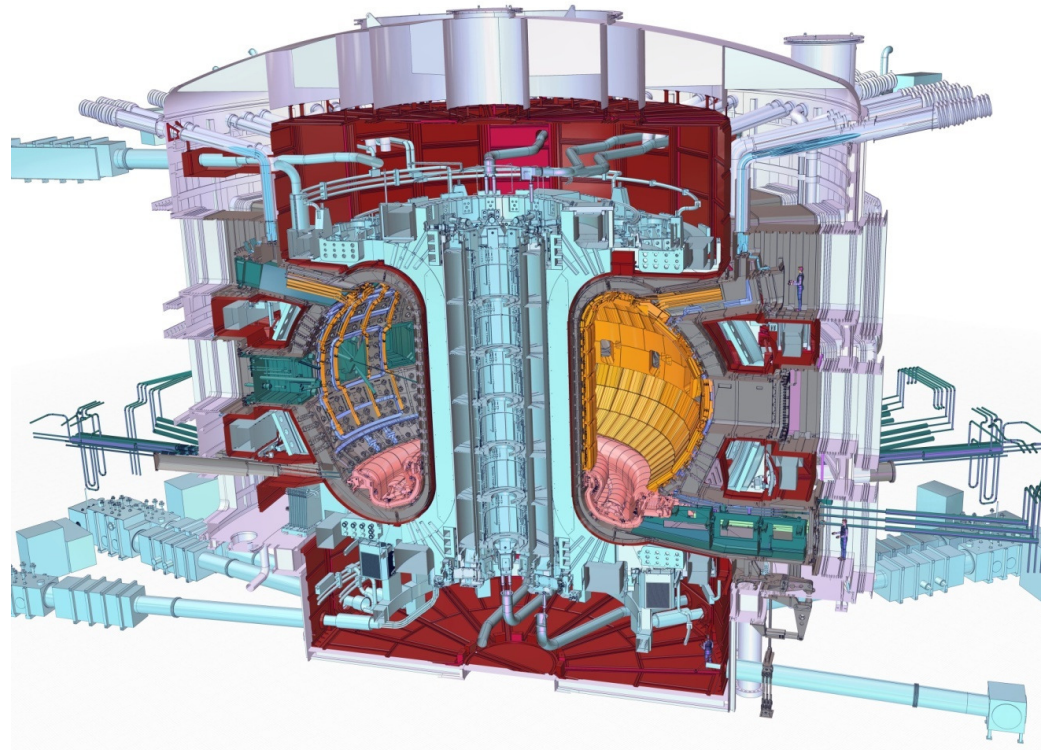


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4 th ITER International Summer School 2010

# Progress of the ITER Project



Gary Johnson

Deputy Director General - Tokamak

Cadarache, France, May 31, 2010

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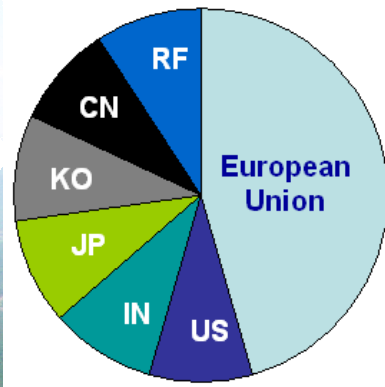
# Contents

- **ITER Project**
- **Scale of ITER**
- **Technical Systems & Status**
- **The Future**

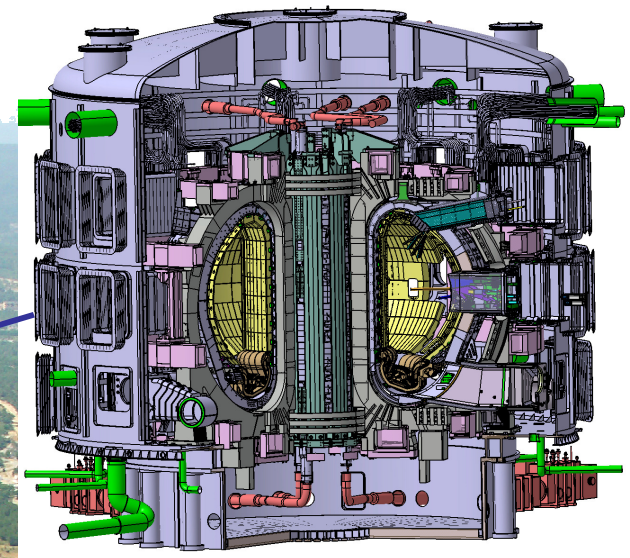
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# ITER Project

# ITER - A Unique Scientific, Technological and Industrial Project



Seven Party Sharing



- **Objective** - Demonstrate the scientific and technological feasibility of fusion energy
- **Goal** - produce a significant fusion power amplification (10x the energy input): **output 500 MW**
- **Costs** - ~5 B € for construction (Based on 2001 FDR) (Note – A new cost baseline is expected to be approved by the IC in June 2010.)  
Plus contributions of local area – 467 M €

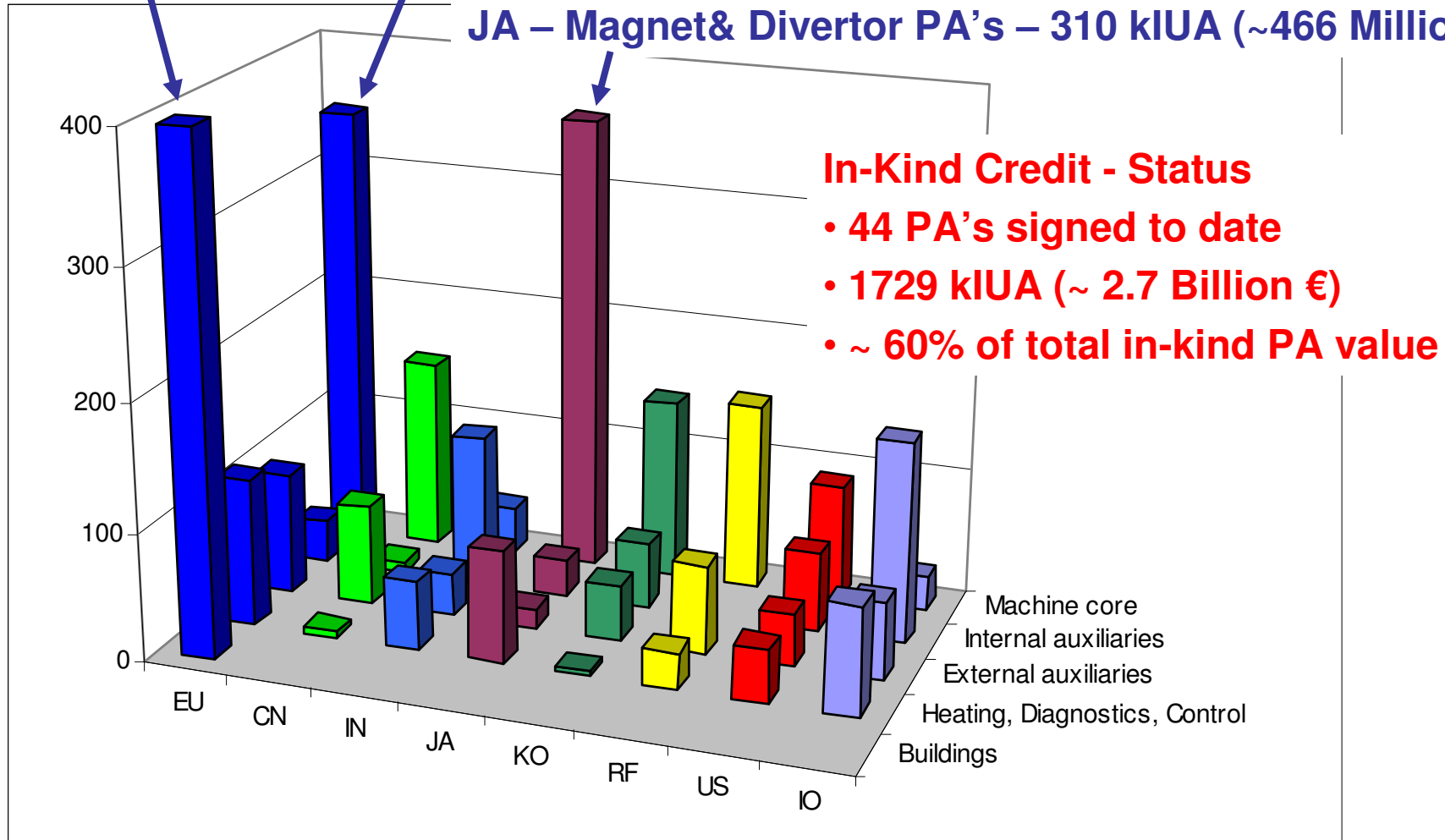


# In-Kind Contributions (Credit Values)

EU – Buildings & Excavation PA's – 377 kIUA (~580 Million €)

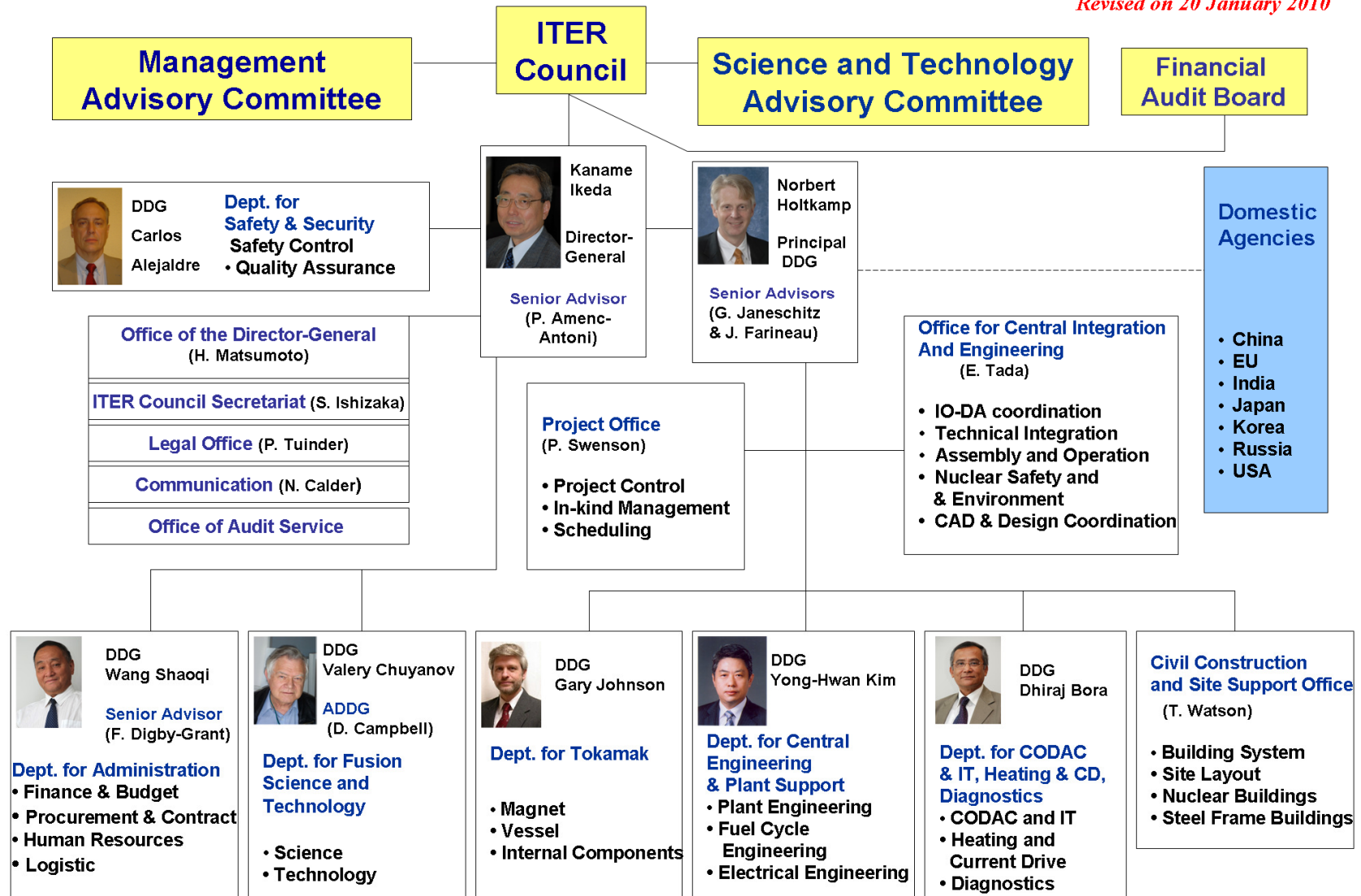
EU – VV & Magnet & Divertor PA's – 297 kIUA (~460 Million €)

JA – Magnet & Divertor PA's – 310 kIUA (~466 Million €)

