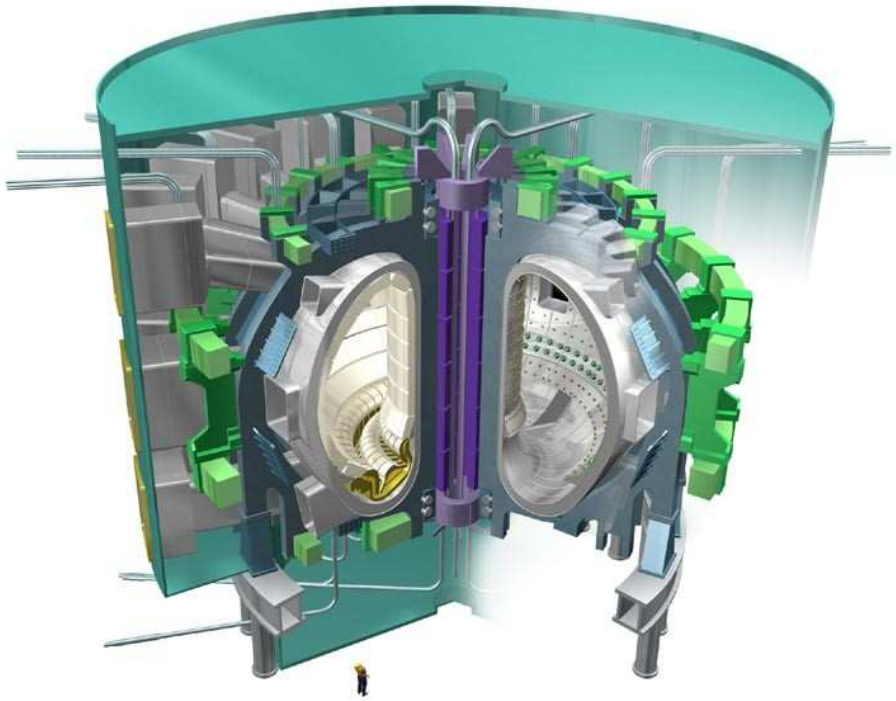
Fusion Energy: Preparing for the NIF and ITER Era

Status of ITER



Gary Johnson

Deputy Director General - Tokamak

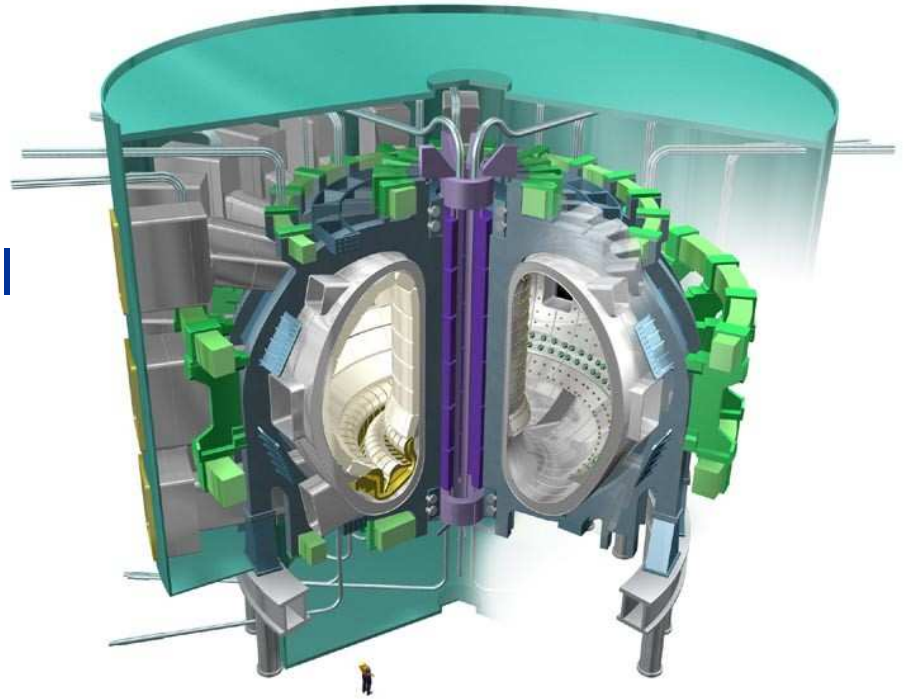
3-4 December 2007

Contents

- Introduction
- Recent Developments
- Scale of ITER
- Technical Status
- Summary

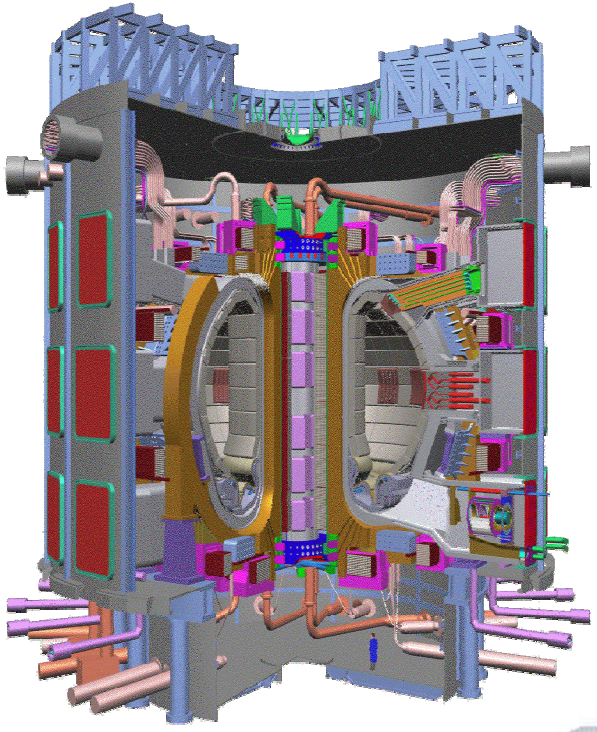
ITER – The way to fusion power

- ITER (“the way” in Latin) is the essential next step in the development of fusion.
- Its objective: to demonstrate the scientific and technological feasibility of fusion power.
- The world’s biggest fusion energy research project, and one of the most challenging and innovative scientific projects in the world today.



ITER – Key Facts

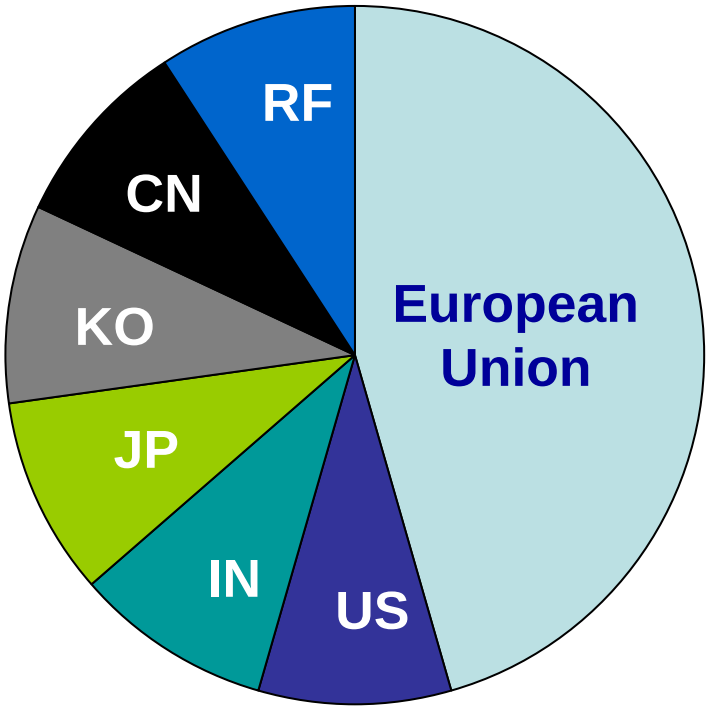
- Mega-Science Project among 7 Members:
  - China, EU, India, Japan, South Korea, Russia & US
- Designed to produce 500 MW of fusion power for an extended period of time
- Will bring together most key technologies needed for future fusion power plants
- 10 years construction, 20 years operation
- Cost: ~5 billion Euros for construction, and ~5 billion for operation and decommissioning



Construction Sharing

Overall sharing:

EU 5/11, other six parties 1/11 each. Overall contingency of 10% of total. Total amount: 3577 kIUA (5079 M€-2007)



