Recent Progress on ITER

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Director of the Department for Administration

20th Topical Meeting on the Technology of Fusion Energy
Nashville, TN

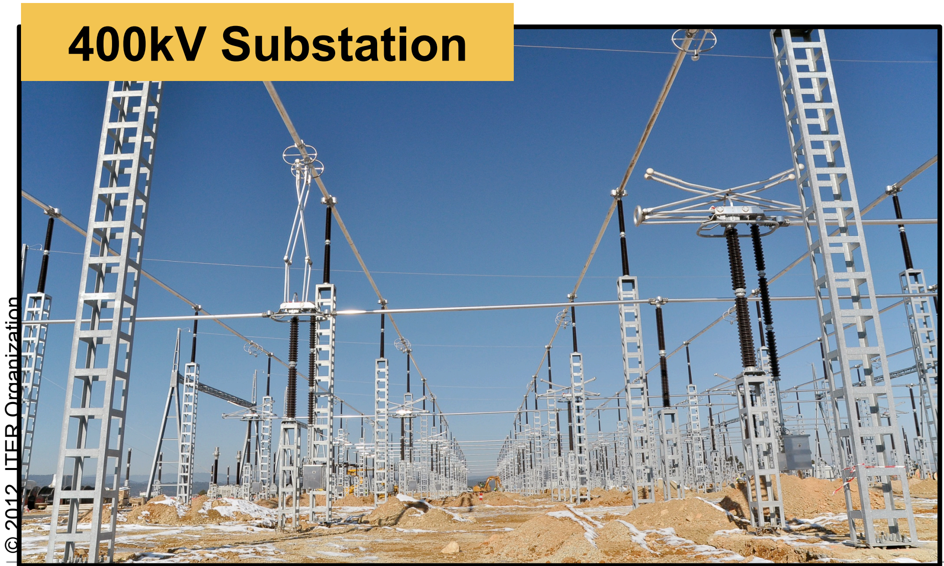
August 28, 2012

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

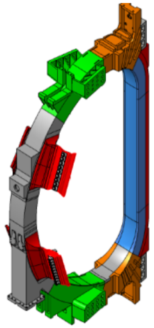
ITER is Successfully Making the Transition from Design to Construction

- **Going from developing requirements to detailed designs**
- **Going from R&D to large-scale prototypes**
- **Going from prototypes to large-scale manufacturing**
- **Beginning construction**
- **Planning for Assembly**

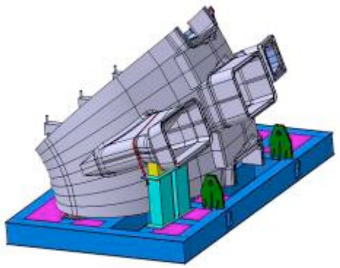
Construction Status at Cadarache by EU



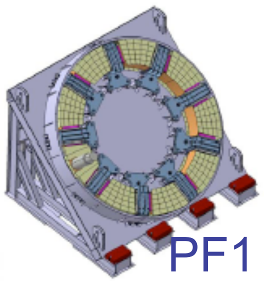
Local Communities Provided Road Upgrades



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

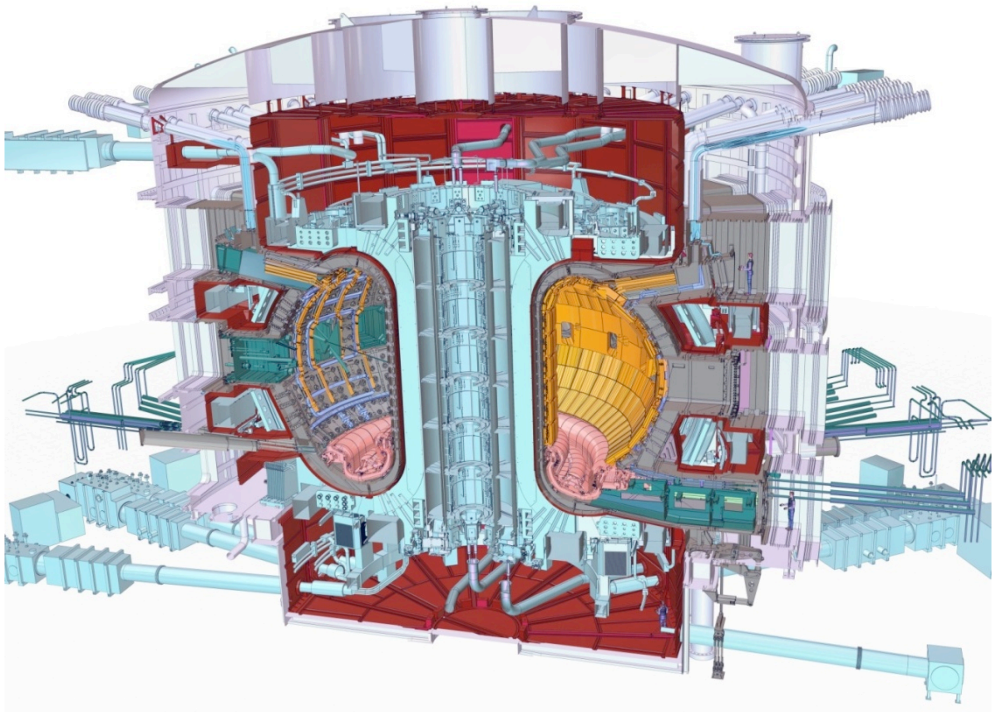
FRANCE

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

Paid with contributions from local area – ~467 M €

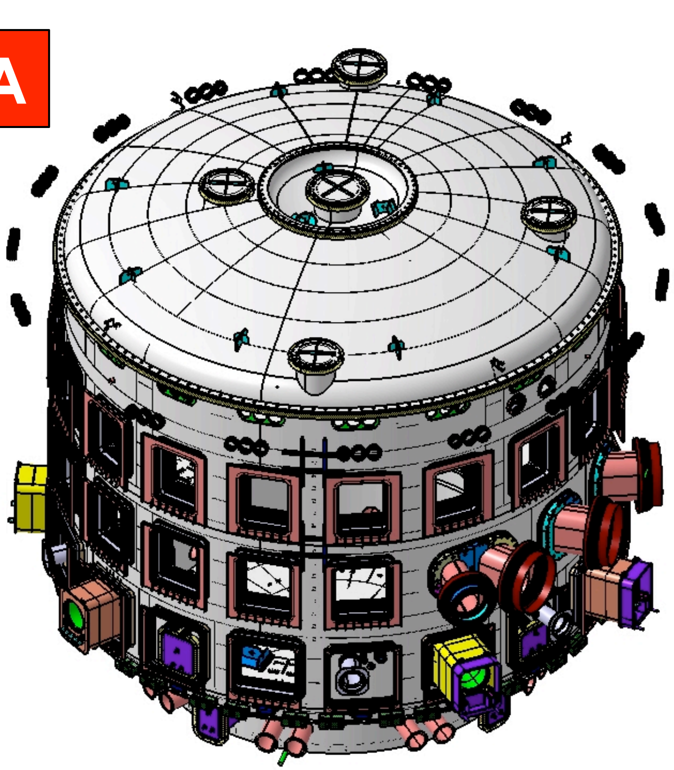
ITER is Addressing the Key Technical Challenges of the Tokamak

- ***Tokamak***
  - Large scale up of many systems
  - High quality high tech components
  - Tight tolerances
  - Highly integrated design
- ***Superconducting magnets***
  - Unprecedented magnet size
  - High field performance ~12T
  - Conductor and magnet manufacturing
- ***Vessel Systems***
  - Large size
  - Safety boundary
- ***Plasma facing components***
  - High heat flux
  - Plasma-Material Interactions
  - RH requirements

