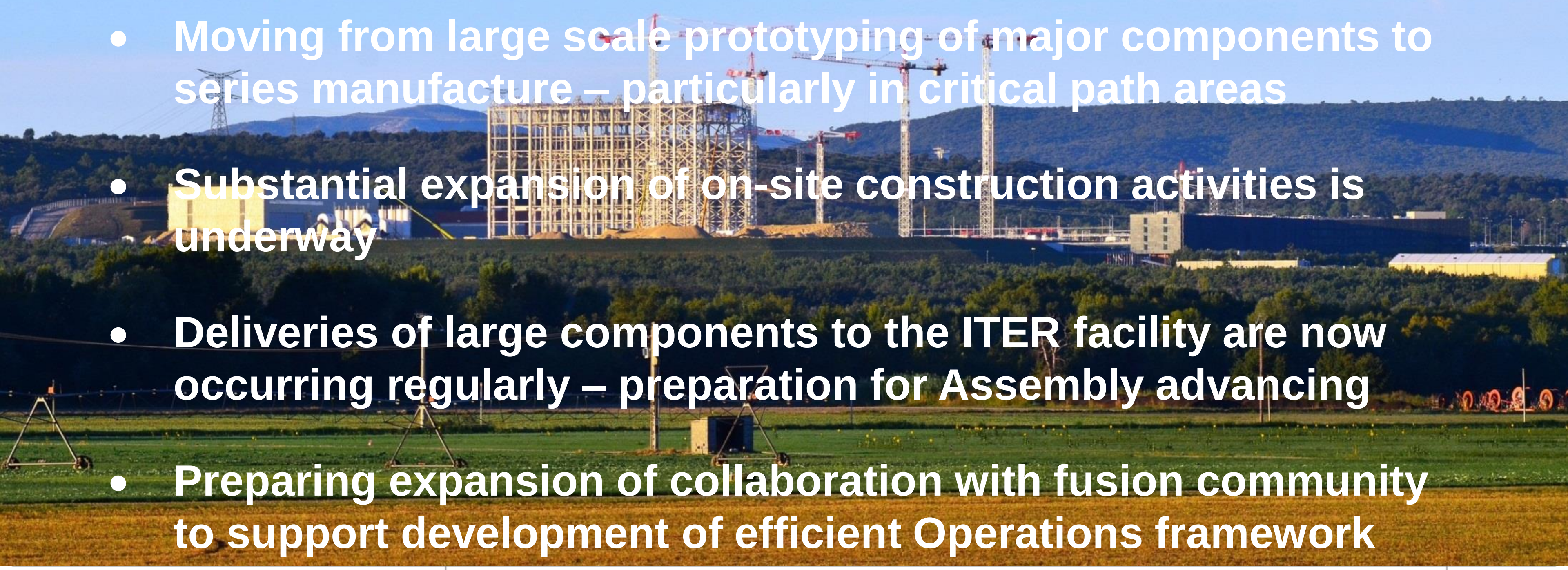
Manufacturing progress

USA

The US is responsible for the design, R&D, and manufacturing of the main central solenoid magnet (using conductor supplied by Japan), as well as the associated structure and tooling. At General Atomics' Magnet Technologies Center in Poway, California, winding operations began in April 2015 on a mockup module.

ITER is moving forward!

ITER is making a successful transition from detailed design to construction



- Tighter integration of technical activities across the project to achieve an improved project implementation and better use of resources
- Moving from large scale prototyping of major components to series manufacture – particularly in critical path areas
- Substantial expansion of on-site construction activities is underway
- Deliveries of large components to the ITER facility are now occurring regularly – preparation for Assembly advancing
- Preparing expansion of collaboration with fusion community to support development of efficient Operations framework

Principality of Monaco/ITER postdoctoral fellowships 2016 - I

- Partnership Agreement between the ITER Organization and the Principality of Monaco to set up a Postdoctoral Fellowship program signed in 2008
- Five young scientists from the seven ITER Member countries or from the Principality of Monaco appointed every two years, and - over a period of two years
- Training in research areas related to the ITER project → development of excellence in research in fusion science and technology within the ITER framework
- Brilliancy creativity, together with understanding of the relevance of the individual research interests to the ITER project are a key requirement

Principality of Monaco/ITER postdoctoral fellowships 2016 - II

- To carry out a research project and to participate in publications of high-quality journal articles in fusion science and technology:
  - Burning plasma physics (confinement, stability, plasma-wall interactions, control, energetic particle physics)
  - Heating and current drive physics and technology
  - Fusion plasma diagnostics
  - Superconducting magnet technology
  - ….

- Conditions for applicants:
  - ✓ You are a national of one of ITER Members or of the Principality of Monaco
  - ✓ Your PhD was awarded after the 1 January 2013 or you will have received your PhD by the deadline for taking up an award.

Principality of Monaco/ITER postdoctoral fellowships 2016 - III

Time schedule :

- December 2015 → External launch of competition (www.iter.org)
- 1 March 2016 → Deadline for application
- 1 April 2016 → Candidate interviews
- 1 September 2016 → Fellows normally on site
- 31 December, 2016 → Latest date for Fellows to take up position on site

On-line application:

- Fill-in online application file
- Upload your Curriculum Vitae (including a selection of your most important publications and photocopies of your highest academic qualification)
- Upload a letter of motivation -- limited to 2 pages
- Three letters of recommendation are also required.