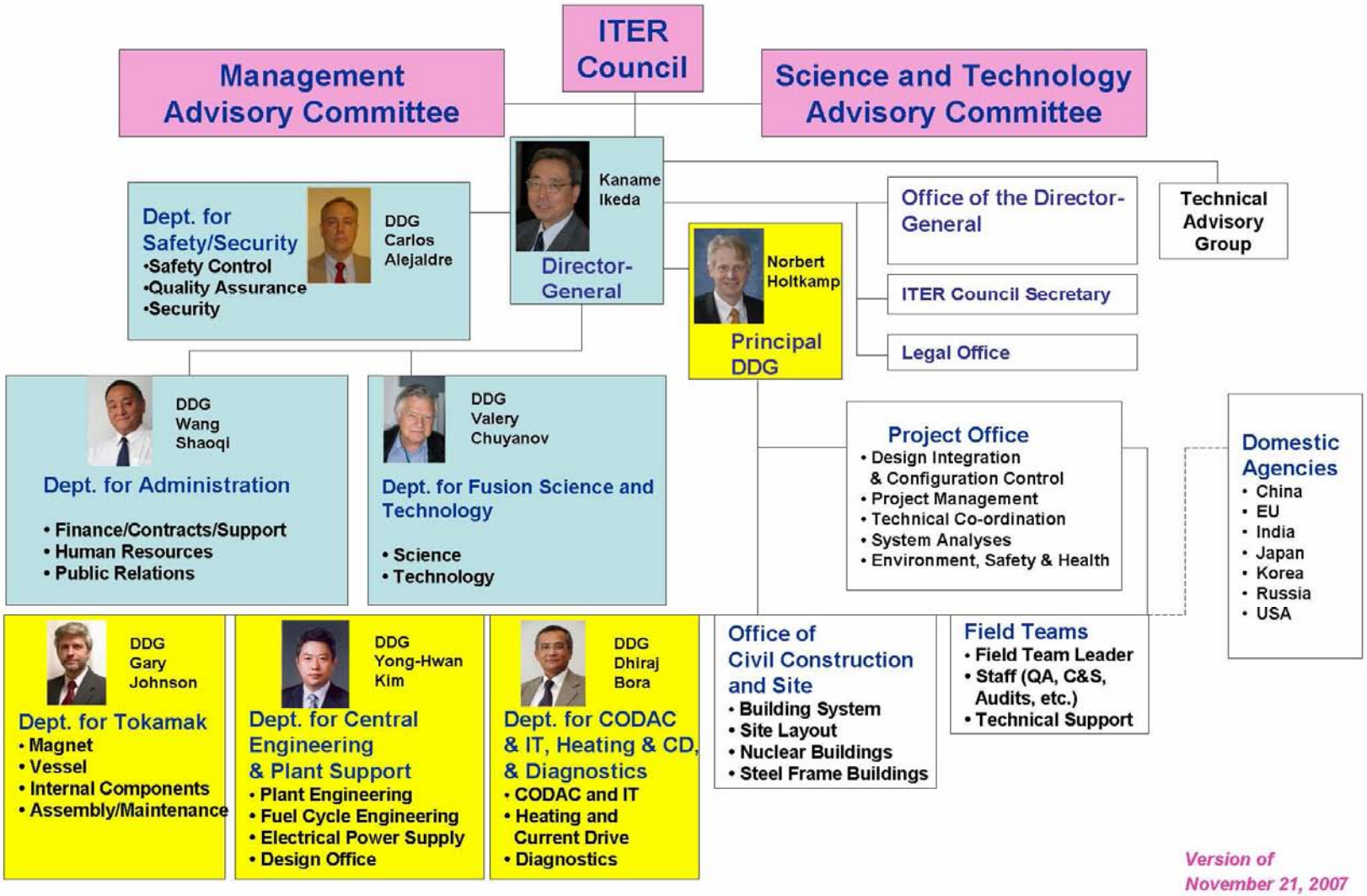
Total procurement value : 3021

Staff: 477

R&D: 80

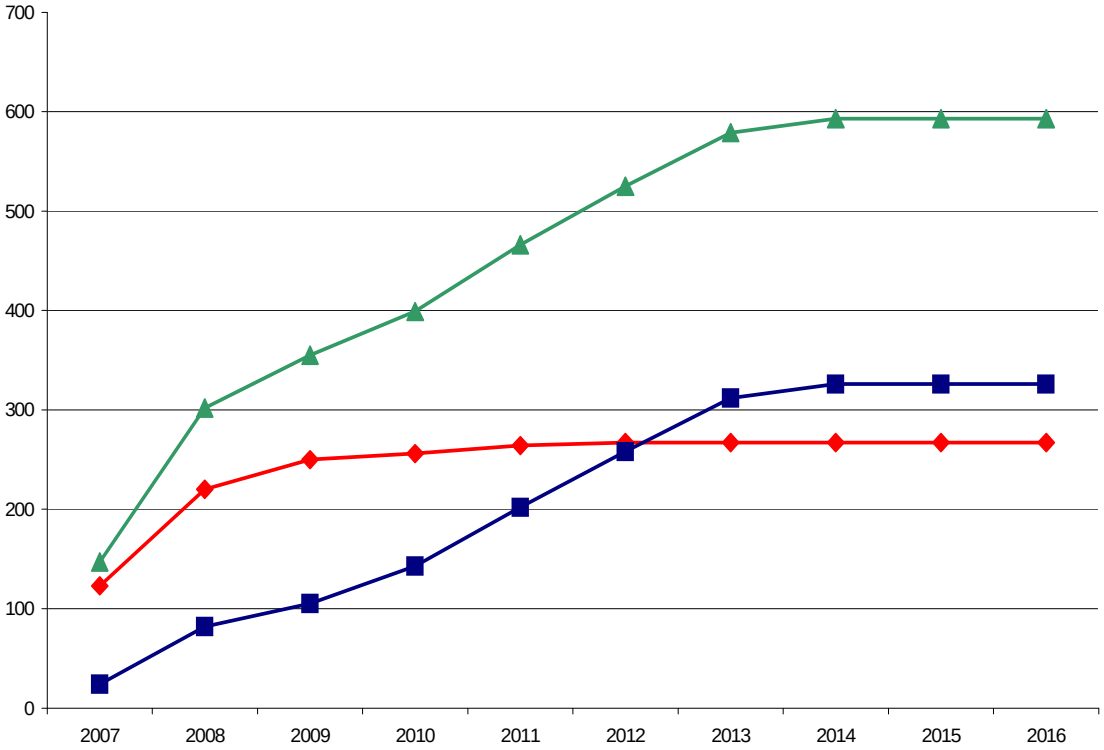
Total kIUA: 3577

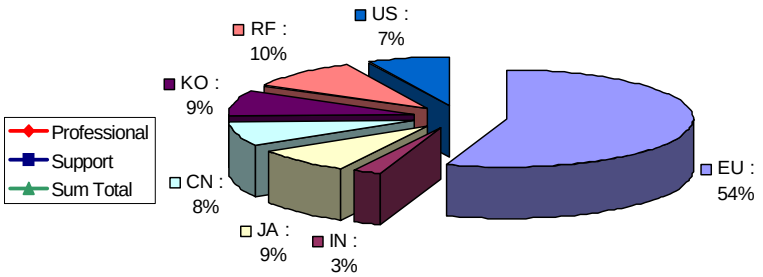
Management Structure of ITER Organization



ITER Staffing

- Currently, about 260 personnel are on site (153 professionals, 41 support, & 65 contract). This will increase to about 280 by the end of the year and about 1000 during peak of construction.
- Worldwide, 3000 – 4000 people will be involved in the ITER project during the peak.



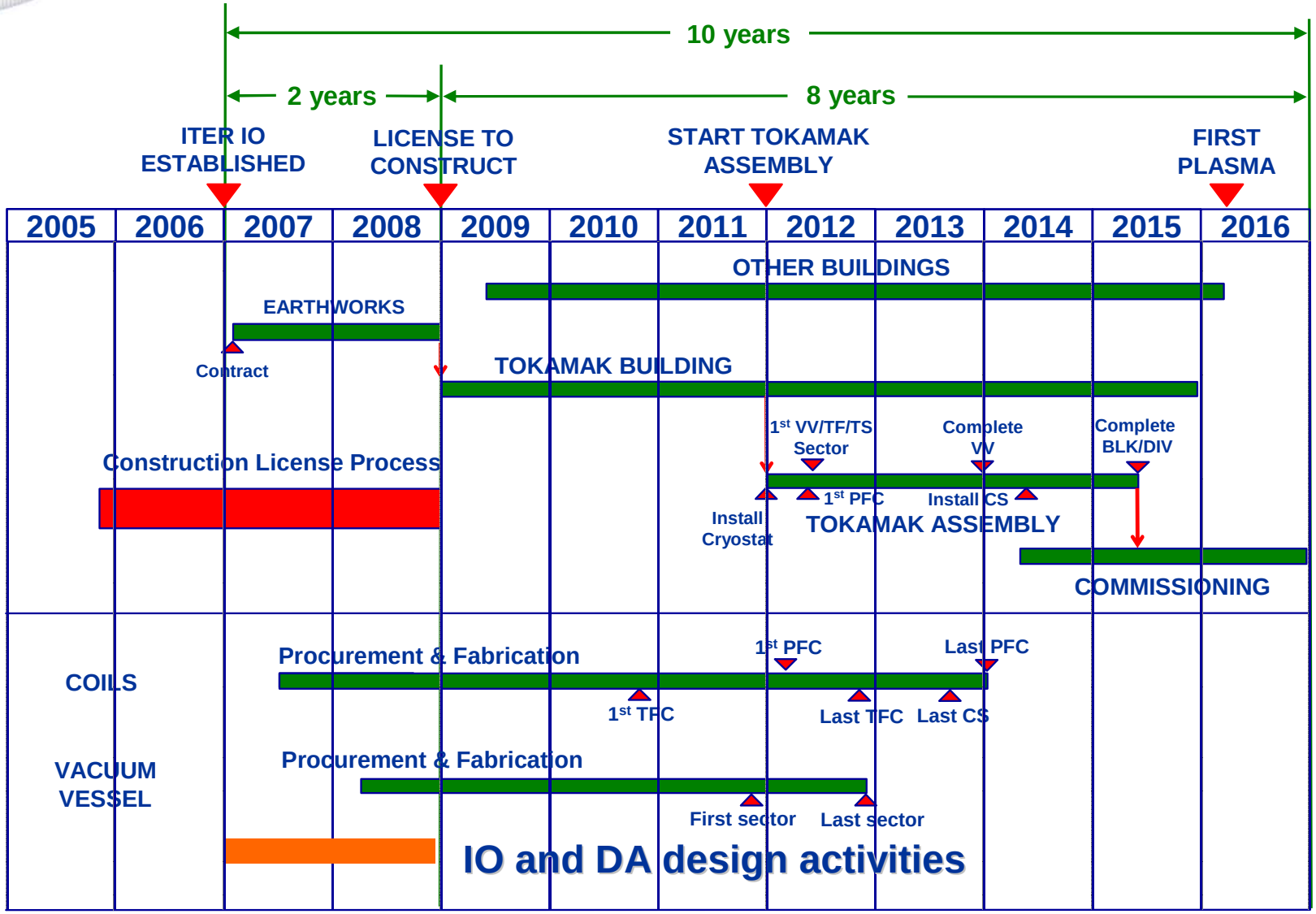


Professional Staff Members

Total: 153

(EU:85; IN:4; JA:13;CN:12;KO:13;RF:15;US:11)

Integrated Project Schedule



Recent ITER Agreements

ITER Agreement Signed - 21 Nov 2006

ITER Agreement Ratification–24 Oct 2007

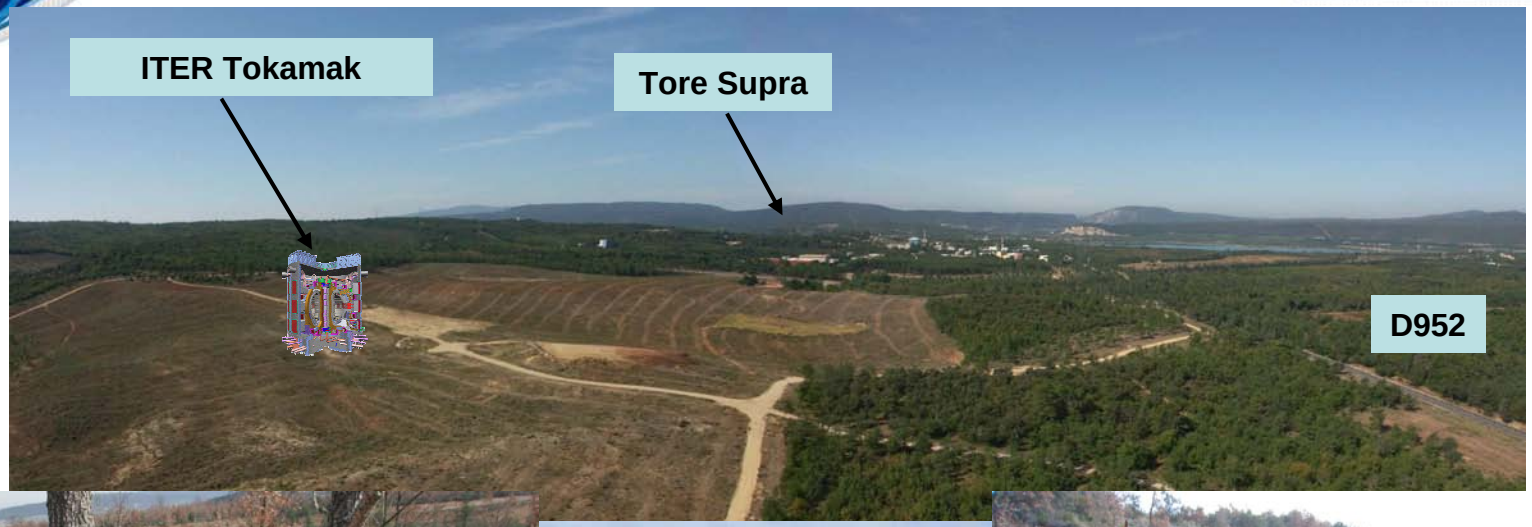
Headquarters Agreement Signed – 7 Nov 2007

