The ITER Project

Moving forward at full speed

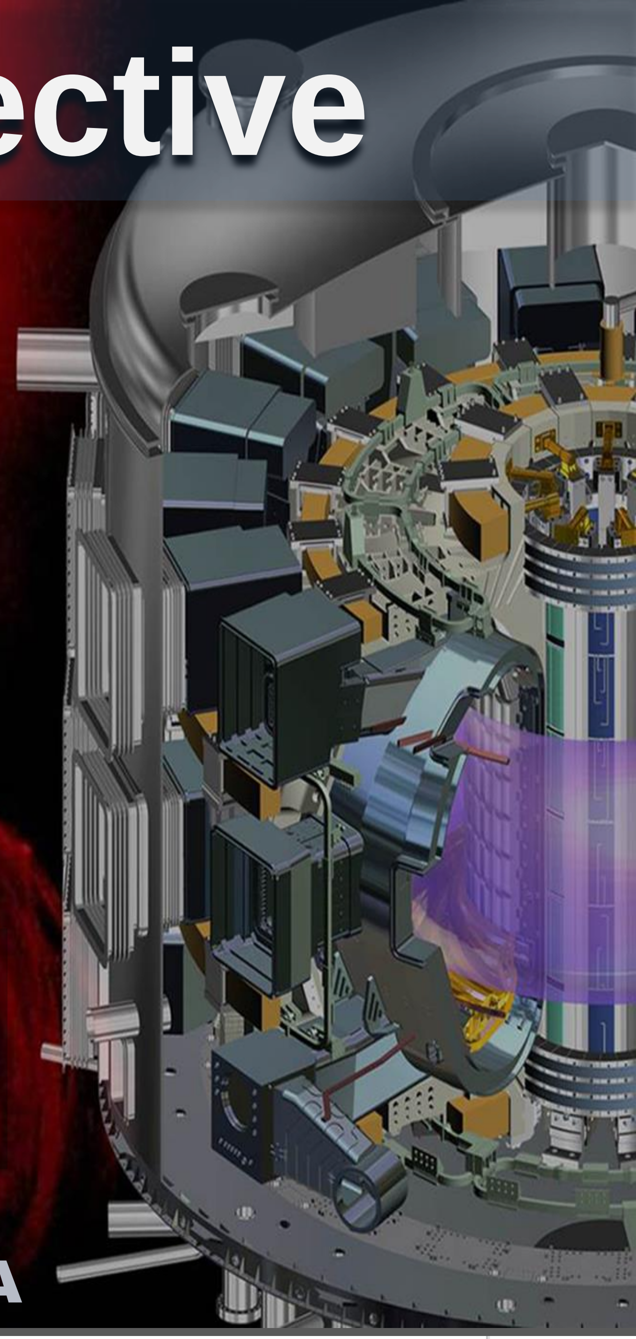
ITER in perspective

Mission: To demonstrate the scientific and technological feasibility of large scale fusion power

ITER is the only magnetic fusion device under construction to produce a burning plasma.