Thank you for your attention

Backup Slides

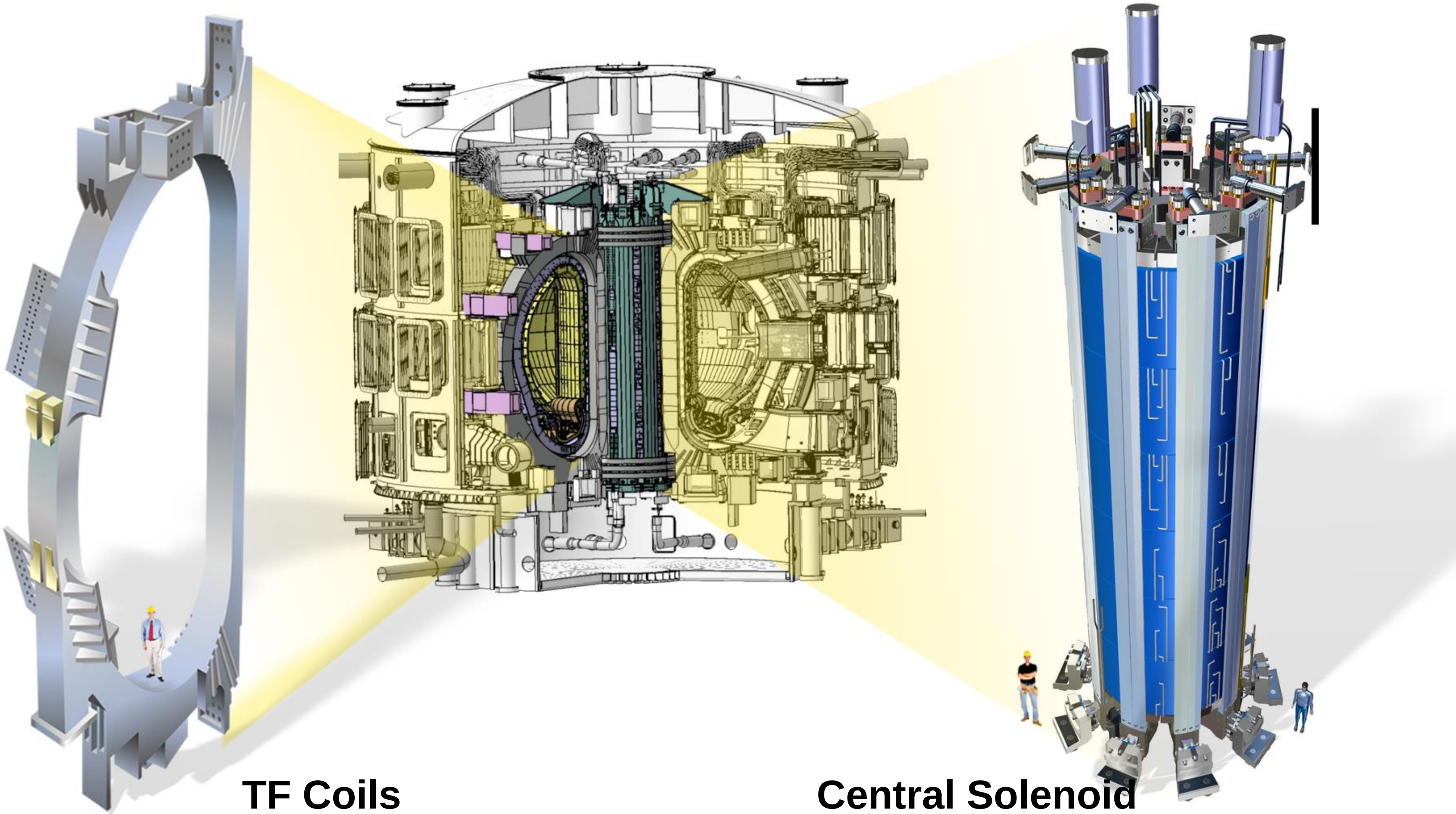
Component Transport

For heaviest components: vacuum vessel sectors, toroidal field coils, poloidal field coil 1 and 6

Road upgrades from south coast to Cadarache complete and paid for by regional funding (115 M€)

ITER itinerary ~104 km by road + 32 km by barge

Magnets - Unprecedented Size and Performance



TF Coils
11.8 Tesla, 41 GJ
400 MN centering force

Central Solenoid
13 Tesla, 7 GJ
20 kV, 1.2 T/s

ITER Magnet Supply: 10 PAs

CS with US (General Atomics)

Pre-compression rings: EU (EADS CAS)

PF1: RF (Efremov)

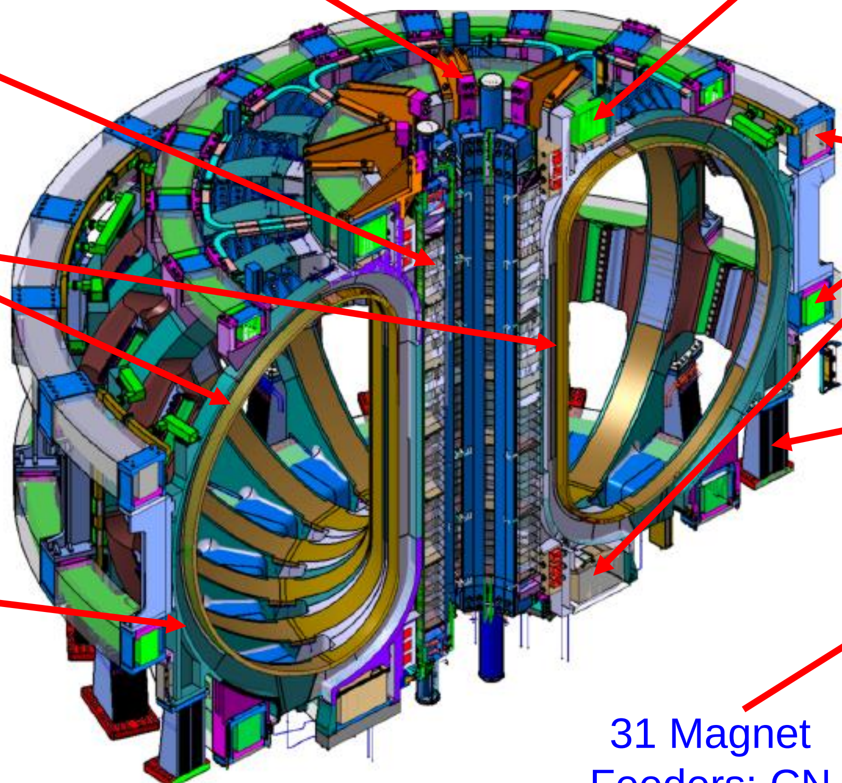
9+1 TF coils with EU (Iberdrola/ASG/Elytt Consort.)

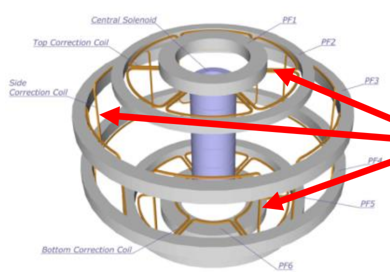
PF2-6: EU (*not decided*)

9 TF coils with JA (MHI)

Magnet Supports: CN (SWIP)

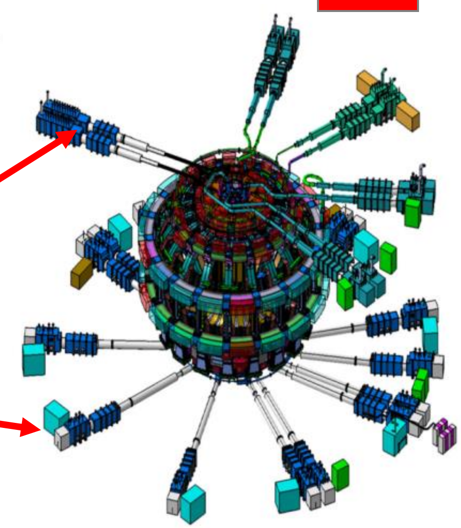
19 TF coil cases: JA (MHI/Hyundai Consort.)