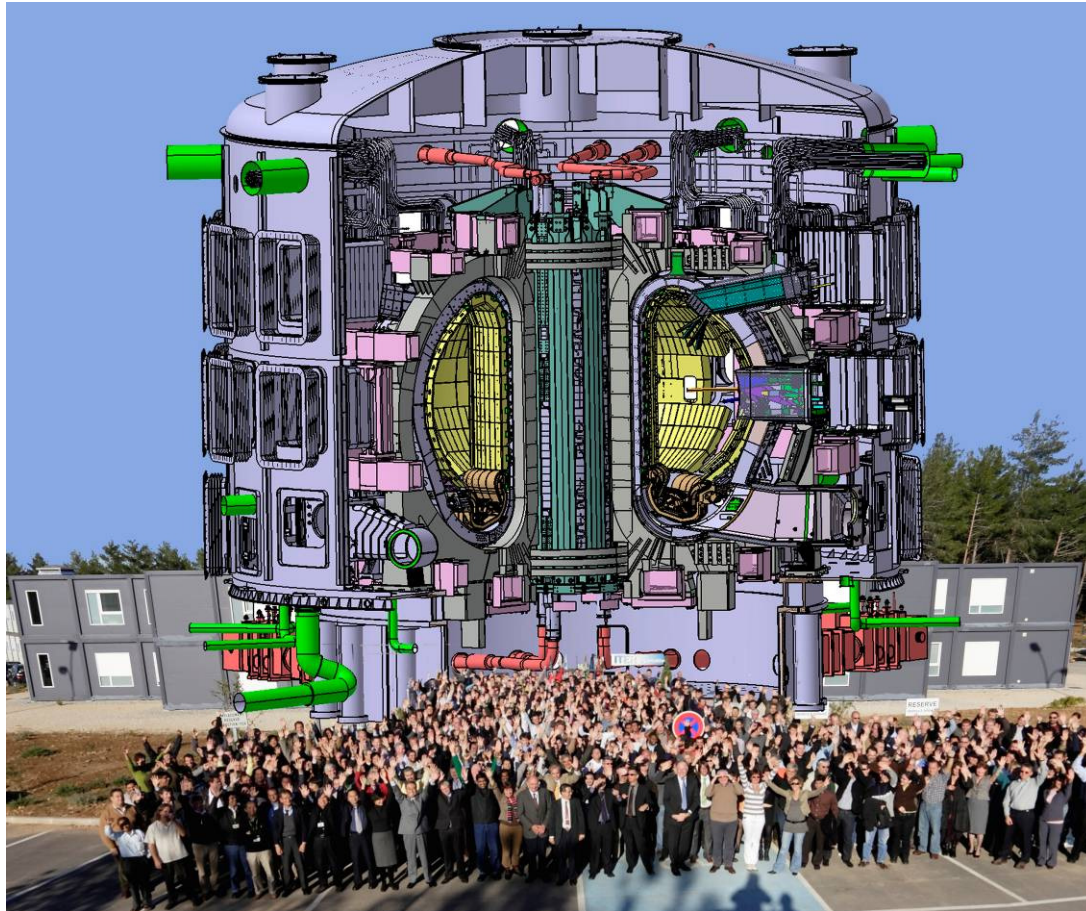


# ITER Organization Structure

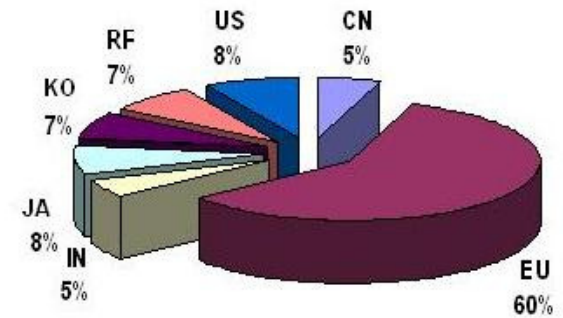
Revised on 20 January 2010



# Staffing (Feb 2010)



Professional Staff



	Professional staff	Support staff	Total
CN	16	2	18
EU	180	115	295
IN	15	14	29
JA	23	6	29
KO	20	5	25
RU	20	2	22
US	24	8	32
<b>Total</b>	<b>297</b>	<b>153</b>	<b>450</b>



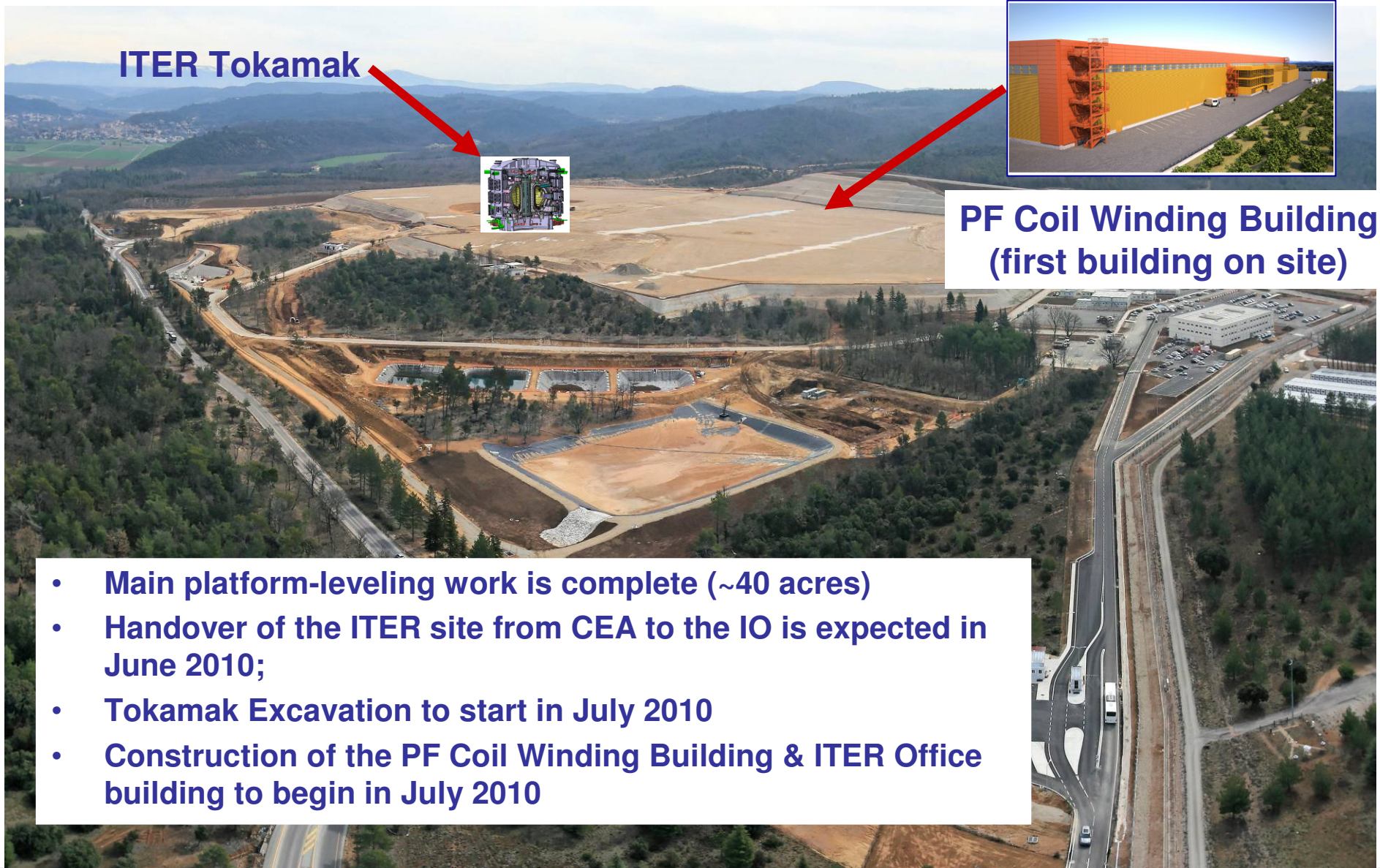


# Licensing Process

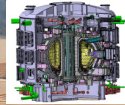


- Construction Permit was awarded in April 2008;
- On 31 January 2008, the files for “*Demande d’Autorisation de Creation*”, including the Preliminary Safety Report, were sent to the French Nuclear Authorities;
- In July 2008, the French Authorities asked questions and requested additional documentation from IO;
- The IO will provide the French Nuclear Authorities with the updated information and RPrS documentation by the end of March 2010;
- The ITER CLI (*Commission Locale d’information*), including international experts, was already established by the end of 2008, and the first meeting of ITER CLI was held on 7 December 2009;
- Public Enquiry is expected in autumn 2010.

# ITER Construction Site



**ITER Tokamak**

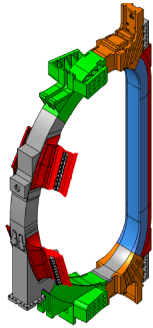


**PF Coil Winding Building  
(first building on site)**

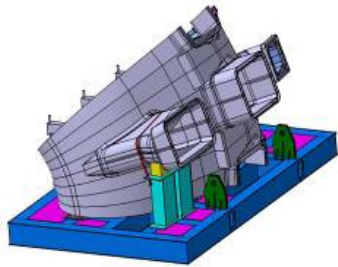
- **Main platform-leveling work is complete (~40 acres)**
- **Handover of the ITER site from CEA to the IO is expected in June 2010;**
- **Tokamak Excavation to start in July 2010**
- **Construction of the PF Coil Winding Building & ITER Office building to begin in July 2010**