Input (heating) 50 MW → Output 500 MW

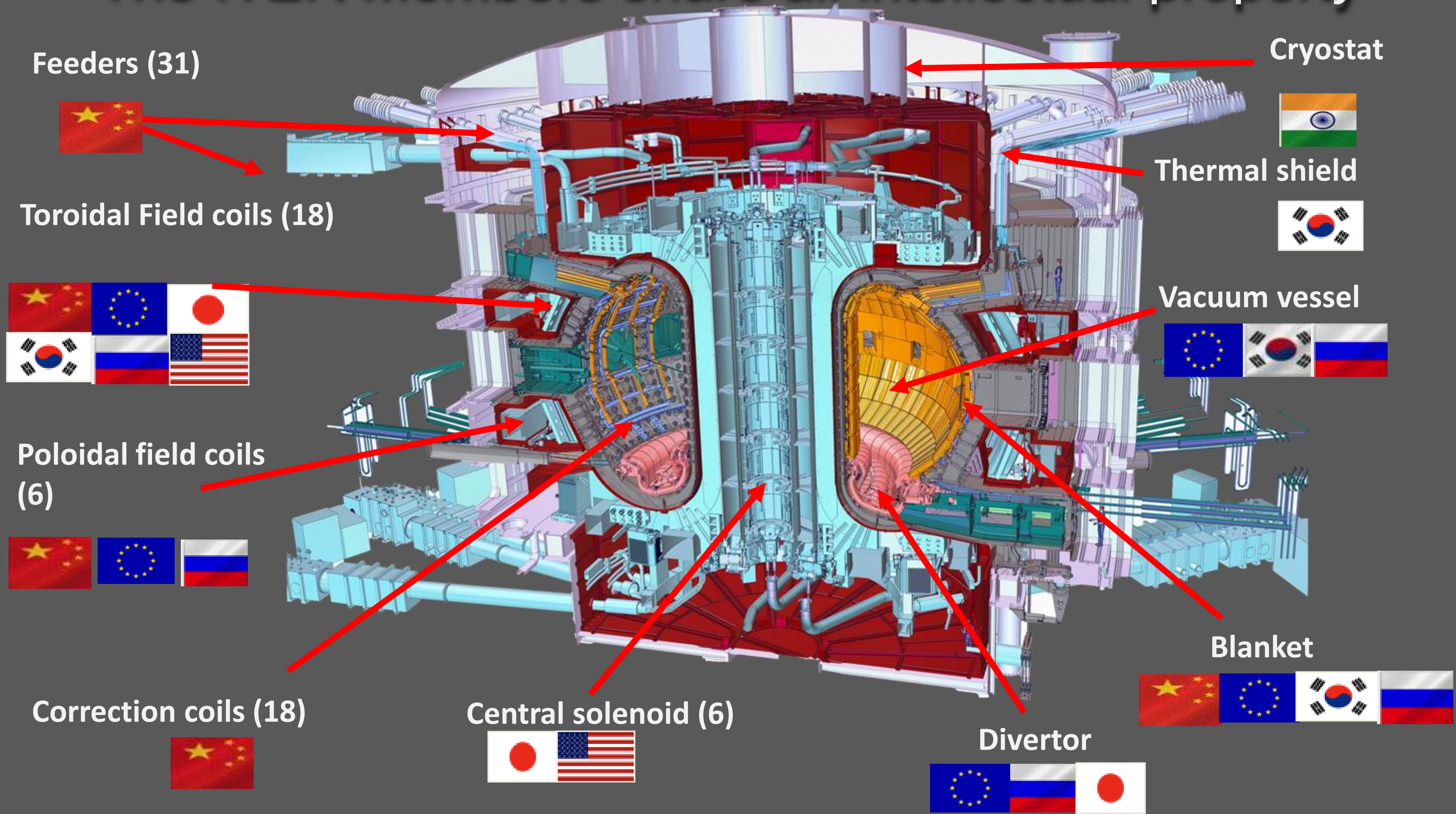
Global Response to a Global Challenge



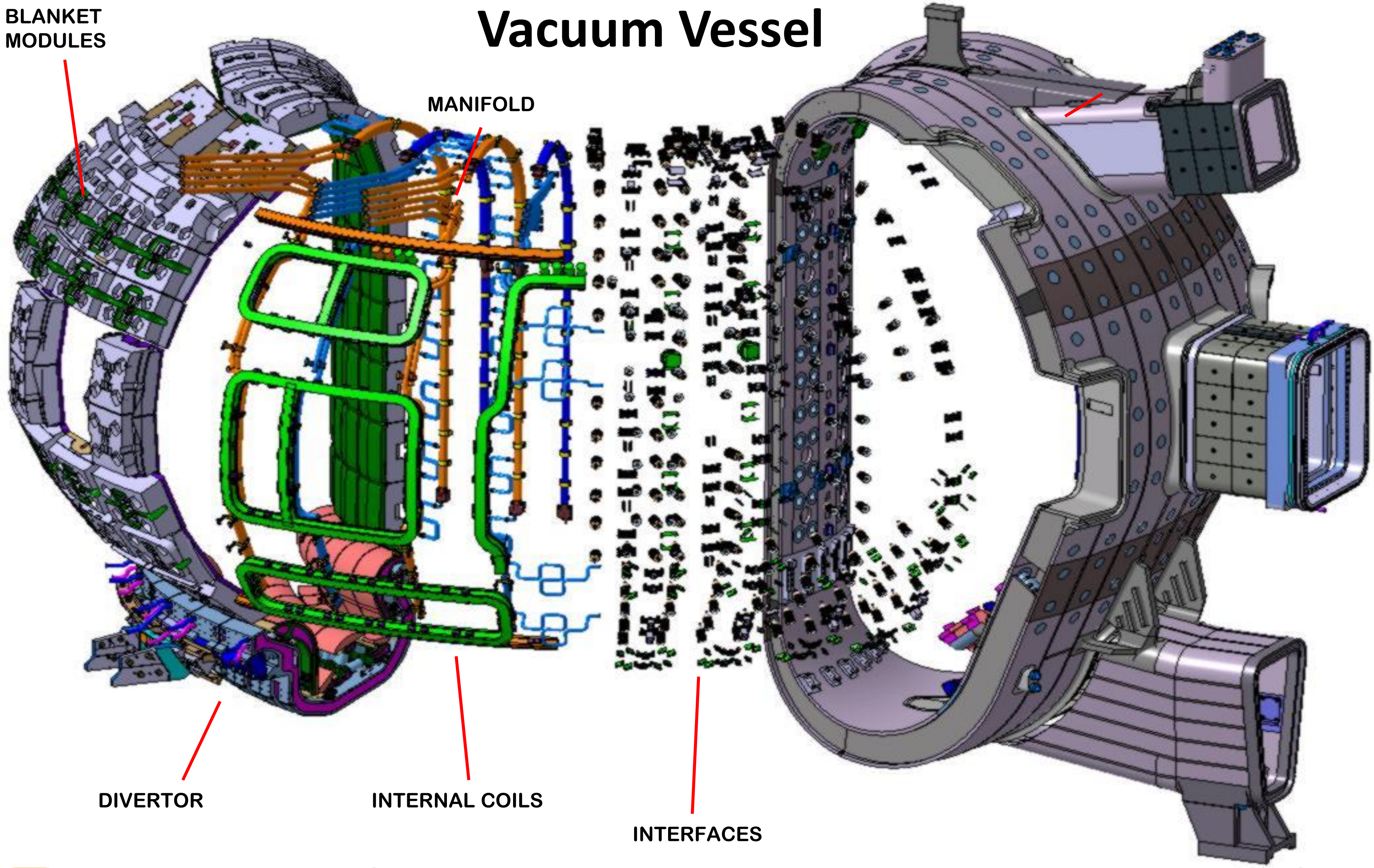
China EU India Japan Korea Russia USA

Who manufactures what?

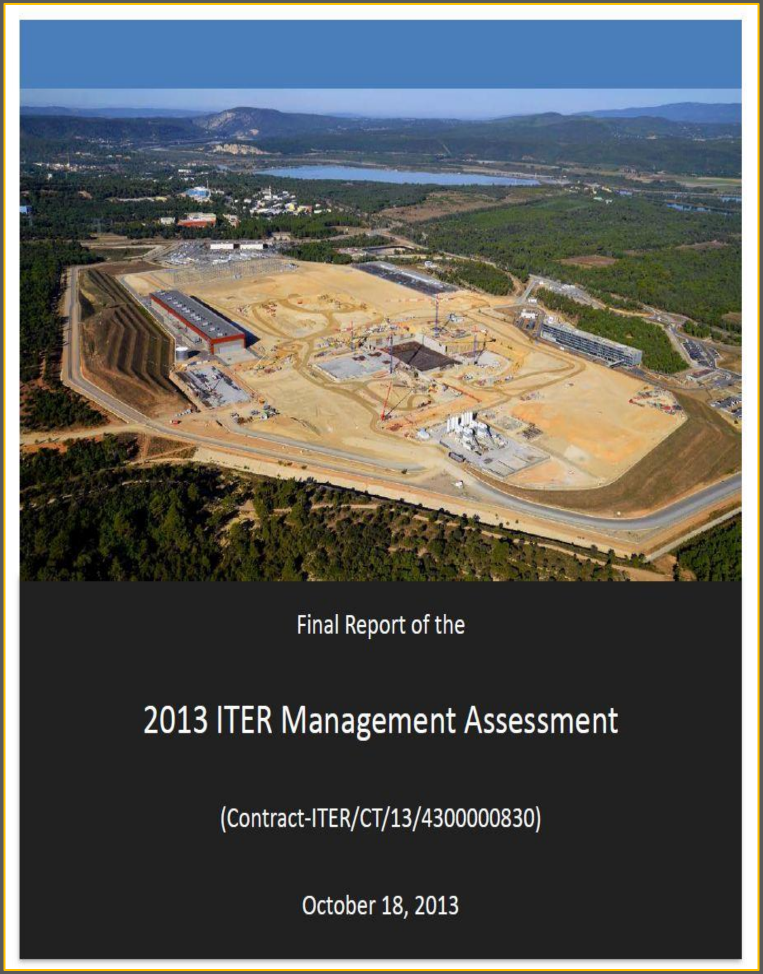
The ITER Members share all intellectual property



The integration challenge



2015: the Action Plan



Set clear priorities and timeline for reform

- ✓ Reorganized and integrated the ITER Central Team with Domestic Agencies:
  - ✓ Clear decision processes and accountability
  - ✓ DG/DDG, Executive Project Board, Reserve Fund, Project Teams
- ✓ Finalized ITER critical component design
- ✓ Promoted an organization-wide nuclear project culture
- ✓ Conducted comprehensive integrated bottom-up review of all activities, systems, structures, and components to build the ITER machine
  - ✓ Identified need for a revised resource-loaded schedule for timely, cost-effective construction and operation through start of D-T plasma.

Baseline Schedule Development

2015: IO and DAs worked intensively to develop a revised resource-loaded baseline schedule

- ✓ September 2015: IO and DAs held Integrated Review Meeting to review proposed schedule and IO resource estimates
- ✓ November 2015: project management proposed to ITER Council:
  - ✓ 'Best technically achievable' schedule
  - ✓ First Plasma in December 2025 and DT Operation in late 2032
- ✓ Council accepted proposal as a basis for managing project over subsequent 2 years:
  - ✓ Monitored via achievement of agreed major milestones
- ✓ Requested independent review of schedule to establish viability
  - ✓ Appointed **Independent Council Review Group** of experts nominated by Members to assess schedule reliability and credibility

2016: Performance & Follow-through

Code	Name	ORG 1	Target	
01	Tier-1 of Cryostat base Section deliver to IN-DA Workshop at ITER Site	IN	Q1 2016	
02	Start of B1 Civil works in Tokamak Building	EU	Q1 2016	
03	Lot-1 Piping - Delivered by IN-DA to IO at ITER-Site	IN	Q1 2016	
04	Erection of Tokamak Main Cranes in Assembly Hall	EU	Q2 2016	
05	Completion of First EU TF Winding Pack	EU	Q2 2016	
06	Fabrication of all TF Conductors from RF, CN and JA Completed	CN,JA,RF	Q2 2016	
07	All Magnet Conductor Fabrication Complete for PF5 and PF2	CN	Q2 2016	
08	Completion of Performance Tests of Full-W Divertor OVT Plasma Facing Units	JA	Q2 2016	
09	Installation of WDS Tanks in Tritium Building	EU	Q2 2016	
10	Complete CS Module 1 Winding	US	Q2 2016	
11	Signature of CMA Contract	IO	Q3 2016	
12	Complete 4th (of 9) TF Conductor Unit Length	US	Q3 2016	
13	First Sub Segment Assembly VV Sector 5 Completed	EU	Q4 2016	
14	First Liquid Nitrogen Refrigerator Equipment Factory Acceptance Tests Completed	EU	Q4 2016	
15	Steady State Electrical Network - Delivery of Power Transformers (Lot 3) to ITER	US	Q4 2016	
16	Liquid Helium plant equipment Factory Acceptance Test Completed	IO	Q4 2016	
17	Vacuu[illegible] ITER S[illegible]	[illegible]	[illegible] 2016	
18	Compl[illegible]	[illegible]	[illegible] 2017	
19	Energis[illegible]	[illegible]	[illegible] 2017	
18	Ct[illegible]	[illegible]	[illegible] 2017	
19	Energis[illegible]	[illegible]	[illegible] 2017	

From July 2016 Progress Report
Blue – completed
Green - on schedule
Yellow – delays anticipated
Red – delayed, mitigation needed

Schedule Control

- ✓ Main issue at present relates to Vacuum Vessel delivery
  - ✓ Back transfer of 2 VV sectors from EU to IO with support of KODA
  - ✓ Reconfigure VV Assembly sequence to maintain FP schedule
- ✓ Technical measures to support schedule/ reduce risk
  - ✓ Accelerate interface freeze
  - ✓ VVPSS redesign
  - ✓ Establish Nuclear Integration Unit to coordinate nuclear analysis
  - ✓ Finalize Tokamak Complex Floor Response Spectra

Strong performance: meeting demands of external validation while maintaining construction and manufacturing at full pace in accordance with agreed milestones

April 2016: intensive, in-depth review by independent expert group declares:

- “…substantial improvement in project performance…”
- “…high degree of motivation…
- “…considerable progress during the past 12 months…”
- “…sequence and duration of future activities have been fully and logically mapped in the resource-loaded schedule…”
- “…resource estimate is generally complete […] and provides a credible estimate of cost and human resources…”

18th ITER Council endorses Updated Schedule

The 18th ITER Council, chaired by Korea's Won Namkung, convened at ITER Headquarters in Saint-Paul-lez-Durance on 15-16 June 2016.