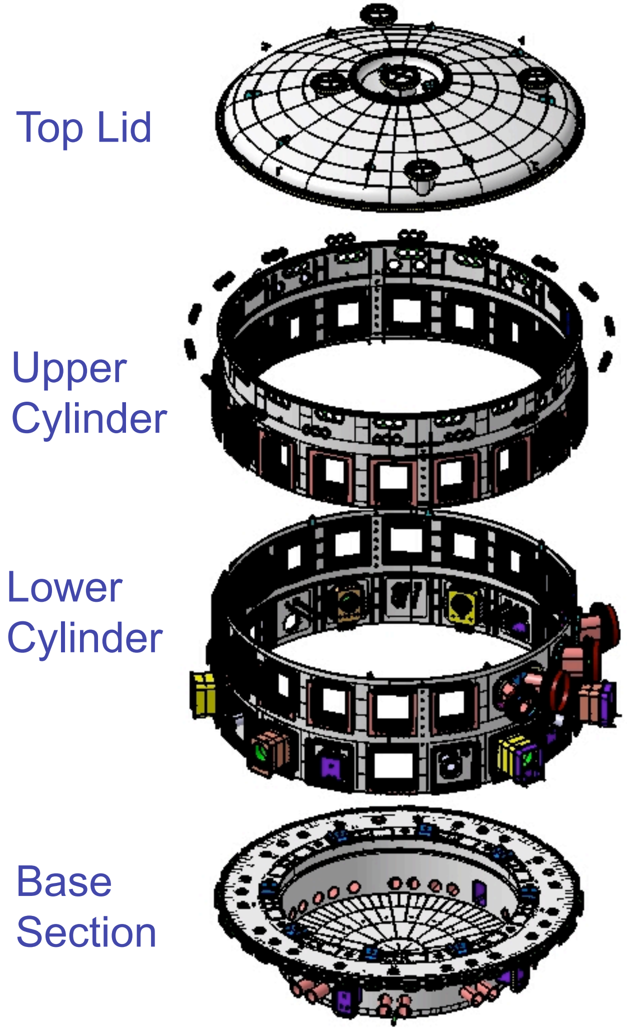


Cryostat Provides Vacuum Insulation for SC Coils

INDIA



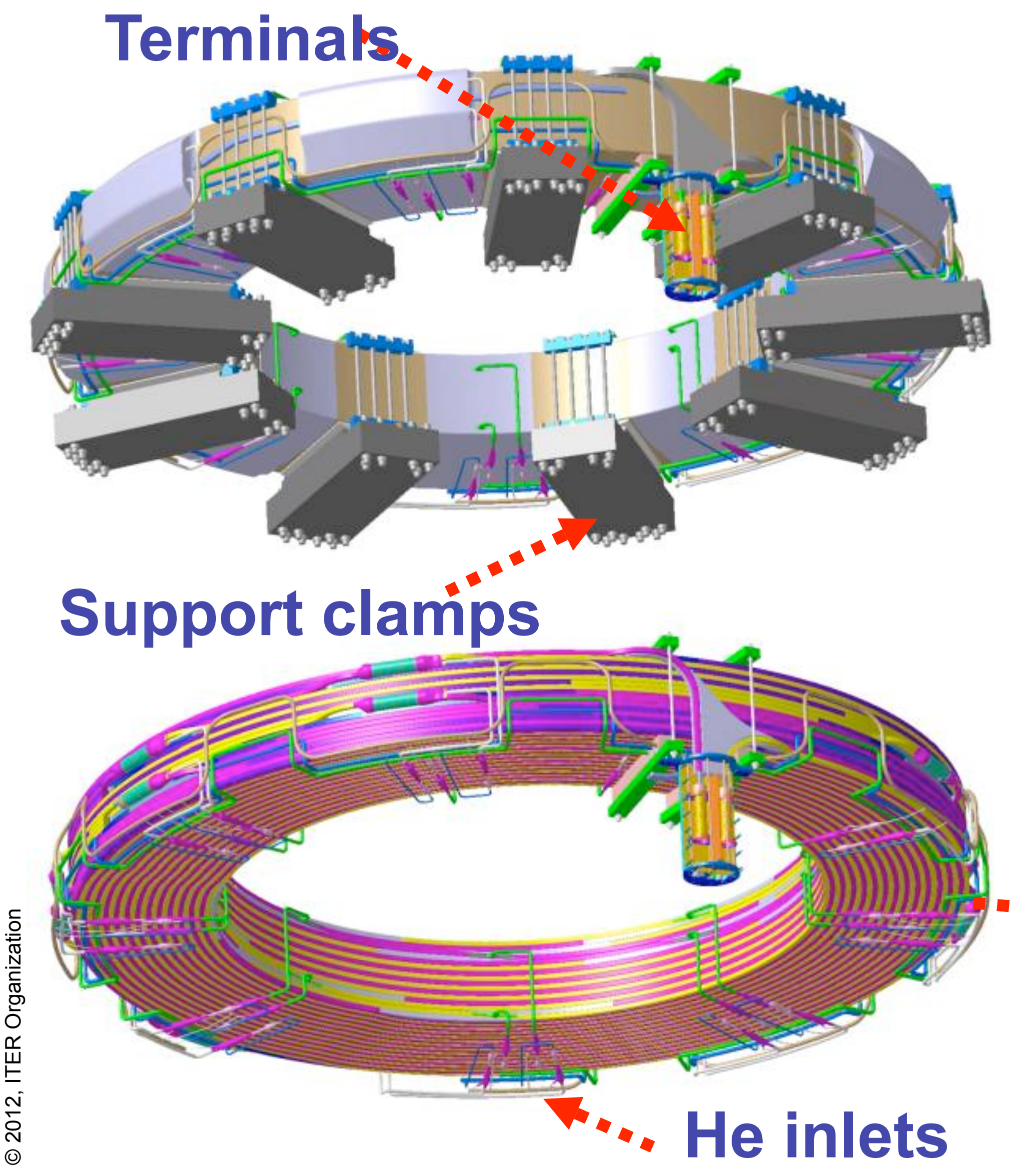
- 304L Stainless steel 40 – 180 mm thick
- Weight ~3500 tonnes
- Transfers loads to tokamak floor



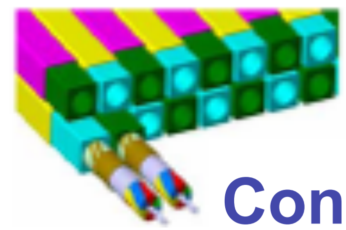
- IN-DA signed PA September 2011
- Contract awarded in August

Poloidal Field Coils

EU & RF

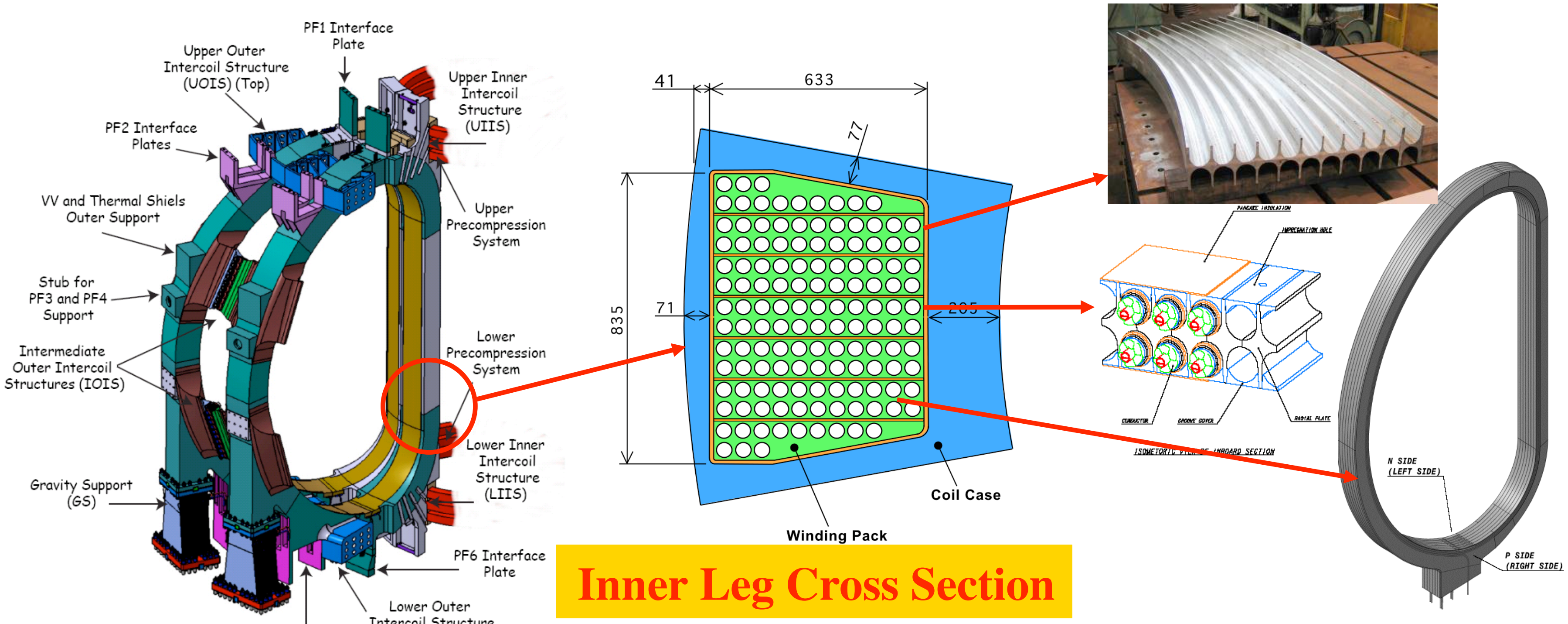


- So large that they most must be manufactured on site
- PF3: 24.5 m dia. & 386 ton
- Building is 250 m long x 45 m wide and is the first building on site!



Conductor Winding

TF Coil Status



Inner Leg Cross Section

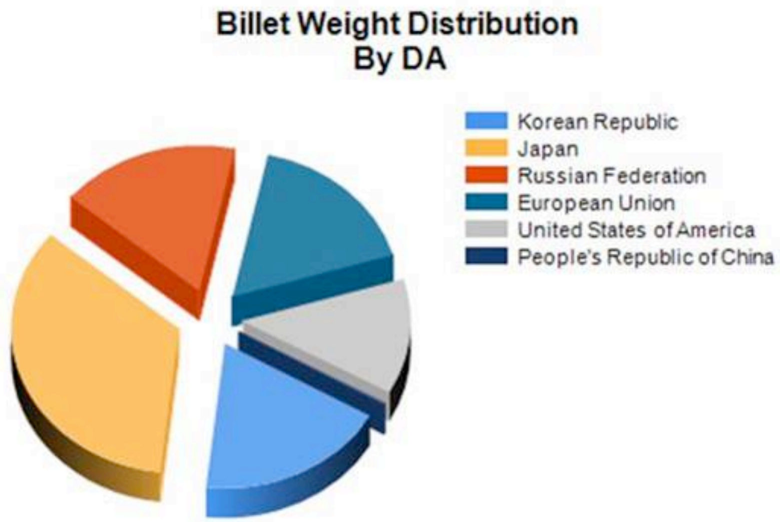
TF Winding Pack

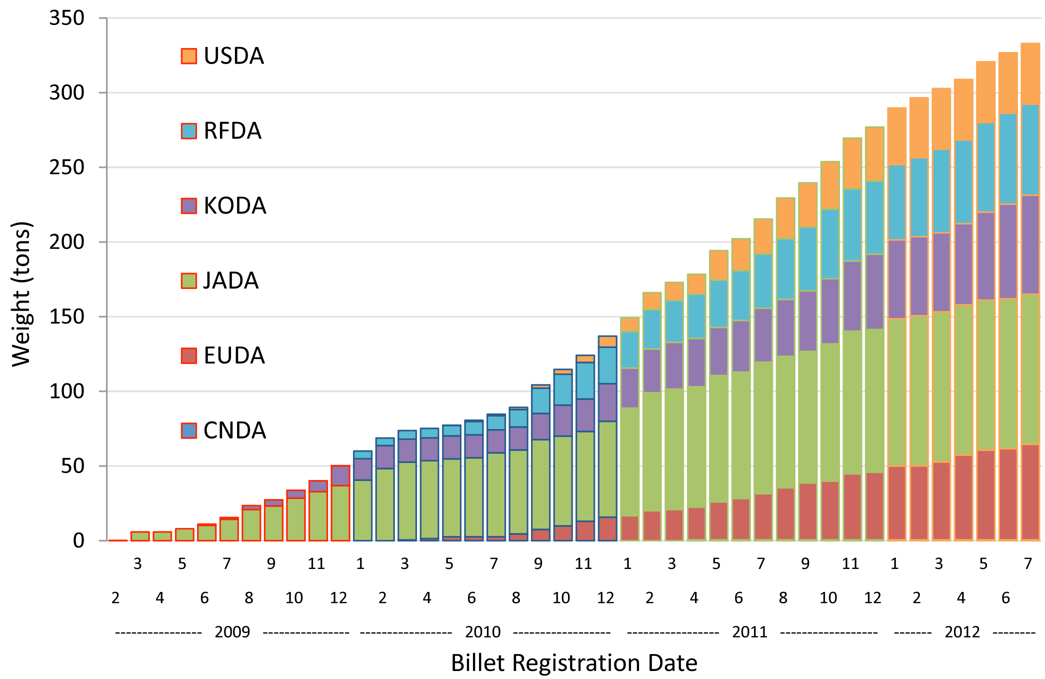
TF coils split into 3 main production areas