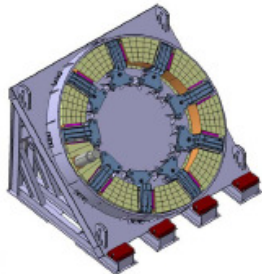
# Roads Upgrades Complete



**TF Coil ~360 t**  
**16 m Tall x 9 m Wide**



**VV Sector ~400 t**  
**12 m Tall x 9 m Wide**



**PF1 Coil ~200 t**  
**9.4 m Dia**

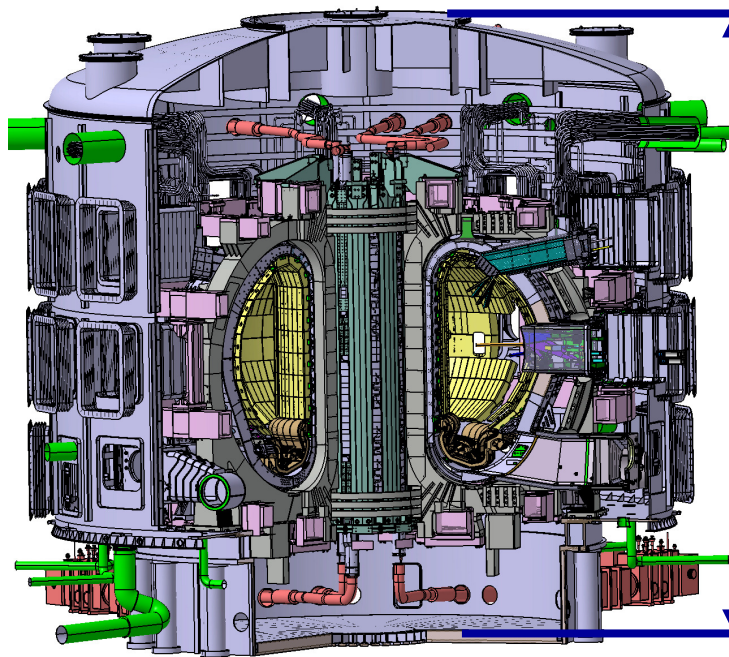


**Heavy Component on Road**  
**(TF Coils, VV Sectors, & PF1 Coil)**

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# The Scale of ITER

# Cryostat Size Comparison

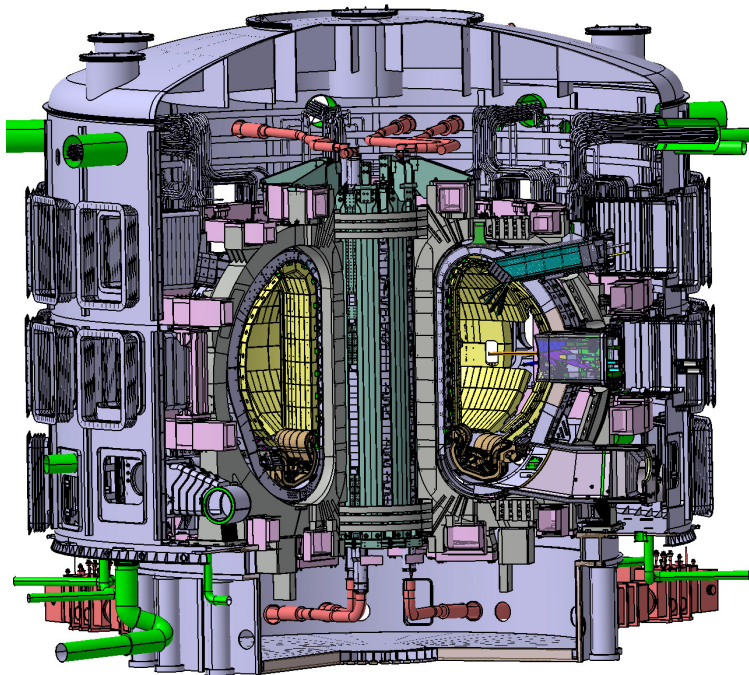


**ITER Cryostat**  
~28 m Tall x 29 m Dia.



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

# ITER Tokamak – Mass Comparison

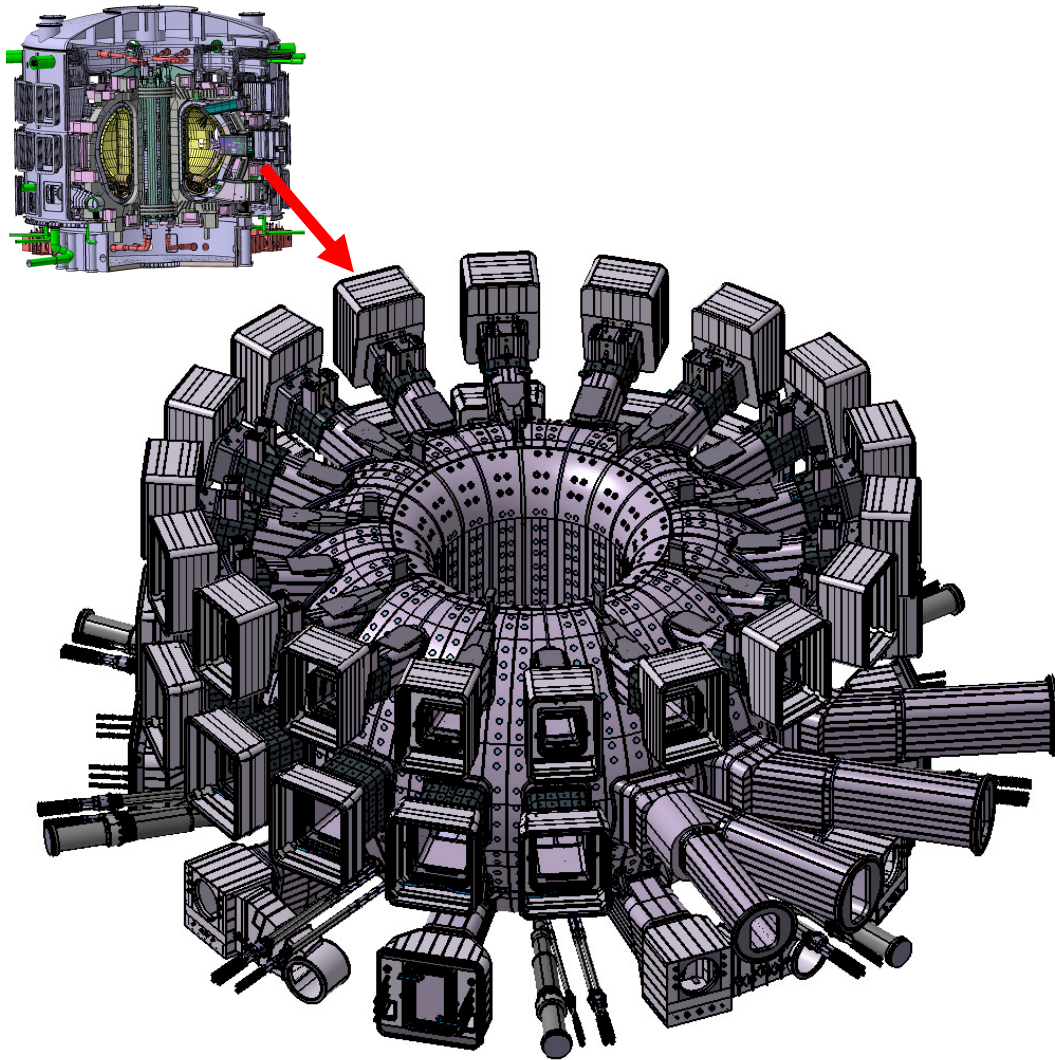


**ITER Machine mass:**  
**~23000 t**  
**28 m Tall x 29 m Dia.**

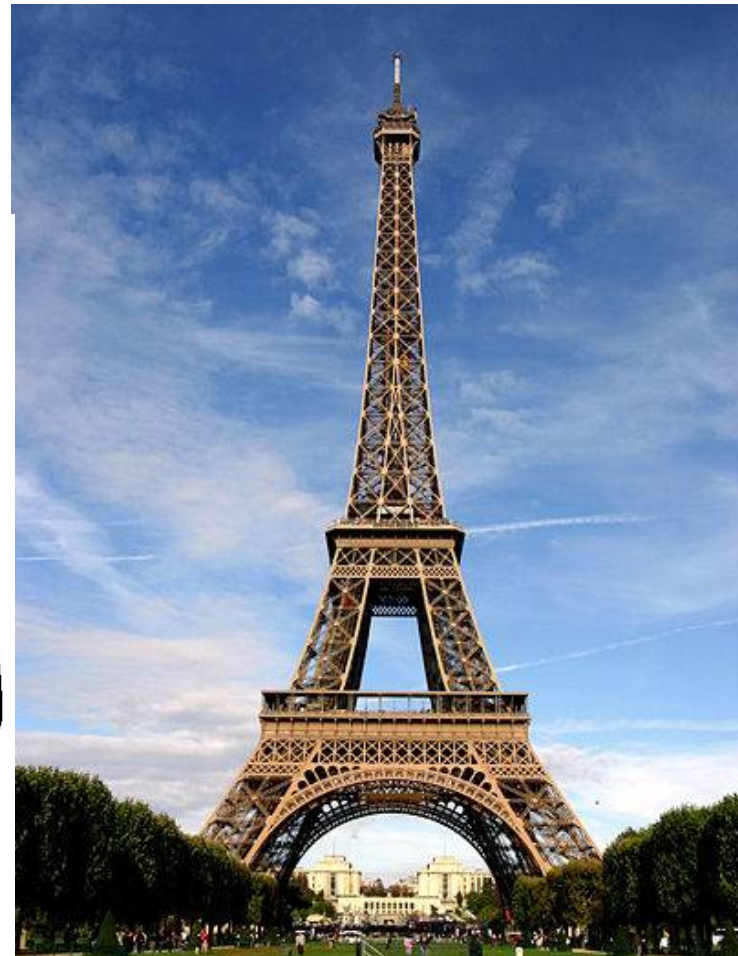


**USS Enterprise mass:**  
**~93000 t** (fully loaded)  
**1123 ft (342 m) long**  
**(Commissioned 1961)**

# Vacuum Vessel - Mass Comparison



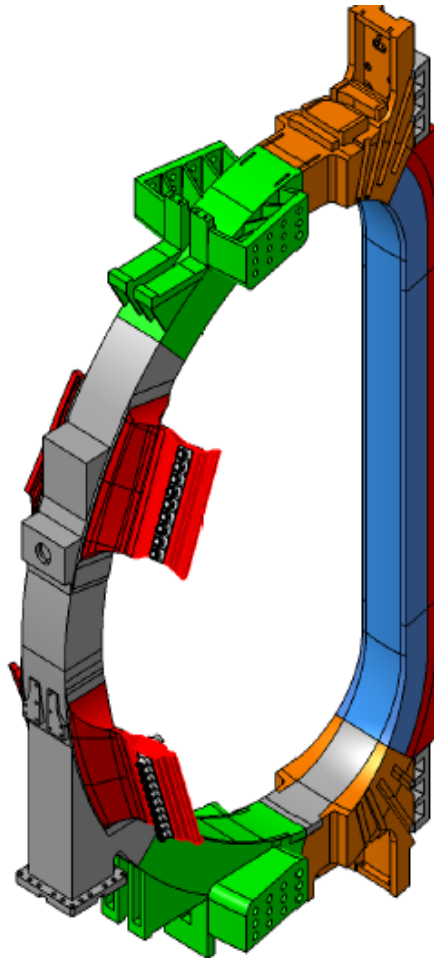
VV & In-vessel components mass: **~8000 t**  
~19.5 m outside diameter x 11.2 m tall



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



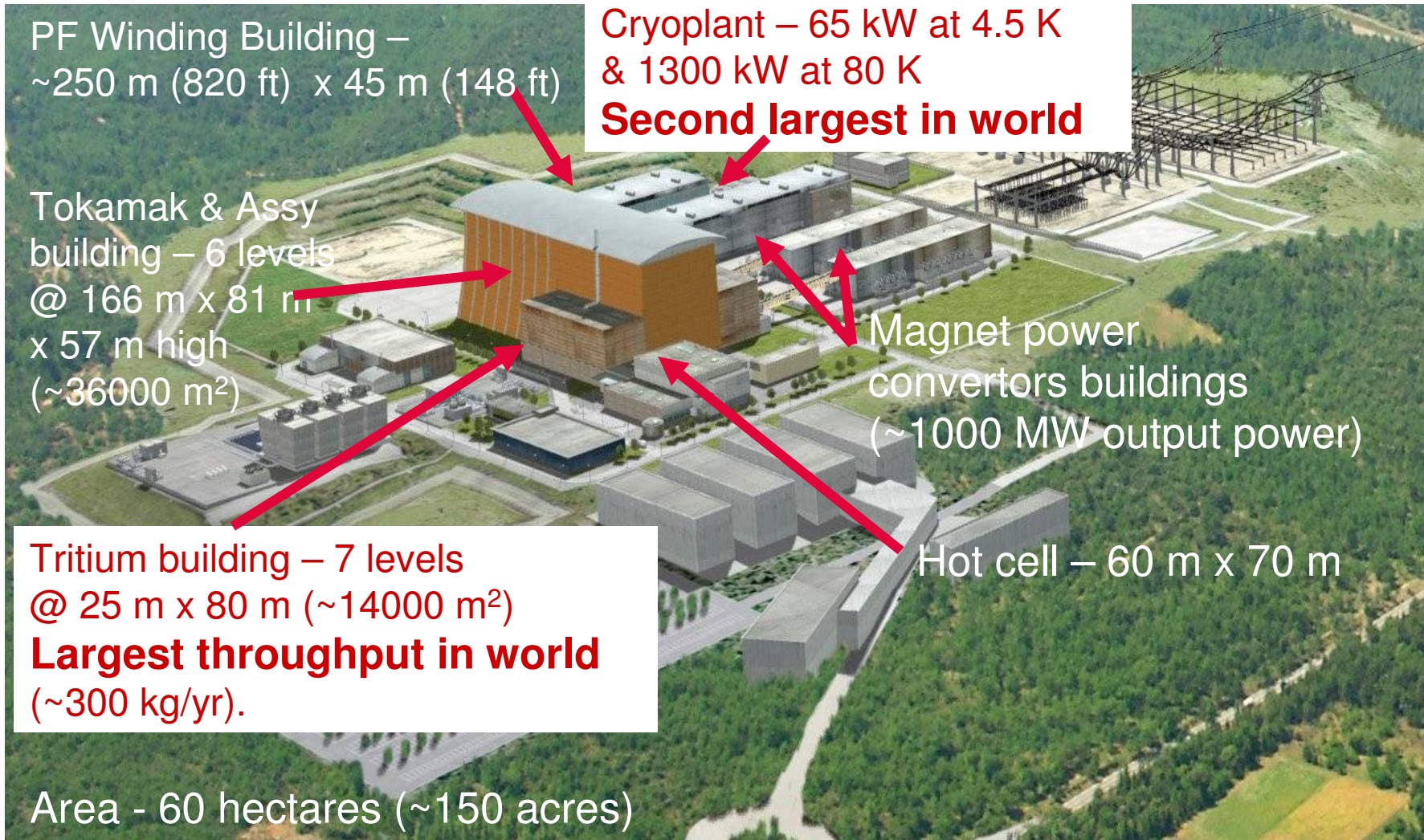
# TF Coil – Mass



**Mass of (1) TF Coil:**  
16 m Tall x 9 m Wide, ~360 t

**Boeing 747-300**  
**(Maximum Takeoff Weight) ~377 t**

# ITER Buildings and Facilities

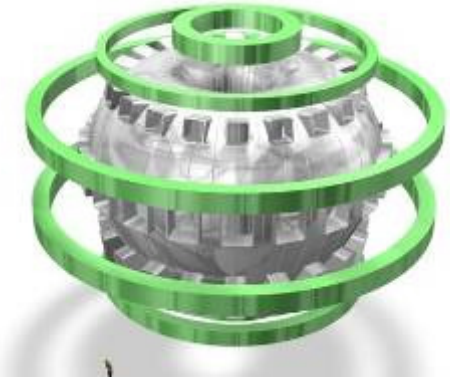
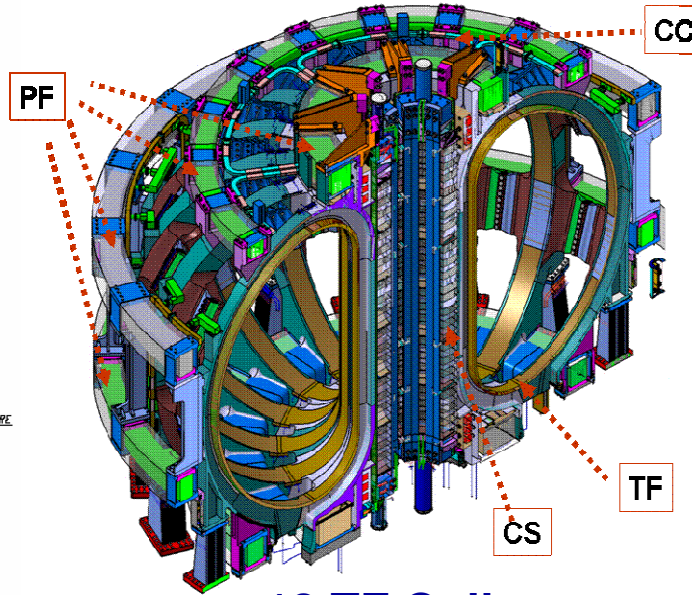
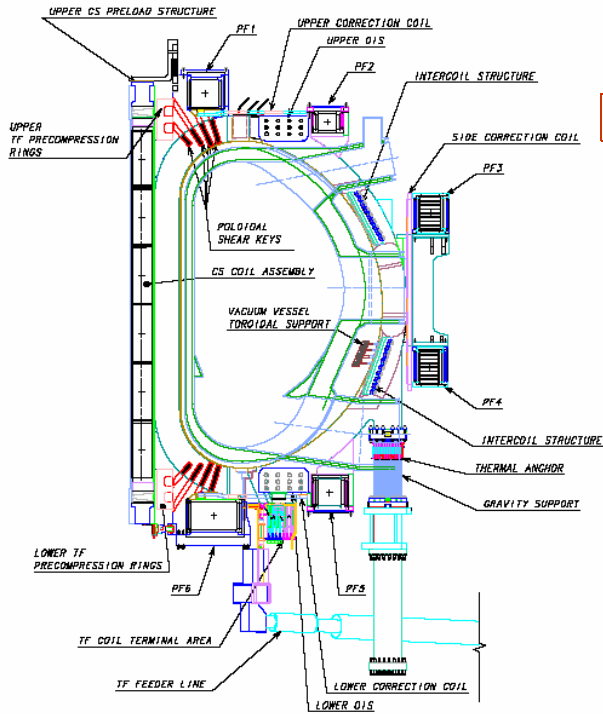


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# Technical Systems & Status



# Magnet System

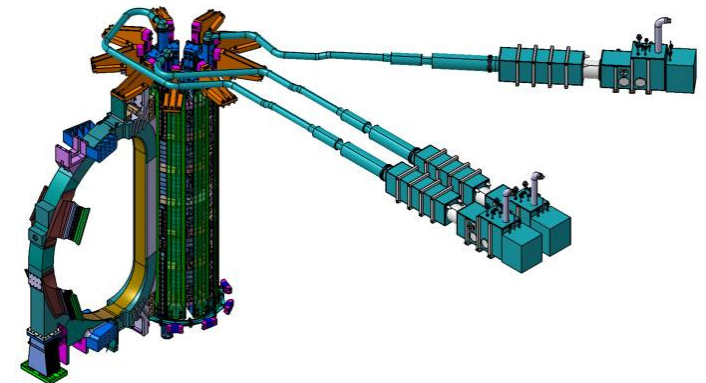


6 PF Coils (EU & RF)

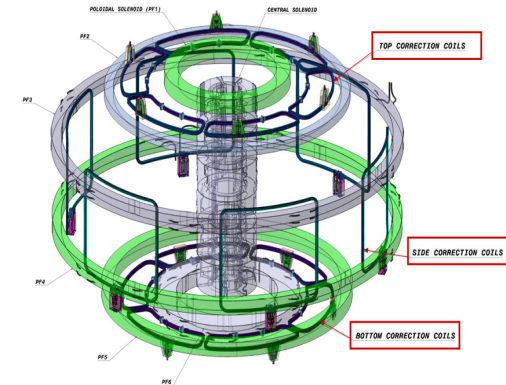
18 TF Coils (EU & JP)