First Plasma in December 2025

The updated Schedule is challenging but technically achievable.

It represents the best technically achievable path forward to First Plasma.

The successful completion of all project milestones to date, on or ahead of schedule, is a positive indicator of the collective capacity of the ITER Organization and the Domestic Agencies to continue to deliver on the updated Schedule.

Members now have all the elements needed to go through their domestic processes of obtaining approval for the Resource-Loaded Integrated Schedule as a basis for 2016 Baseline

Baseline Schedule: Staged Approach

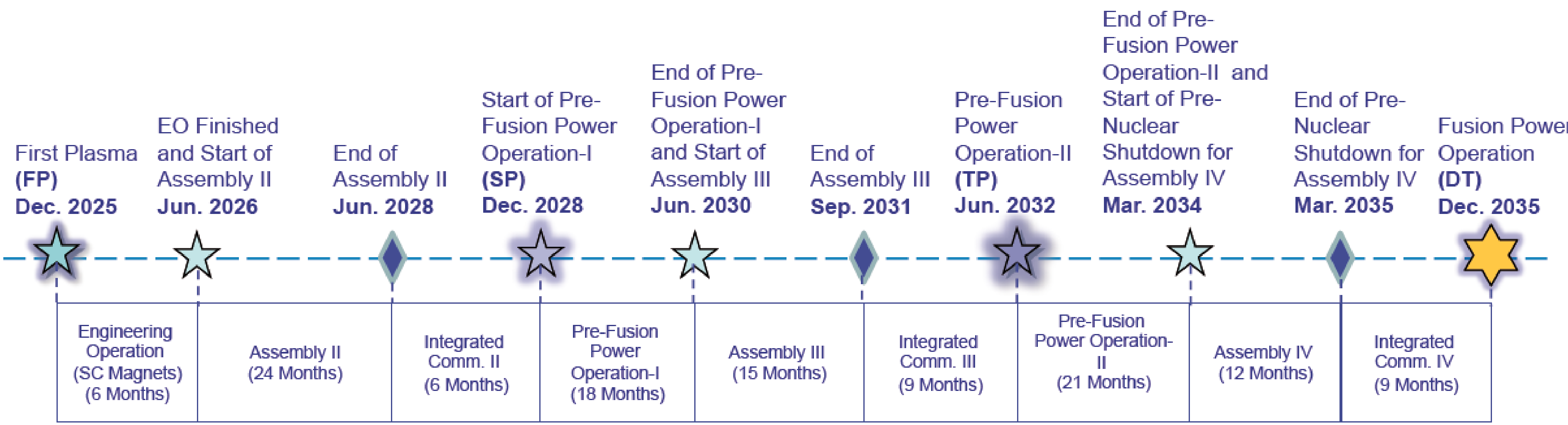
Developed in parallel with ICRG assessment to incorporate resource constraints of Members

- ✓ 4-stage approach foresees several phases of operation from FP to DT
  - ✓ Staged upgrades of ITER facility following FP in December 2025
  - ✓ First DT operations phase scheduled for December 2035
- ✓ April 2016: ICRG recommended to Extraordinary Council that Staged Approach provides most appropriate framework for revised schedule
- ✓ June 2016: ITER Council approved *ad referendum* schedule to First Plasma in December 2025
- ✓ Council requested DG to develop revised overall schedule and IO resource estimate to DT Commissioning within framework of Staged Approach
  - ✓ Updated Baseline schedule and IO resource estimate to FP
  - ✓ Indicative schedule and cost baseline from 2026 to initial DT operations

Staged Approach: Baseline Schedule

Extensive interactions among IO and DAs to resolve outstanding issues to finalize revised baseline schedule proposal

- ✓ Schedule and IO resource estimate to First Plasma consistent with Members' budget constraints
- ✓ DG proposed resolution of 4-stage/3-stage approach in favor of 4-stage: consistent with Members' financial and technical constraints



Key ITER Physics R&D

Extensive Physics R&D programme in collaboration with international fusion community – addresses remaining design issues and preparation for Operations

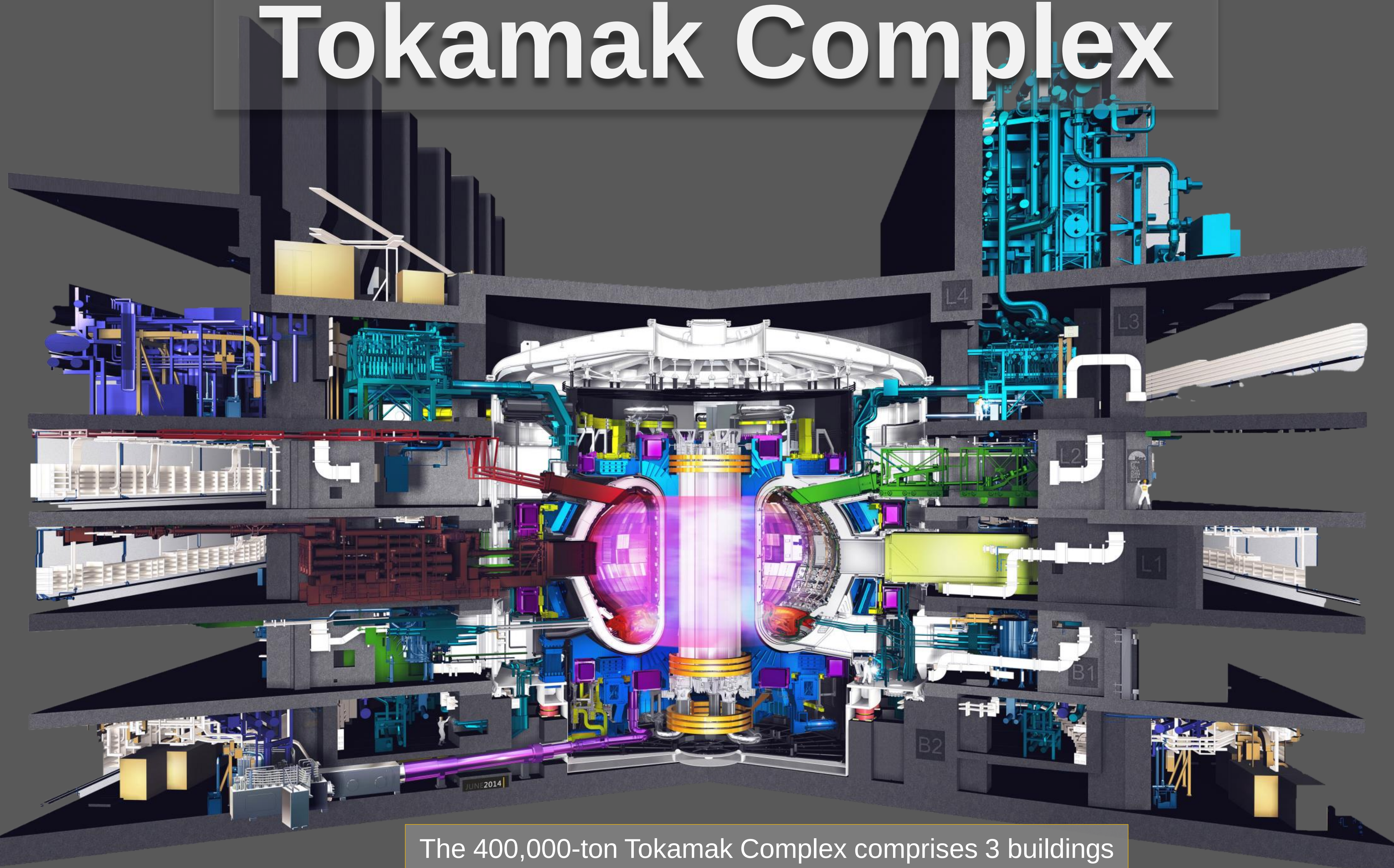
- ✓ Effective disruption management essential to reliable operation
  - ✓ Addressing disruption detection, avoidance and mitigation
  - ✓ International collaboration on development of shattered pellet injector concept for disruption mitigation (IO/ USIPO/ DIII-D/ JET)
- ✓ ELM control by magnetic perturbations, including spectral requirements and control of divertor heat loads
- ✓ Understanding impact of fuel and impurity transport on plasma performance in ITER
- ✓ Divertor and PWI studies:
  - ✓ Experimental and simulation studies to support specification of divertor monoblock shaping
  - ✓ Dust production, tritium retention and tritium removal