- **TF conductors**
  - **450t of Nb3Sn (Europe, Russia, Japan, Korea, China and USA)**
- **TF structures**
  - **4500t of high precision stainless steel forgings and plates, assembled by welding in Japan**
- **TF windings and coils**
  - **19 coils, 12T peak field, 20kV maximum voltage (Europe and Japan.)**

TF Superconducting Strand Procurement is Largest in History

- Over **70%** of required **450t of Nb_3Sn strand** has been produced around the world





TF Strand Production Summary

TF Conductor Production In Russia

RUSSIA

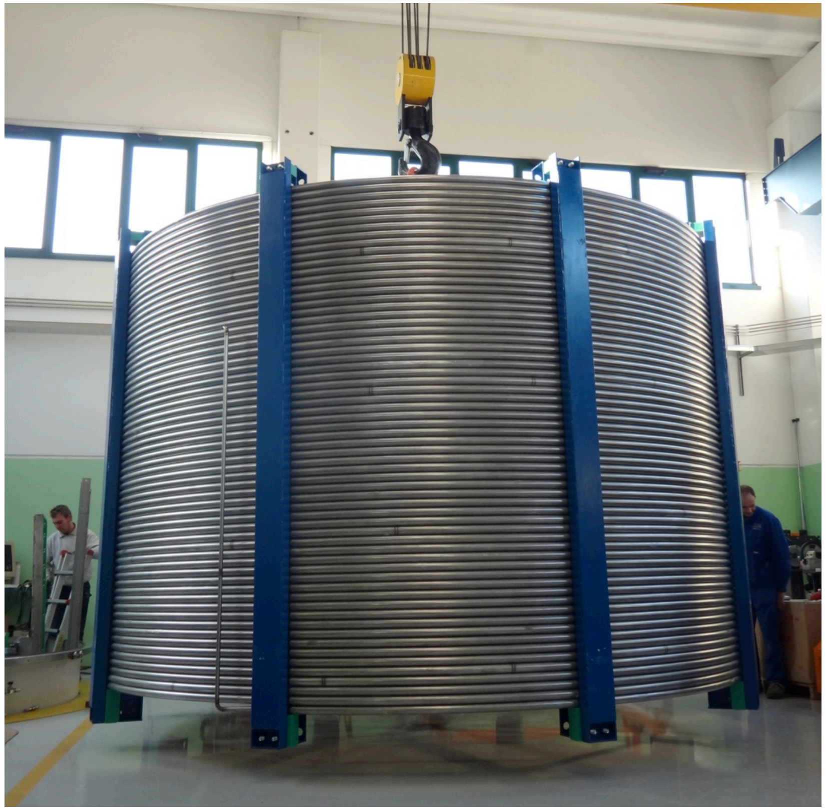
Cabling of 760 m Cu Dummy
at VNIIKP, RF (Feb. 09)

The jacketing installation at Moscow's JSC VNIIKP Research Center where 760 metres of toroidal field dummy conductor were successfully produced in 2011.

China and Korea Have Fabricated TF Dummy Conductor

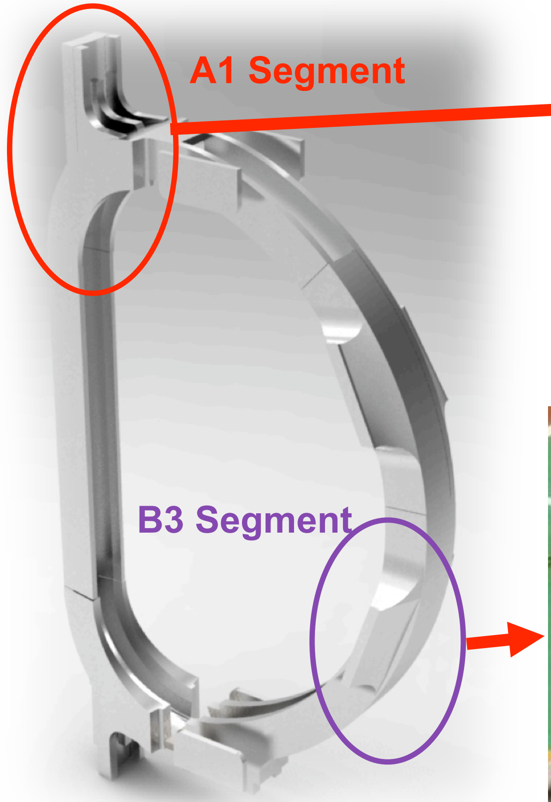
CN

KO

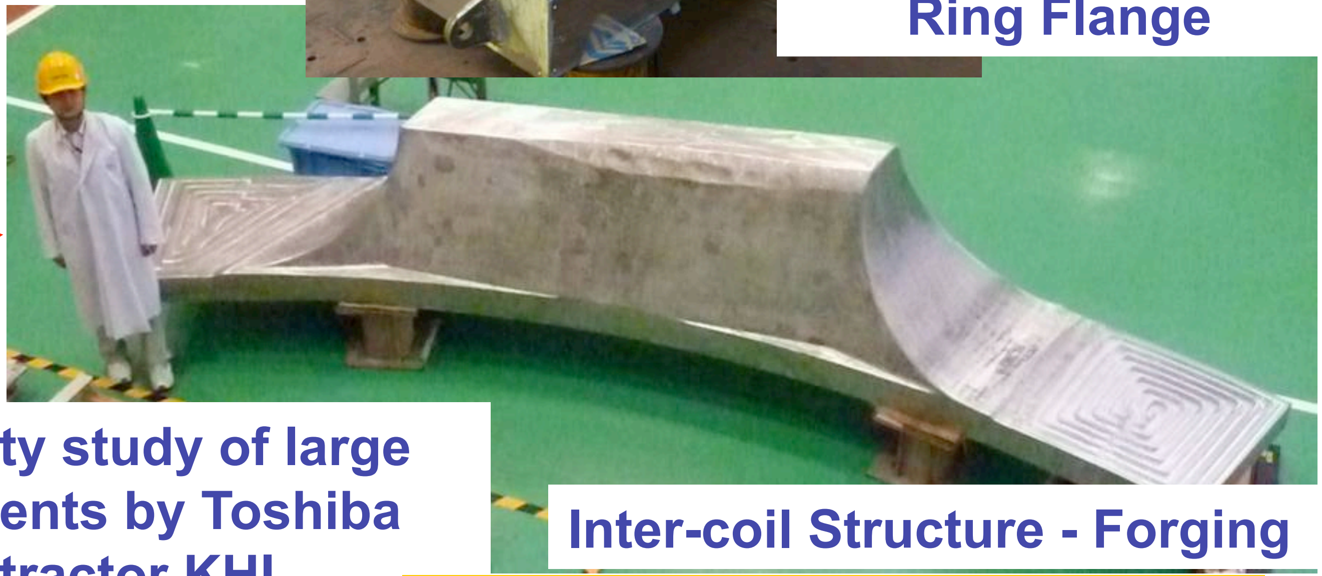


TF Coil Structures Progress – JADA

JA



Pre-compression Ring Flange



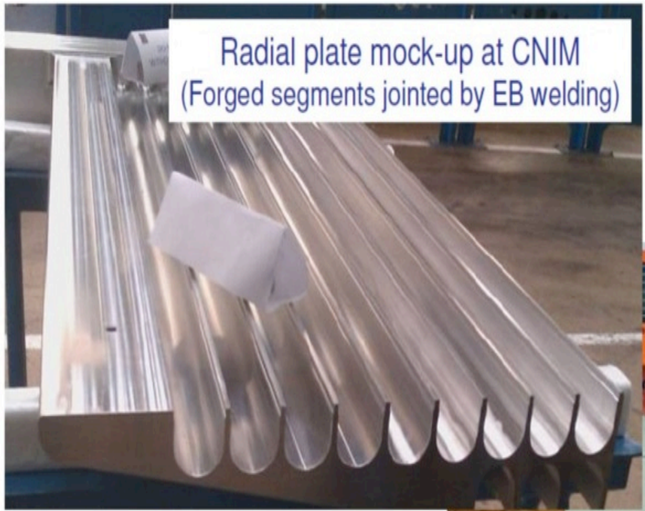
Inter-coil Structure - Forging

Manufacturability study of large TF coil components by Toshiba and its sub-contractor KHI