## Facts

- 48 superconducting coils
- ~9800 tons
- ~187 km of conductor
- 11.8 T (peak TF field)
- 68 kA (peak current)
- Stored energy – 51 GJ



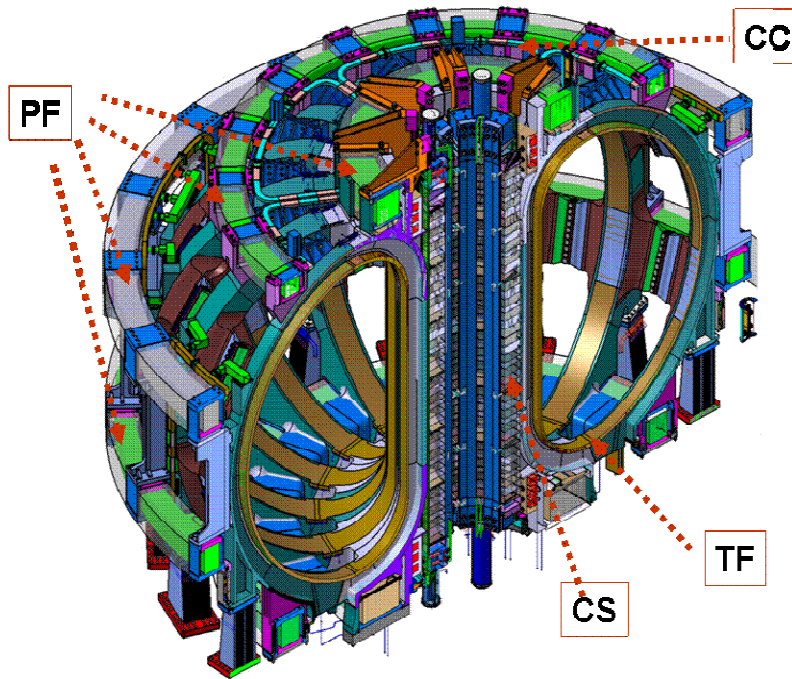
31 Feeders (CN)



9 Pairs of Correction Coils (CN)

CS Coils – Stack of 6 (US)

# Magnet Energy Comparison



**Superconducting  
Magnet Energy:**  
**~51 GJ**

**Charles de Gaulle Energy:**  
**~38000 t at ~180 km/hr**  
or

**The energy of ~19000**

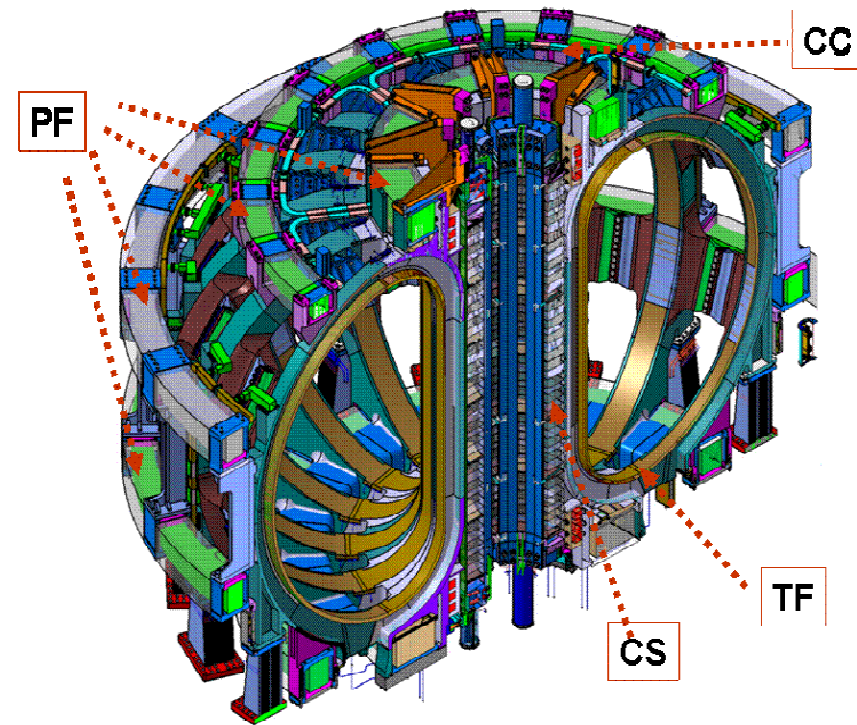
**Audi A5's each at ~180 km/hr**



# ITER Magnet Field

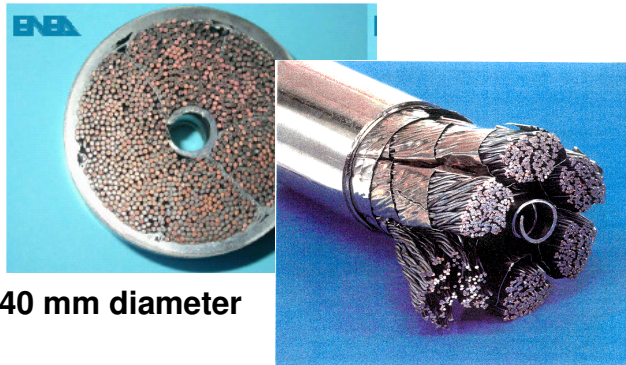


**Earths Magnetic Field**  
~ 0.5 gauss or  $0.5 \times 10^{-4}$  Tesla



**ITER Field**  
~10 Tesla or 200,000 x Higher

# Conductor Status

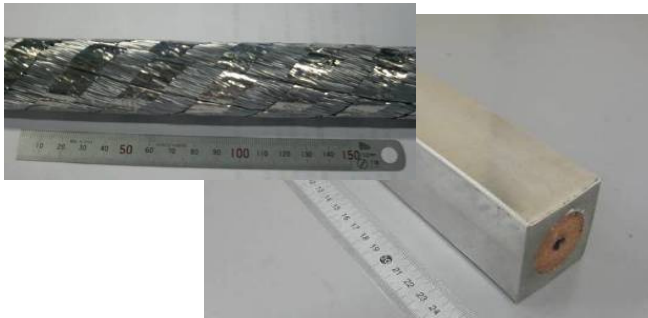


40 mm diameter

## TF Conductor



## PF Conductor



## CS Conductor

### TF - Status

- All six TF conductor PA's signed
- Contracts placed in JA, CN, KO, RF, US for TF cond. proc.
- Three jacketing lines built (TF, PF, & CS)
- Strand production underway in JA, KO, RF, US, and EU
- Strand production non-conformances issued and resolved in Japan, Korea, Russia, and US (QA documentation issue)
- Cabling underway in Japan, Korea and Russia
- Jacketing underway in Japan

### PF - Status

- All three PF conductor PA's signed (CN, RF, & EU)
- Contracts placed in CN for PF conductor procurement
- Agreement between EU and RF for collaboration on P6-P1 conductor supply to reduce duplication

### CS Status

- CS conductor PA signed (JA)
- 316LN (low carbon material as in TF conductor) selected for CS jacket and trial batch fabricated by Cevifal

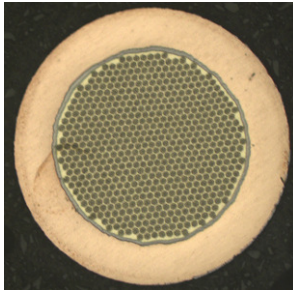
### CC & Feeder Status

- CC & feeder conductor PA signed in May 2010 (CN)

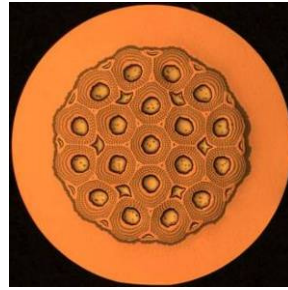


# TF Strand Production Status

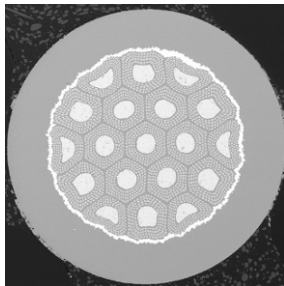
- JA, KO, RF, EU, US have launched strand industrial production and started data input into ITER Conductor Database.



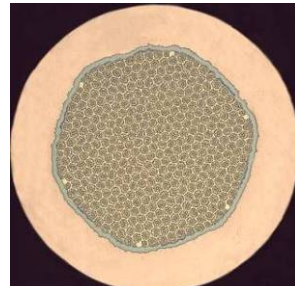
Hitachi, JA  
(Br)



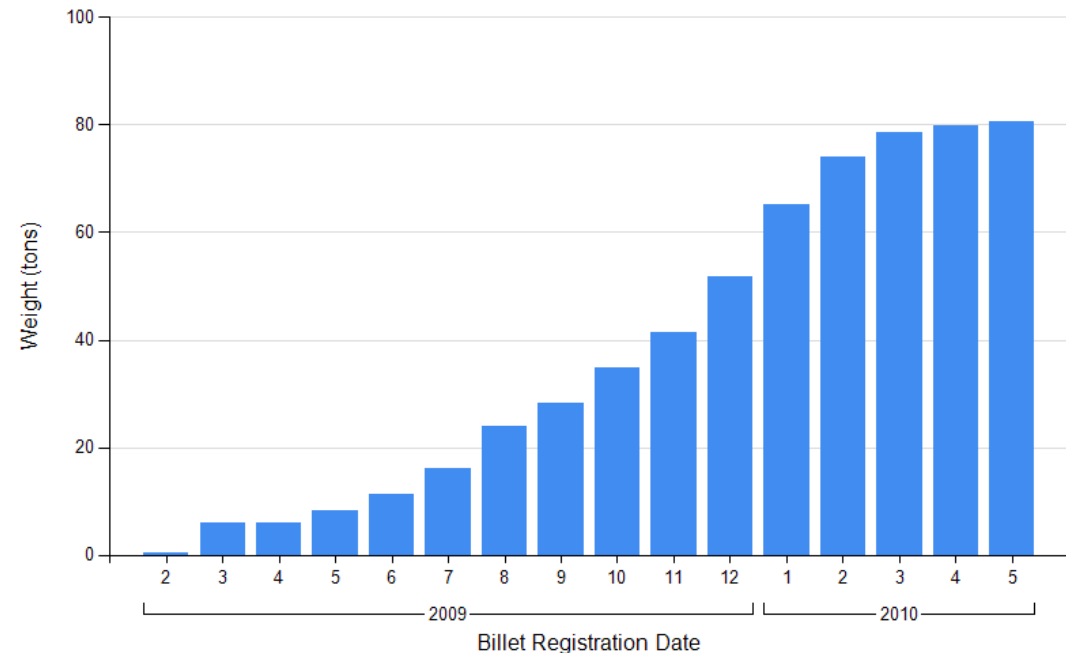
KAT, KO  
(IT)



OST, EU/US  
(IT)



ChMP, RF  
(Br)



- As of today, ~80 tons (>15 000 km) of strands have been registered into the Database; this corresponds to the material needed to manufacture ~4 TF coils.

# TF Cable Production Status

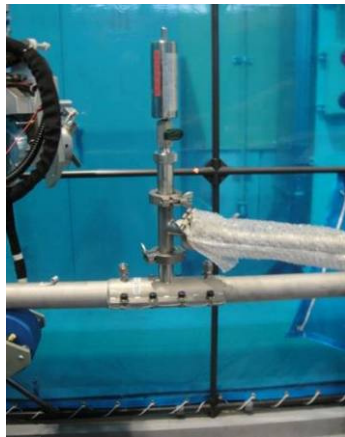
- JA, KO and RF have produced **760 m Cu dummy cable qualification** lengths, and JA and KO have produced **first superconducting cable** lengths.



Cabling of 760 m Cu Dummy  
at VNIIEP, RF (Feb. 09)

# TF Conductor Production Status

- JA has completed jacketing of 760 m Cu dummy cable and first three superconducting cables (100m and 2 x 420m).