Recent ITER Activities

First ITER Council Meeting
27 November 2007

First Procurement Arrangement Signed
28 November 2007

ITER Site Clearing Activities Complete

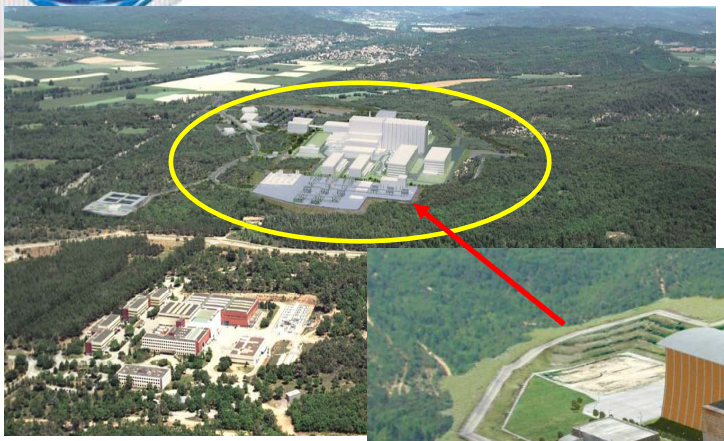


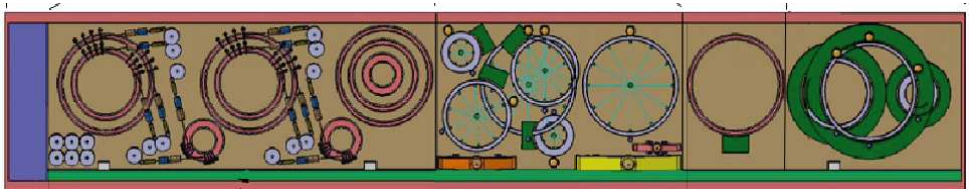
Tree cutting complete - March 2007

Initial Site Road Construction - Complete

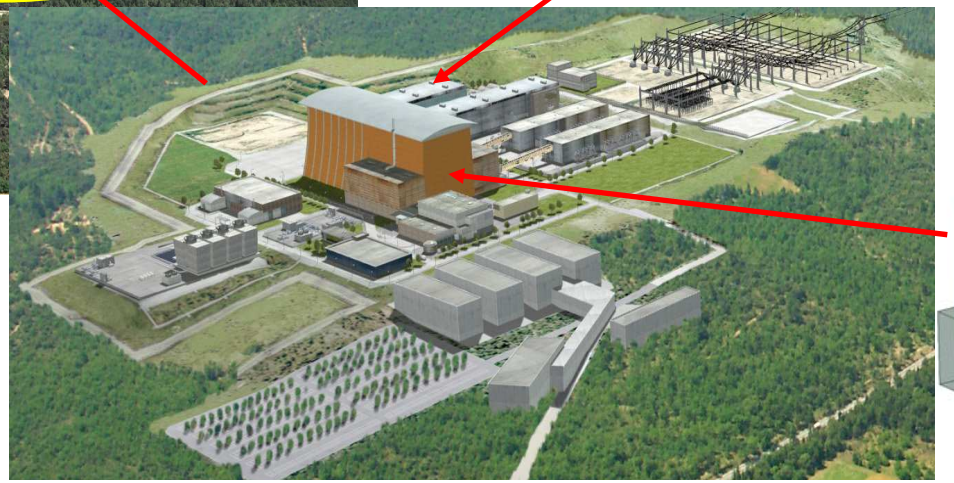
Archeological survey essentially complete – No major findings

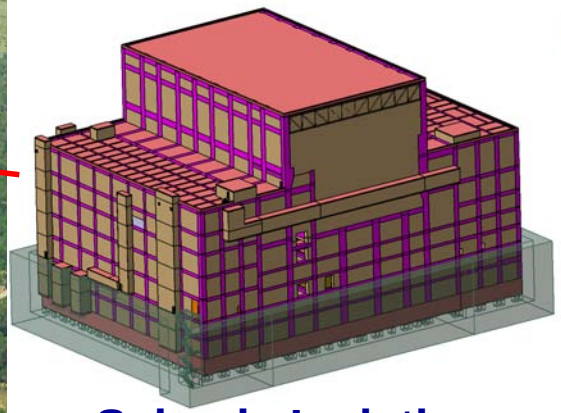
ITER Site & Building Status





PF Winding Building
~250 m x 45 m





Seismic Isolation
120 m x 85 m x 25 m deep

Site & Buildings Status

- Application for the Construction Permit submitted to St Paul Lez Durance on 28 September 2007. Permit approval is required for excavation work to start in 2008.
- Site leveling to begin March 2008 and last ~9 months
- PF coil building construction is planned to begin late 2008 (Non-nuclear building)
- Pre A/E contract to complete preliminary building designs to be placed early 2008
- Seismic isolation system design for tokamak buildings being developed
- Nuclear building construction to begin 2009

Safety & Licensing Status

Safety & Licensing Status

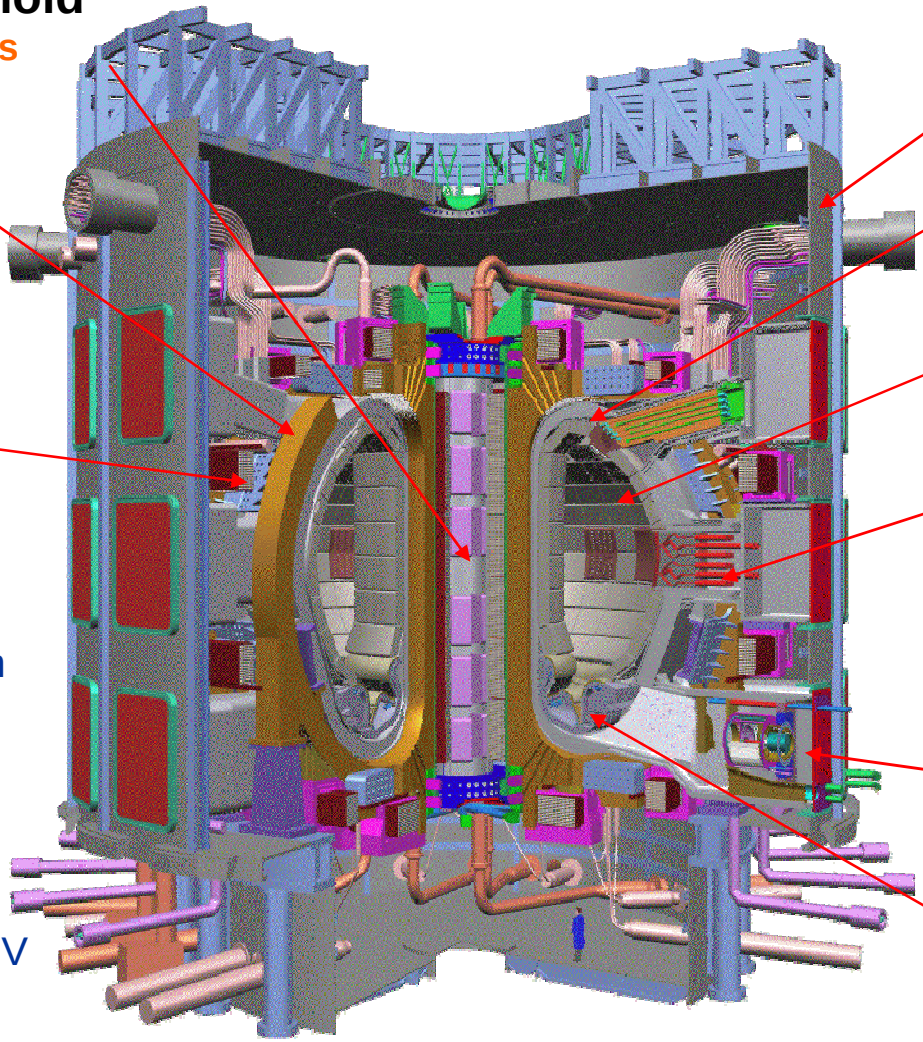
- Formal submission of Licensing Documents planned for early 2008
- Public hearings and regulatory safety review planned for mid 2008
- Start of nuclear related building construction beginning in 2009

The Core of ITER

Central Solenoid
Nb_3Sn, 6 modules

Toroidal Field Coil
Nb_3Sn, 18, wedged

Poloidal Field Coil
Nb-Ti, 6



Cryostat
29 m high x 28 m dia.

Vacuum Vessel
9 sectors

Blanket
440 modules

Port Plug
heating/current drive, test blankets limiters/RH diagnostics

Torus Cryopumps, 8

Divertor
54 cassettes

Major Plasma Radius 6.2 m

Plasma Volume: 840 m^3

Plasma Current: 15 MA

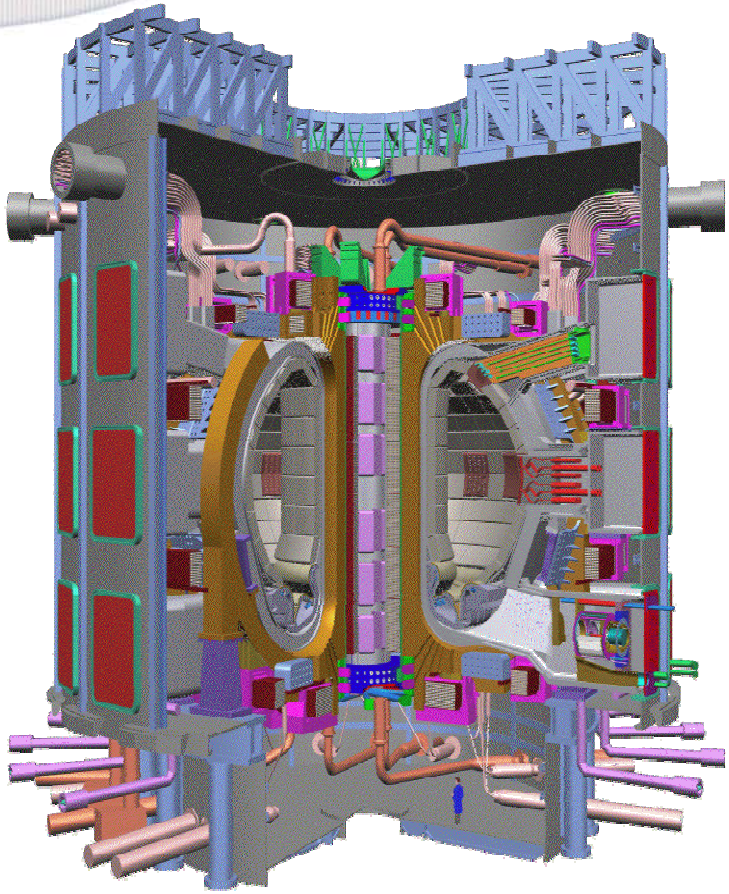
Typical Density: 10^{20} m^{-3}

Typical Temperature: 20 keV

Fusion Power: 500 MW

Machine mass: 23350 t (cryostat + VV + magnets)
- Shielding, divertor and manifolds: 7945 t + 1060 port plugs
- Magnet systems: 10150 t; cryostat: 820 t