Pictures courtesy JAEA & Contractors Toshiba & KHI

EU

TF Coil Production in Europe



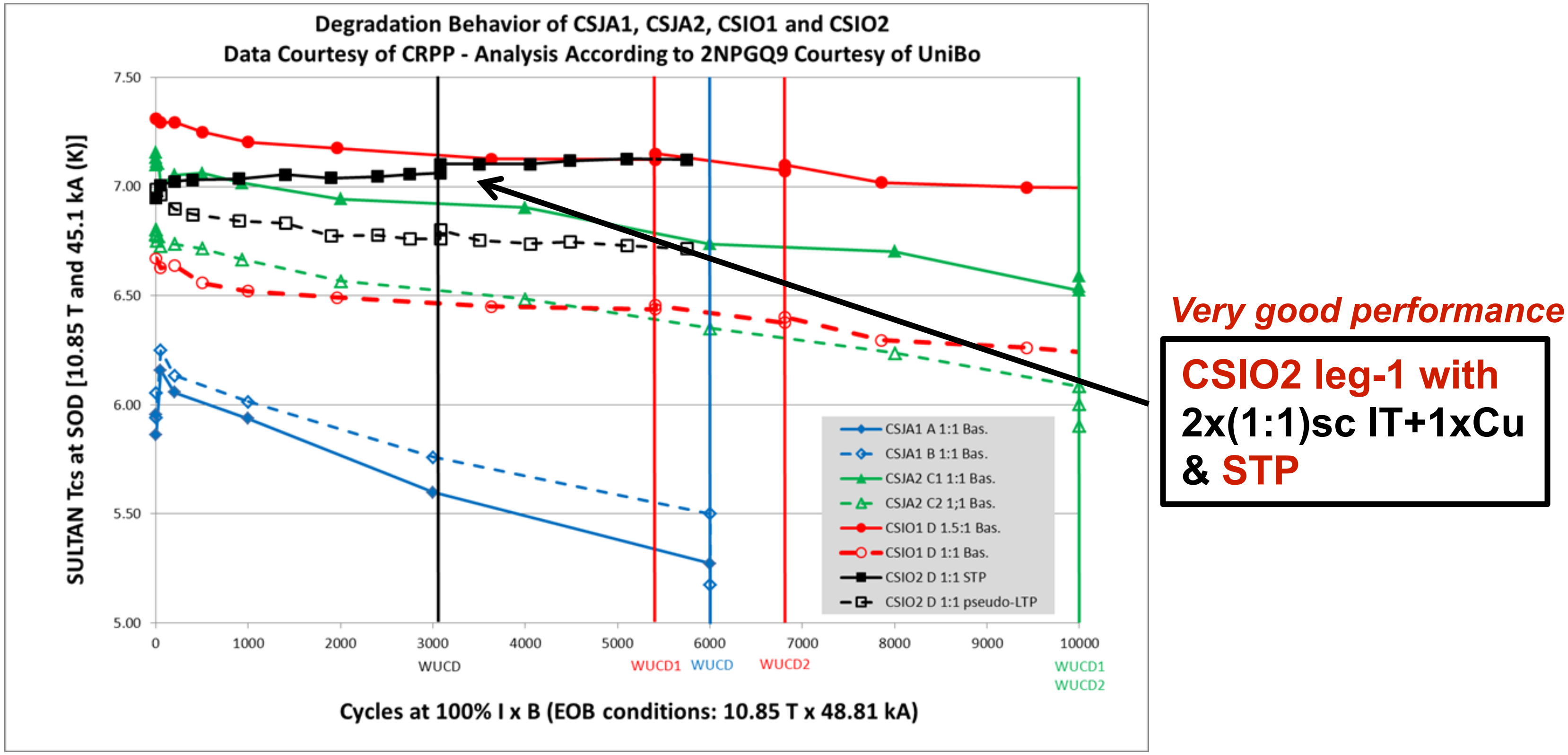
Radial plate mock-up at CNIM
(Forged segments jointed by EB welding)

Radial plate welding mock-up at SIMIC
(Powder hipped segments joined by narrow gap TIG welding)

Prototype radial plate at CNIM

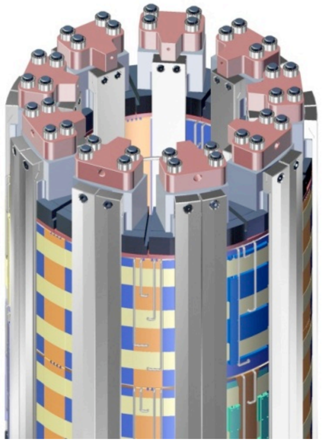
Double Pancake Winding Line
ASG La Spezia
Commissioned May 2012

CS Conductor Meeting ITER Specifications Has Been Qualified

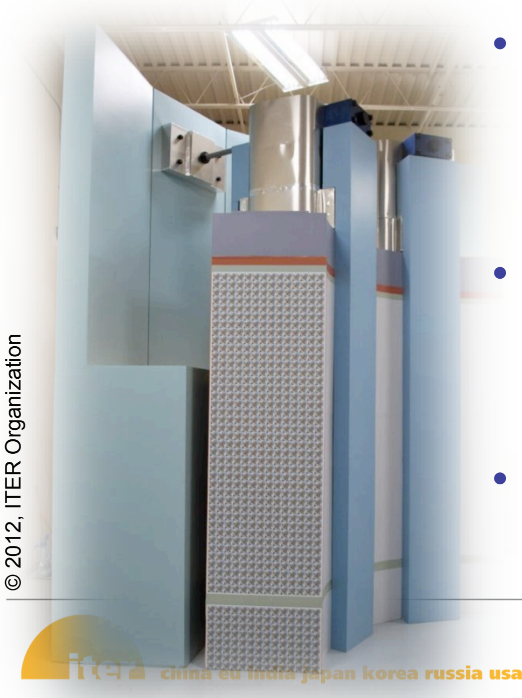


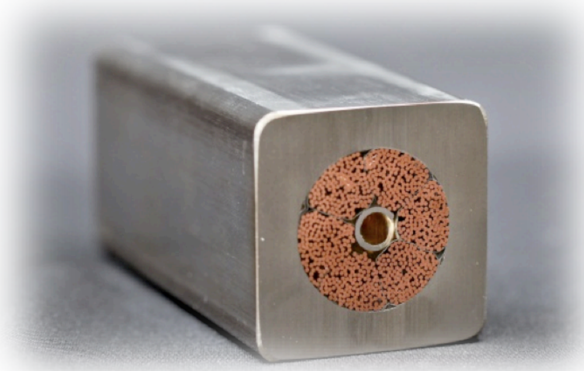
- Testing of additional conductors will be conducted this year to select the vendor

Progress and Plans Central Solenoid



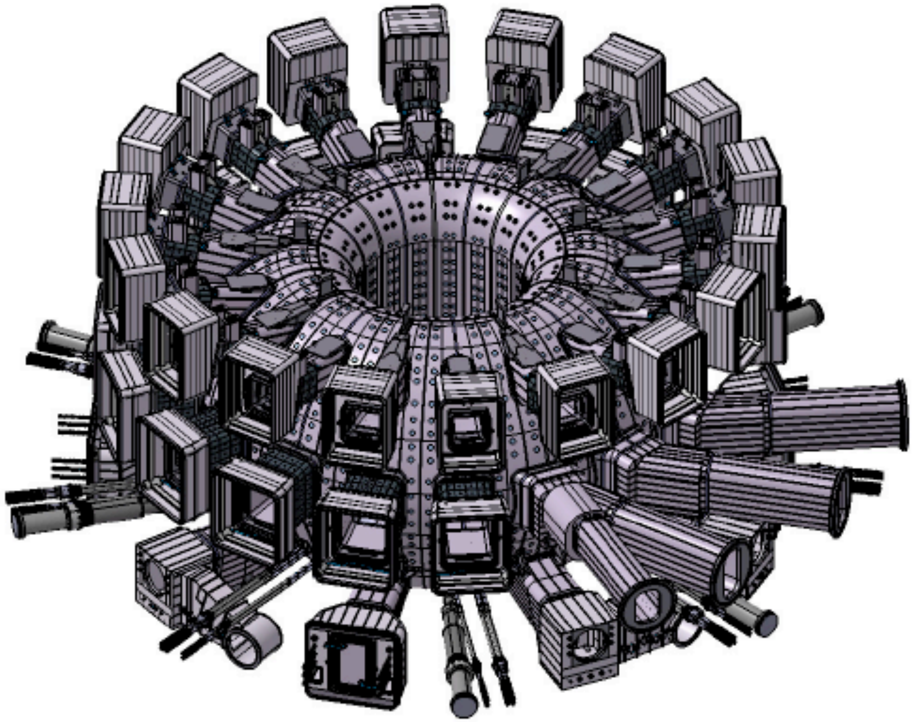
- Contract placed for module fabrication with General Atomics (July 2011)
- Successful Preliminary Design Review (September 2011)
- Manufacturing input to structures design is being provided by industry
- Assembly tooling on track for Preliminary Design Review (September 2012)
- Technical and schedule issues are being addressed