Welding  
& Leak Checking

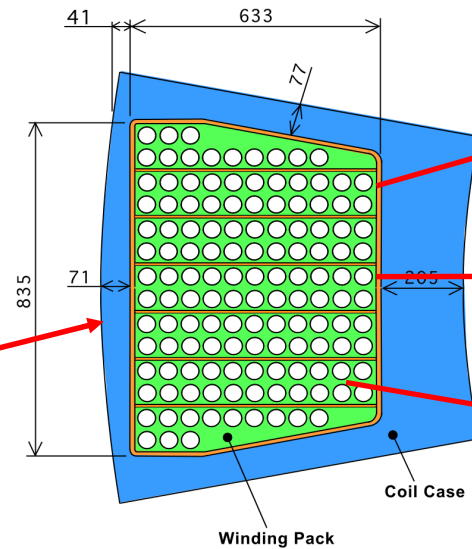
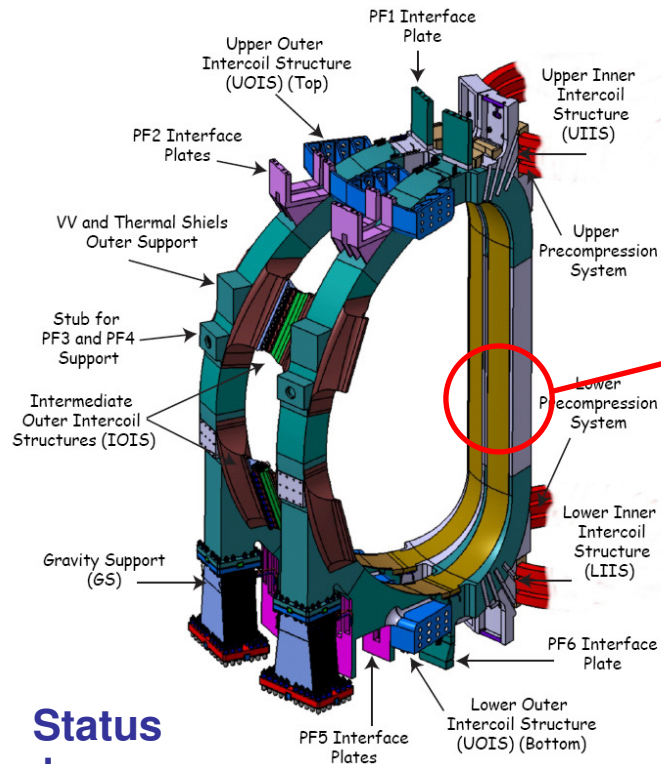


Cable Insertion

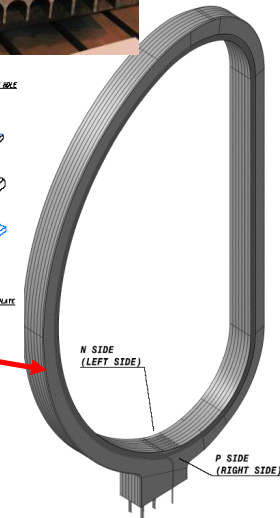
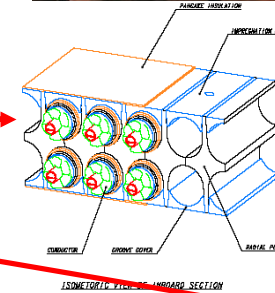


Compaction  
& Spooling

# TF Coil Status



**Inner Leg Cross Section**



**TF Winding Pack**

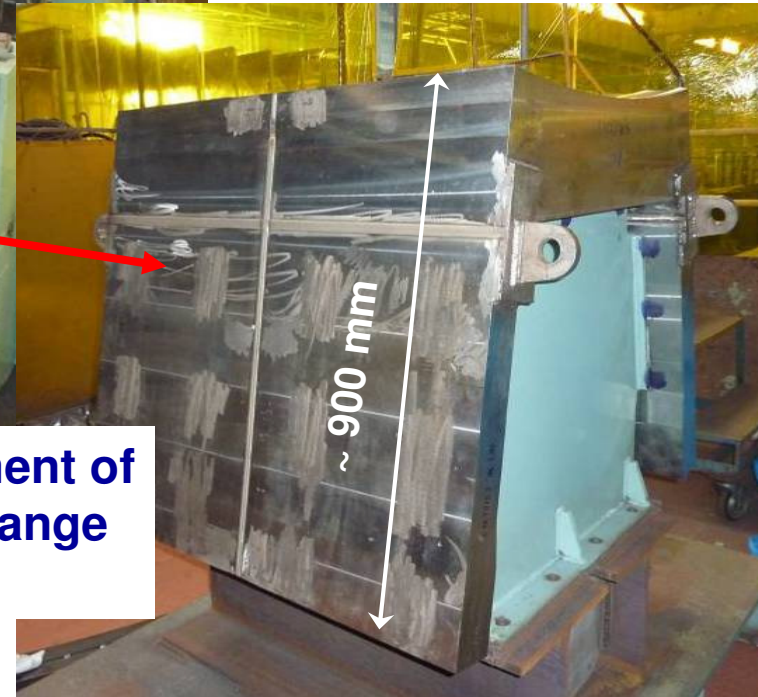
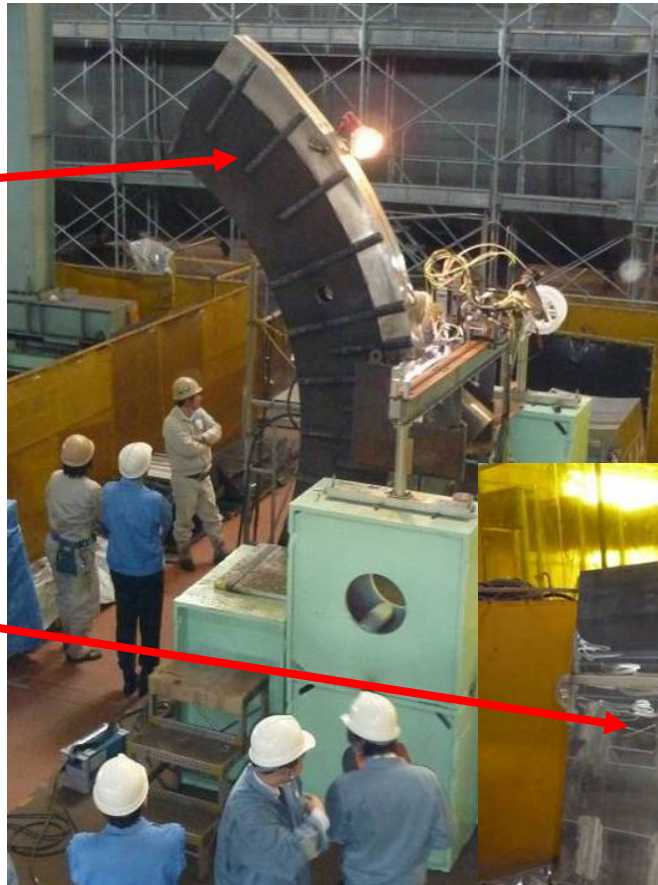
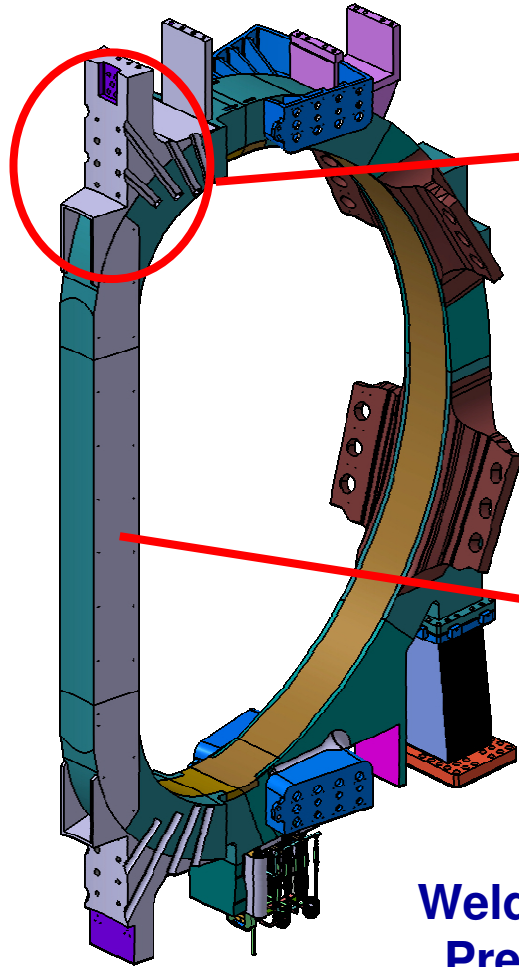
## Status Japan

- Signed a procurement contract for TFC PA's (Toshiba is main contractor; KHI and CNIM are sub's).
- Commissioning of winding machine @ Toshiba in progress
- Welding trials in progress @ KHI for TFCS and TFC Case

## Europe

- Signed a procurement contract with CNIM (FR) and SIMIC (IT) for prototype radial plates
- Winding Package (WP) call-for-tender underway
- Contract signed with CSM (Centro Sviluppo Materiali - IT) for the qualification of the TFC Case

# TF Coils Progress (KHI-JA)



**Welding Trials for attachment of  
Pre-compression Ring Flange  
to TF Coil Case**

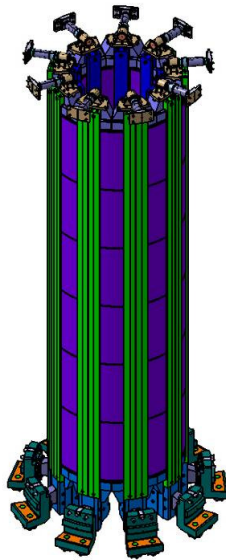
**TF Coil Case Straight Leg**

# TF Coils - A Worldwide Collaboration



**The biggest Nb<sub>3</sub>Sn conductor procurement in history!**

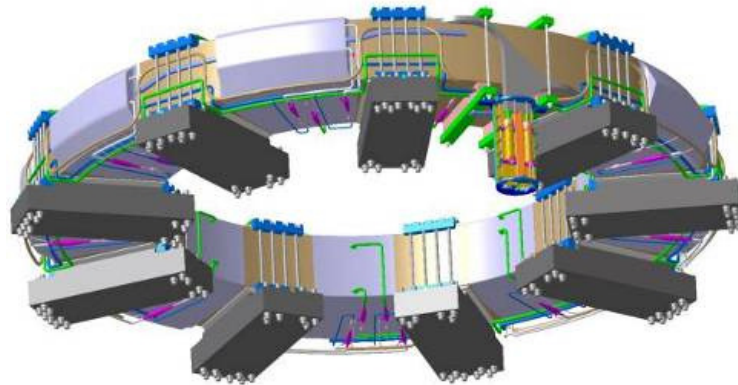
# CS, PF, & CC Status



**Central Solenoid**  
(13.6 m tall x 4.2 m dia  
~1000 ton)

## Status

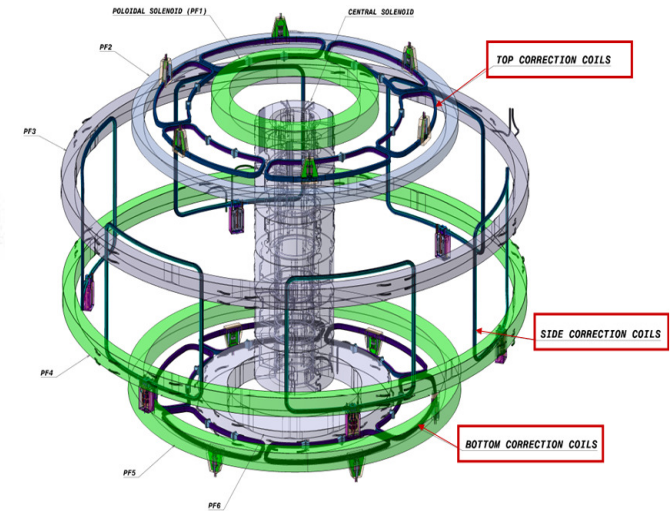
- CS Conductor FDR - Sept 09
- CS Coil CDR - Sept 09
- Design in progress in US



**PF Coils (6)**  
(PF3 - 24.8 m dia &  
~386 ton)

## Status

- PF Coil 2,3,4,5,&6 PA signed with EU
- PF Coil 1 drawings being prepared for RF
- PA signing expected in June 2010.

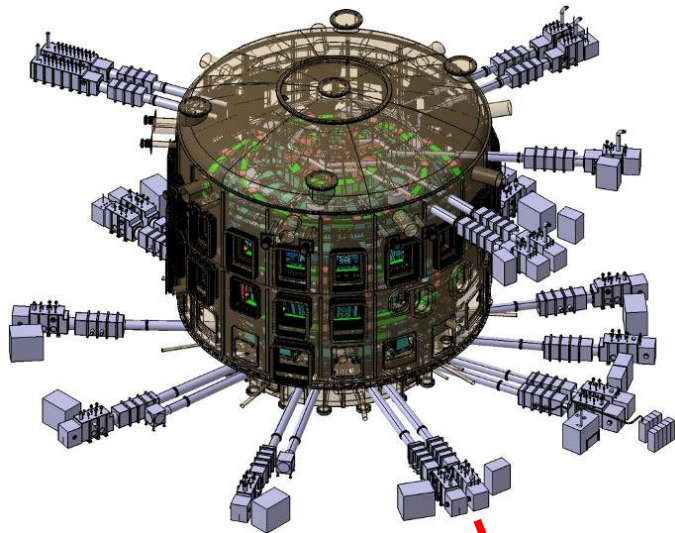


**Correction Coils (9 pairs)**

## Status

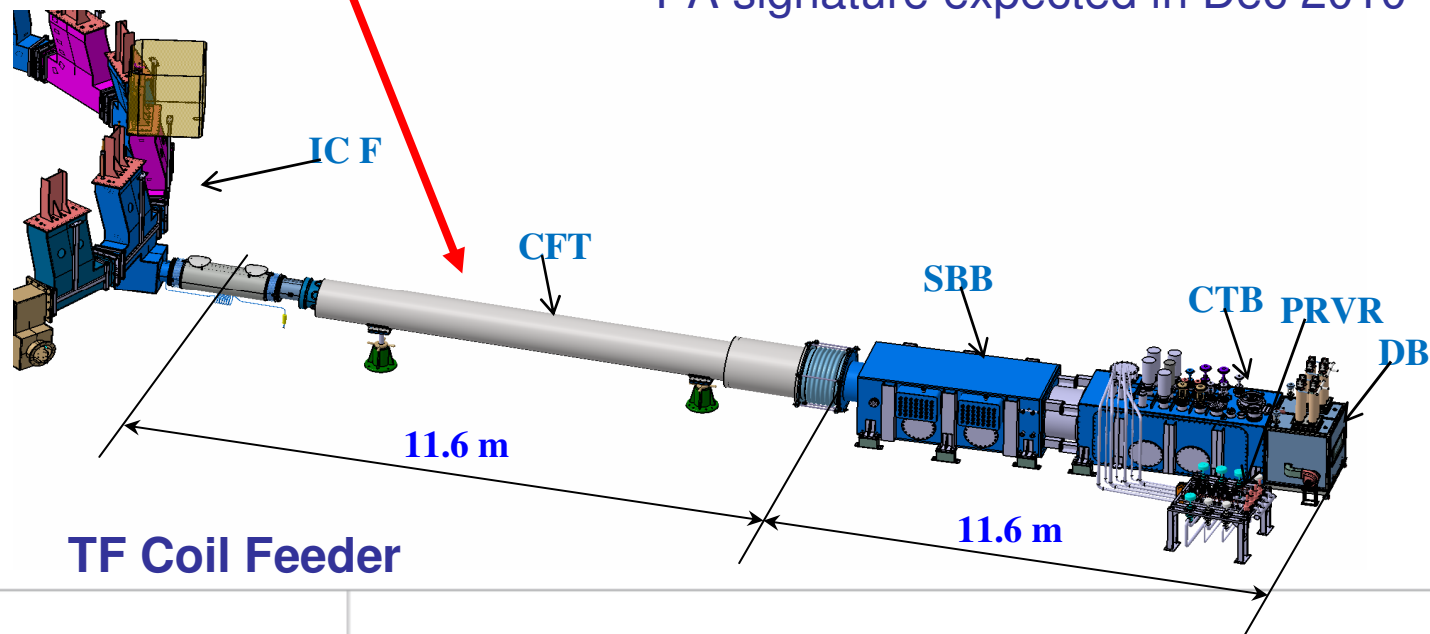
- Design complete
- PA signed May 2010 with China