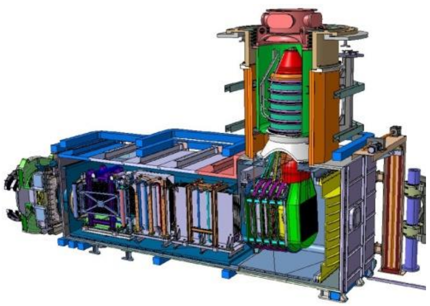
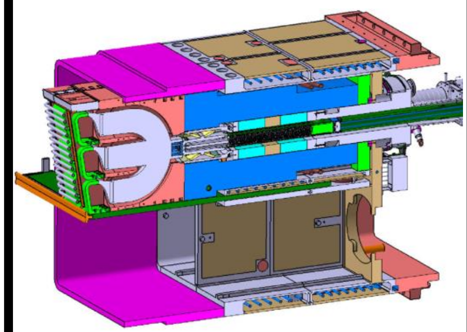
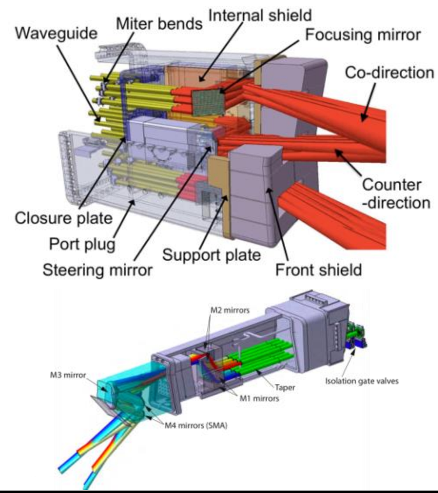
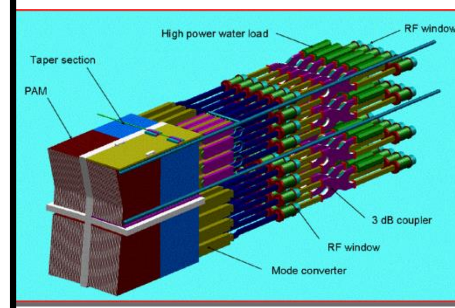


9 pairs of CCs: CN (ASIPP)

31 Magnet Feeders: CN (ASIPP)



ITER heating and current drive systems

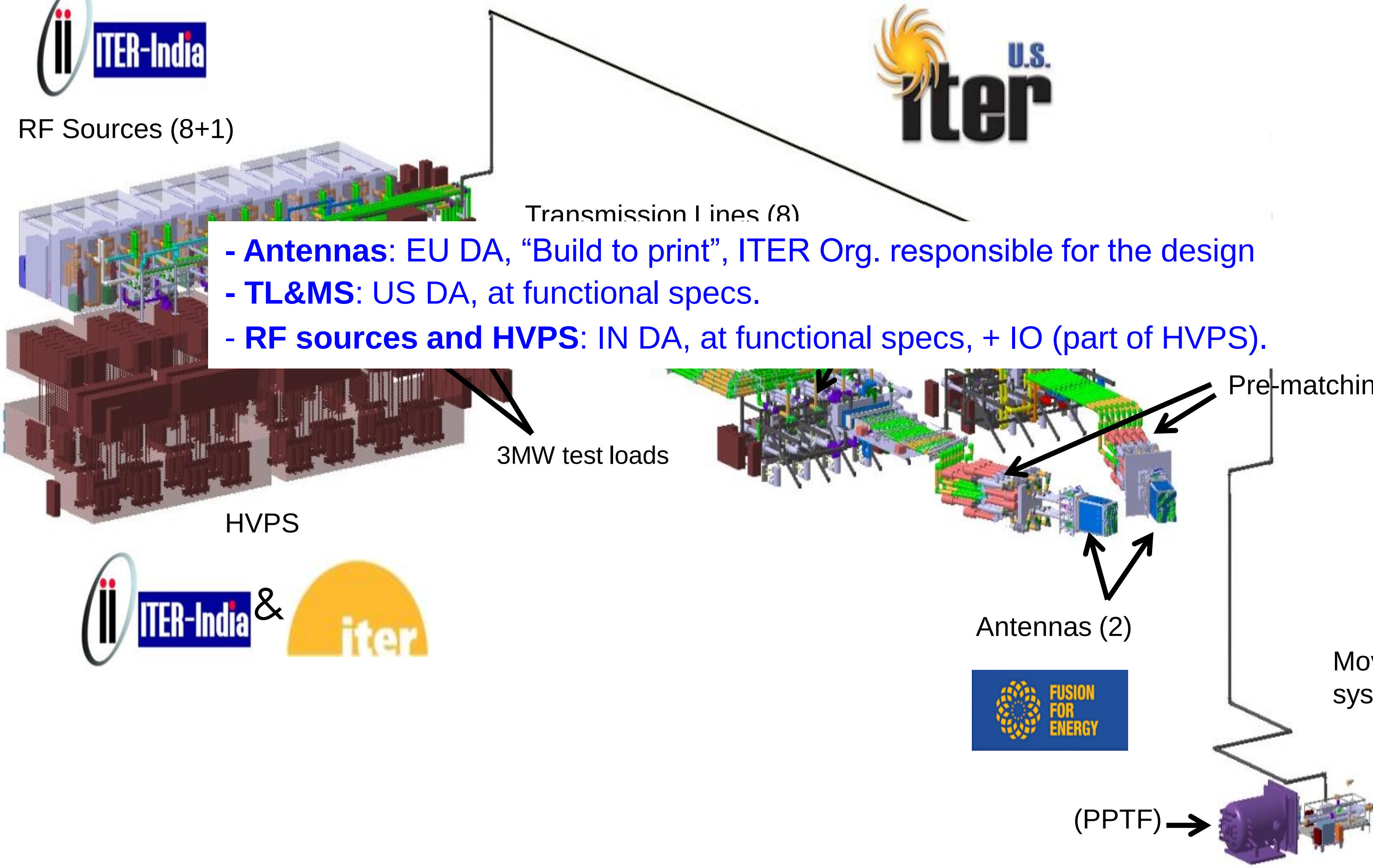
<table>
<tr><th>NB</th><th>IC</th><th>EC</th><th>LH</th></tr>
<tr><td>Neutral Beam
- 1 MeV</td><td>Ion Cyclotron
40-55MHz</td><td>Electron Cyclotron
170GHz</td><td>Lower Hybrid
~5 GHz</td></tr>
<tr><td></td><td></td><td>
</td><td>
</td></tr>
<tr><td>33MW*
+16.5MW#</td><td>20MW*
+20MW#</td><td>20MW*
+20MW#</td><td>0MW*
+40MW#</td></tr>
<tr><td>Bulk current drive
limited modulation</td><td>Sawtooth control
modulation < 1 kHz</td><td>NTM/sawtooth control
modulation up to 5 kHz</td><td>Off-axis bulk current
drive</td></tr>
</table>

*Baseline Power

#Possible Upgrade

IC H&CD layout and procurement packages

- **Antennas**: EU DA, “Build to print”, ITER Org. responsible for the design
- **TL&MS**: US DA, at functional specs.
- **RF sources and HVPS**: IN DA, at functional specs, + IO (part of HVPS).