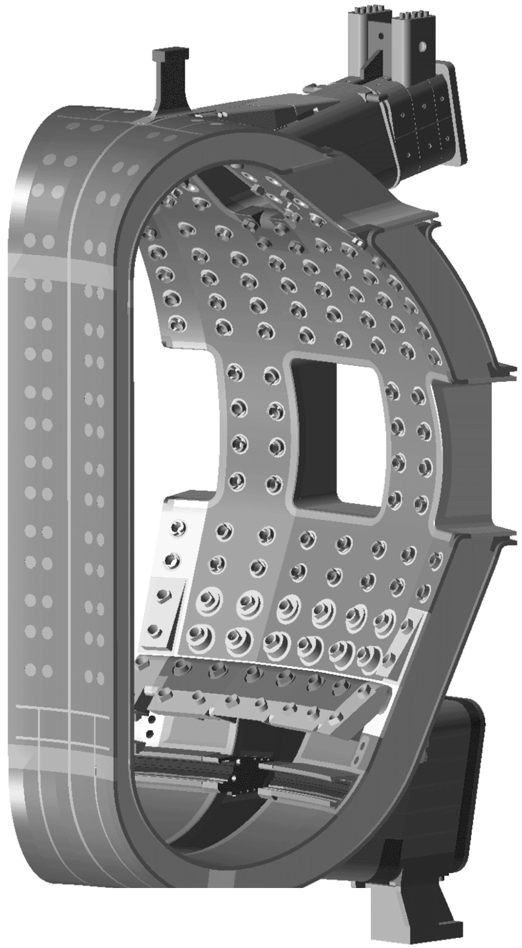




Vacuum Vessel Status

EU, KO, IN, RF



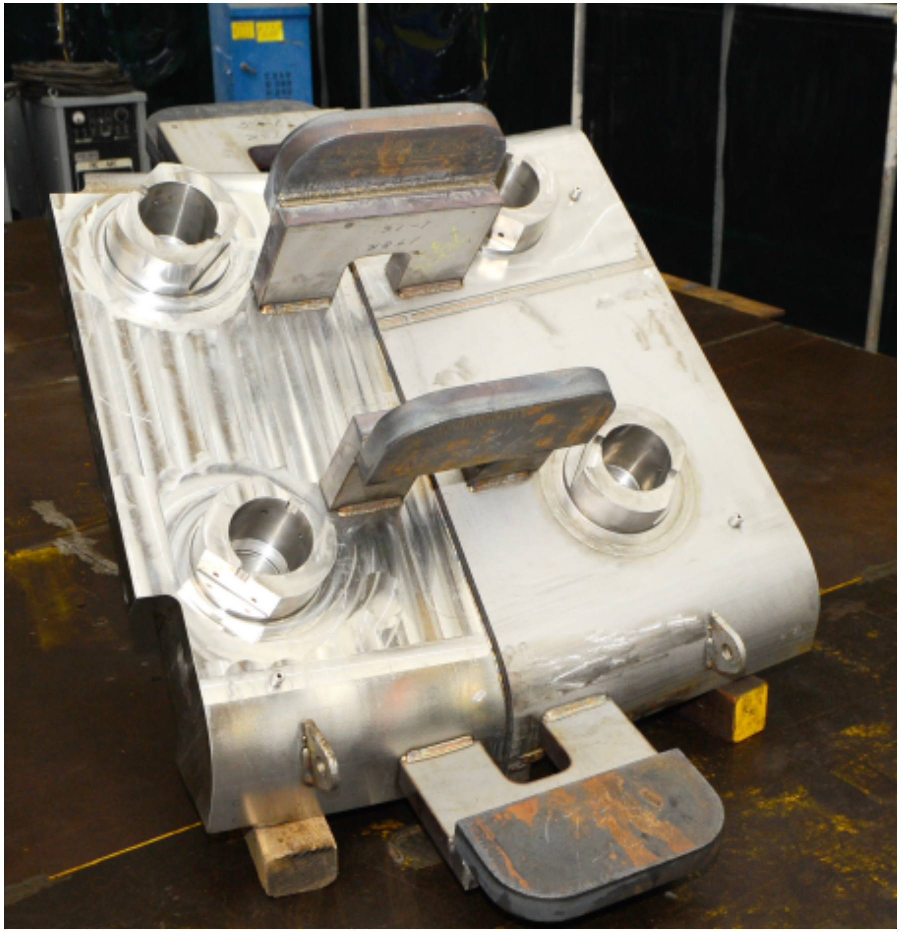


- **Vacuum Vessel is double-walled stainless steel**
  - 19.4m outer diameter, 11.3m height, 5300 tonnes
  - provides primary tritium confinement barrier
- **VV sector and port PAs signed (EU, KO, IN, & RF)**
- **EU- VV awarded to AMW (Ansaldo Nucleare S.p.A, Mangiarotti S.p.A and Walter Tosto S.p.A)**
- **KO - VV & port contract awarded to Hyundai Heavy Industries**

KO

Extensive Use of Mock-ups to Verify Manufacturing Design and Fabrication Methods

Inboard Segment Mock-up



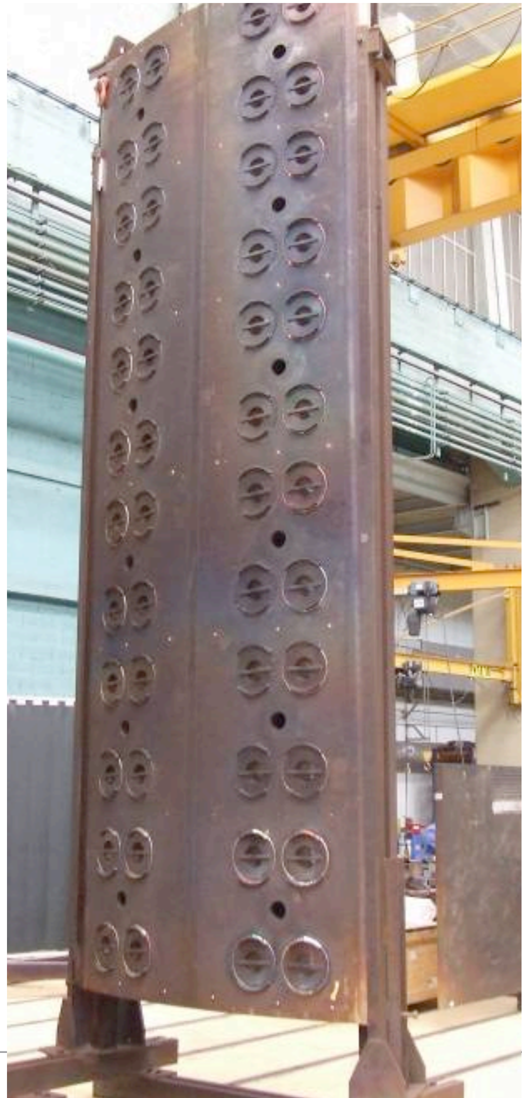
Triangular Support Mock-up

KO

Mock-Up of Upper Segment

EU

EU Fabricated an Inboard Segment Mock-up.



- **EB welding successfully demonstrated**

Operational Instrumentation Will Be Used to Increase and Define Operational Envelope

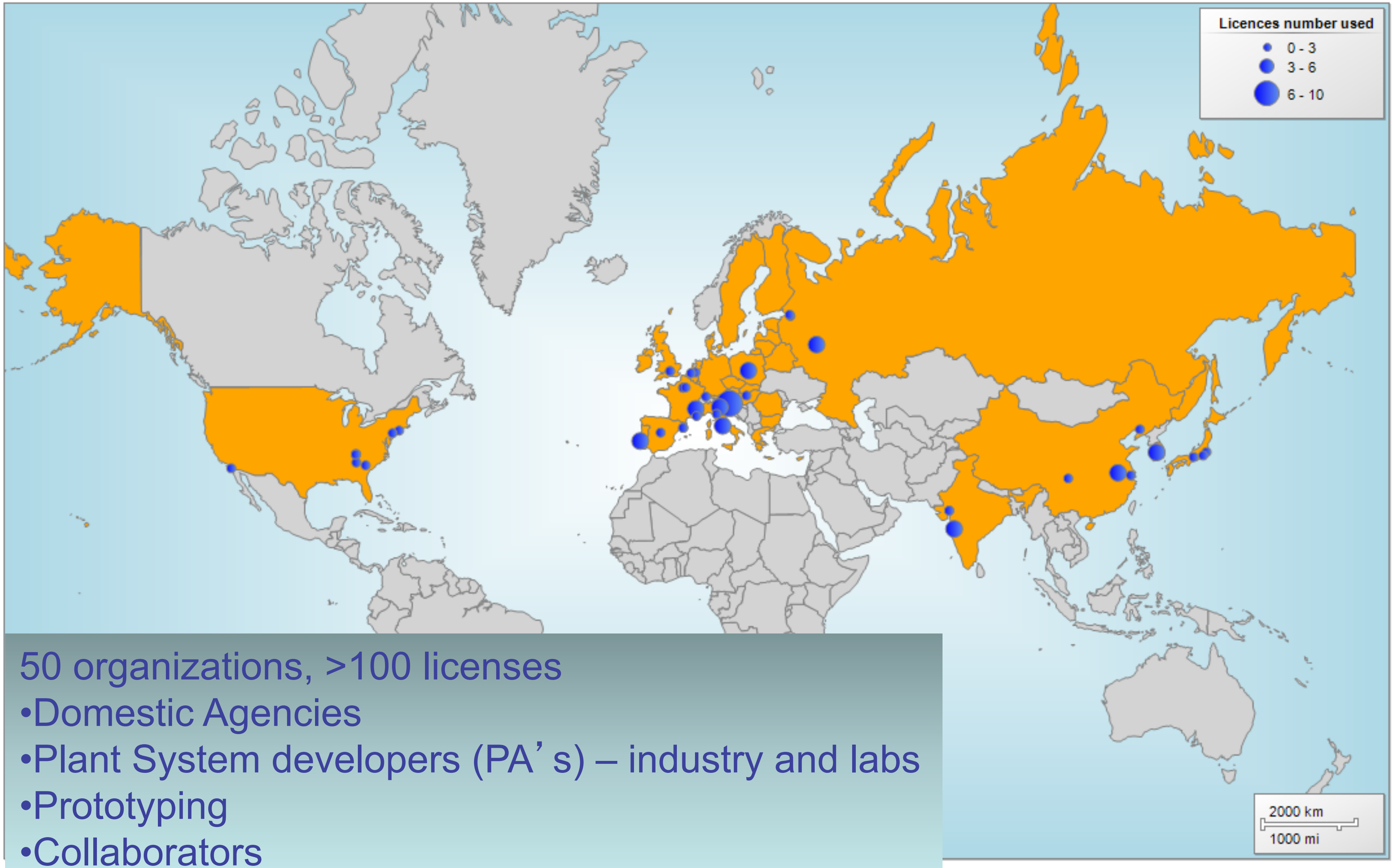
- **Current understanding of disruption loads** will be extended by experience on ITER based on detailed measurements to evaluate the operating space.

- **This is foreseen in the licensing application.**

- **Operational Instrumentation will include:**
  - Electromagnetic Monitoring System (EMS)
  - Mechanical Monitoring System (MMS)
  - Temperature Monitoring System (TMS)

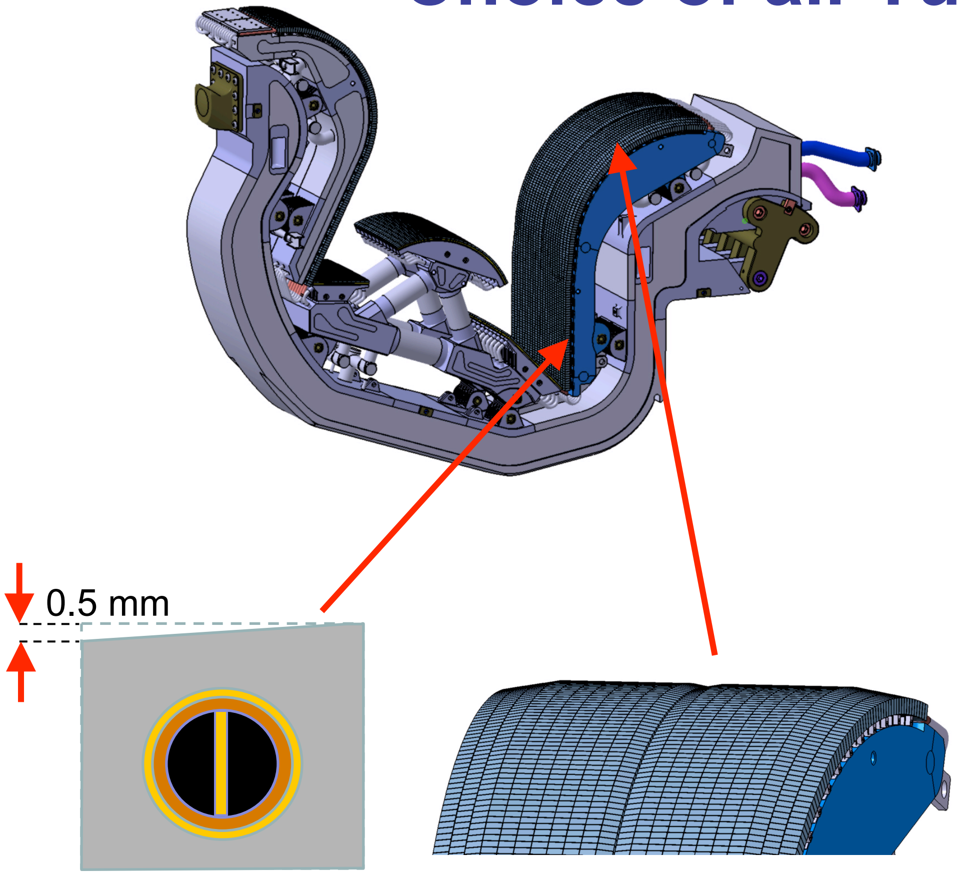
- **Combined with numerical modeling**

Registered User Organizations of CODAC Core System (July 2012)