Coordinating ITER Physics R&D

First ITER Scientist Fellows' Workshop
ITER HQ, September 2016

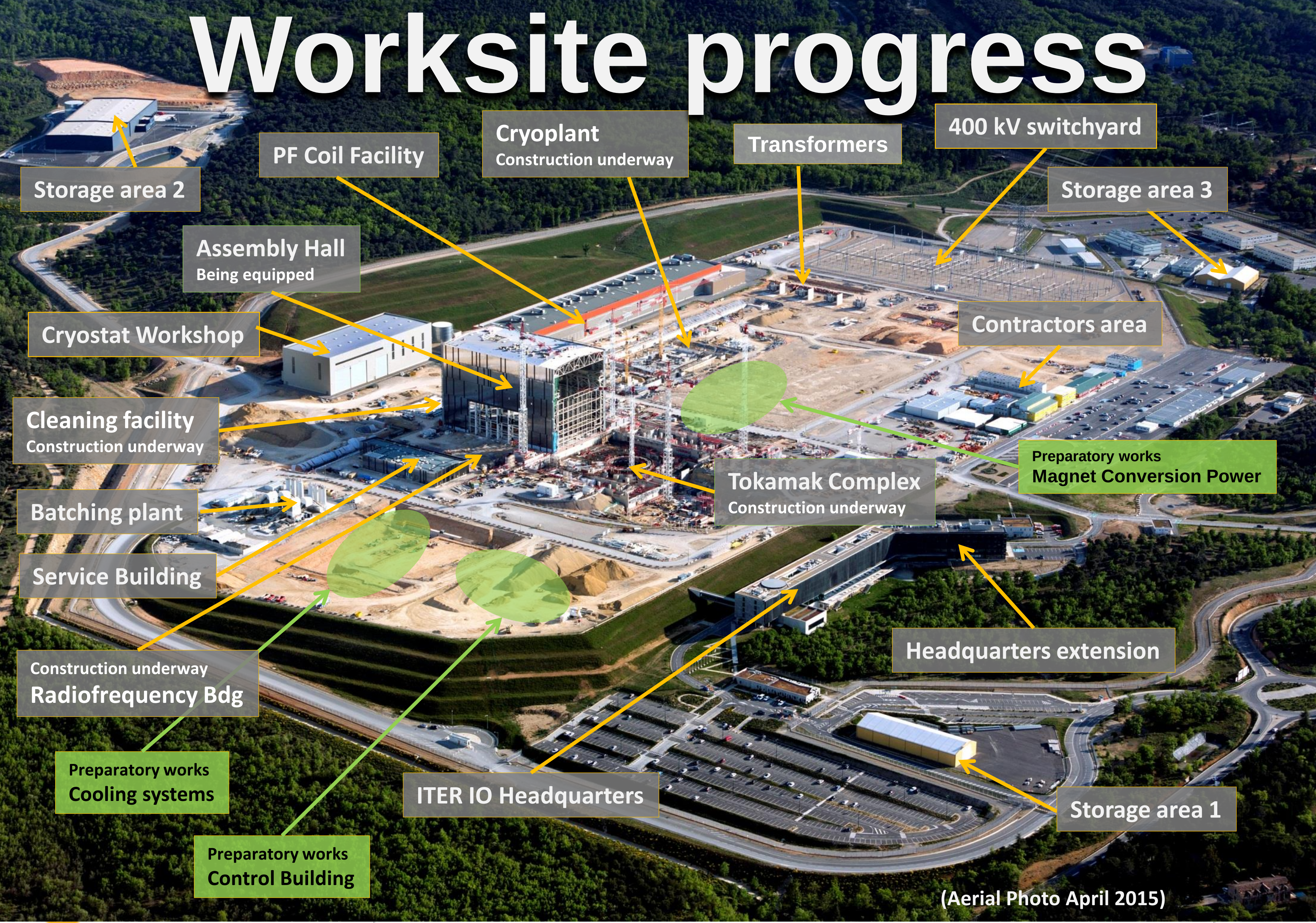
- ✓ Emphasis on mobilization of fusion community:
  - ✓ Develop key R&D activities
  - ✓ Support Research Plan development
  - ✓ Prepare for efficient operation
- ✓ Mechanisms to integrate fusion community into ITER programme:
  - ✓ International Tokamak Physics Activity (ITPA)
  - ✓ IEA TCP on Co-operation on Tokamak Programmes (CTP)
  - ✓ MoUs with fusion facilities and academic institutions
  - ✓ ITER Scientist Fellows' Network

Tokamak Complex



The 400,000-ton Tokamak Complex comprises 3 buildings — Diagnostics (right), Tokamak (centre) and Tritium (left).

Worksite progress



Tokamak Complex

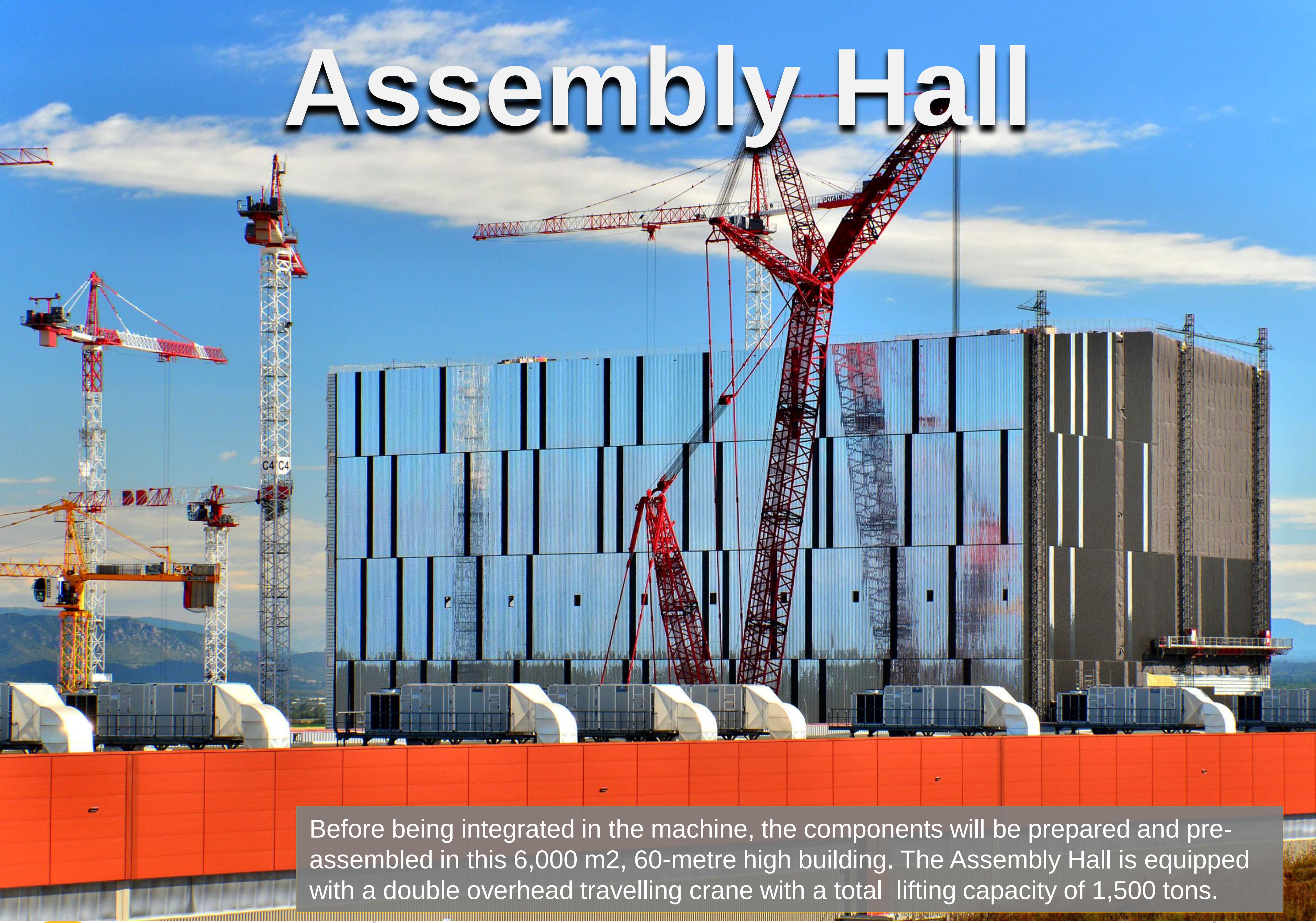
Resting on 493 seismic pads, the reinforced concrete “B2” slab bears the 400 000-ton Tokamak Complex. Concrete casting of the B2 slab was finalized on August 27, 2014. Diagnostic Building (right): B1 level slab and walls/columns now complete; Tokamak Building (centre): completion of the BioShield wall B2 level. Start of the B1 slab on 26 April 2016, and construction of interior walls/columns is on-going. Tritium Building (left): steel reinforcement on B1 level.

Tokamak Complex

First plant components installed (detritiation tanks)

The six water detritiation tanks (four 20 m³ tanks and two 100 m³ tanks) and the drainage tank are the first plant components installed in the ITER Tokamak Complex.

Assembly Hall



Before being integrated in the machine, the components will be prepared and pre-assembled in this 6,000 m2, 60-metre high building. The Assembly Hall is equipped with a double overhead travelling crane with a total lifting capacity of 1,500 tons.