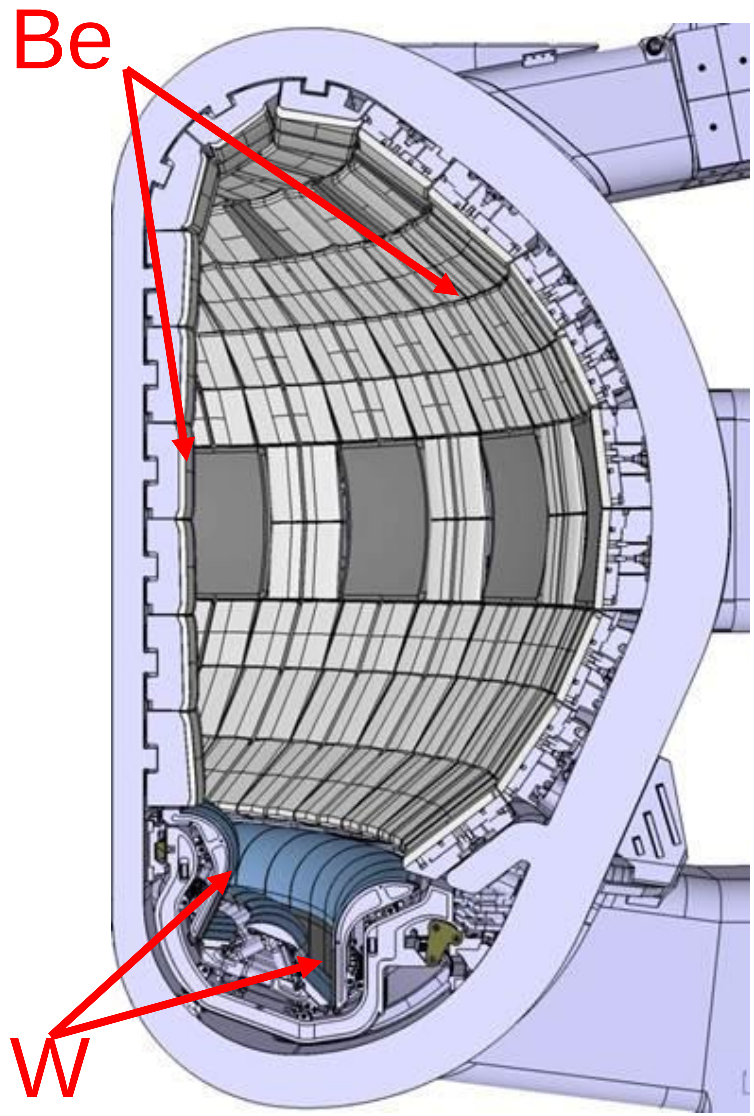
1 MeV NBTF under construction at Padua

ITER plasma facing components

ITER will operate with all-metal Plasma Facing Components

- **Beryllium (Be) first wall (~700m^2):**
  - low-Z limits plasma impurity contamination
  - low neutron activation
  - low melting point – plasma transients!
  - erosion/ redeposition $\Rightarrow$ fuel retention
  - dust production

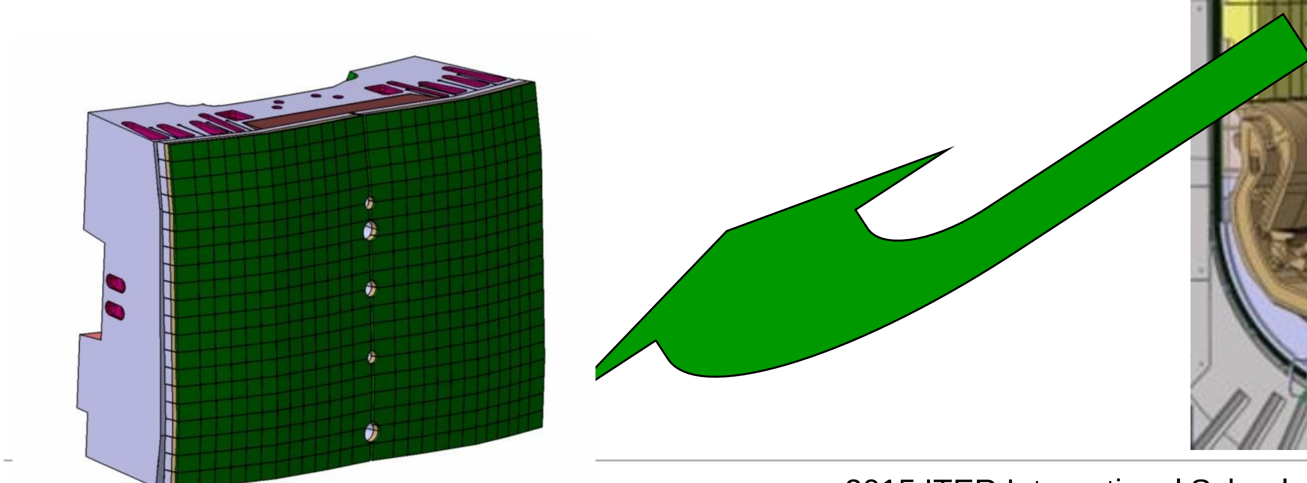
- **Tungsten (W) divertor (~150m^2):**
  - resistant to sputtering
  - limits fuel retention (Be dominates)
  - melting during plasma transients
  - W concentration in core must be held below ~ 2.5×10^{-5}