ITER Tokamak – Mass Comparison



ITER Machine mass:

~23000 t

28 m diameter x 29 m tall

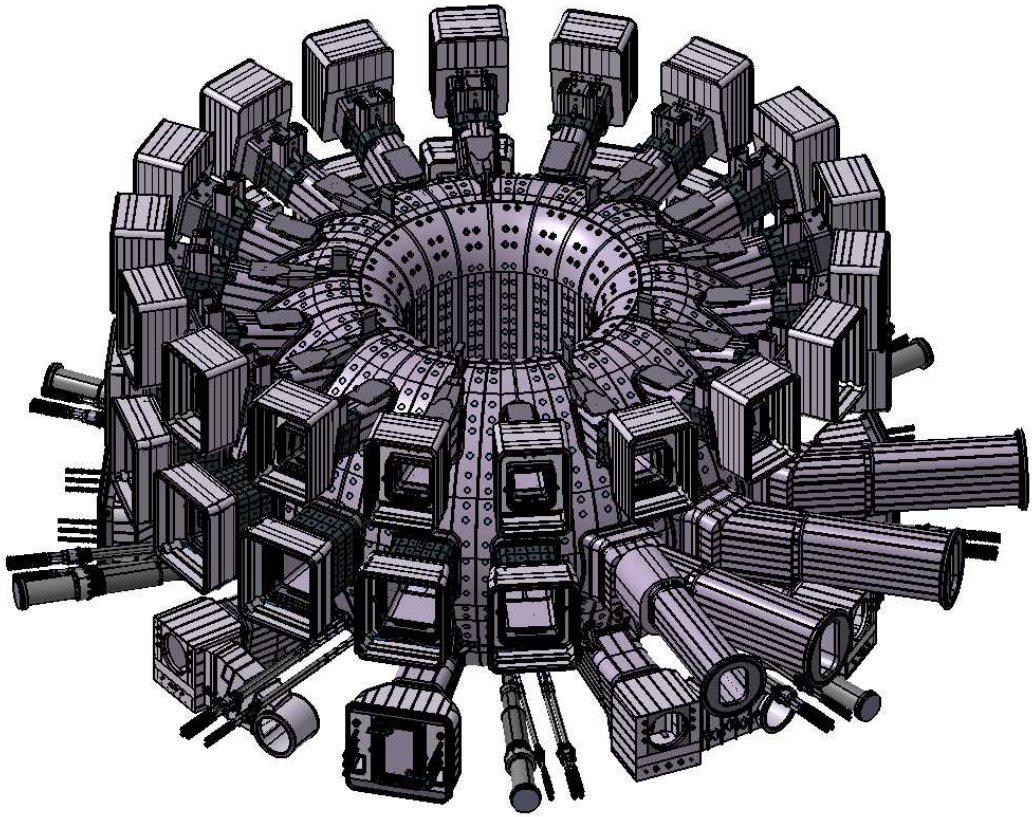
Charles de Gaulle mass:

~38000 t (empty)

856 ft (261 m) long

(Commissioned 2001)

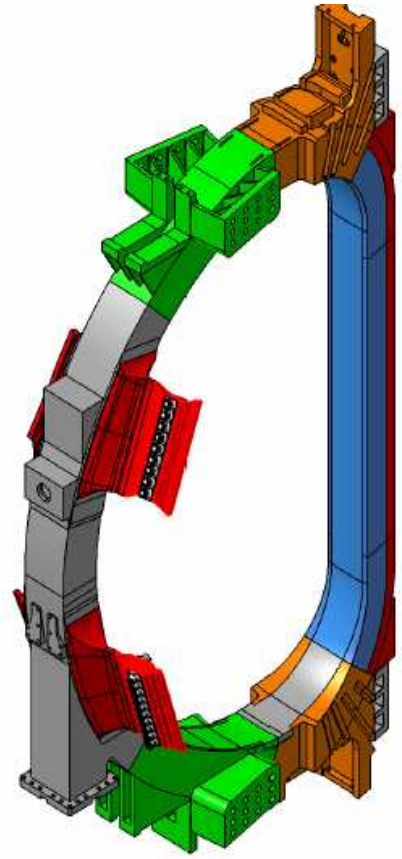
Vacuum Vessel Mass Comparison



VV & In-vessel components mass: ~8000 t
19.4 m outside diameter x 11.3 m tall

Eiffel Tower mass: ~7300 t
324 m tall
(Completed 1889)

TF Coil – Mass Comparison



Mass of (1) TF Coil:

~360 t

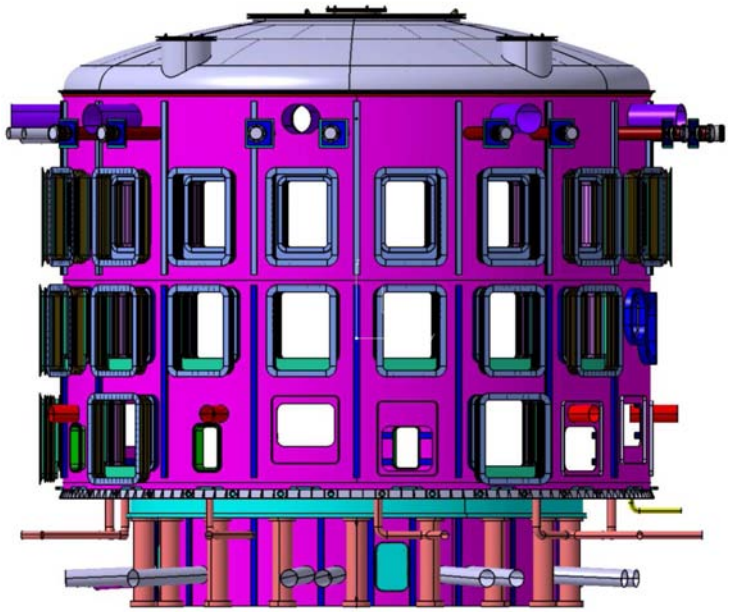
16 m Tall x 9 m Wide

D8 Caterpillar Bulldozer

~35 t

X 10

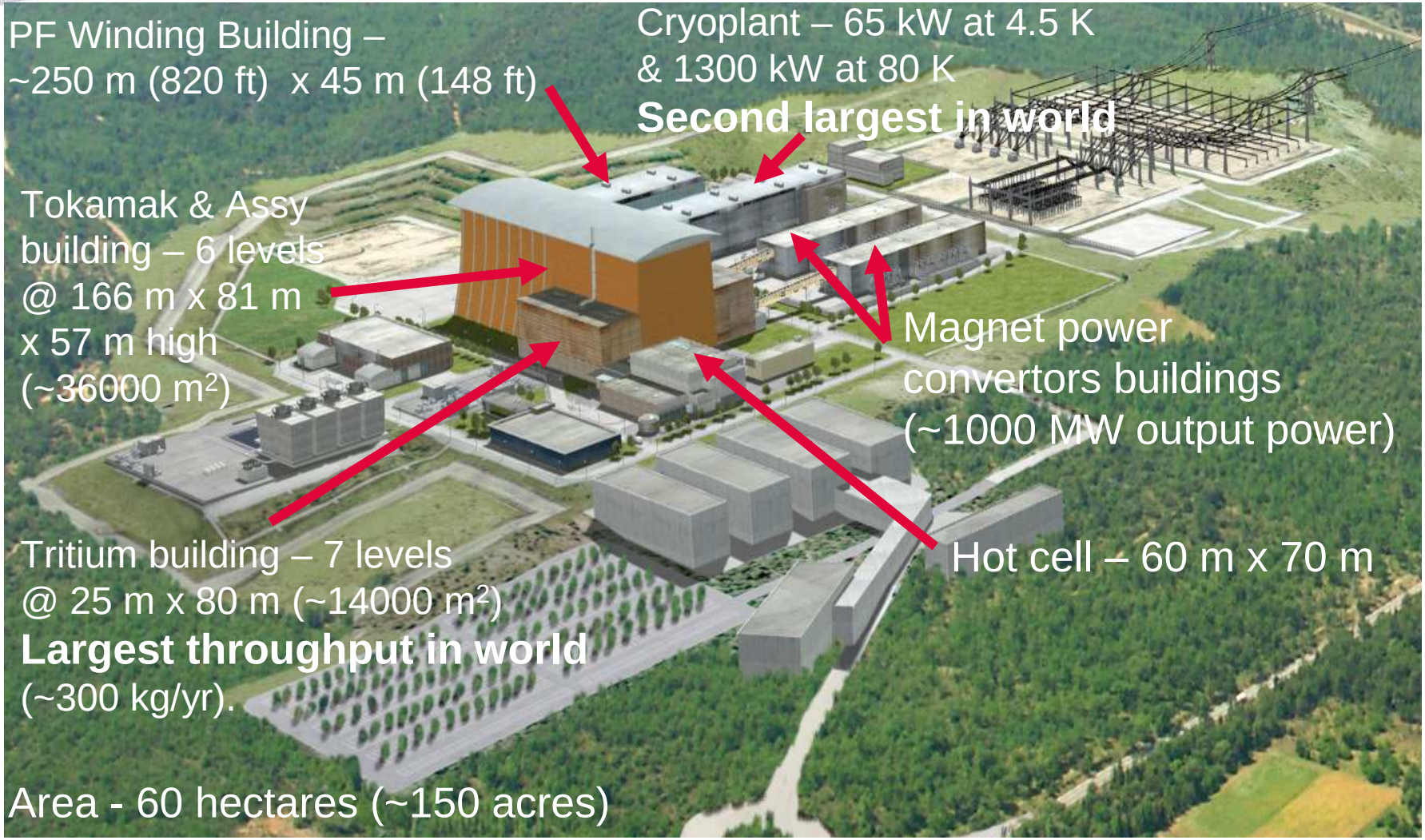
Cryostat Size Comparison



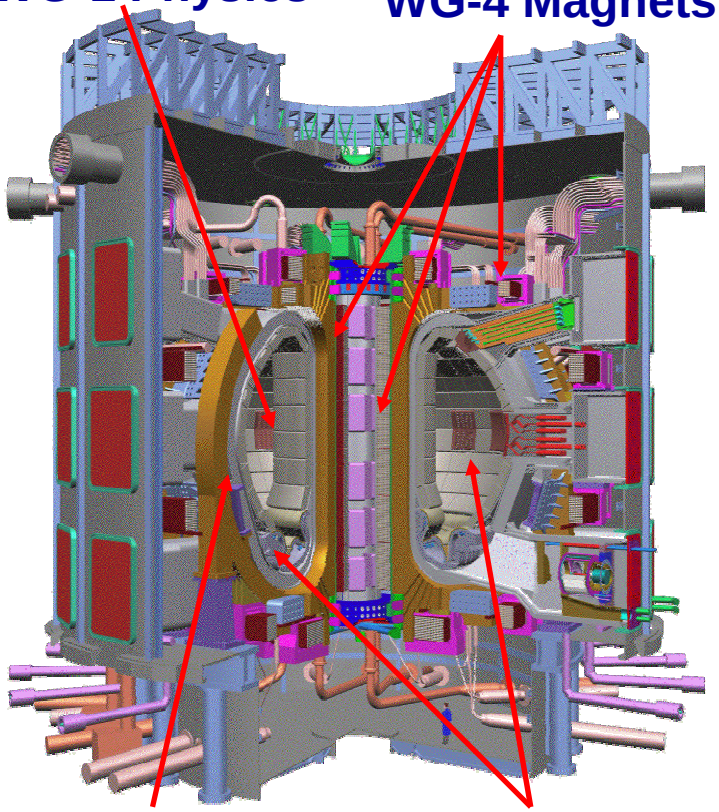
ITER Cryostat
~92 ft (28 m) Tall x
95 ft (29 m) Wide