# Feeders Status



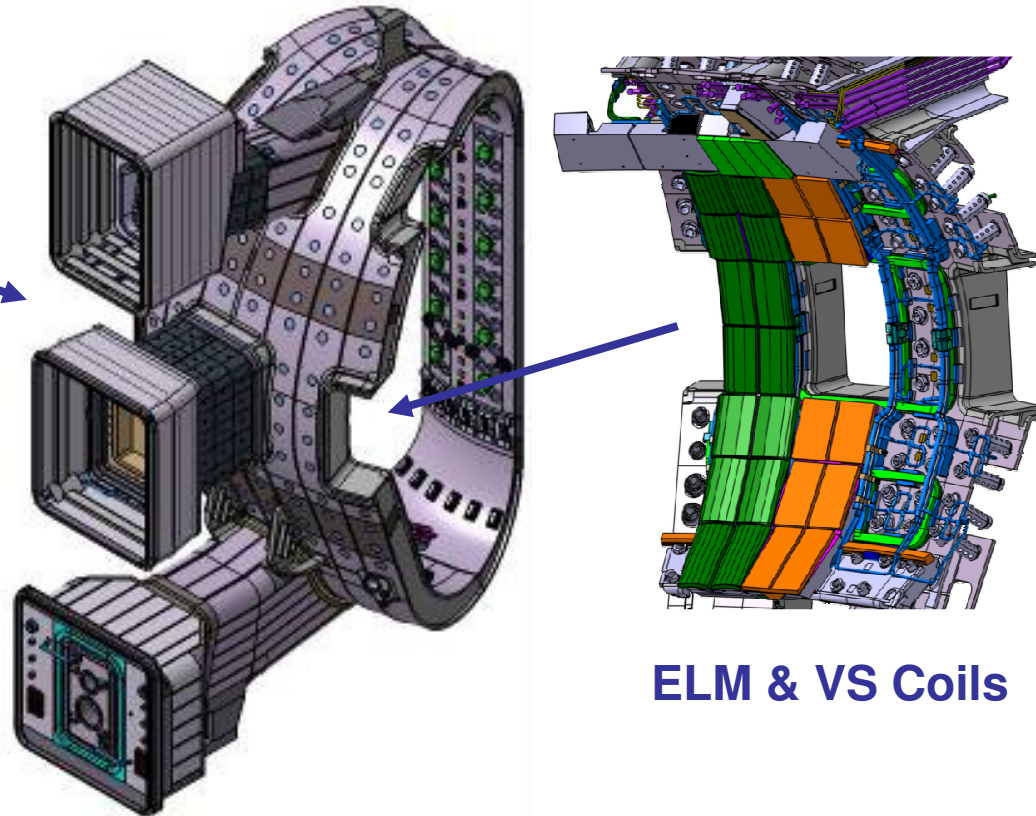
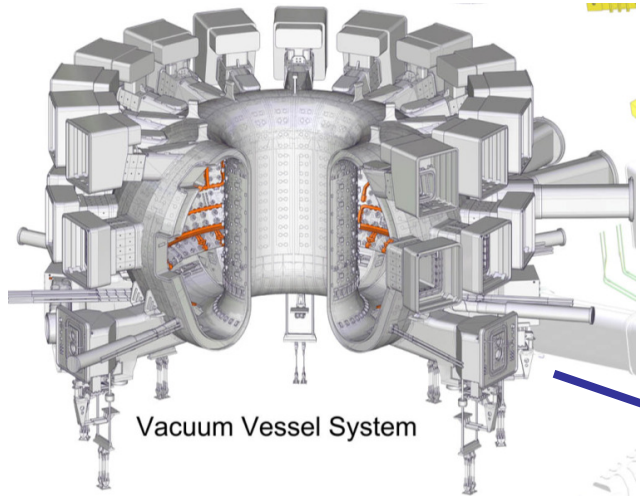
## Status

- TF feeder design complete (9 of 31 feeders)
- Extensive design collaboration with ASIPP-CN
- Feeder Busbars designed
- 10 kA HTS Current Lead prototype in preparation
- Completion of the designs in 2010
- PA signature expected in Dec 2010





# VV Status



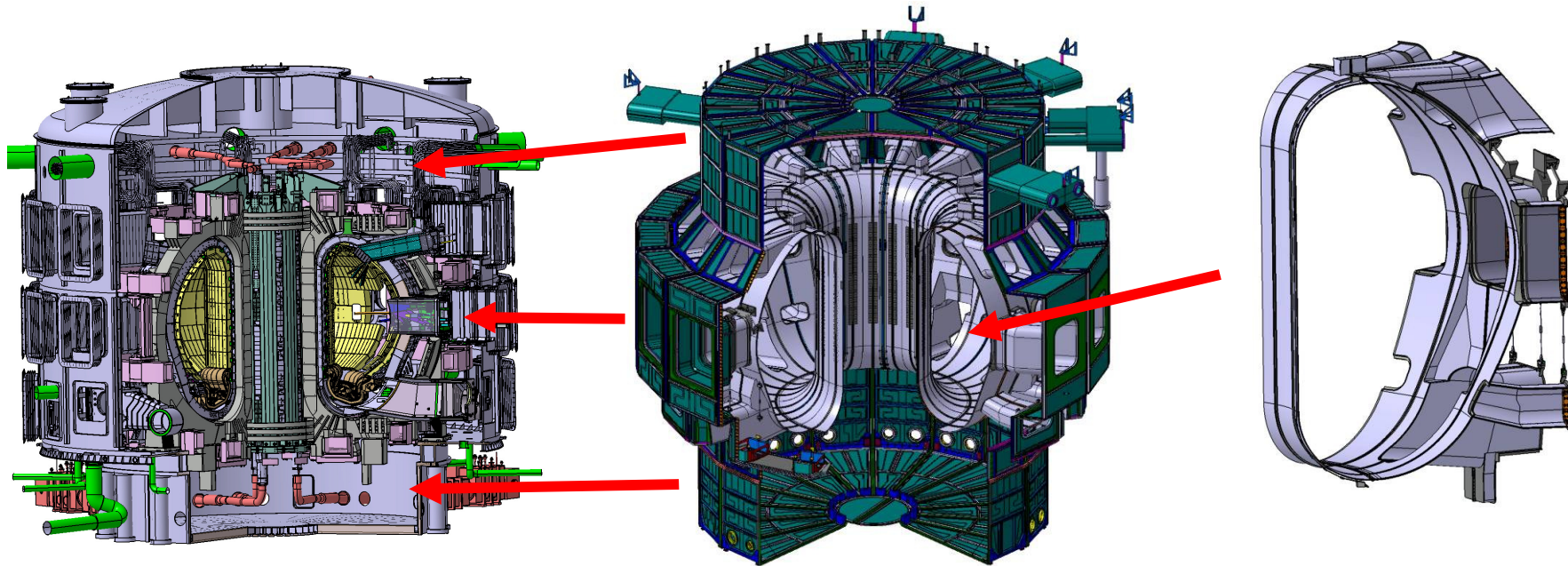
## Facts

- 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

## Status

- Received preliminary approval of VV design at end of phase 1 (from ANB)
- ELM & VS coil interfaces fully implemented in the VV
- VV sector and port PA's signed (EU, KO, IN, & RF)
- KO - VV & port contract awarded to Hyundai Heavy Industries
- Final VV models & drawings issued May 31
- Manufacturing schedule is on critical path!!!

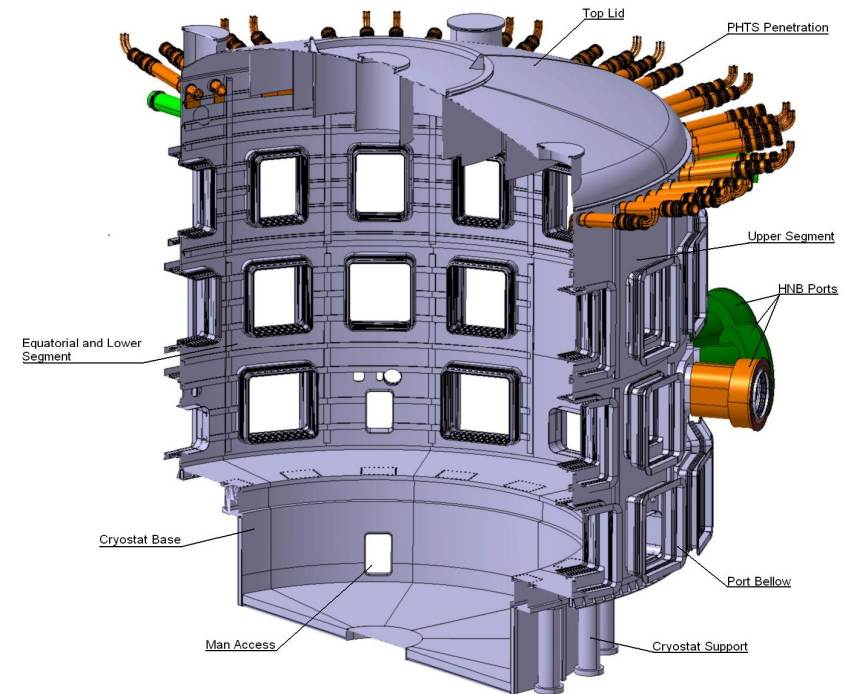
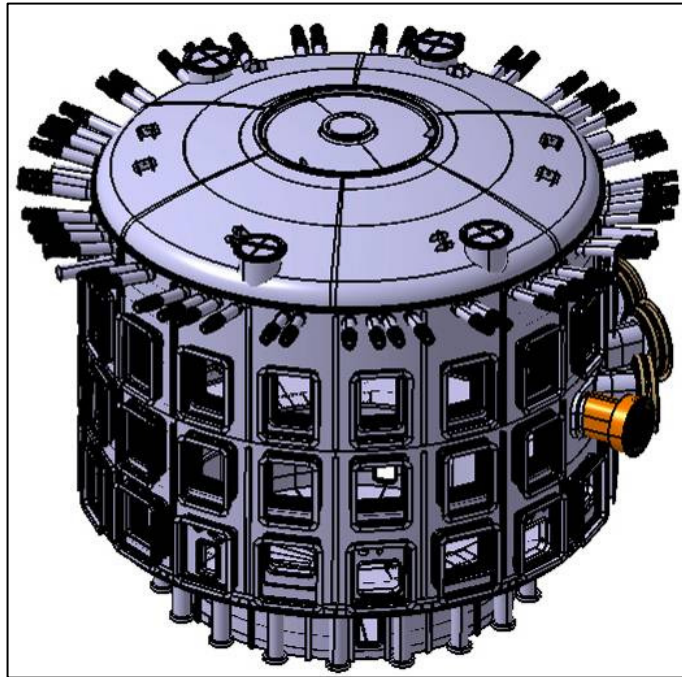
# Thermal Shield Status



## Status

- PA signed in May 2010
- Final drawings issued Oct 2010

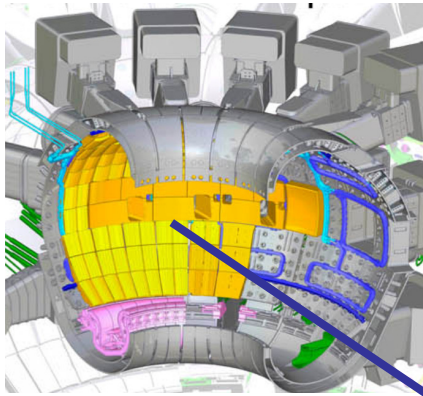
# Cryostat Status



## Status

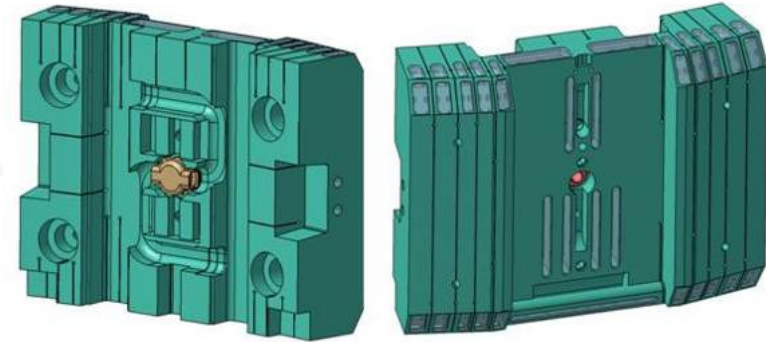
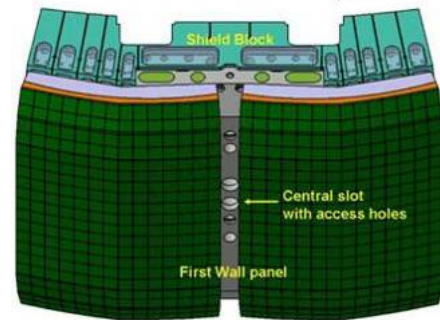
- CDR completed in November 2009
- PDR planned for June 2010 and FDR planned for Sept 2010
- PA signing planned for October 2010
- Interfaces with major Tokamak systems are identified and ICDs are prepared.
- Global Structural, EM, thermal and seismic analysis report is under review.