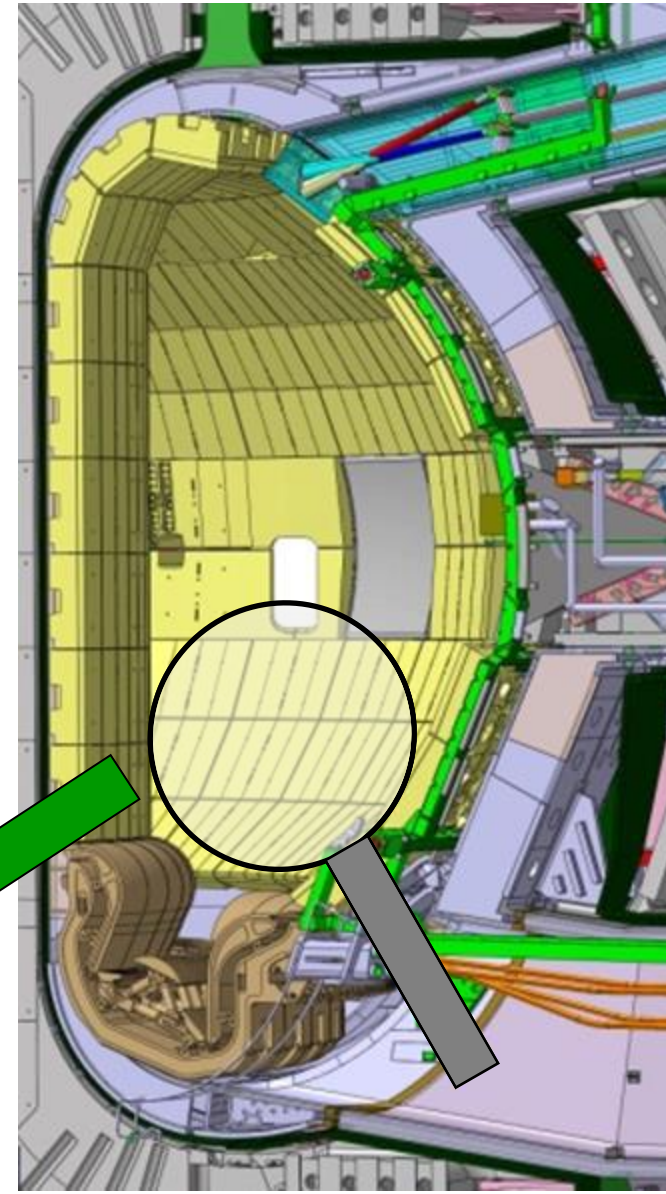


Blanket System

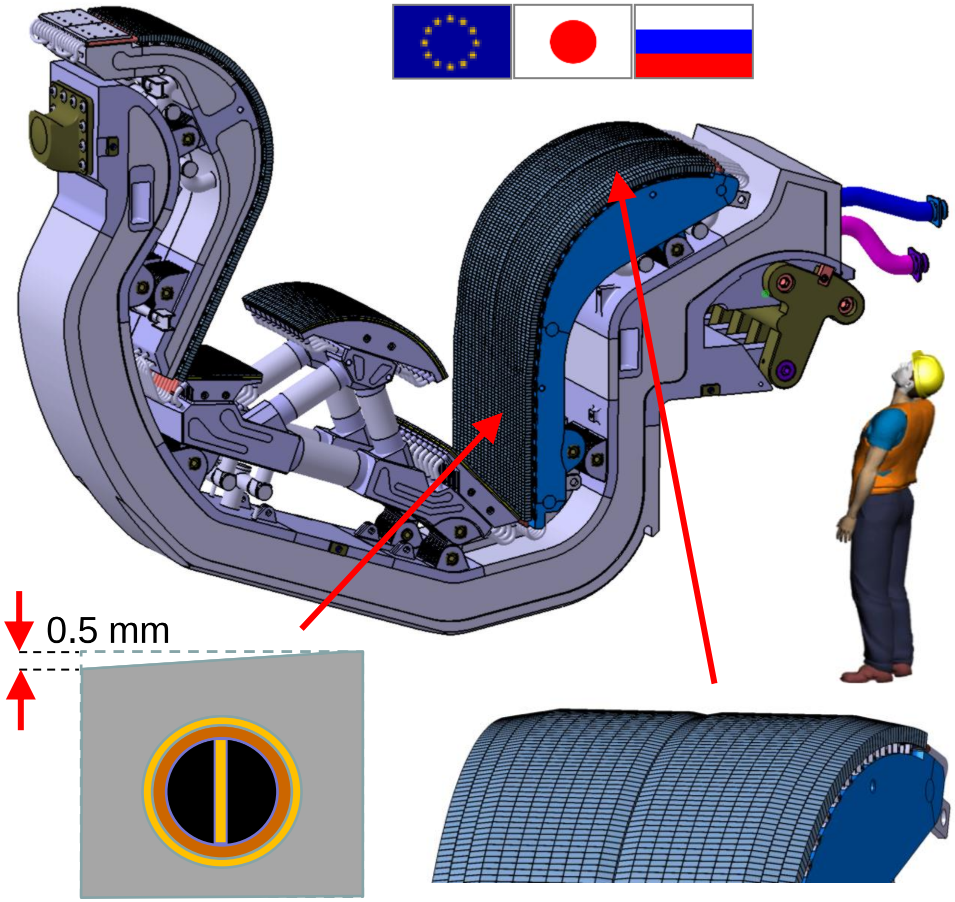
Main functions of ITER Blanket System:

- Exhaust the majority of the plasma power.
- Contribute in providing neutron shielding to superconducting coils.
- Provide limiting surfaces that define the plasma boundary during startup and shutdown.
- Provide passage for and accommodate interface requirements of the plasma diagnostics





All-Tungsten Divertor



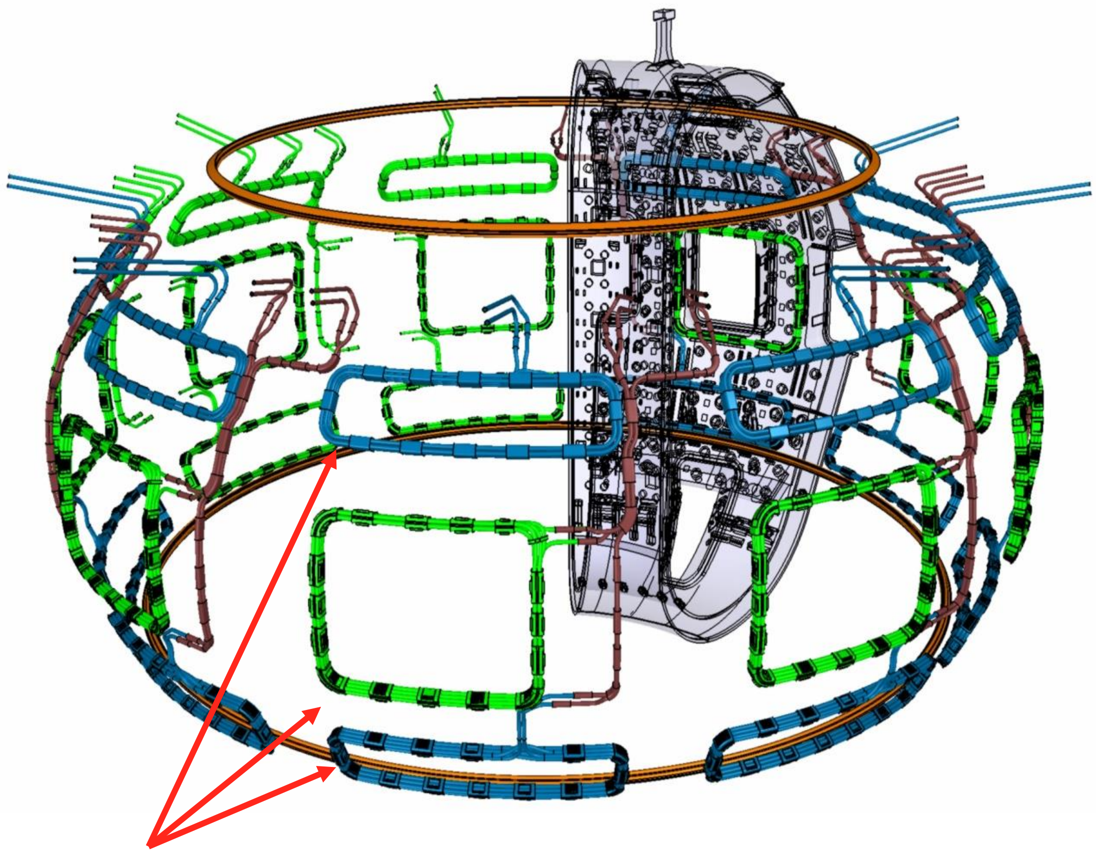
- Significant contribution to cost containment for ITER Project
- Experience gained in operation with W-divertor in non-active phase, including development of ELM-mitigation techniques
- Low fuel retention and lower dust inventory

But:

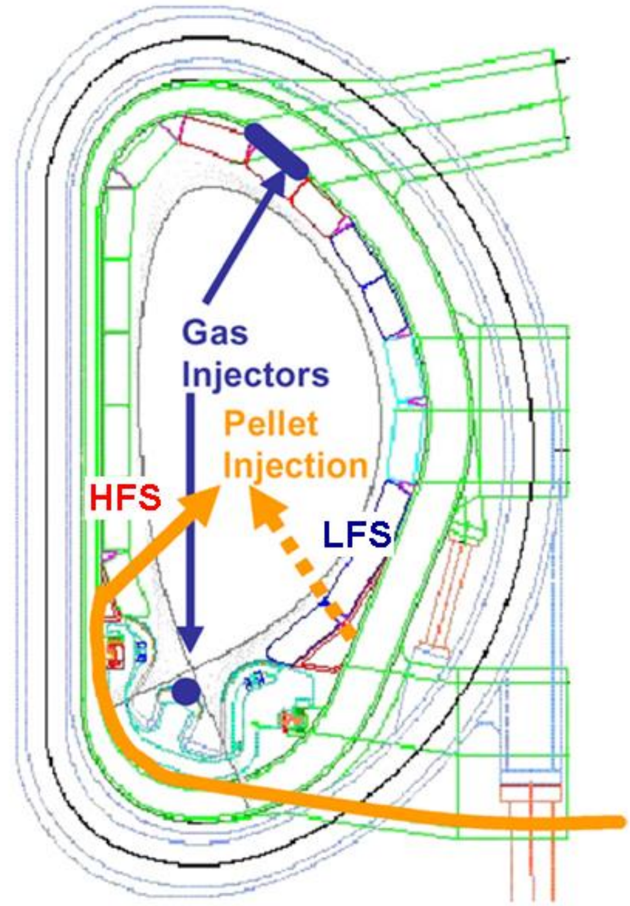
- Will require more cautious approach in non-active phase
- Need to ensure effective disruption and ELM mitigation early in operational period
- Need to develop suitable operational scenarios, particularly for non-active phases of operation

- Particular attention required to shaping for leading edge protection $\Rightarrow$ avoid worst cases of melting due to transients

ITER ELM Control Techniques



Pellet Injection geometry



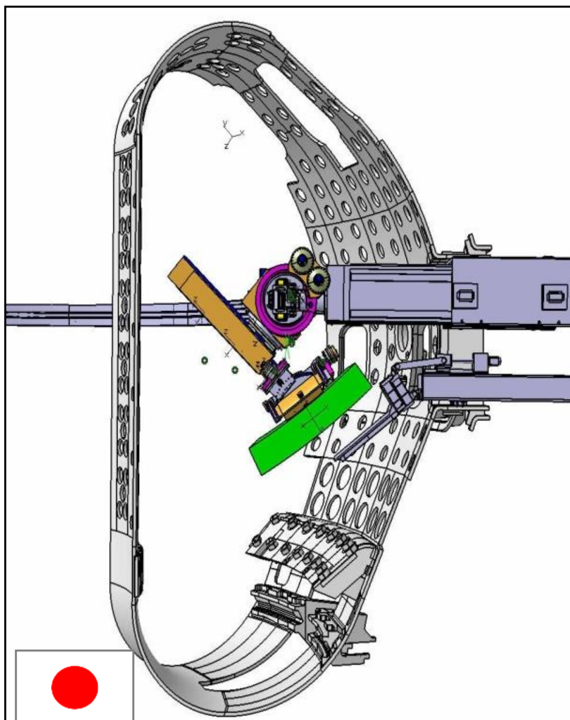
- **Two principal techniques under development**:
  - 3 × 9 array of RMP coils, launching mainly n=4, with 90 kAturn capability
  - high frequency (f ≤ 16 Hz) pellet injection system, allowing f_{inj} ~ 50 Hz

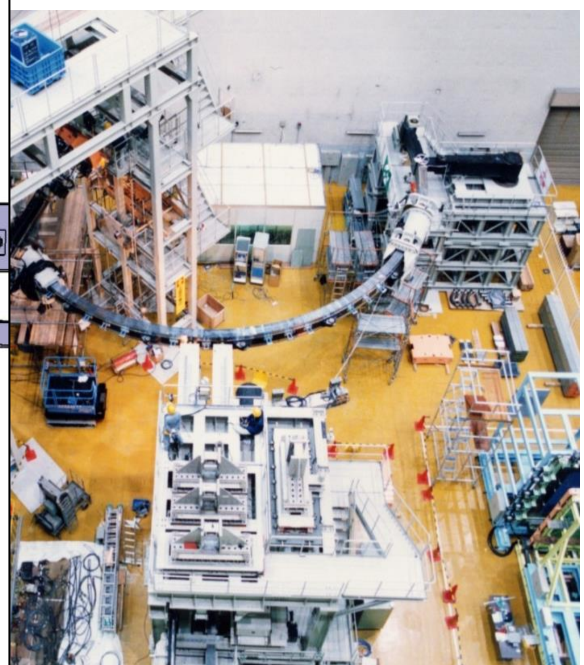
Remote Handling

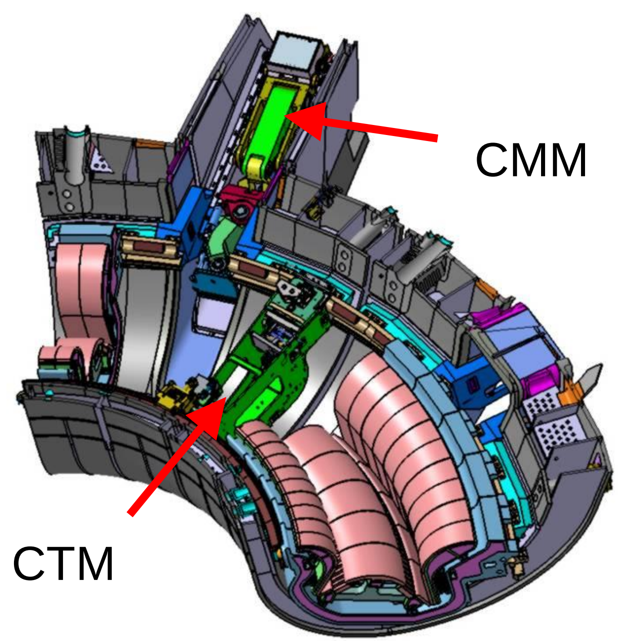
- **A major part of the ITER activity ⇒ extremely challenging to repair and replace complex and heavy components in a nuclear environment**
  - Dedicated, state-of-the art systems for both Blanket and Divertor
  - Divertor replacement 2-3 x in the machine lifetime (~6 months to exchange)
  - First wall panels replaced at least once