Jefferson Memorial (Washington DC)
~95 ft (29 m) Tall (floor to top of dome)

ITER Buildings and Facilities



Design Review is Complete



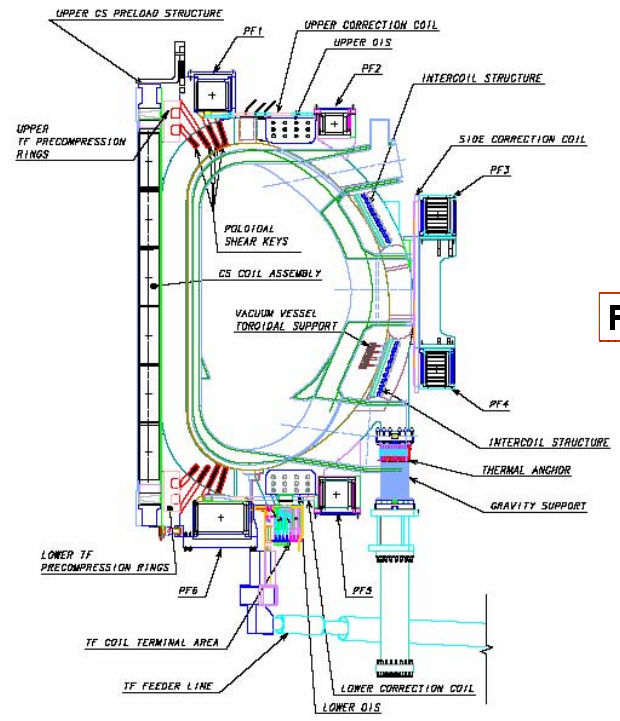
Background

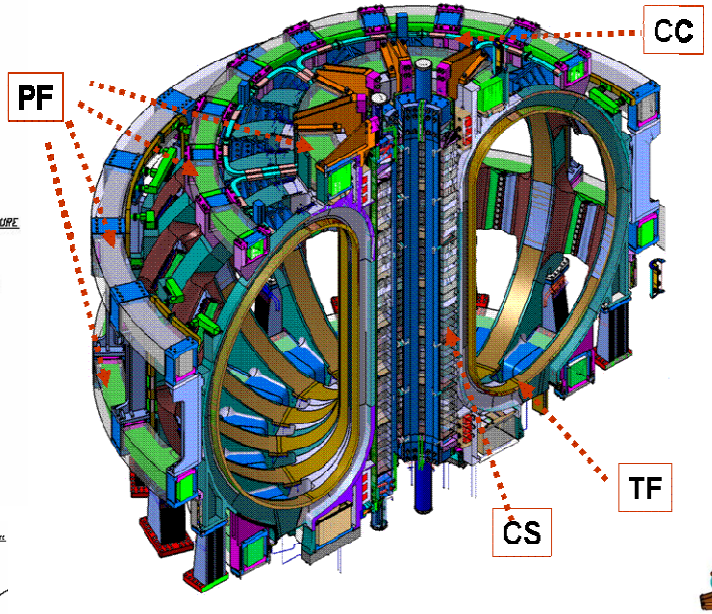
- Launched November 2006
- Goal was to arrive at new baseline design in 2007 & be endorsed by the ITER Council
- Involved worldwide fusion community
- Activities in 8 main working areas involved hundreds of experts from around the world

Conclusions

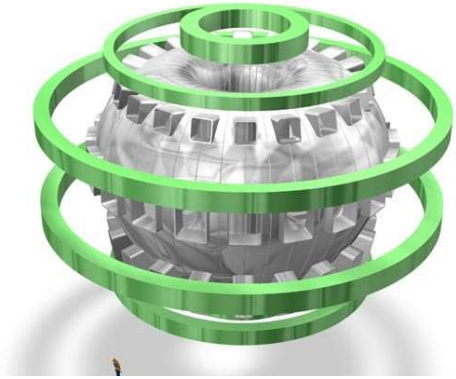
- Design review is finished (November 2007)
- ~80 design changes were identified (few have major impact)
- Sound basis for 2007 Baseline Design has been established (provisionally accepted by ITER Council Nov 07)
- Cost and schedule baseline will be updated in mid 2008

ITER Magnet Design

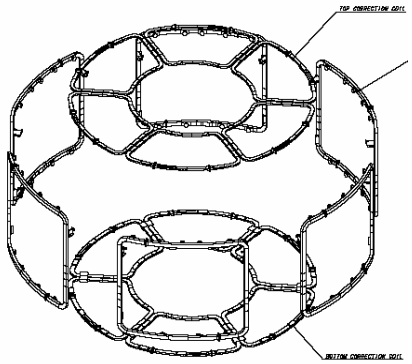




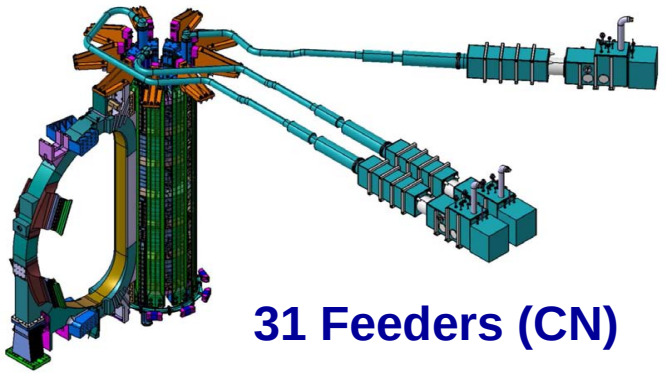
18 TF Coils
(EU & JP)



6 PF Coils (EU & RF)



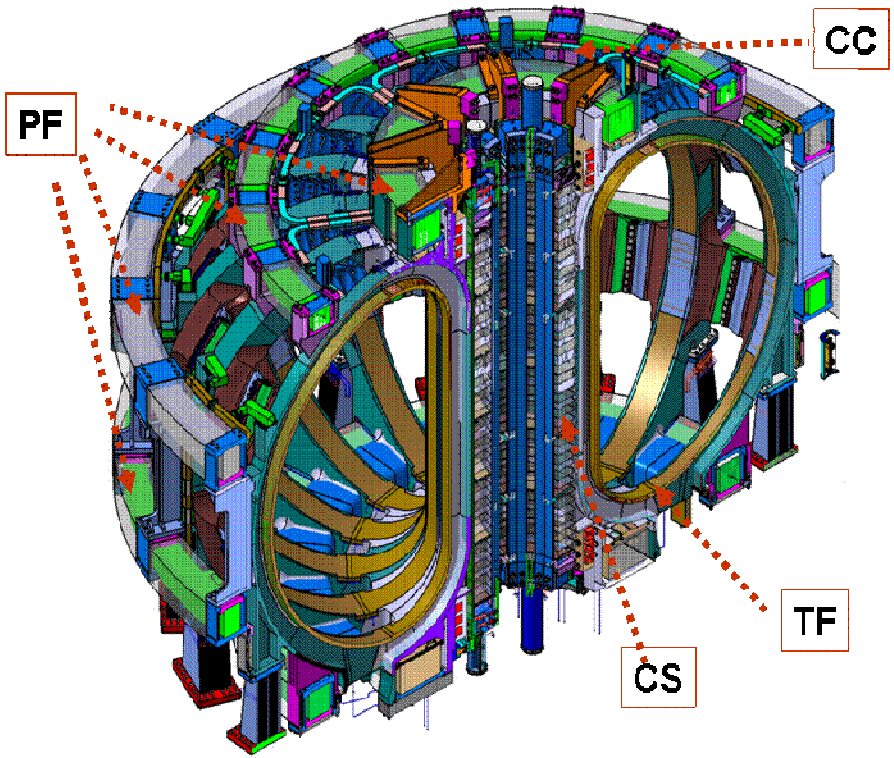
9 Pairs of Correction Coils (CN)



31 Feeders (CN)

CS Coils – Stack of 6 (US)

Magnet System Status



Scope

- 48 superconducting coils
  - ~9800 tons
  - ~115 mile of conductor
  - 11.8 T (peak TF field)
  - 68 kA (peak current)
  - Stored energy – 51 GJ
- 802 kIUA ITER Credit (~$1.5 Billion)

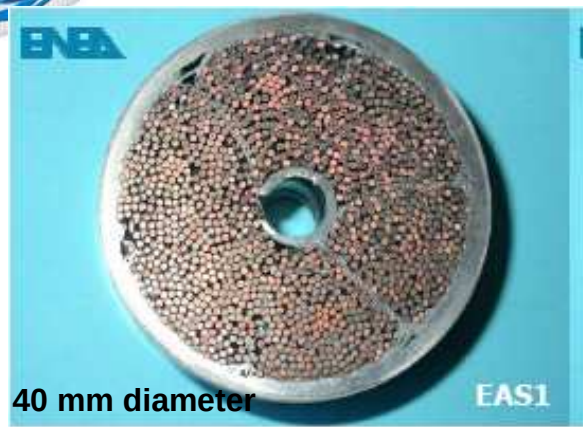
Challenges

- QA / QC
- Tolerances
- Testing requirements
- Schedule

Status

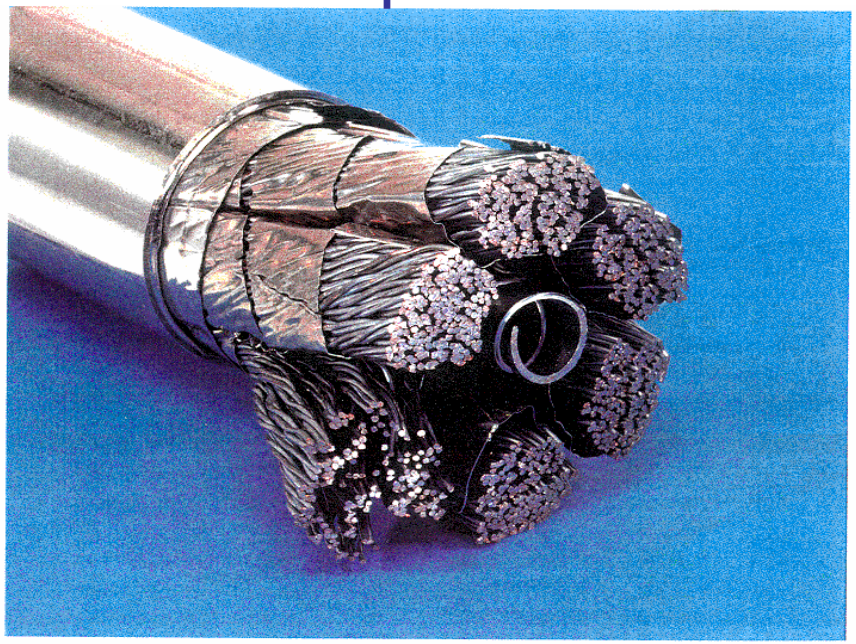
- Procurement arrangements for all major magnets systems are expected in 2008