50 organizations, >100 licenses
- Domestic Agencies
- Plant System developers (PA's) – industry and labs
- Prototyping
- Collaborators

Choice of 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 phases and:

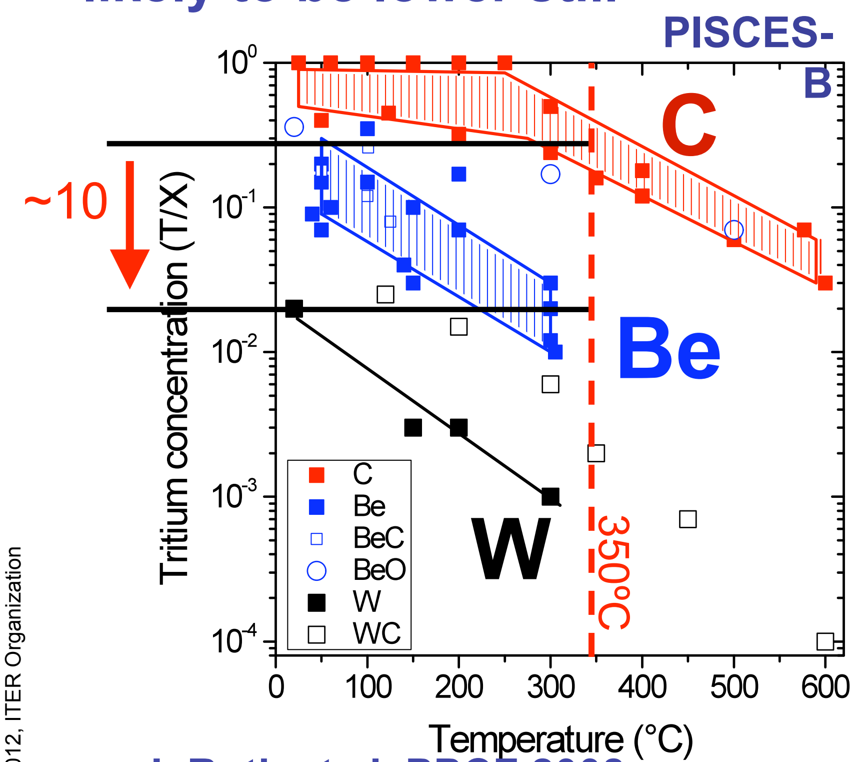
- Development of reliable and effective disruption mitigation very early on

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

R A Pitts et al, PSI-20, May 2012

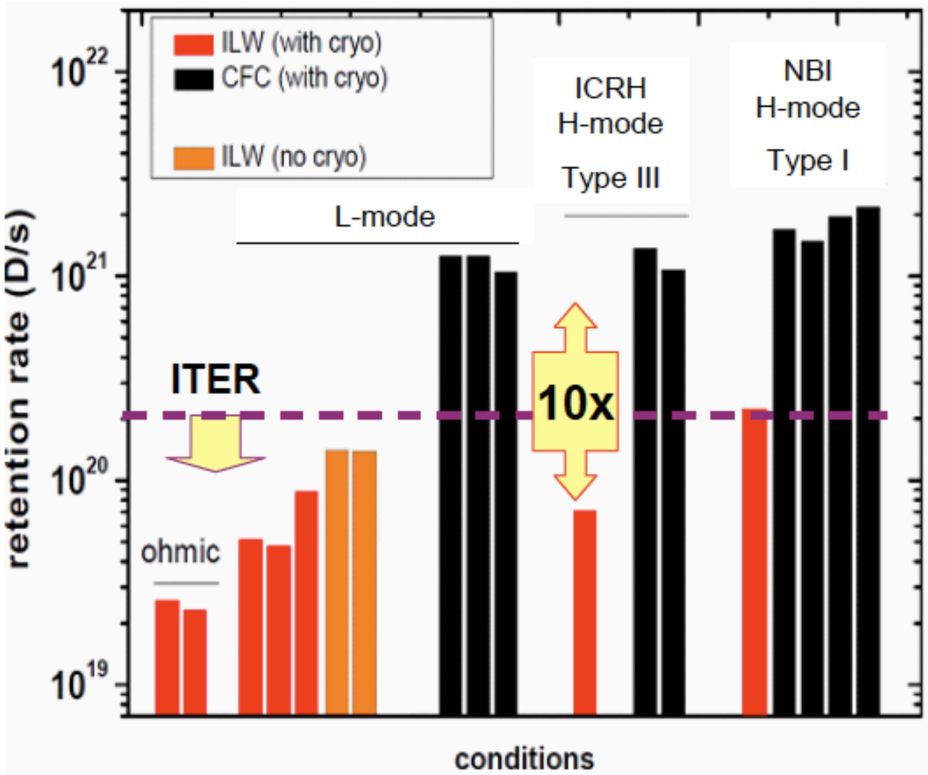
Low fuel Retention Results from JET ITER-like Wall are Very Encouraging for ITER

- Initial results indicate reduction by at least a factor of ~10 compared with carbon PFCs → in agreement with laboratory studies
- True long term retention value likely to be lower still



J. Roth et al. PPCF 2008

JET C-wall & ILW

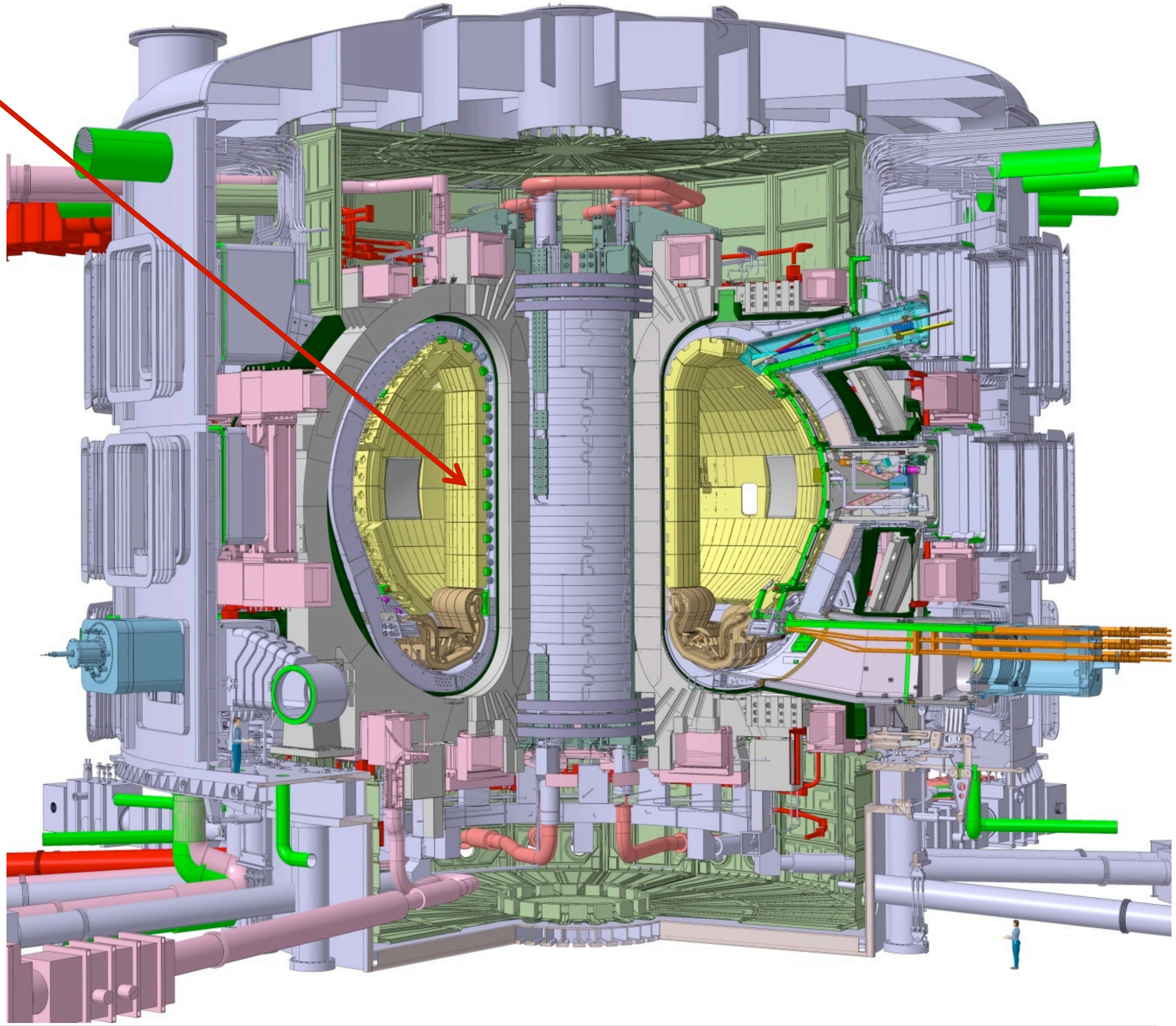


T. Loarer et al, PSI-20, May 2012

Blanket System Functions

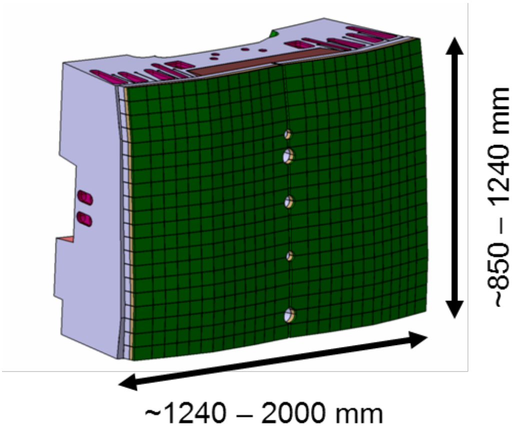
Main functions of ITER Blanket System:

- 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.