# Baseline Blanket Status

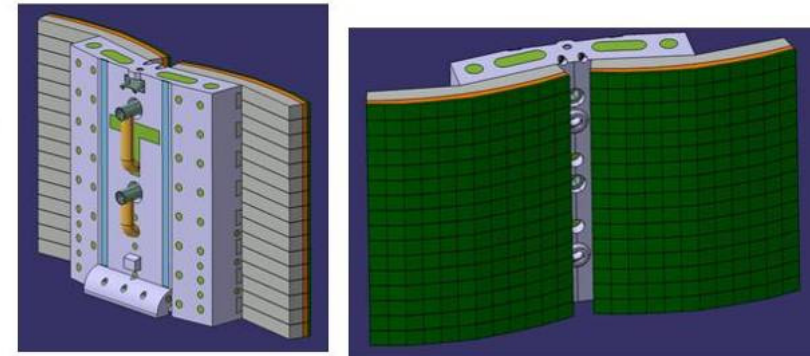


## Facts

- 440 blanket modules
- ~4 tons each
- 18 poloidal rows
- 18 or 36 toroidal rows
- ~40 different modules
- Mass: 1530 tons



Shield Module

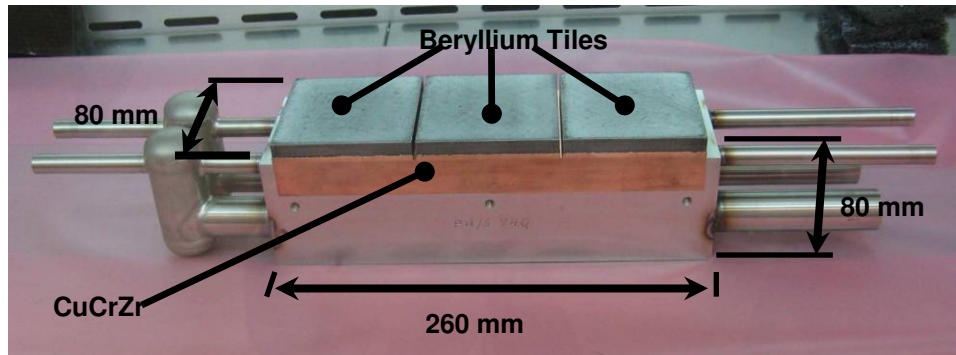


First Wall Panel

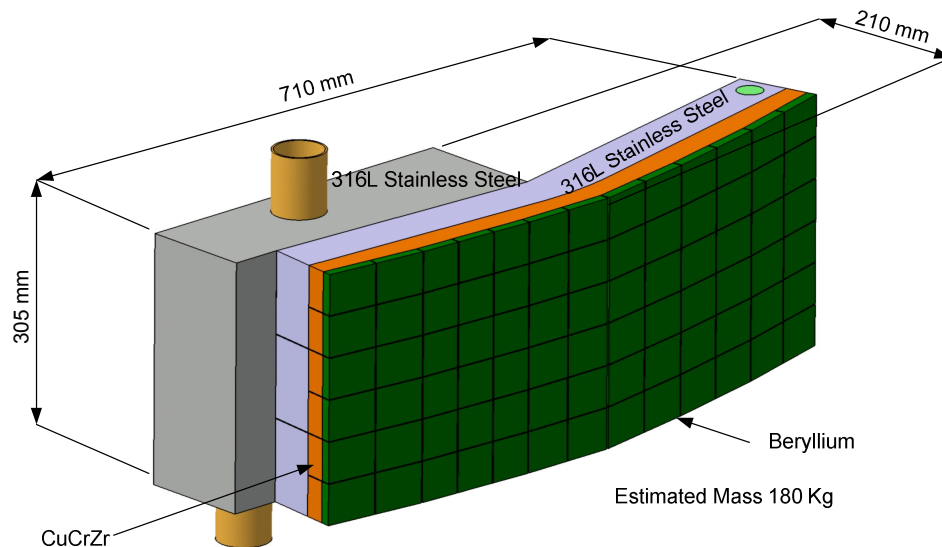
## Status

- CDR held in February, 2010
- Conceptual blanket / FW design for typical modules Nos. 4, 8 and 12 completed
- Design supporting analysis completed for the above modules
- FW shaping in progress

# FW Pre-qualification



Mock-ups



Semi-prototype

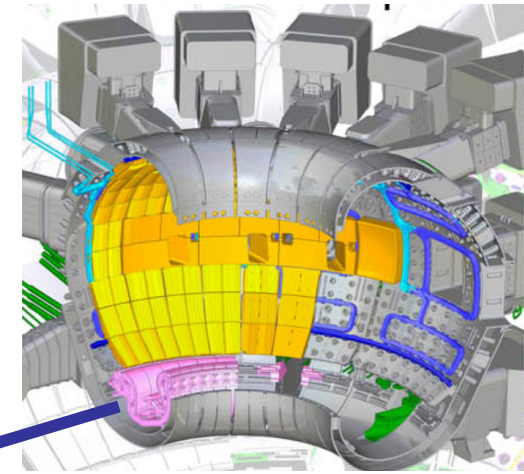
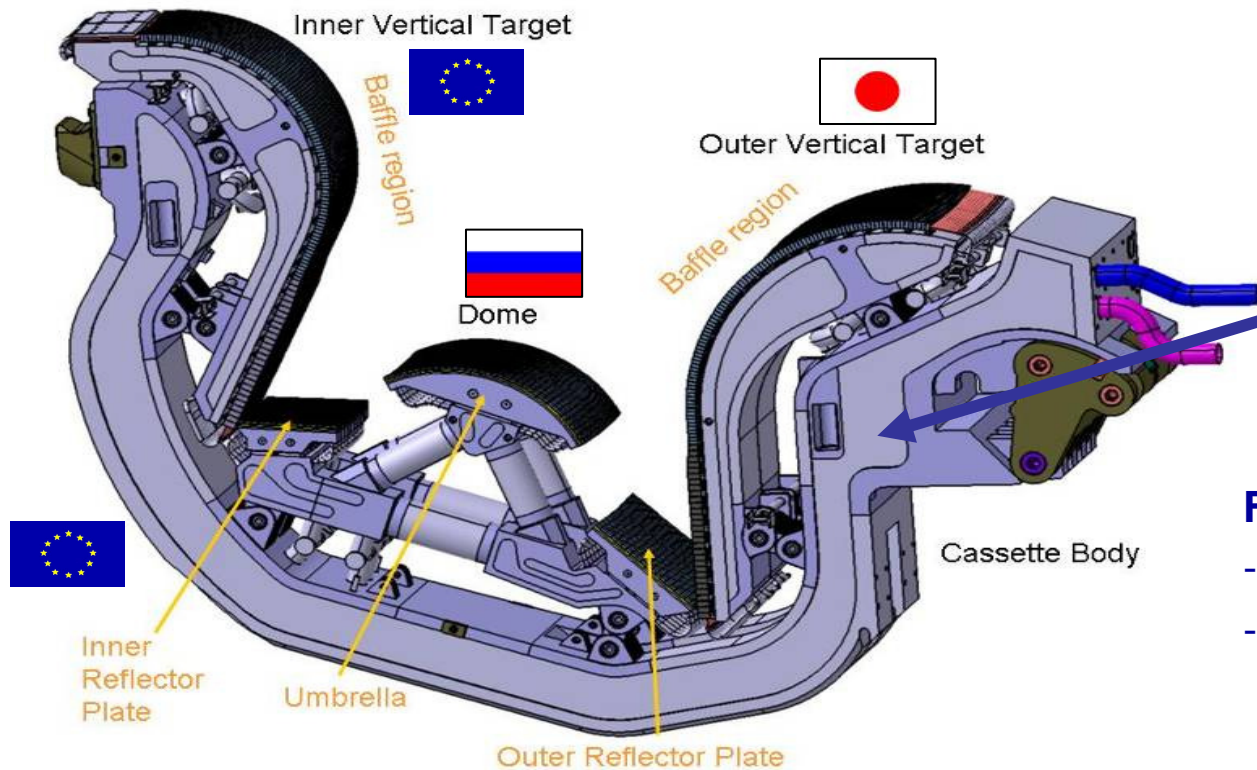
## Objectives

- Demonstrate technical capability prior to start procurement
- Phased approach
  - Mock-up: Demonstration/validation joining of Be/CuCrZr & SS/CuCrZr
  - Semi-prototype: Production/validation of large scale components

## Status

- Mock ups provided by US, EU, RF, KO, CN and JP
- Nearing completion of the formal test program - 12,000 normal cycles at 0.875MW/m<sup>2</sup> and 1000 MARFE cycles at 1.4MW/m<sup>2</sup>.
- First wall semi-prototype phase will start with (US, EU, RF and CN) within the next few months.

# Divertor Status



## Facts

- 54 Divertor assemblies
- 4320 Heat flux elements

## Status

- Design complete
- Four of five PA's Signed
- Licensing classification of Divertor components being resolved (PED/ESPN are out of scope)

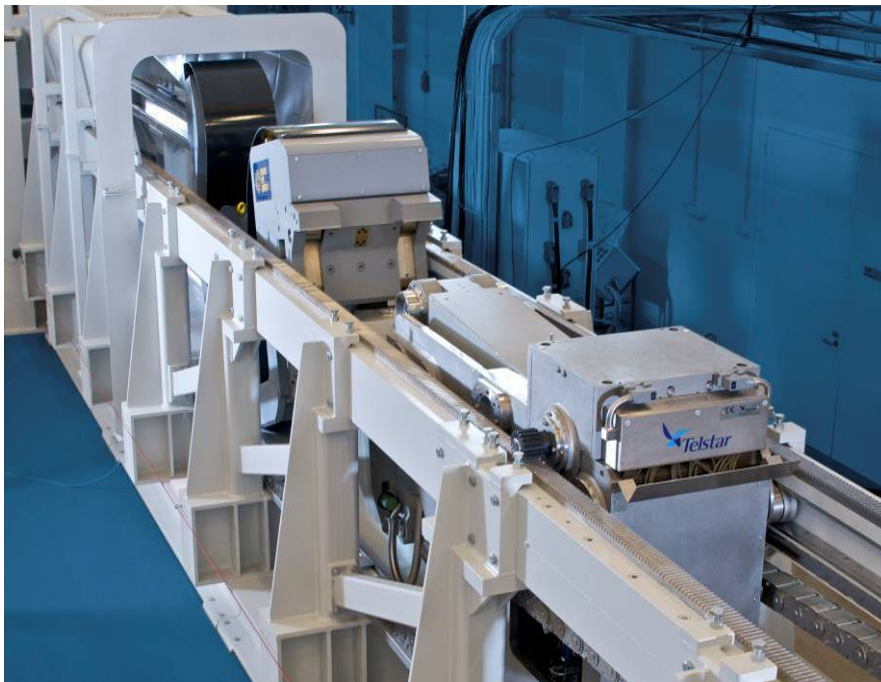
# Full-scale Divertor Installation into the Vacuum Chamber at DTP2

## Objectives:

- Demonstrate the feasibility to install the divertor assembly into the vacuum vessel by means of RH tools

## Status

- Installation of the “second” cassette successfully demonstrated at DTP2 in Finland



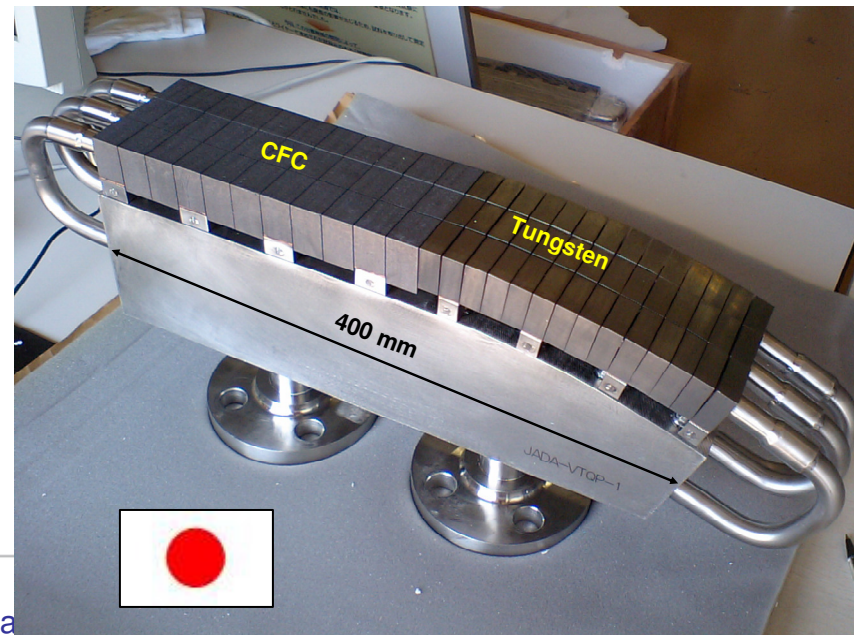
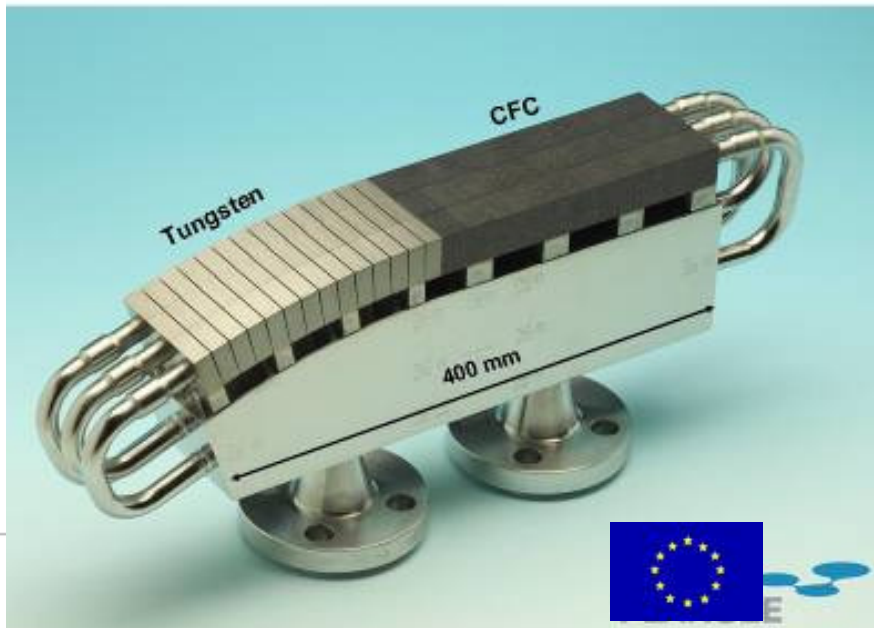
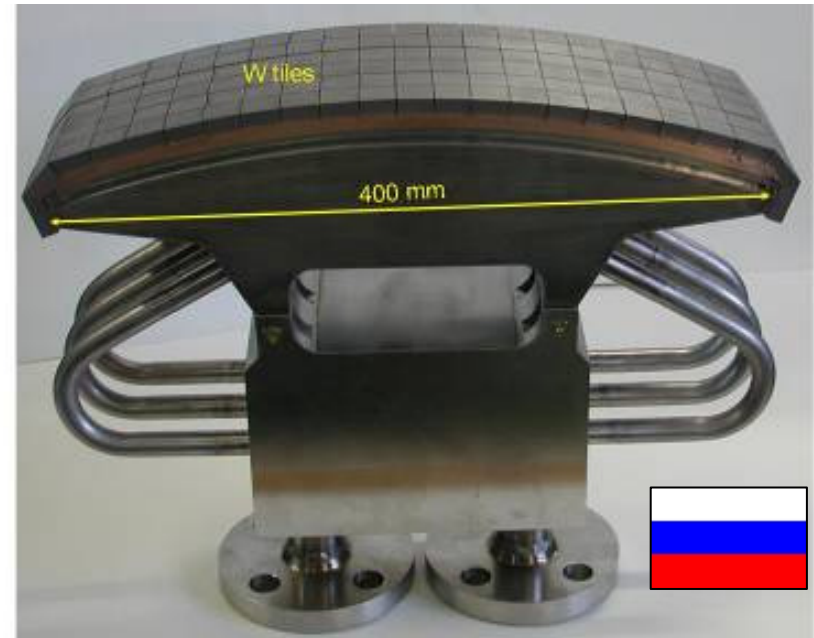
# Divertor Qualification Prototypes