Assembly Hall

43 metres above the building's basemat the double overhead crane is now installed

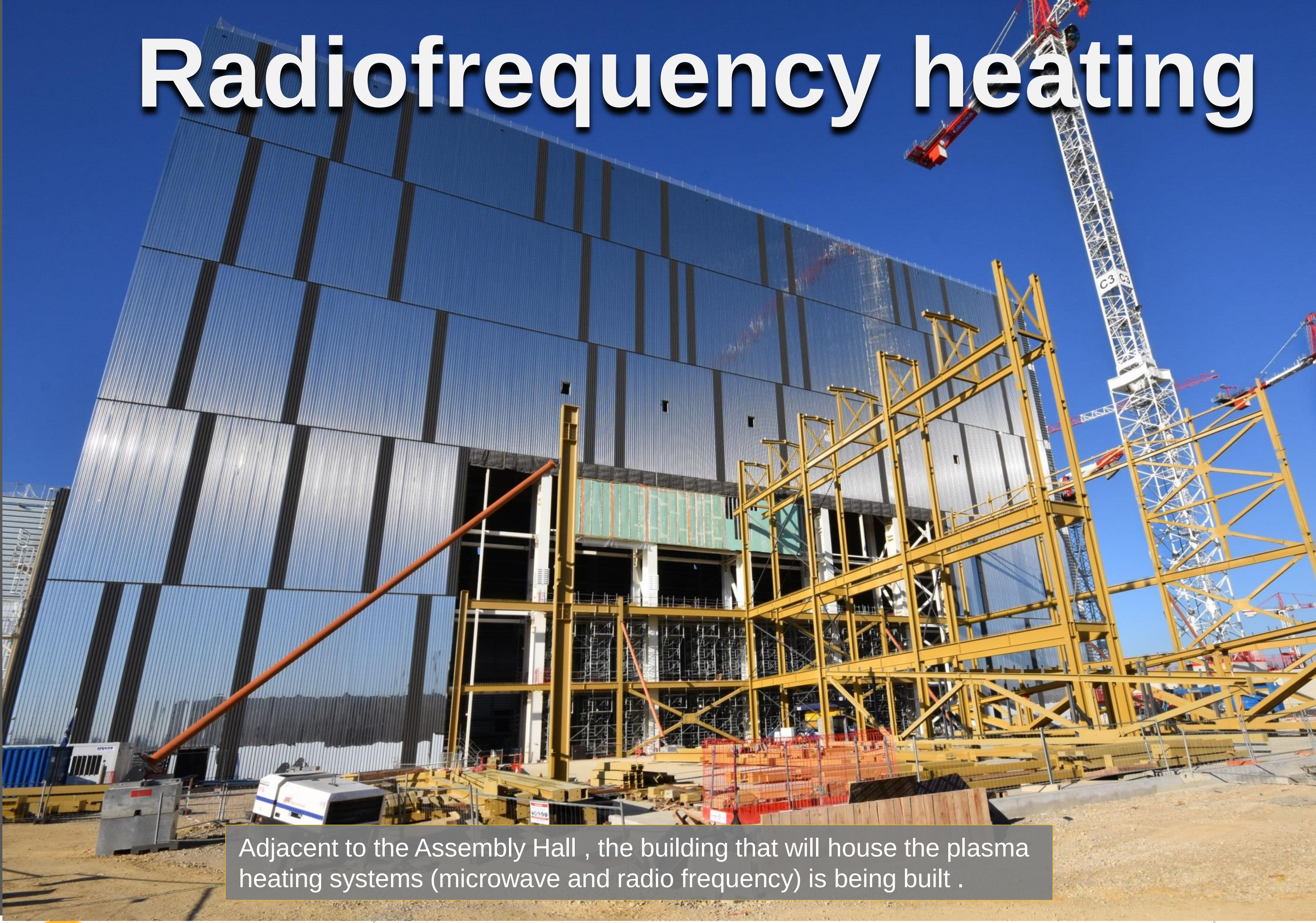
On 14 June lifting operations begin.

Complete with gear-motors, wheels, braces, electrical gear, etc. , the beam now weighs 186 tons.

Each pair of cranes will have a lifting capacity of 750 tons.

On 22 June, the 4 beams and 2 of 4 trolleys (100 t.) are installed.

Radiofrequency heating



Adjacent to the Assembly Hall , the building that will house the plasma heating systems (microwave and radio frequency) is being built .

Cryostat Workshop

The welding operations of the cryostat base (1 250 t.) start 8 september 2016.

Cryoplant

It will be the largest single-platform cryoplant in the world. The ITER Cryoplant will distribute liquid helium (-270 °C) and liquid nitrogen (-193 °C) to various machine components (superconducting magnets, thermal shield, cryopumps, etc.).

PF Coil winding facility

Entering the industrial phase with highly challenging specifications

Manufacturing ITER components is standing at the cutting edge of technology:

- **Geometrical tolerances measured in millimetres for steel pieces up to 17 m tall weighing several of**
- **Superconducting power lines cooled to *minus* 270 degrees Celsius**
- **Plasma facing components to withstand heat flux as large as 20 MW per m^2**
- **Cryoplant cooling capacity up to 110 kW at 4.5 K; maximum cumulated liquefaction rate of 12,300 lit**
- **Etc.**

Manufacturing progress

China

Tooling for Poloidal Field coil #6 (the second-smallest ring-shaped ITER magnet, at 350 tons, 10 m in diameter), is complete and is being commissioned at ASIPP in Hefei, China.

The first of three power transformers for the pulsed electrical network. Delivery is underway.

Magnet Systems, Power Systems, Blanket, Fuel Cycle, Diagnostics

Manufacturing progress

China

Internal components of a cryostat feeder prototype.

Correction coil at ASIPP in Hefei, China.

Magnet Systems, Power Systems, Blanket, Fuel Cycle, Diagnostics

Manufacturing progress

Europe

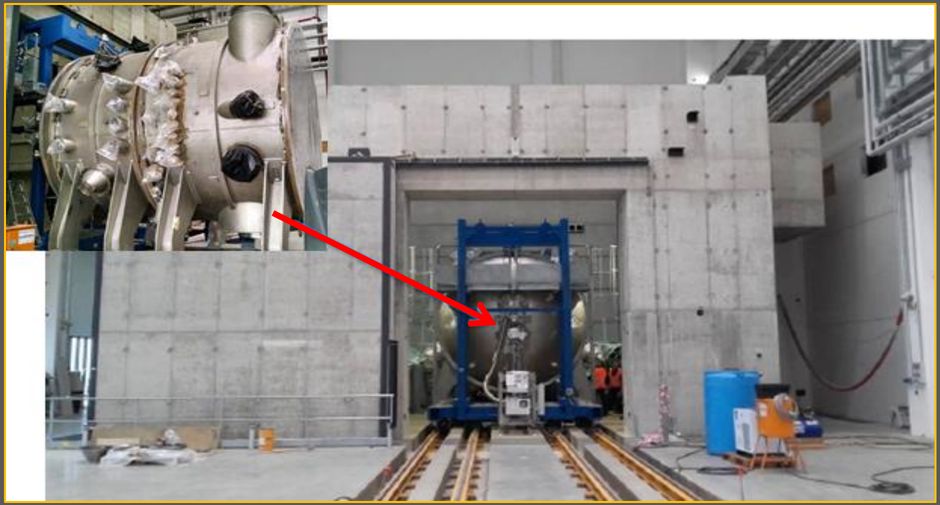
The first toroidal field coil winding pack – the 110-ton inner core of ITER's D-shaped superconducting TF Coils – was completed in April.

Inspection of the liquid helium tank inner vessel for the ITER cryoplant.

Buildings, Magnet Systems, Heating & Current Drive Systems, Vacuum Vessel, Divertor, Blanket, Power Systems, Fuel Cycle, Tritium Plant, Cryoplant, Diagnostics, Radioactive Materials

Manufacturing progress

Europe



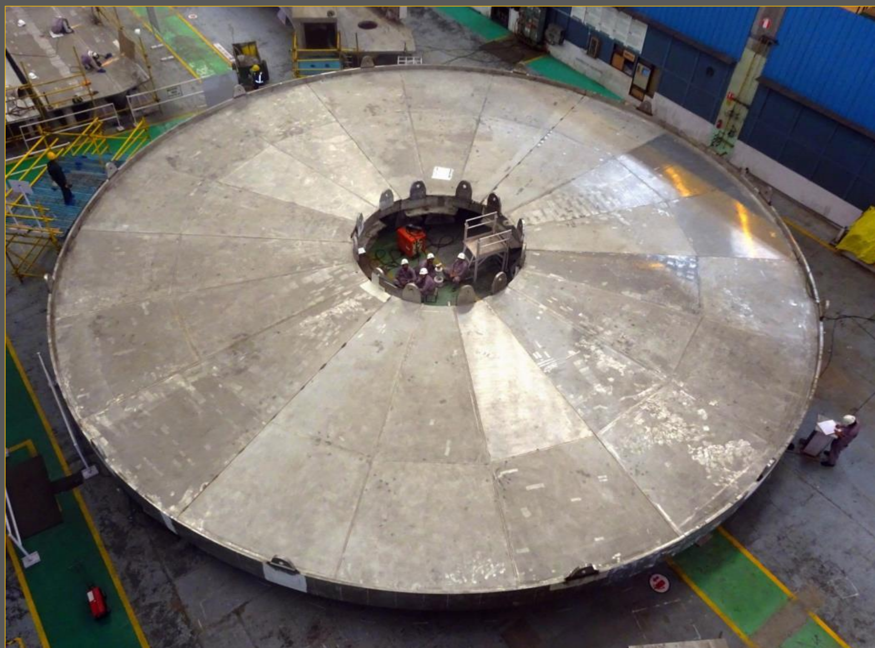
SPIDER vacuum vessel installed inside bio-shield at the PRIMA Neutral Beam Test facility in Padova, Italy.