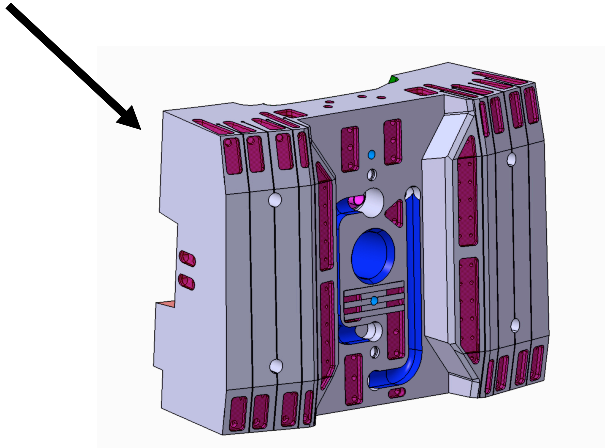


Blanket Shield Module and First Wall Panels Have Been Redesigned for Remote Maintenance

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



Shield Module

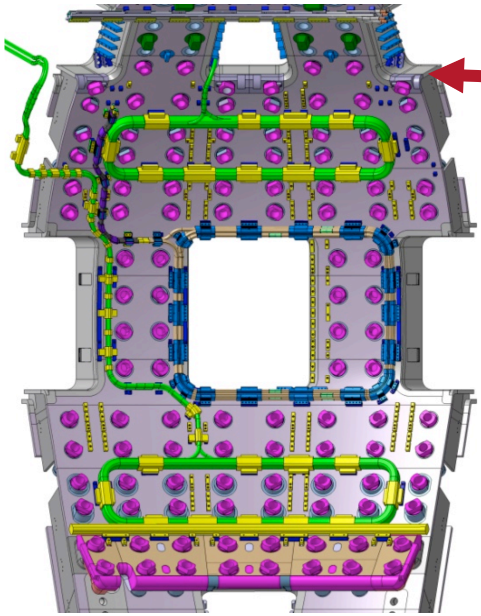
Technical Challenges:
- Large electromagnetic loads
- High heat flux ~ 5 MW/m^2
- Material bonding techniques
- Plasma-material interactions
- Integration with in-vessel coils, diagnostics and blanket manifold.
- Remote handling requirements

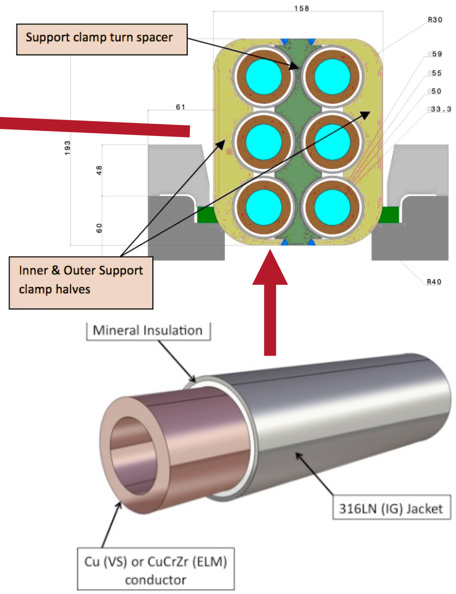
For more information see talks by Sawan, Kotulski and Ying.

US

CN

In-Vessel Coils for Vertical Stability and ELM Control Are Very Challenging





Conductor

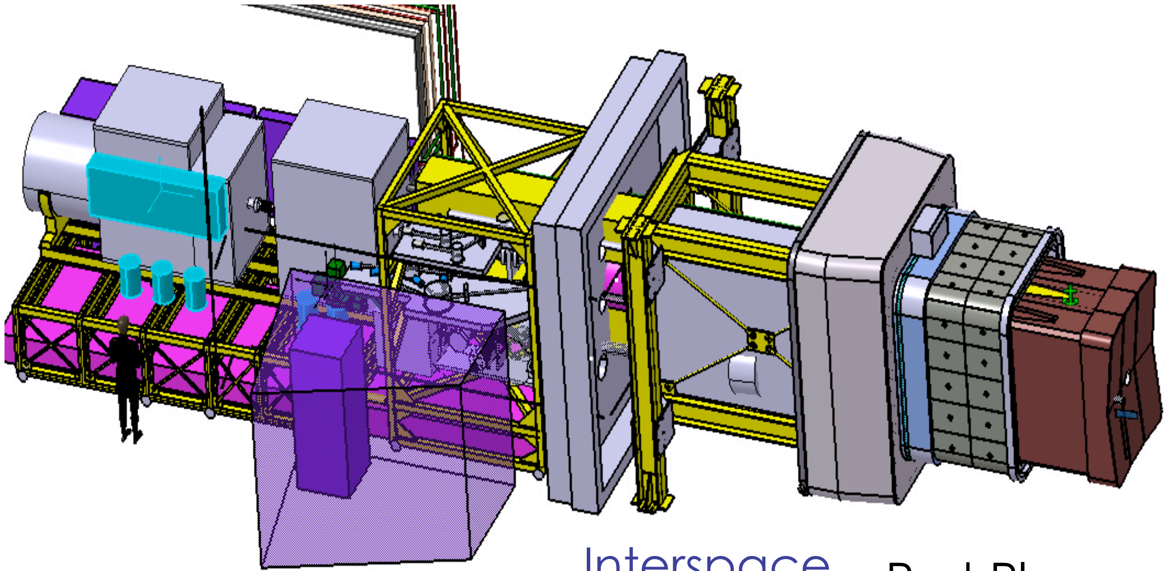
Conductor Production, Bending and Forming

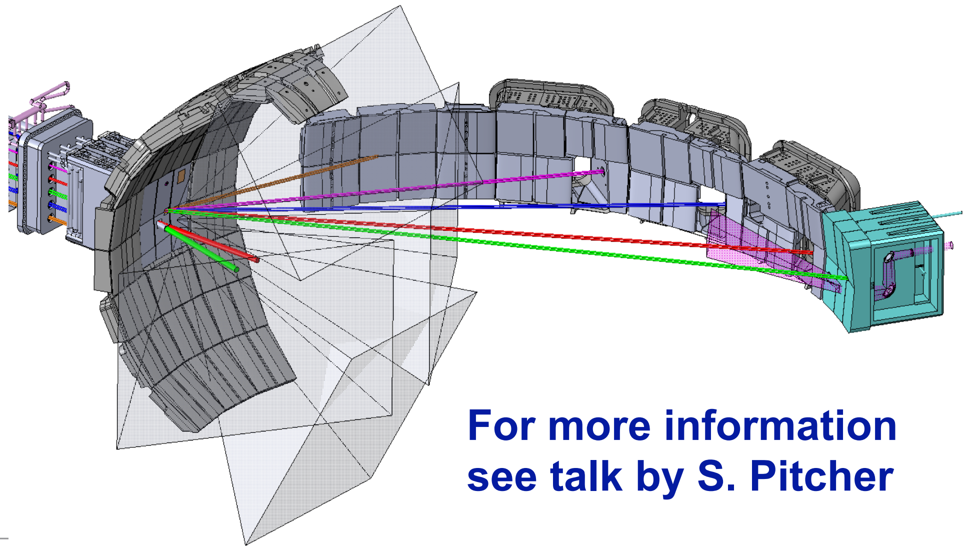
Technical Challenges:

- High currents in neutron environment (~60 kA @ 2.3 kV)
- Scale up of conductor (26 to 59 mm diameter)
- Very encouraging results from R&D program
  - Prototype coils will be developed in 2013.
  - Final Design in 2013

For more information see talk by E. Daly

Diagnostic Design in Port Plug is Underway





Port Plug 9 incorporates:

- TIP, VIR, and ECE
- Detailed optical layout is being performed

For more information see talk by S. Pitcher

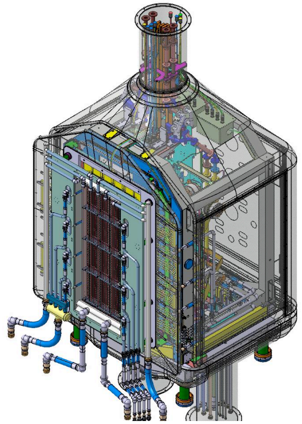
NNBI Prototype and R&D is Underway

Mission of SPIDER:

Develop the plasma source which operates at the ITER specifications

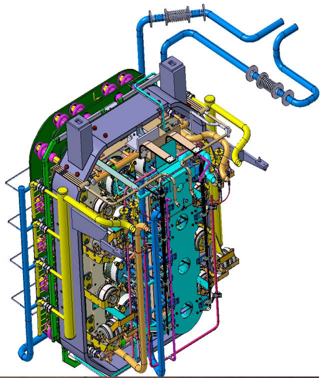
Beam Source:

Contract for the beam source and the vacuum vessel is at contract signature stage



EU

IN

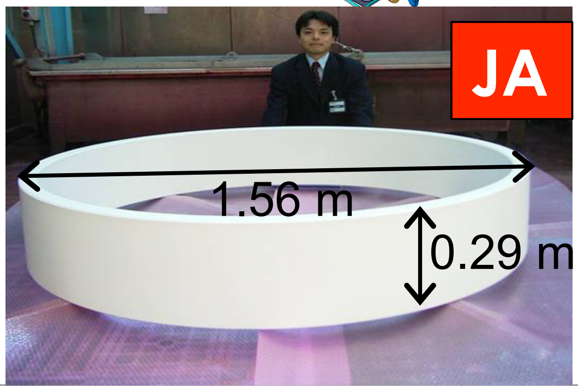


DNB will enter the manufacturing phase with the CfT of the Beam source.

This component will be tested at the (Indian test facility)

A full-size mock-up bushing has been manufactured

Voltage holding of -240 kV for 1 h has been demonstrated in the single-stage full-size mock-up bushing and 370kV over a two-stage mock-up.