TF Conductor Procurement Status



40 mm diameter

ITER TF Conductor Option 1



Scope

- ~90 km / 400 t of Nb_3Sn conductor
  - Cable in conduit type
  - Operates at ~5 K
  - 11.8 T (peak TF field)
  - 68 kA (peak TF current)
- 215 kIUA ITER credit (~$400 Million)

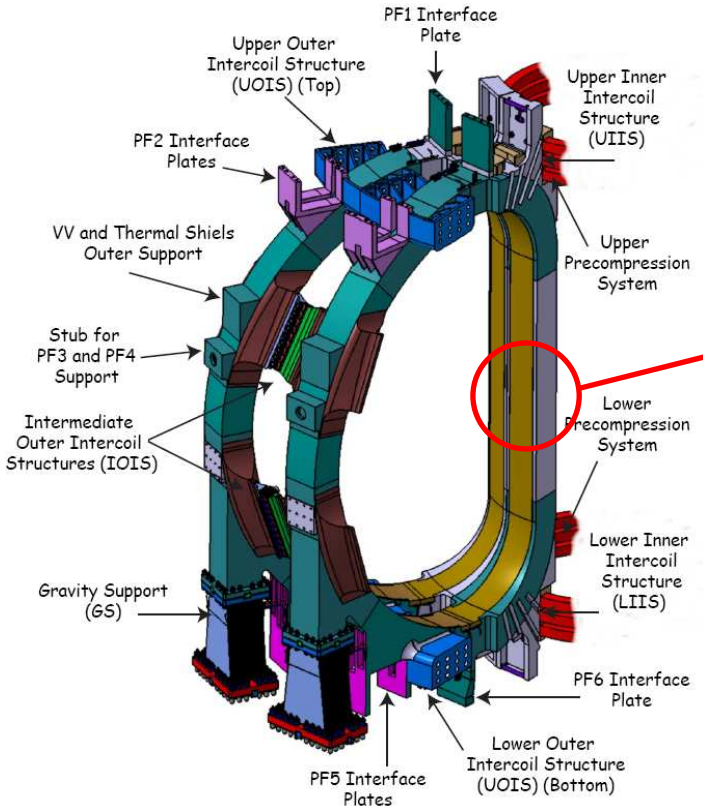
Challenges

- Six parties involved
- Tight design margins
- Available test facilities
- QA / QC

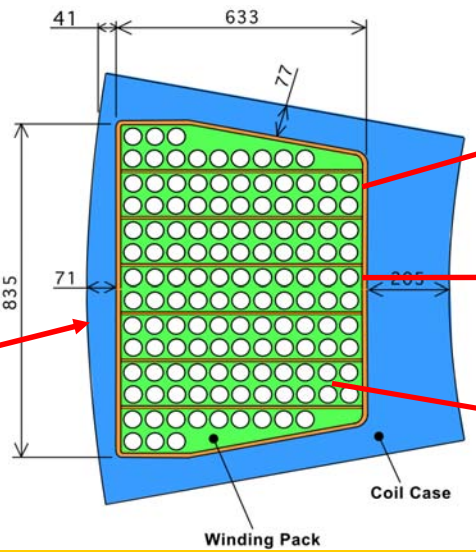
Status

- First ITER PA signed for TF conductor on November 28, 2007
(Japanese – 25% of TF conductor total)
- Additional parties are expected to sign in the coming months