## Objectives

- Qualification of critical divertor components

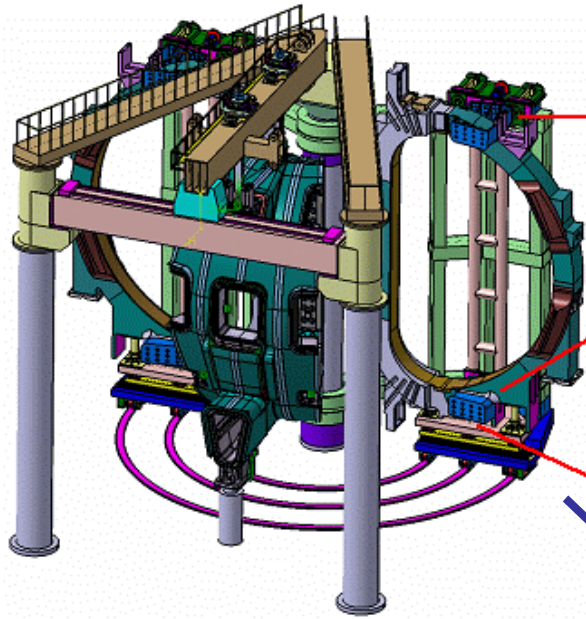
## Status

- All the 3 Domestic Agencies have qualified
- Pre-PA Qualification process successfully completed in all the concerned DAs.





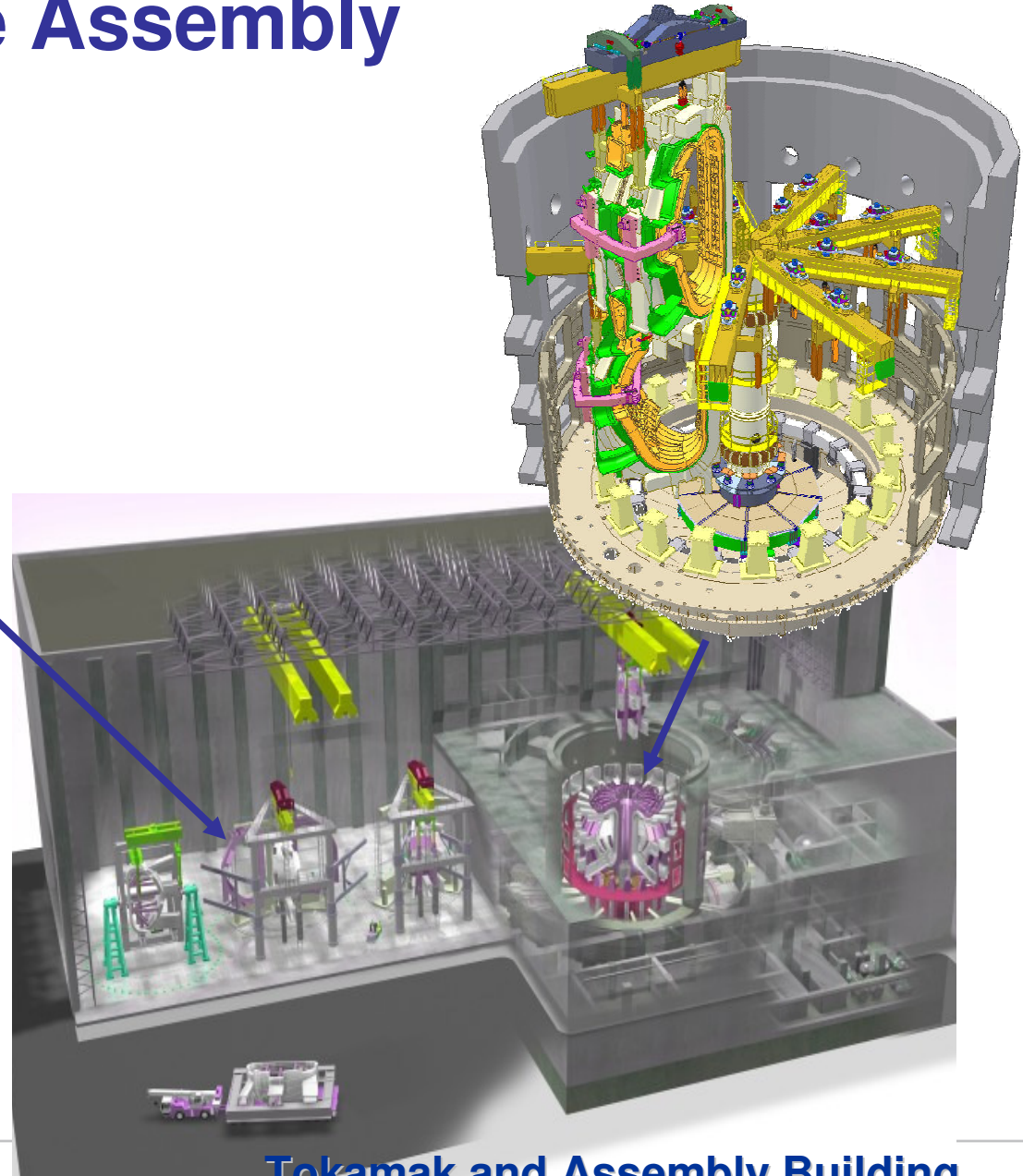
# Machine Assembly



**TF Coil / Sector Assembly**  
~1400 ton

## Status

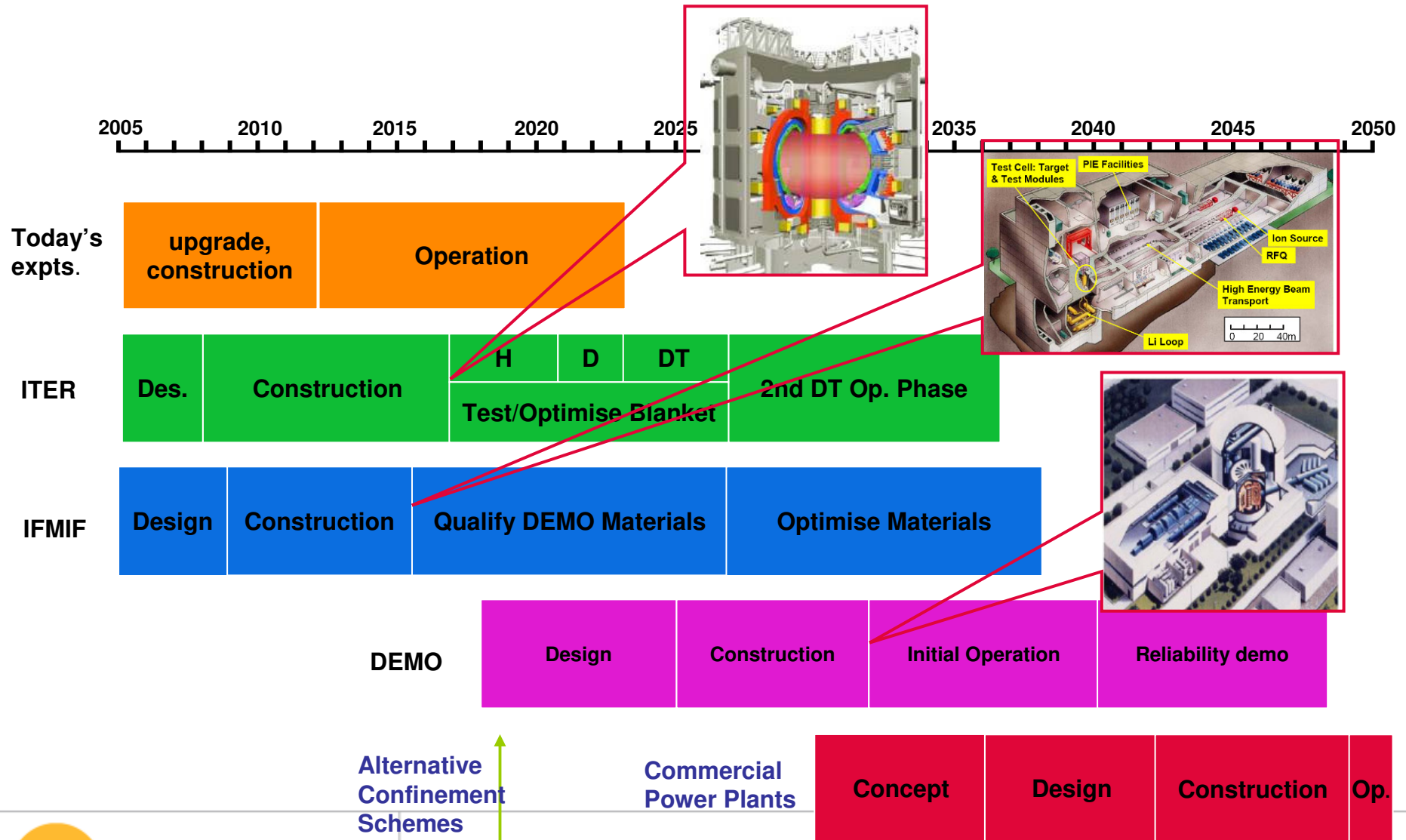
- Detailed assemble plans developed
- Assembly tool PA signed with Korea



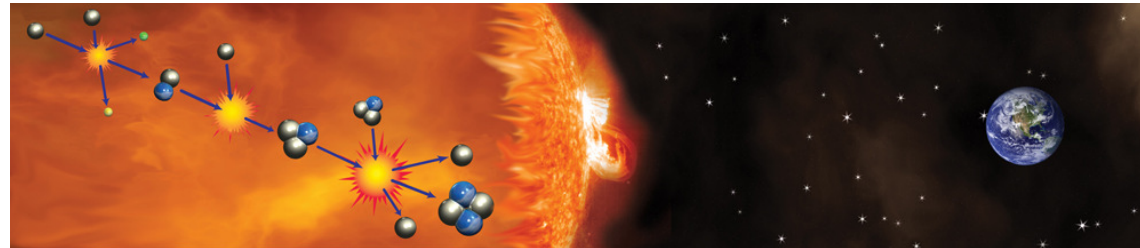
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# Where do we go from here?

# The Roadmap Beyond ITER

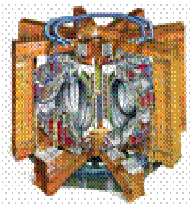


# Now we are firmly on ITER (the way)...



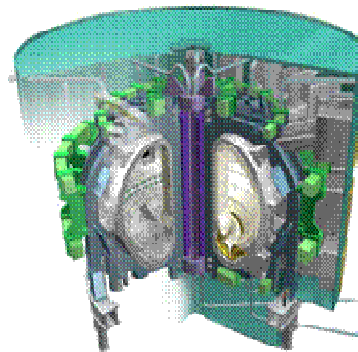
**Tore Supra**

**25 m<sup>3</sup>**  
**~ 0 MW<sub>th</sub>**



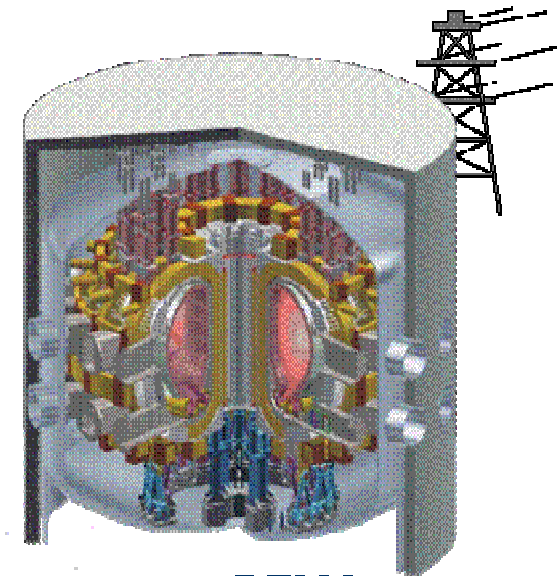
**JET**

**80 m<sup>3</sup>**  
**~16 MW<sub>th</sub>**



**ITER**

**800 m<sup>3</sup>**  
**~ 500 MW<sub>th</sub>**



**DEMO**

**~ 1000 - 3500 m<sup>3</sup>**  
**~ 2000 - 4000 MW<sub>th</sub>**

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