Blanket RH procured by JA

Divertor RH procured by EU





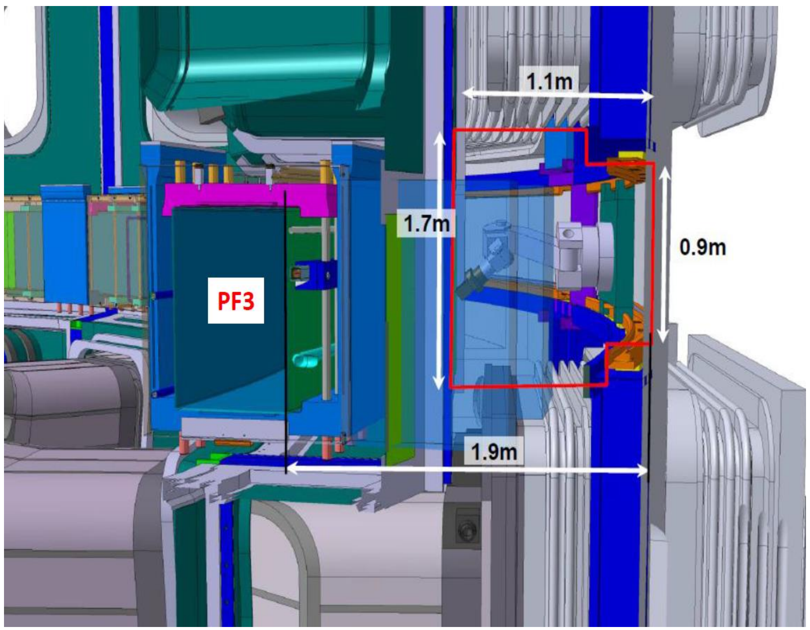


RH System Procurement Approach

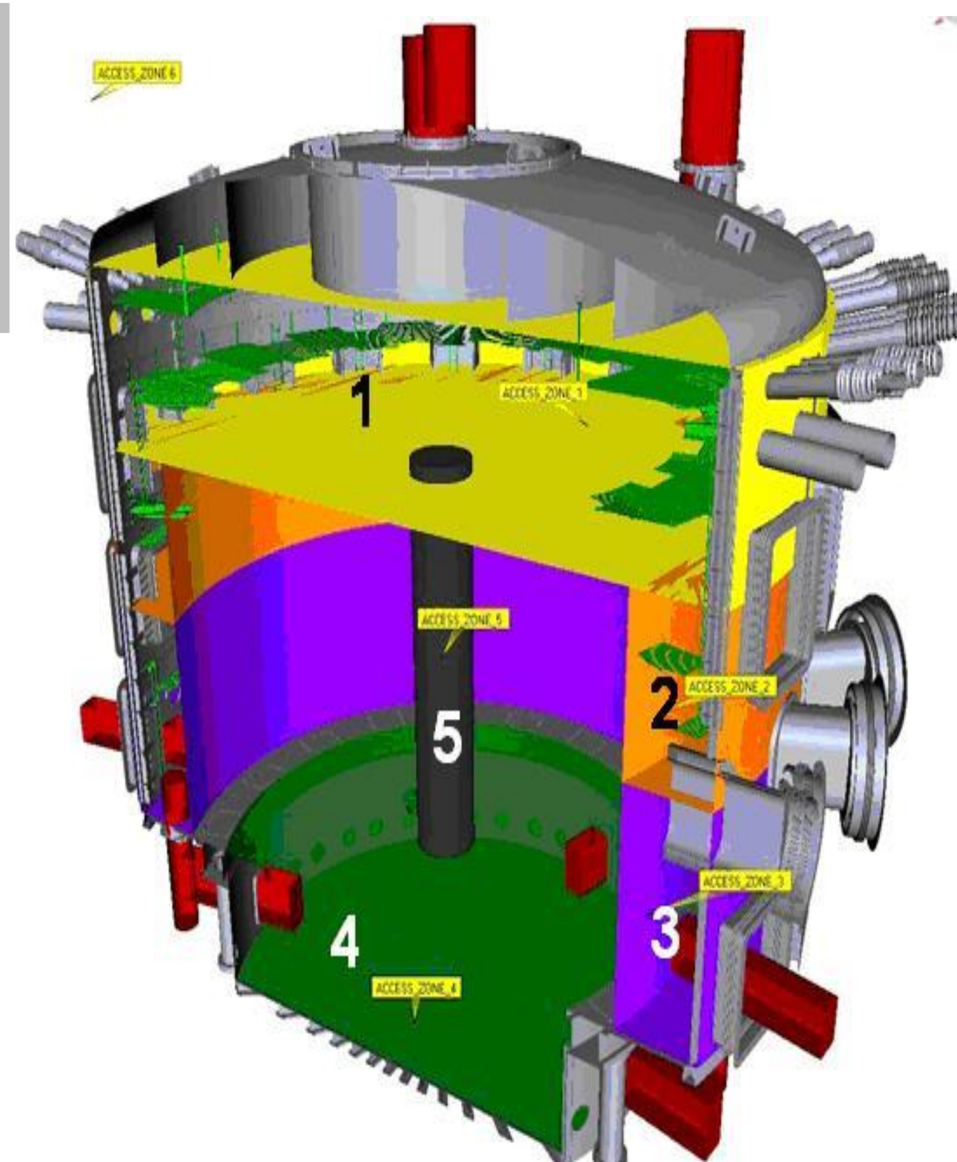
RH System	Procurement Responsibility	Design Status (ongoing)	Industrial Supplier
Blanket RH System		Final Design	Toshiba
Divertor RH System		Preliminary Design	Assystem UK
Multi-purpose deployer		Preliminary Design	-
Neutral Beam RH System		Preliminary Design	ERHA
Cask and Plug Handling System		Preliminary Design	-
Hot Cell RH Equipment		Concept Design	-
RH Supervisory Control System		Preliminary Design	-

Remote Intervention Inside Cryostat

Zone 1: Top Cryostat
Zone 2: From Equatorial Ports to Upper Ports
Zone 3: From the Pedestal Ring to the Equatorial Ports
Zone 4: Basement of the Cryostat
Zone 5: Inside the Central Solenoid Bore