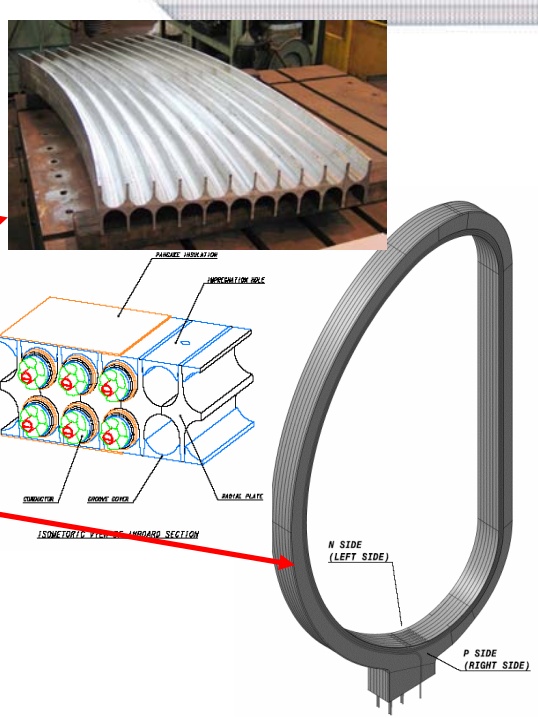
TF Winding Pack



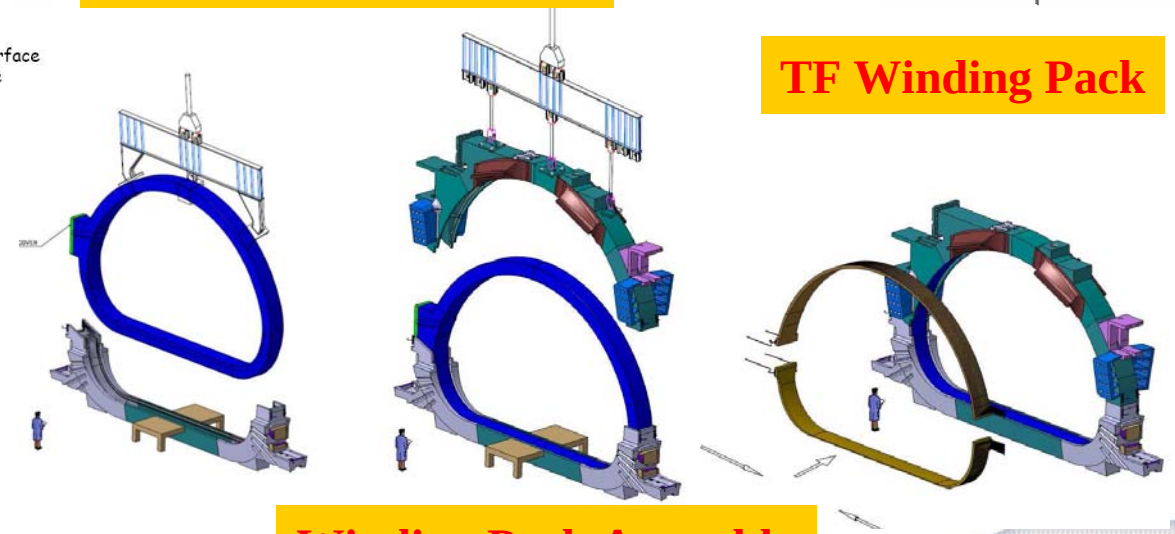
TF Coil



Inner Leg Cross Section

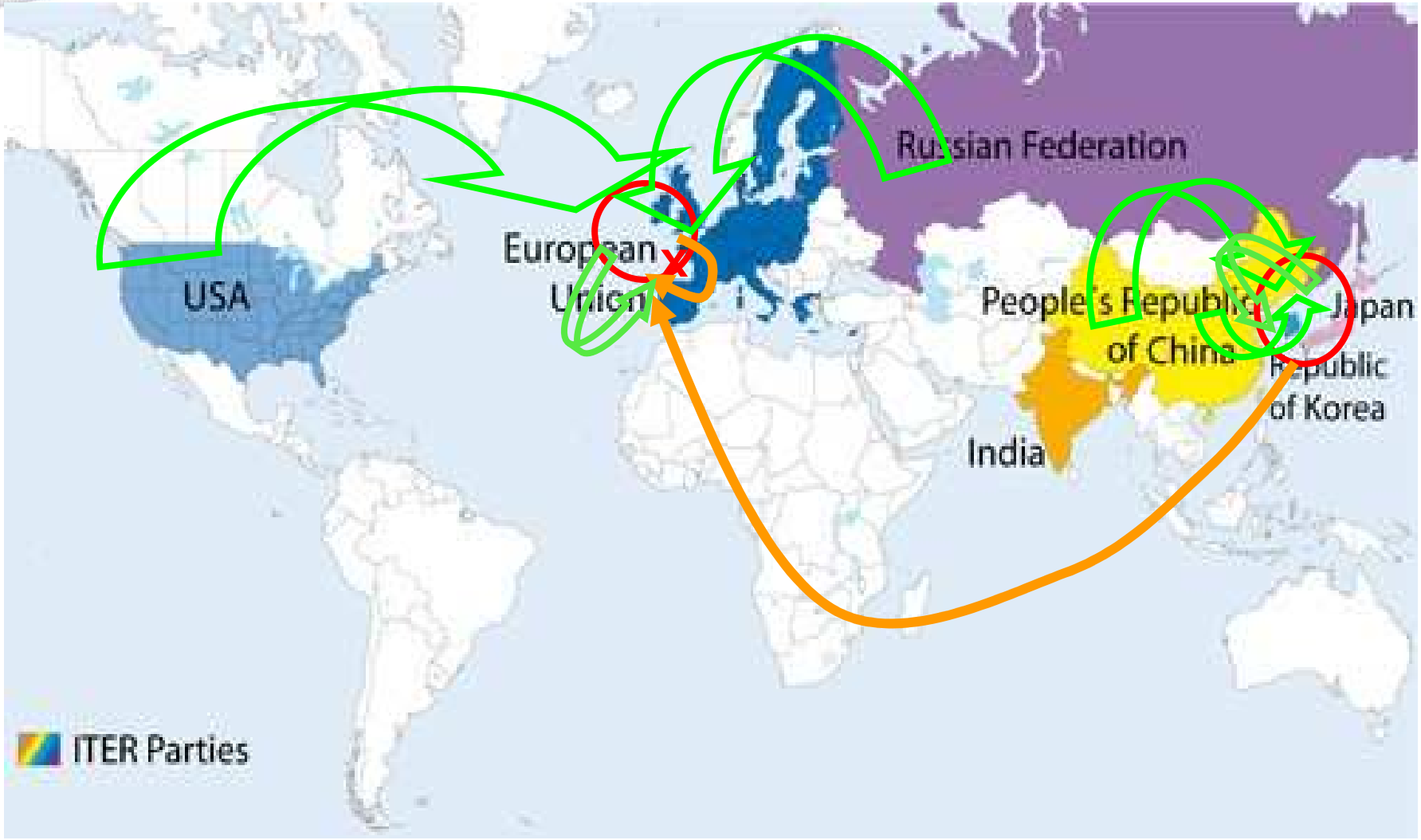


TF Winding Pack



Winding Pack Assembly

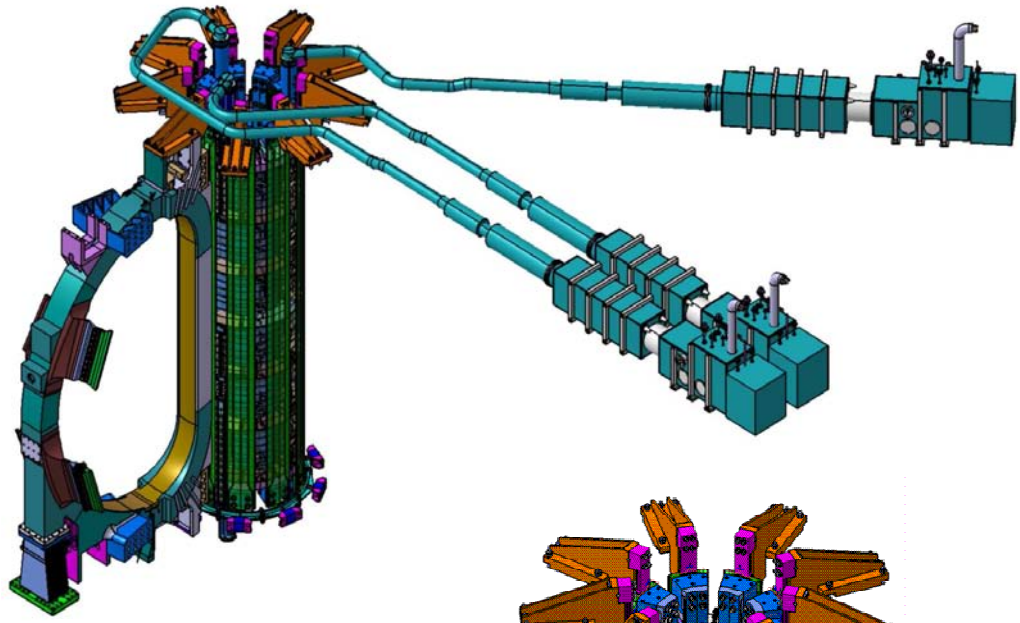
TF Coils - A Worldwide Collaboration

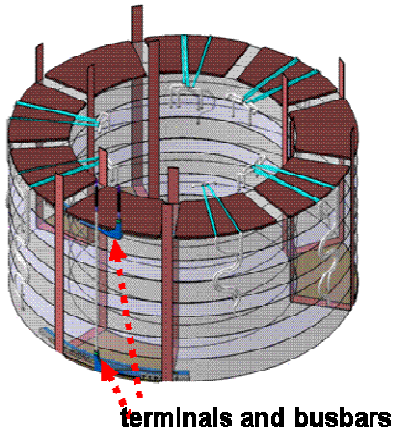


conductor

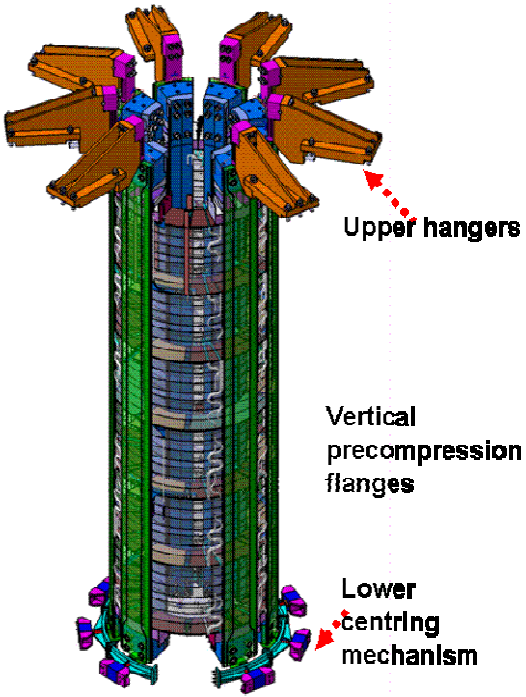
coils

CS Coils Status





Single CS Module



Scope

- Central Solenoid Stack –
  6 independently powered modules
  - Nb_3Sn conductor
  - ~1000 tons
  - 13 T (peak CS field)
  - 45 kA (peak CS current)
- ~40 kIUA ITER credit (~$75 Million)
  – Magnets (US)
- ~90 kIUA ITER credit (~$175 Million)
  – Conductor (JA)

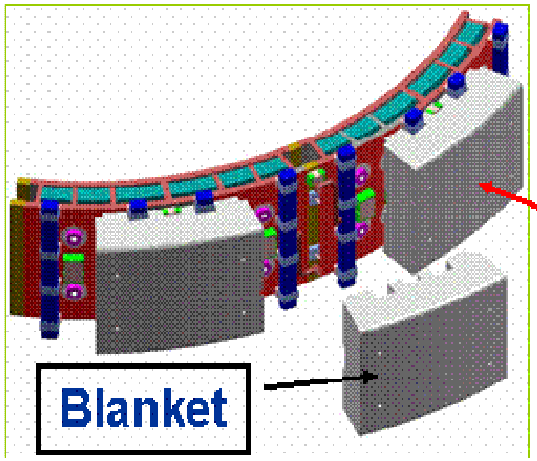
Challenges

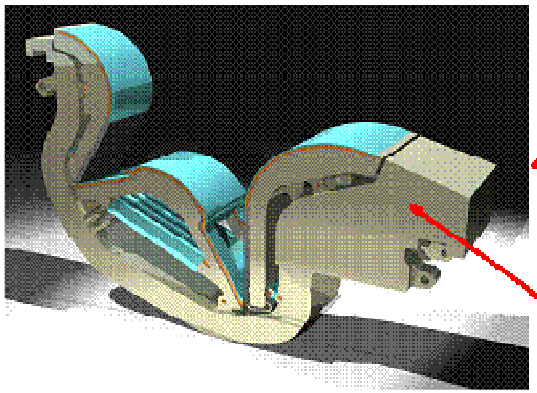
- Strong precompression flanges to support repulsion forces
- High voltage requirements for vertical stability
- QA / QC
- Testing requirements

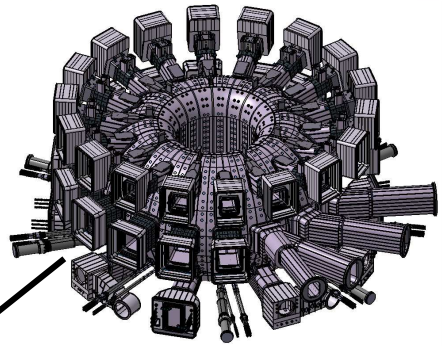
Status

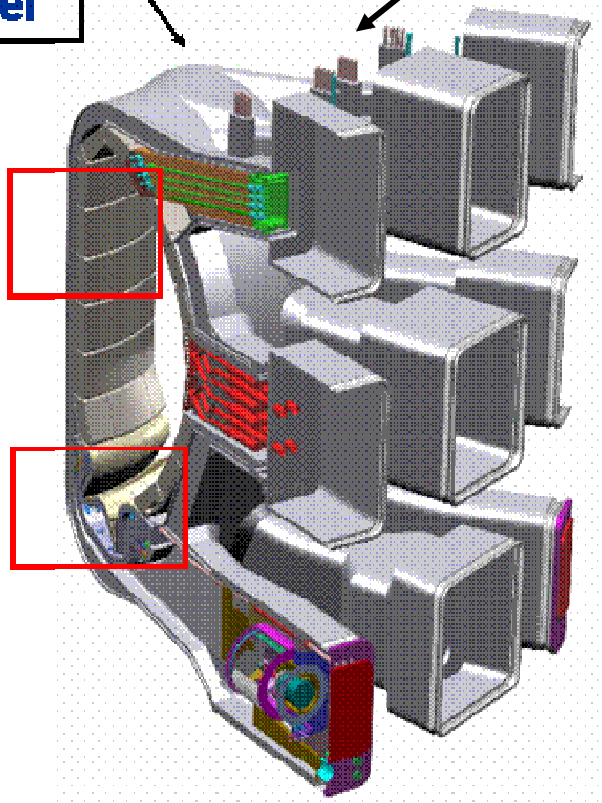
- US aggressively moving ahead with detailed design

VV and In-vessel Components

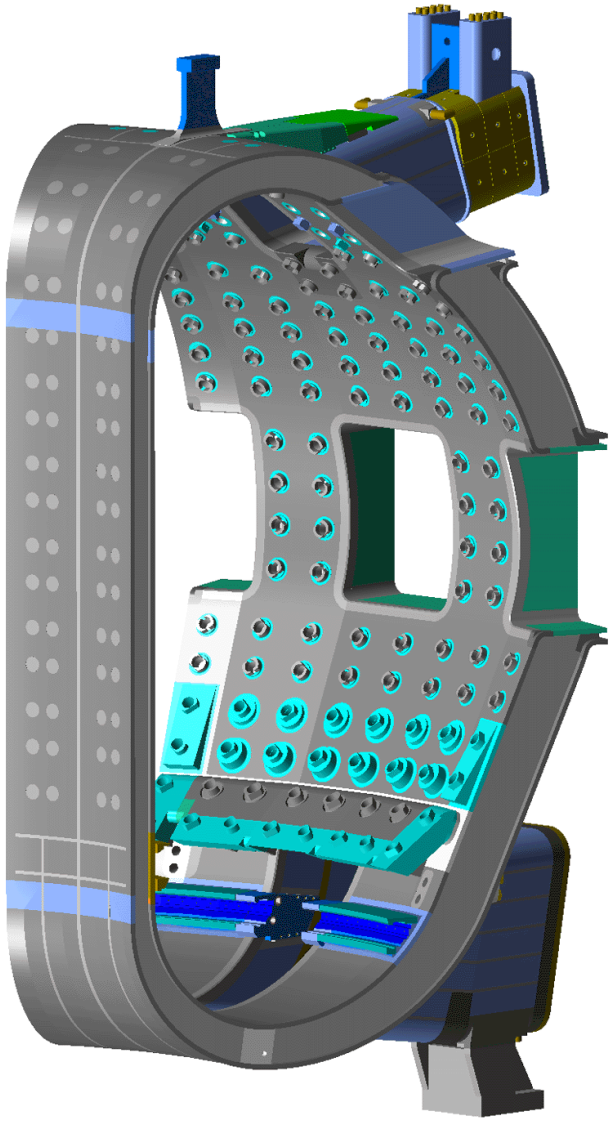








Vacuum Vessel Status



Scope

- Main vacuum vessel and first safety barrier for ITER
  - SS 316 LN-IG
  - ~5300 tons (VV, ports, shielding only)
  - 19.4 m (63 ft) torus outer diameter
  - 11.3 m (37 ft) torus height
- ~240 kIUA ITER credit (~$470 Million)
  – VV, Ports, & Shielding (EU, KO, RF, & IN)