SPIDER TL connected to vacuum vessel electrical bushing.

Buildings, Magnet Systems, Heating & Current Drive Systems, Vacuum Vessel, Divertor, Blanket, Power Systems, Fuel Cycle, Tritium Plant, Cryoplant, Diagnostics, Radioactive Materials

Manufacturing progress

India



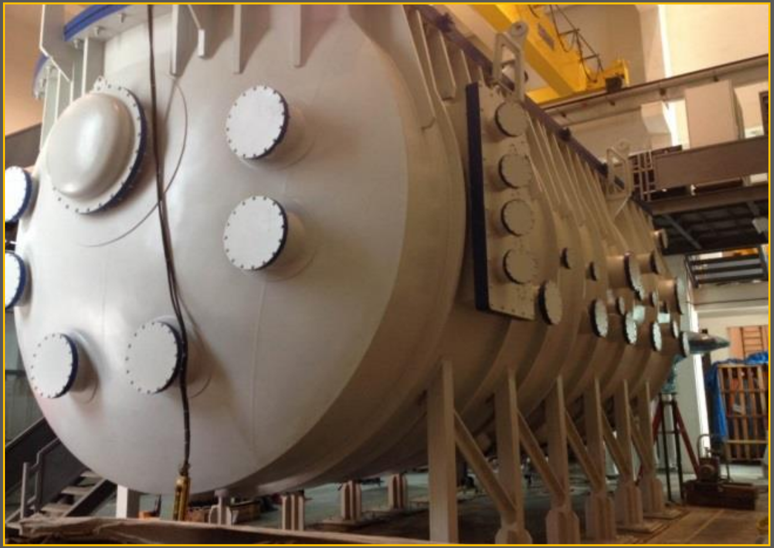
India is responsible for fabrication and assembly of the 30x30 meter ITER cryostat. The base plates were delivered to ITER in December 2015.

The transportation frame/assembly and welding support for the cryostat has been assembled in the Cryostat Workshop where welding began in August.

Cryostat, Cryogenic Systems, Heating and Current Drive Systems, Cooling Water System, Vacuum Vessel, Diagnostics

Manufacturing progress

India



Diagnostic neutral beam vacuum vessel.

A cold test was successfully completed on a prototype cryoline.

Cryostat, Cryogenic Systems, Heating and Current Drive Systems, Cooling Water System, Vacuum Vessel, Diagnostics

Manufacturing progress

Japan

Connection of segments for the first inboard Toroidal Field Coil structure (completed in November 2015), a significant achievement for TF coil procurement.

Toroidal field coil heat treatment.

Magnet Systems, Heating & Current Drive Systems, Remote Handling, Divertor, Tritium Plant, Diagnostics

Manufacturing progress

Japan

Series production of central solenoid conductor continues. 19 conductors have already been delivered to the US.

In October 2015, the first batch of components for the neutral beam test facility were shipped to the PRIMA facility in Italy.

Magnet Systems, Heating & Current Drive Systems, Remote Handling, Divertor, Tritium Plant, Diagnostics

Manufacturing progress

Korea

At Hyundai Heavy Industries, where 2 of 9 vacuum vessel sectors are under construction, welding on the upper section of the inner shell for Sector #6.

Inner shell assembly of a lower port stub extension for the vacuum vessel.

Vacuum Vessel, Blanket, Power Systems, Magnet Systems, Thermal Shield, Assembly Tooling, Tritium Plant, Diagnostics

Manufacturing progress

Korea

At Sam Hong Machinery in Changwon, fabrication is progressing on all nine 40° thermal shield sectors.

Welding has begun on parts of the first 800-ton Sector Sub-Assembly Tool. Korea is designing and manufacturing 128 purpose-built tools for assembly.

Vacuum Vessel, Blanket, Power Systems, Magnet Systems, Thermal Shield, Assembly Tooling, Tritium Plant, Diagnostics

Manufacturing progress

Russia

Russia completes its share of toroidal field conductor in June 2015, marking the end of a 5-year campaign to manufacture 28 production lengths (more than 120 tons of material).

In December 2014, specialists at the Efremov Institute successfully tested a prototype of the fast discharge resistor module, designed to rapidly discharge energy stored in the coils of the ITER magnetic system. Tests results demonstrated full conformance with ITER Organization technical requirements.

Power Systems, Magnet Systems, Blanket, Divertor, Vacuum Vessel, Diagnostics, Heating & Current Drive Systems

Manufacturing progress

Russia

Fabrication and qualification tests of PF1 winding pack stack sample were successfully completed.

Winding of first double pancake for poloidal field coil #1 inside the clean room.

Power Systems, Magnet Systems, Blanket, Divertor, Vacuum Vessel, Diagnostics, Heating & Current Drive Systems

Manufacturing progress

USA

General Atomics is fabricating the 1000-ton Central Solenoid (CS). In April 2016, winding of the first CS module was completed.

Module tooling stations are in place and being commissioned, including the heat treatment furnace shown here.

Cooling Water System, Magnet Systems, Diagnostics, Heating & Current Drive Systems, Fuel Cycle, Tritium Plant, Power Systems

Manufacturing progress

USA

Steady state electrical network transformers have been delivered to the ITER site.

US will complete toroidal field coil production in 2017.

Cooling Water System, Magnet Systems, Diagnostics, Heating & Current Drive Systems, Fuel Cycle, Tritium Plant, Power Systems

The deliveries succeed one another...

… to provide door-to-door delivery

14 January 2015:	First of four 90-ton transformers procured by the US and manufactured in Korea
20 March 2015:	Detritiation tank (20 tons), procured by Europe
2 April 2015:	Detritiation tank (20 tons), procured by Europe
20 April 2015:	Second of four 90-ton transformers procured by the US and manufactured in Korea
7 May 2015 :	Two 80-ton, 61,000-gallon drain tanks for the tokamak cooling water system, procured by US
21 May 2015:	Three 90-ton transformers procured by the US and manufactured in Korea
17 Sept 2015:	Two drain tanks (79 t.) for the cooling system, one (46 t.) for the neutral beam system
10 & 17 Dec. 2015:	Six 60° segments for tier 1 of the cryostat base by India (*photo*)
18 & 25 March 2016:	Girder # 1 & 2 (out of 4) for the Assembly Hall gantry crane (Europe)
21 April 2016:	Girder # 3 & 4 for the Assembly Hall gantry crane (Europe) – *pictured*
10 June 2016	First of three 300-ton PPEN transformer (China)

CMA contract for assembly and installation

In June, ITER Organization signed a 10-year €174 million contract with the MOMENTUM joint venture, to manage and coordinate the assembly and installation of the Tokamak and associated plant systems.