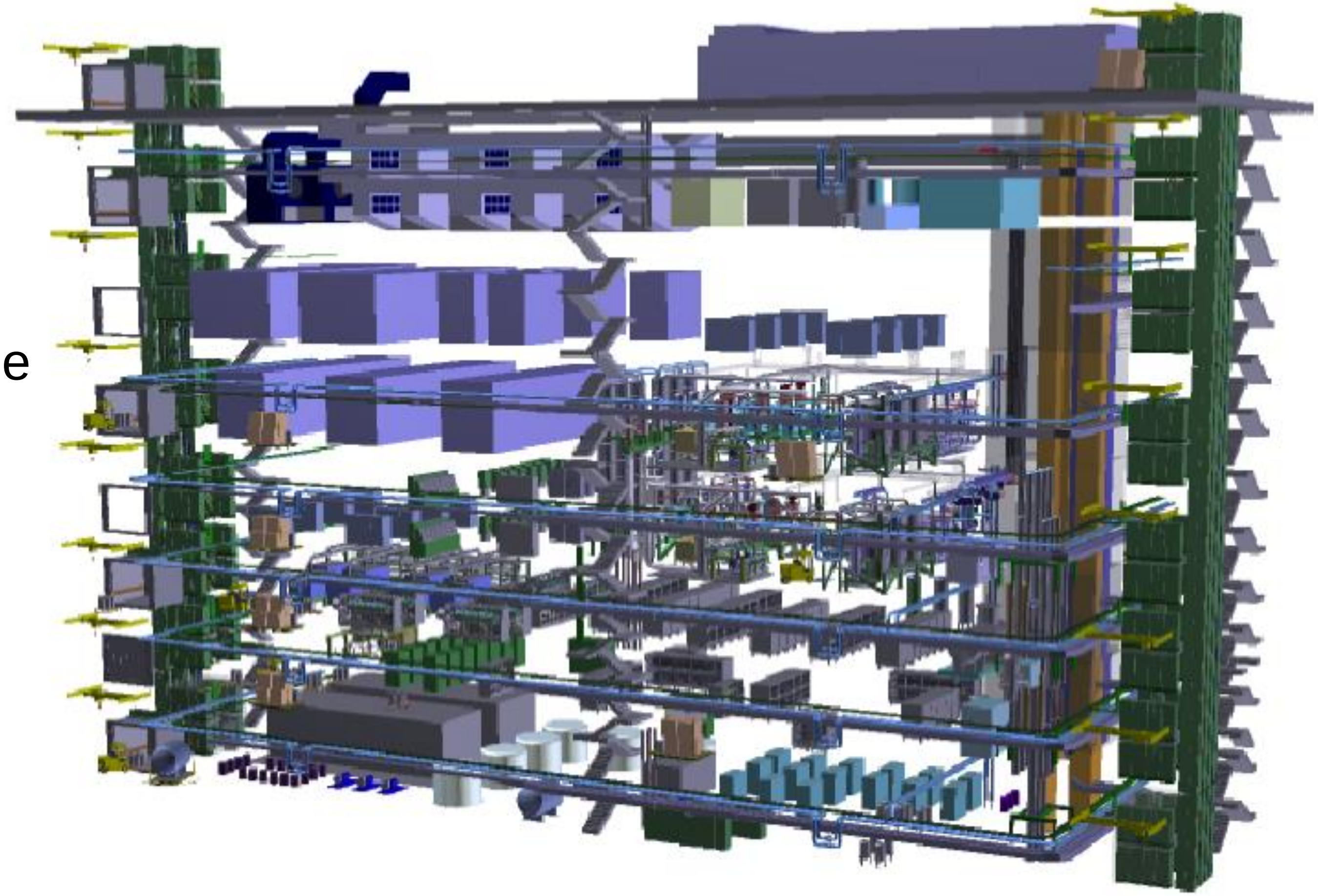


Zone 2: Trolley and manipulator between upper and equatorial ports



Tritium Plant

- **4 kg of tritium will be stored on-site**
- **~100 g tritium required for a standard Q=10 pulse, but only <1% is actually burned:**
  – tritium reprocessing required



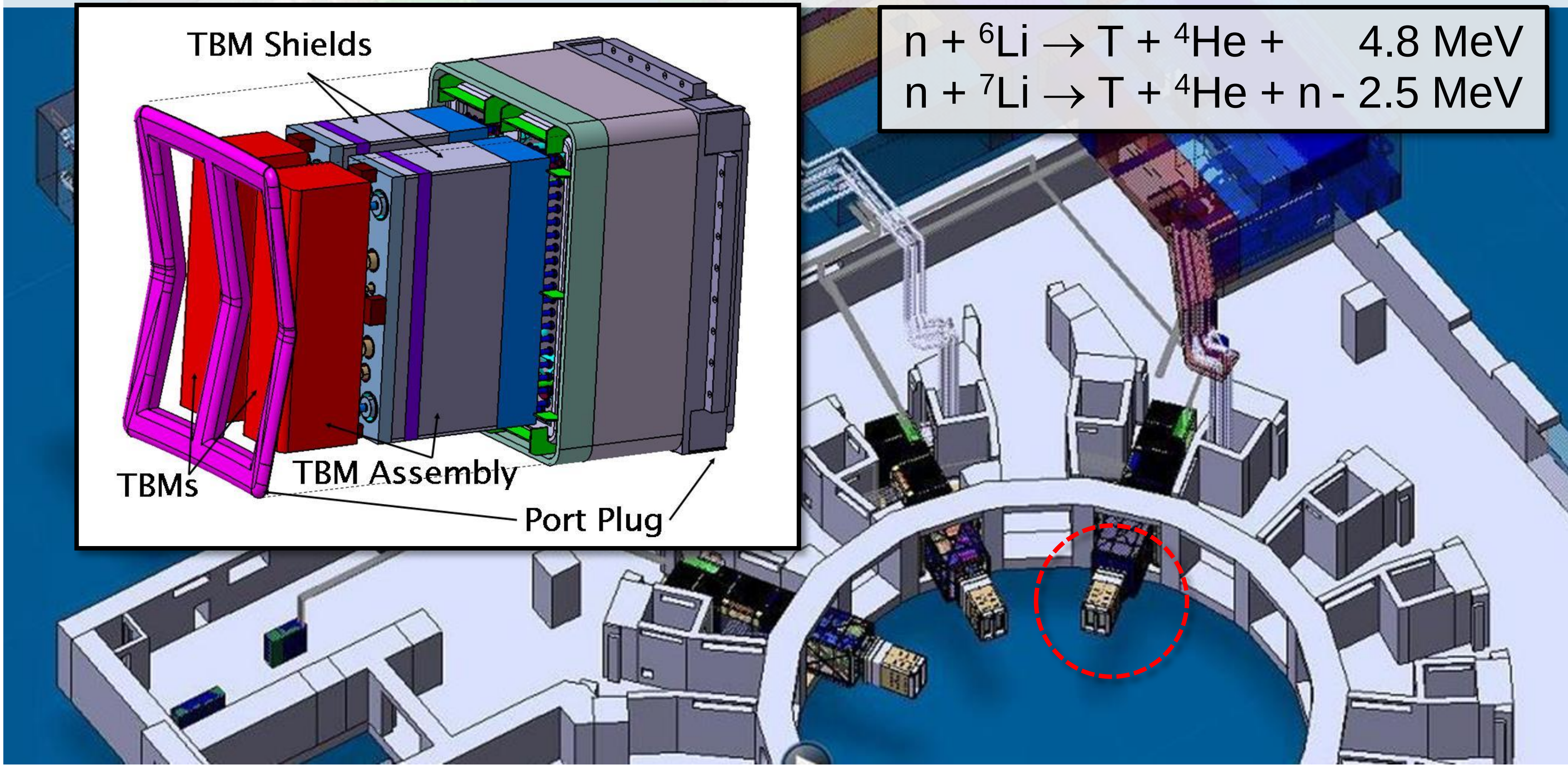
- 7 Stories
  – 2 below grade
- L = 80 m
- W = 25 m
- H = 35 m

Test Blanket Modules

Tritium fuel cycle is a <u>major</u> challenge for <u>all</u> DT fusion devices

$\Rightarrow$ ITER will test concepts

- 6 modules with different designs, all ITER parties involved



$$n + {}^{6}Li \rightarrow T + {}^{4}He + 4.8\ MeV$$
$$n + {}^{7}Li \rightarrow T + {}^{4}He + n - 2.5\ MeV$$