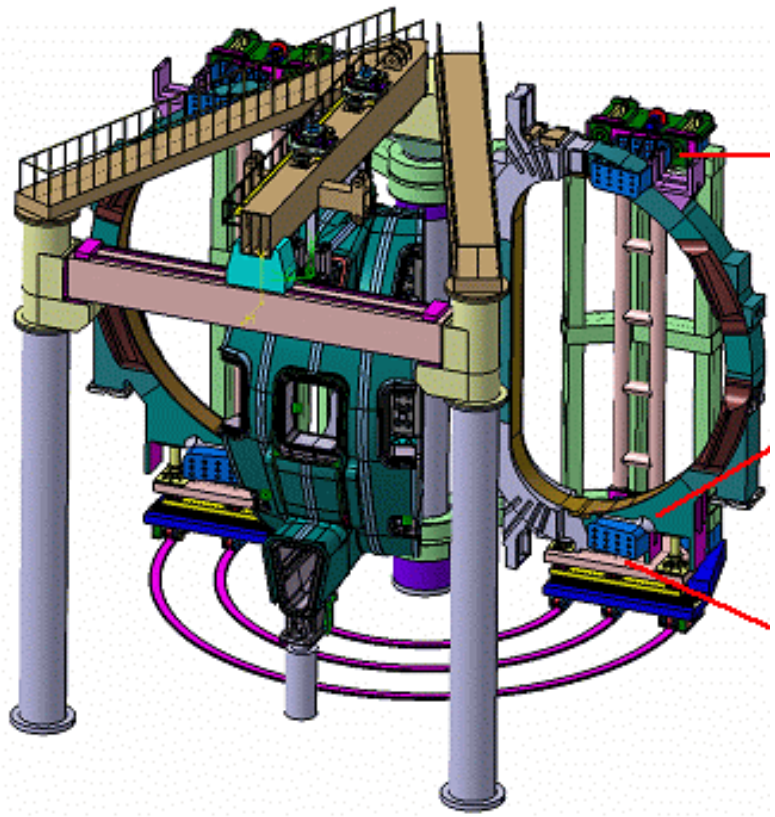
Challenges

- Finalizing requirements
- Tolerances
- QA / QC (First safety barrier)
- Schedule

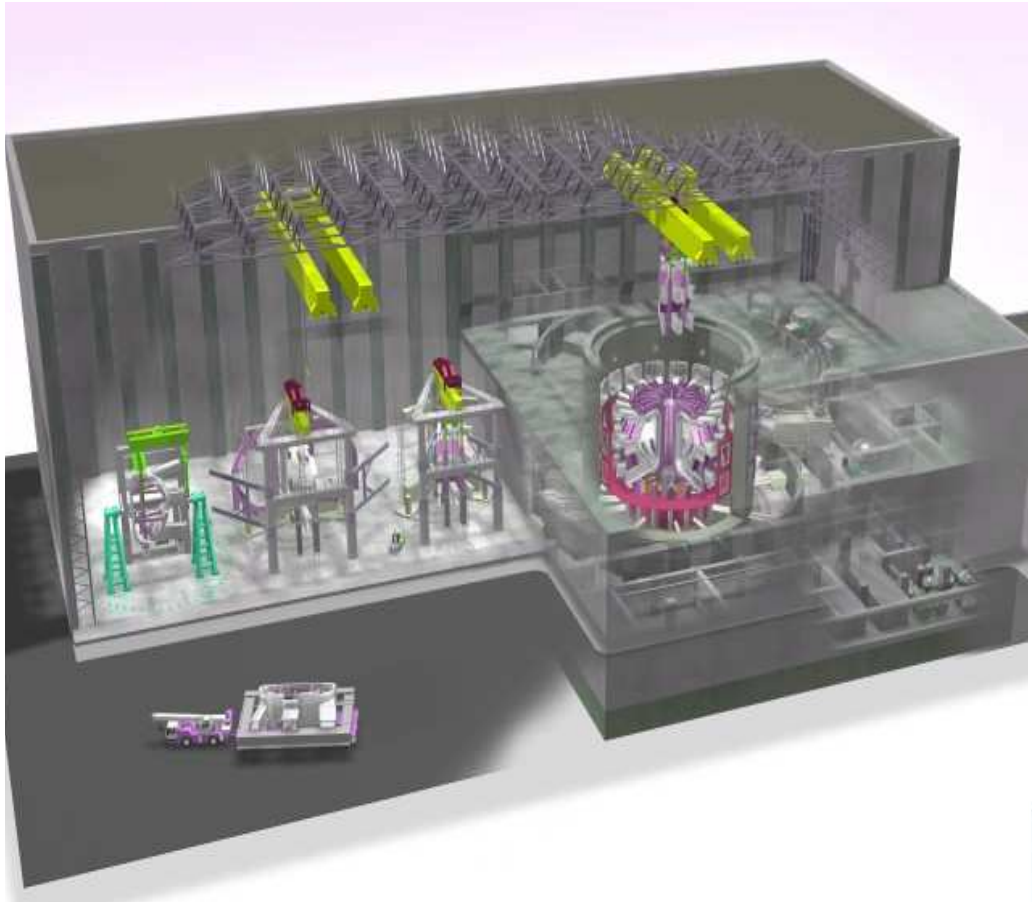
Status

- Main VV & port PA planned for mid 2008

Assembly Operations

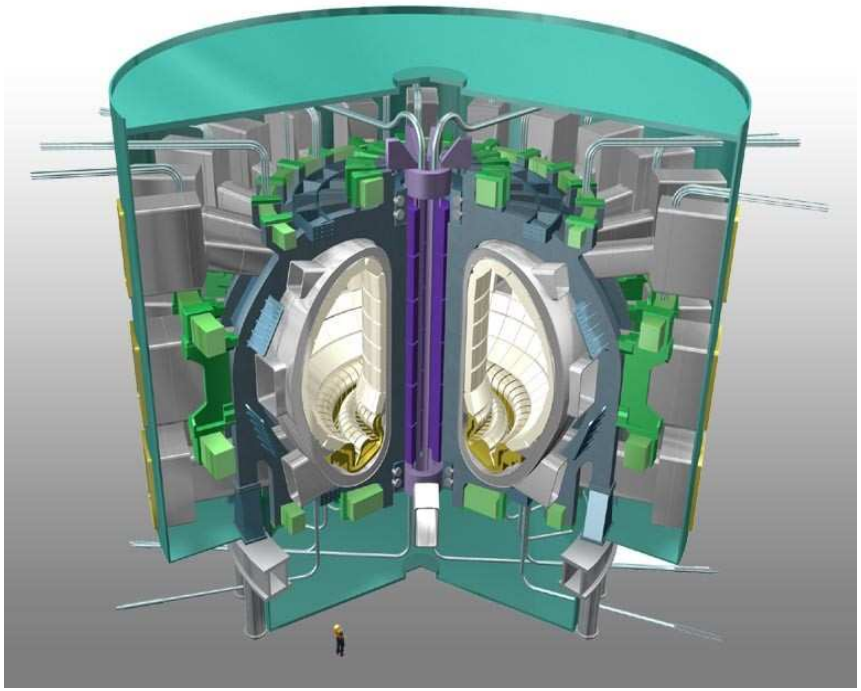


TF Coil / Sector Assembly
~1400 ton



Challenges Abound

- Project Management
  - Tight schedule and budget
  - Limited resources
  - New organization
  - 7 Party coordination
- Design and Procurement
  - Complex design, requirement, & interfaces
  - Severe QA / QC requirements
  - Complex procurement split
  - >90 procurement packages
- Superconducting magnets
  - Unprecedented size of the superconducting magnets and structures
  - High field performance ~12T
- Plasma facing components
  - >10 MW/m2 steady heat flux
  - >10000 cycles
- Remote maintenance
- Vacuum and Tritium technology
  - Active recycling of tritium
  - Test of lithium blankets
- Cryogenic technology
- Heating and current drives
  - ~ 100 MW continuous
  - Neutral particles accelerators up to 1 MeV
  - Ion cyclotron, electron cyclotron



Summary

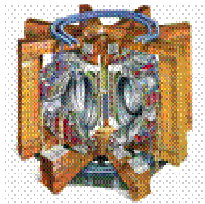
- ITER is worldwide one of the largest, if not the largest scientific project.
- It is the first project based on “in kind” contributions to such an extent.
- During the first year of the ITER project, great strides have been made building a team, defining a new baseline, and beginning procurement.
- Technical and management challenges are immense, but the project is moving aggressively ahead.

Now we are firmly on ITER (the way)…

Tore Supra

25 m^3

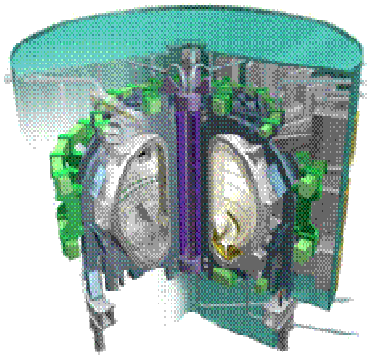
~ 0 MW_{th}



JET

80 m^3

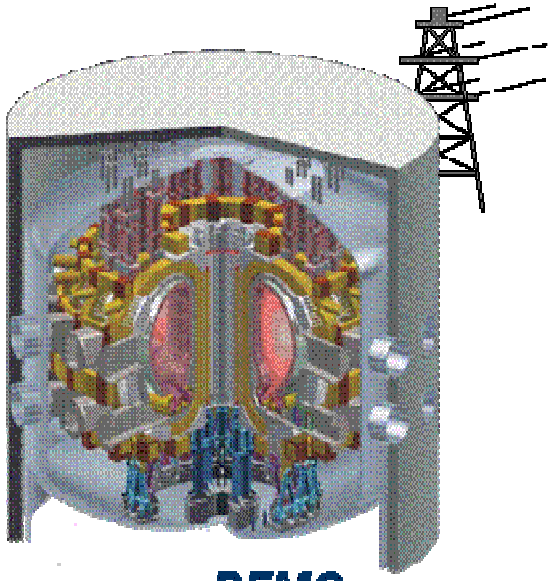
~16 MW_{th}



ITER

800 m^3

~ 500 MW_{th}



DEMO

~ 1000 - 3500 m^3

~ 2000 - 4000 MW_{th}

- Dominant self heating ---------->