MOMENTUM
amec foster wheeler
assystem
KEPCO

Engineering innovation: superconductors

200 km, 2,800 tons of superconductors (80% of the total required) have been manufactured and validated

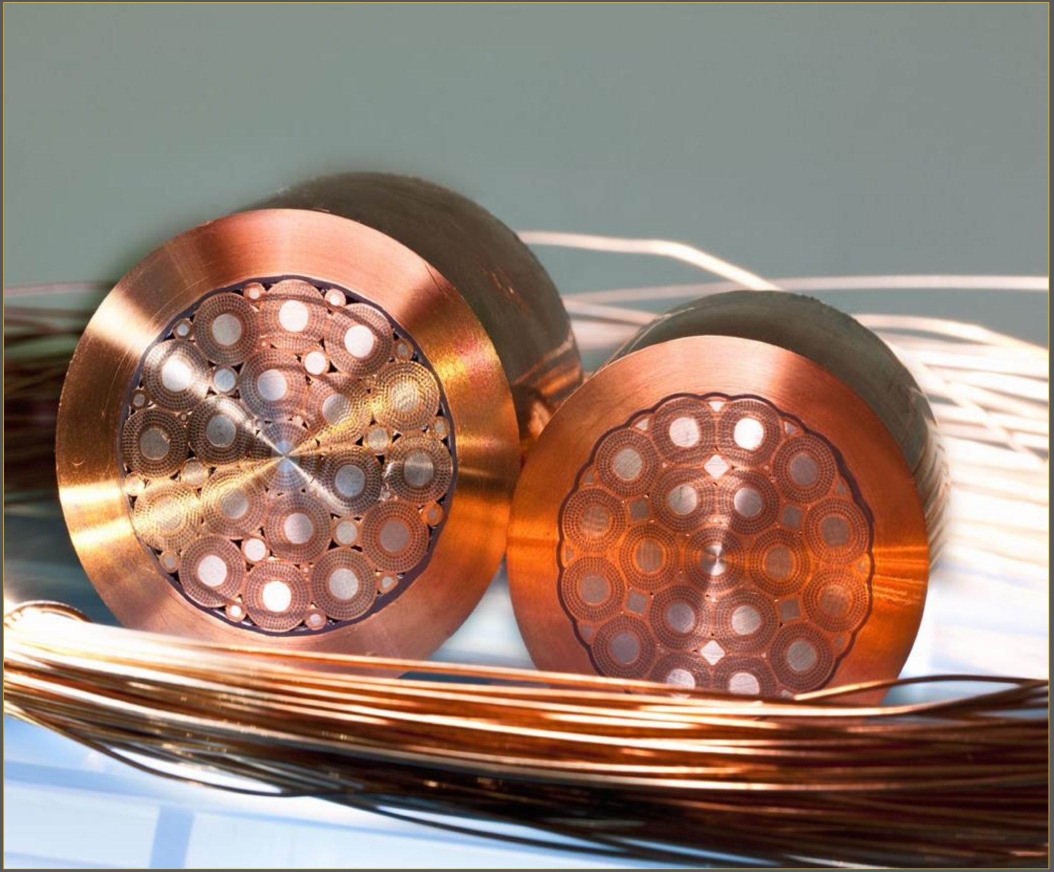
Six ITER Members—China, Europe, Japan, Korea, Russia and the United States—have been responsible for the production of cable-in-conduit conductors worth a total of EUR 610 million.

The eight-year campaign to produce the superconductors for ITER's powerful magnet systems is in its final stages.

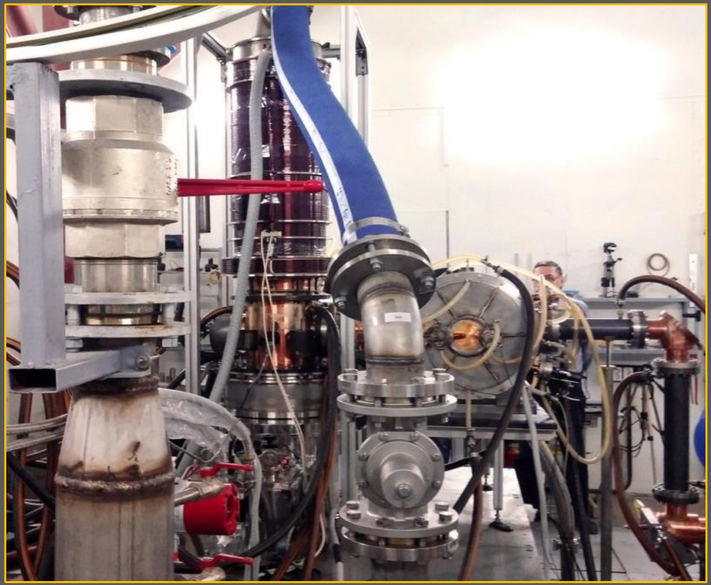
*Harmonized global standards for production methods, quality controls, testing protocols, etc.

*Groundbreaking work in materials science.

*Largest superconductor procurement in industrial history.



Engineering innovation: gyrotrons



Gyrotron prototype developed by RF-DA.

Gyrotron prototype developed by F4E (EU-DA).

Gyrotron prototype developed by JA-DA.

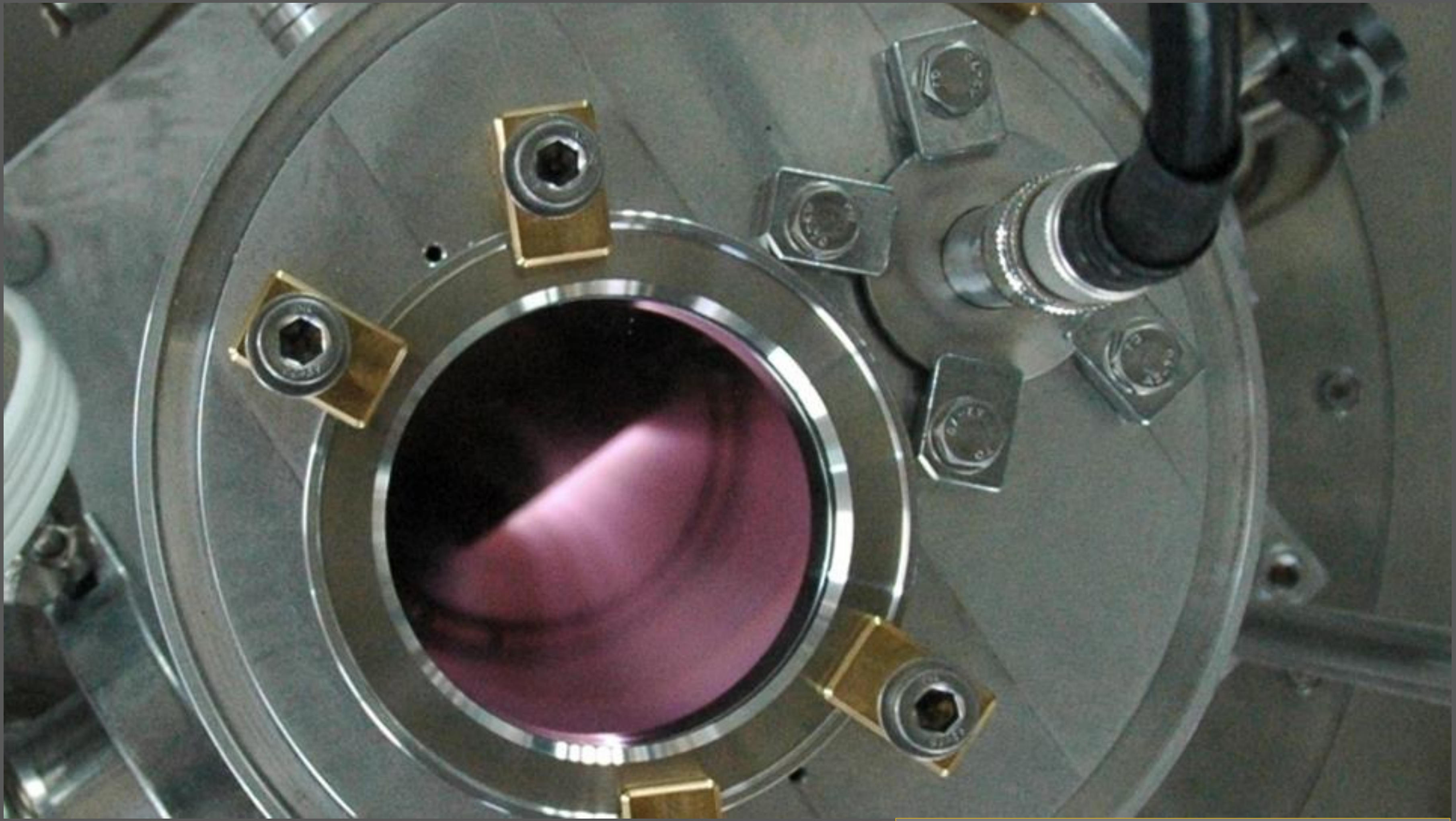
Engineering innovation: pellet fueling and ELM (edge-localized mode) pacing

Dual nozzle prototype developed at ORNL (Oak Ridge National Laboratories, USA).

Twin screw pellet extruder developed at ORNL.

View of the drive shaft gears and top of the twin-screw extruder mechanism.