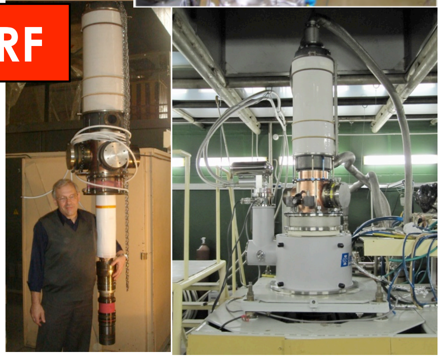


Components for Electron Cyclotron H&CD System are Under Development

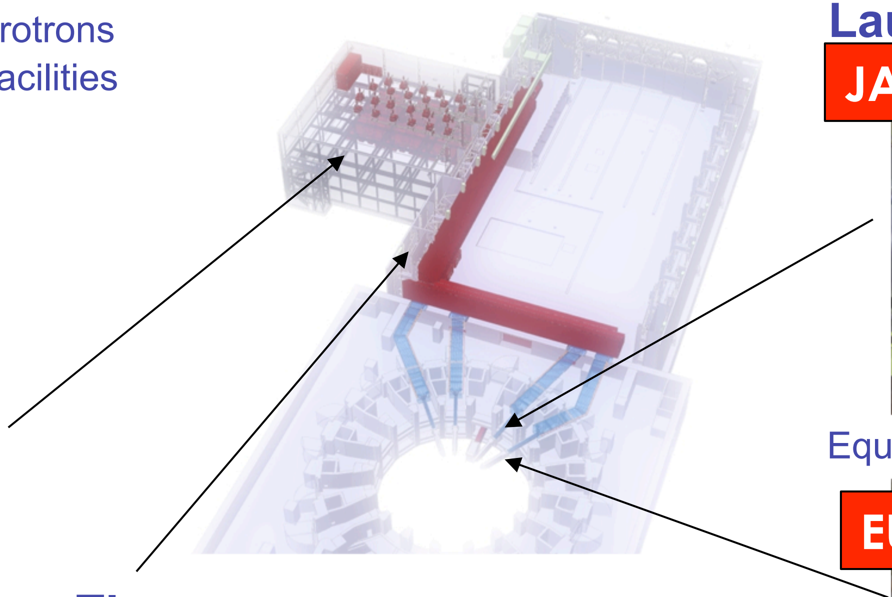
Sources: JA and RF Gyrotrons and their Test Facilities

JA

RF

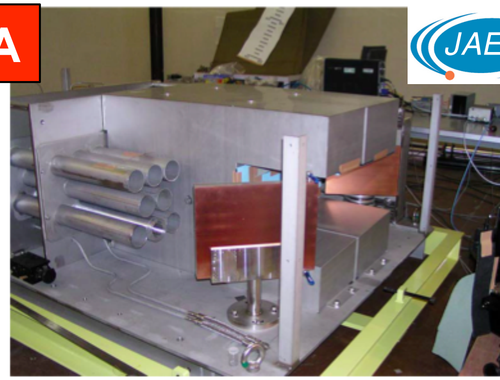


IAP RAS GYCOM INF



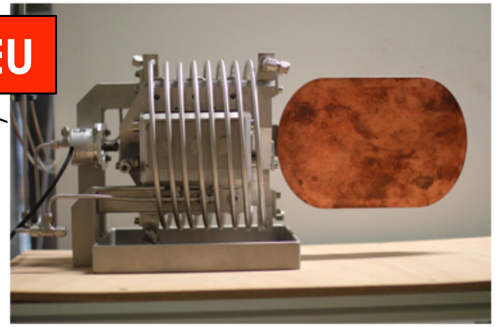
Launchers: JA and EU Tests

JA



Equatorial Launcher High Power tests

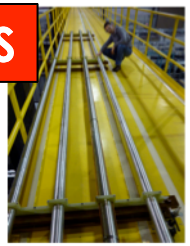
EU



Friction-free Stering Mechanism

TL: Tests at USIPO and JAEA test Facilities

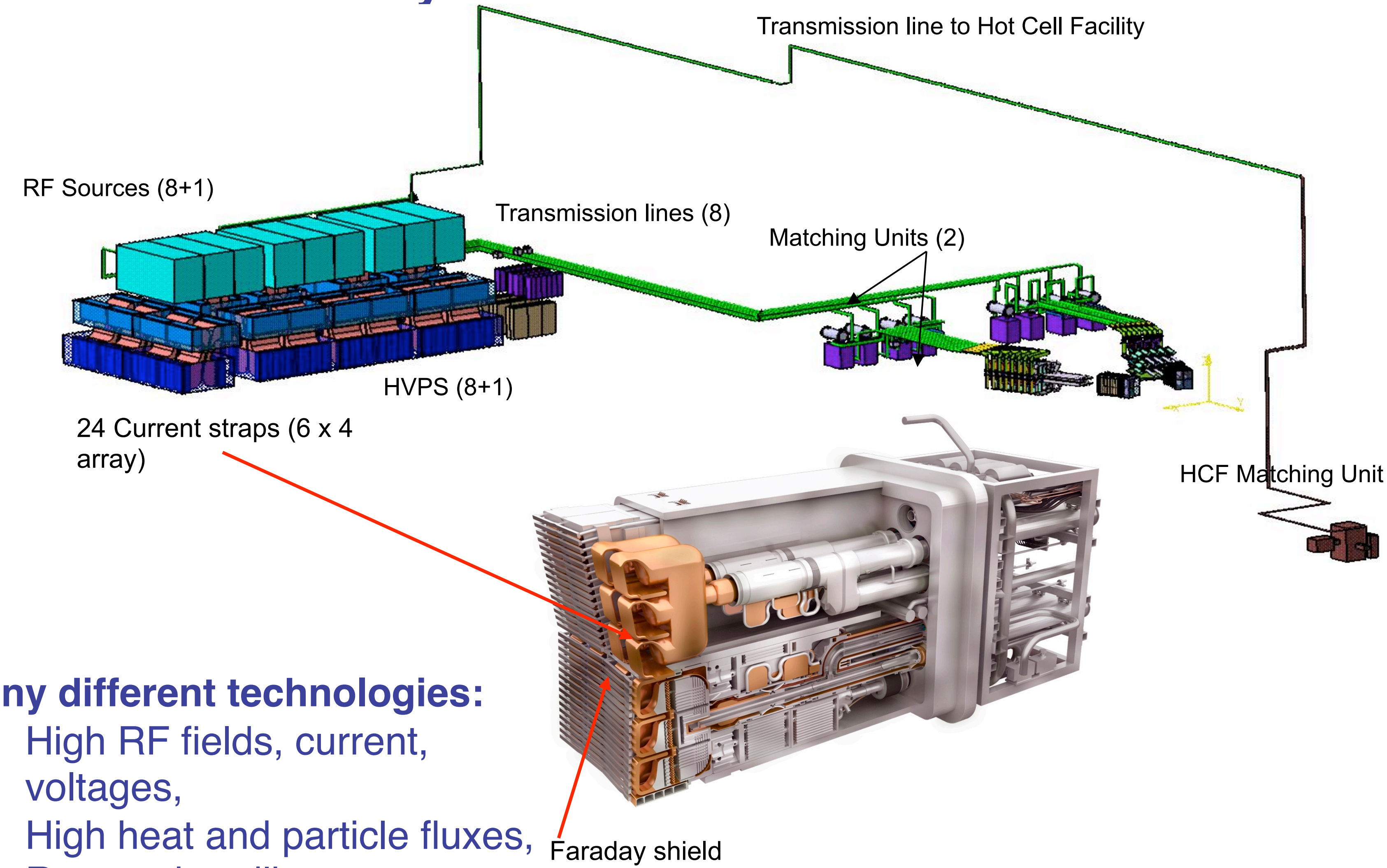
US



JA

- **HV power supplies (55kV, 100A) and (50kV, <1A) (EU, IN)**
- **Microwave Sources (1MW, 170GHz) (EU, IN, JA, RF)**
- **Evacuated waveguide components (US, EU)**
- **Launching Antennas (EU, JA)**
- **Control systems (JA, EU, RF, IN, US)**

ITER will Evaluate the Compatibility of Ion Cyclotron H&CD System in a Nuclear Environment



Many different technologies:

High RF fields, current, voltages,
High heat and particle fluxes,
Remote handling

ITER Will Contribute to Tritium Breeding

- **In Equatorial Port # 16: the Helium Cooled Lithium Lead (HCLL) TBM and the Helium Cooled Pebble Bed (HCPB) TBM.**
  - The HCLL TBM uses the liquid metal LiPb as Tritium breeder and neutron multiplier and Helium as coolant.
  - The HCPB TBM uses a Lithiated Ceramic as Tritium breeder, Beryllium as neutron multiplier, and Helium as coolant.

- **In Equatorial Port #18: the Water Cooled Ceramic Breeder (WCCB) TBM and the Helium Cooled Ceramic Reflector (HCCR) TBM**.
  - The WCSB TBM uses a Lithiated Ceramic as Tritium breeder, Beryllium as neutron multiplier, and pressurized water as coolant.
  - The HCCR TBM uses a Lithiated Ceramic as a Tritium breeder, with (SiC coated) Graphite "neutron reflector" pebbles to reduce the volume of Beryllium required for neutron multiplication, and Helium as coolant. .

- **In Equatorial Port # 2: the Helium Cooled Ceramic Breeder (HCCB) TBM and the Lithium Lead Ceramic Breeder (LLCB) TBM.**
  - The HCSB TBM uses a Lithiated Ceramic as Tritium breeder, Beryllium as neutron multiplier, and Helium as coolant.
  - The LLCB TBM uses the liquid metal LiPb as Tritium breeder, neutron multiplier and also as coolant for the breeder region. Helium is used to cool the structures and a Lithiated Ceramic is used as an additional breeder.

ITER Licensing Process Is Proceeding

- **In December 2010, the ITER safety files were formally accepted by the French Authorities**, which allows the process of technical evaluation by the Nuclear Safety Regulator (ASN) to be launched as well as the public evaluation of the files organized by the local authorities.

- Public Enquiry was carried out in the period June – August 2011.

  – **A positive recommendation on the ITER Project was received on 19 September from the Inquiry Commission.**

- **Two final meetings of the “Groupe Permanent**,” a formal group of independent experts (standing group) to analyze the safety of Nuclear Installations undergoing a licensing process by ASN, took place on 30 November and 7 December 2011

- In conclusion, the standing group believes that the measures described by the IO in their request for authorization to establish the ITER facility are satisfactory on the whole, **and therefore gives its approval for its construction;**

For more information see talk by N. Taylor

ITER Will Address Key Technology Issues for Tokamak Demo

- **The large size and unique requirements of ITER have presented many technical challenges for the design and manufacturing**

- **ITER designs, R&D, and manufacturing mock-ups are addressing these challenges**

- **ITER will develop key components necessary for the development of fusion.**
  - ***We are learning a great deal from ITER!***