Engineering innovation: cleaning methods

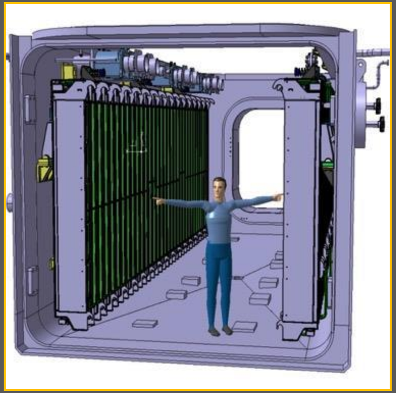


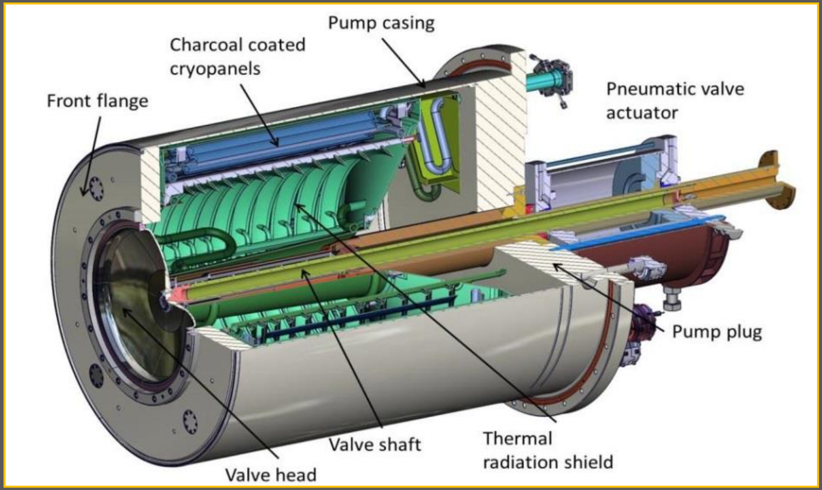
New cleaning techniques are being developed for ITER first mirrors.

Engineering innovation: vacuum systems

8-tonne machined flange of the first Torus Cryo-pump

Neutral Beam Injection Cryo-pump: 8 meters long, 2.8 meters high





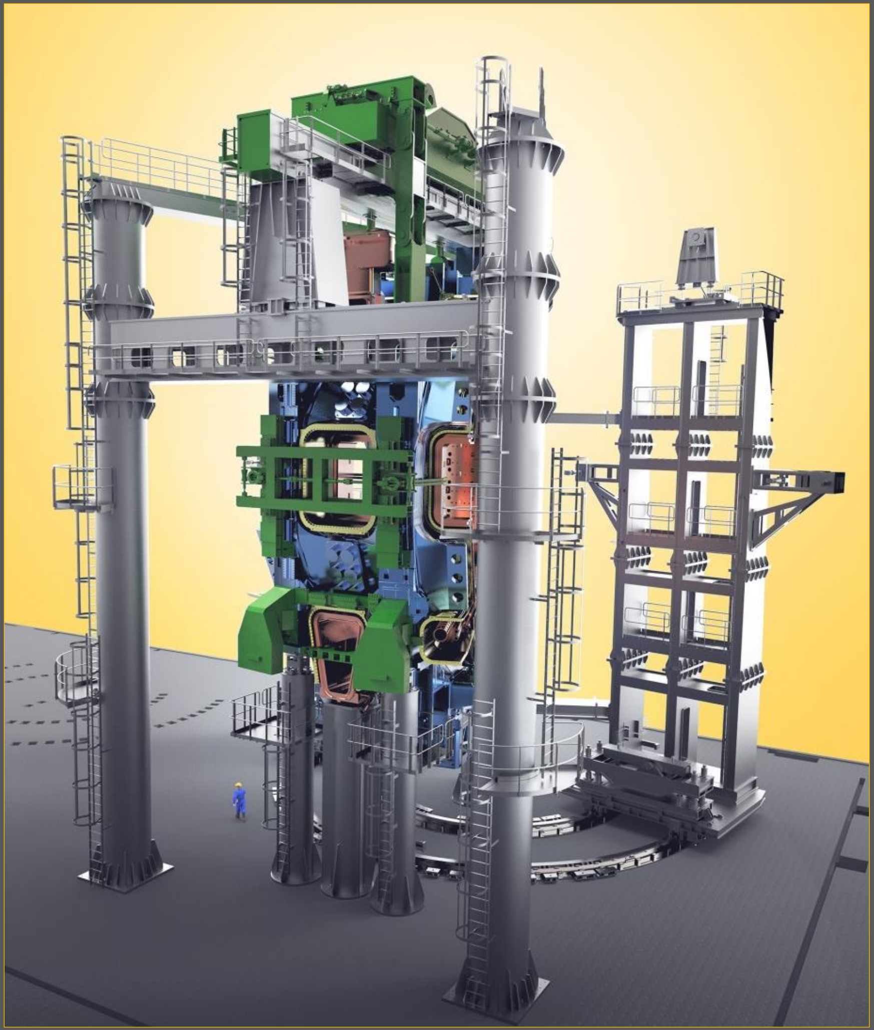
Torus and Cryostat Cryo-pump (1.8 meter diameter)

The ITER vacuum system will be one of the largest, most complex vacuum systems ever built: the cryostat, at ~ 8500m3; the torus, at ~1330 m3; the neutral beam injectors at ~180m3 each; plus lower volume systems.

More than 400 vacuum pumps will employ 10 different technologies.

Final design involved new fabrication methods to reduce cost and manufacturing time of cryo-panels and thermal shields within the pumps.

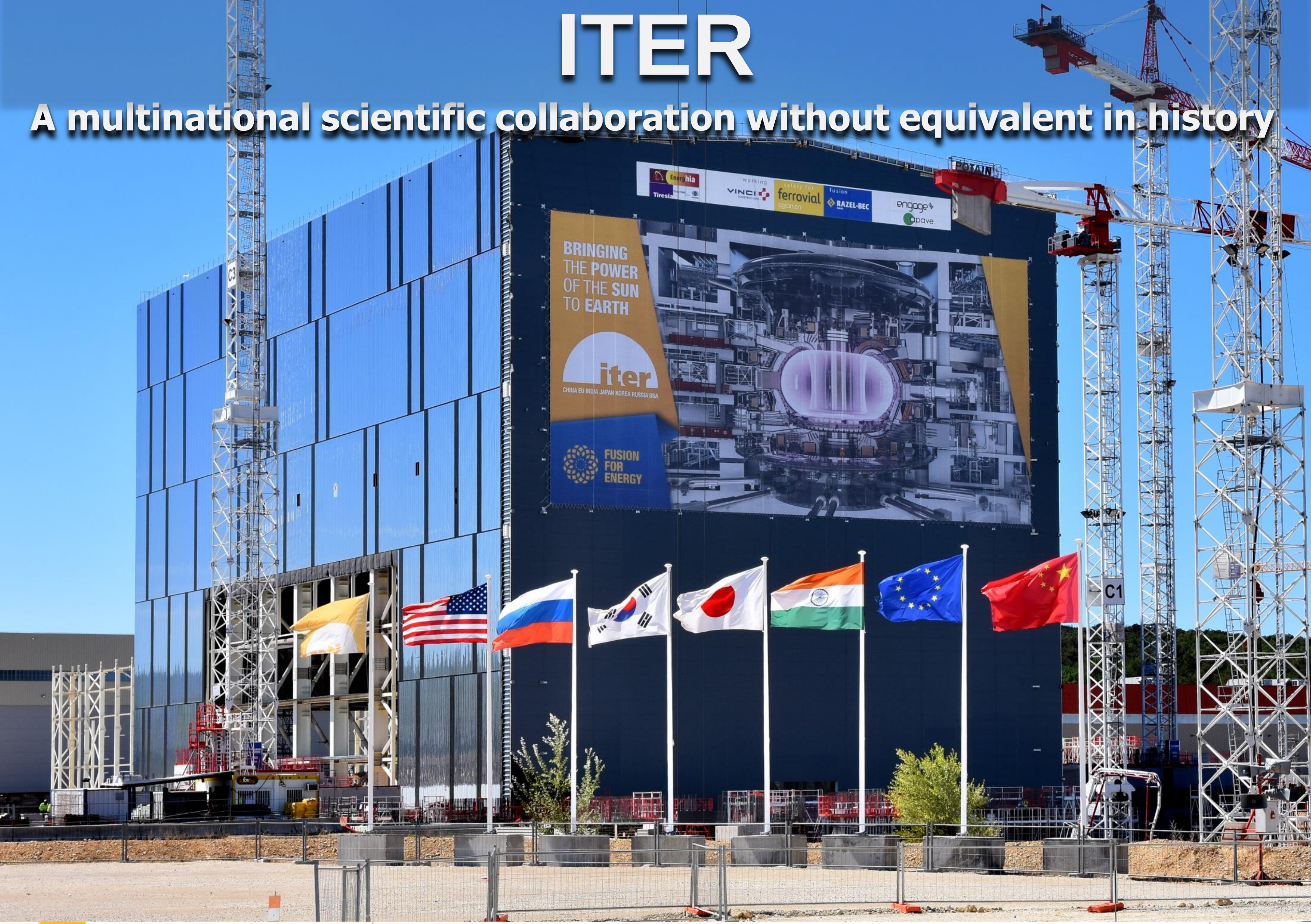
Engineering innovation: robotics and remote handling



Due to the massive size of the ITER Tokamak components, as well as the intense neutron flux that will occur during operations, the ITER machine has required the development of cutting-edge robotics and remote handling tools, which will be used in both the assembly and operational phases.

ITER

A multinational scientific collaboration without equivalent in history



ITER is moving forward!

ITER is moving forward!

ITER is moving forward!

http://www.iter.org