Status of ITER Project

24th IAEA Fusion Energy Conference

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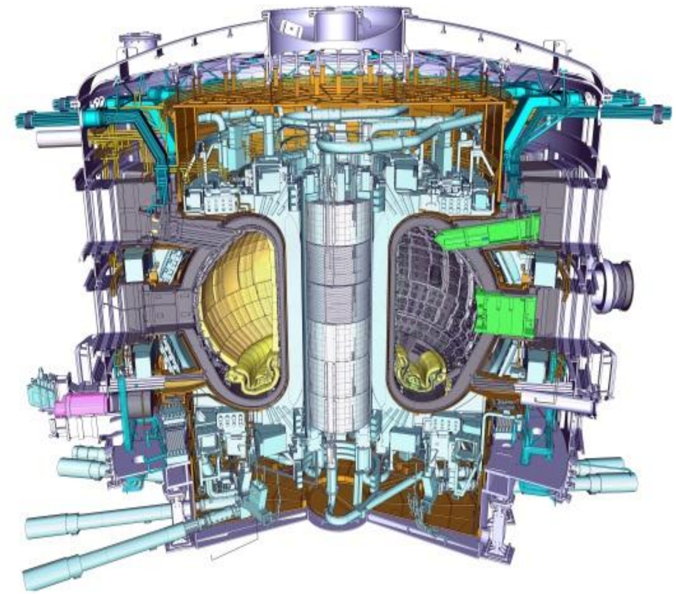
Introduction

- The 24th Fusion Energy conference marks the 5th anniversary of the establishment of the ITER Project;
- Over the last two years, the ITER project has made the transition from building up the infrastructure of IO and 7 DAs;
- Design completion is leading a real construction of in-kind components;
- Our aim and responsibility are to show the progress of ITER construction keeping the project risk for ITER scope, cost, and schedule to an acceptable level.
- A new IO management structure was introduced in 2010;
- Decision making processes were streamlined and procedures simplified;
- Establish several new communication channels with 7 DAs;
- Faster decision making and a better performance of the combined Unique ITER Team (IO + DAs);

Contents to Report you

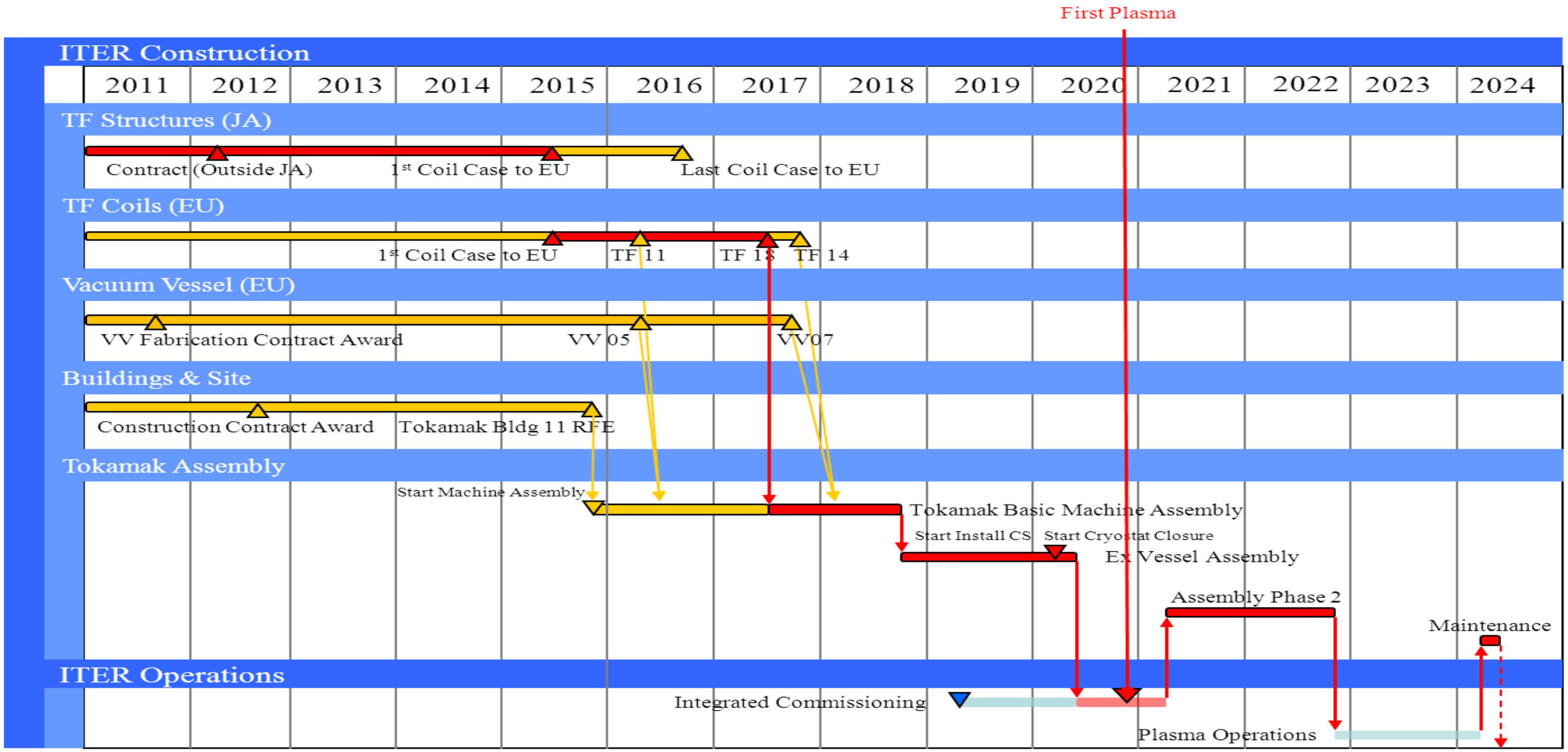
- Introduction/General ITER Project Status
- Schedule Structure and Management
- ITER Research Plan and Physics Operations
  - Disruption Mitigation/ELM Mitigation
- The Key Technical Challenges
  - Vacuum Vessel/Cryostat/Coils/In-Vessel Components
- Site Construction and Logistics
- Summary



R=6.2 m, a=2.0 m, I_p=15 MA, B_T=5.3 T, 23,000 tons

Schedule
ITER Level 0 Reference Schedule

- Machine completion and First Plasma November 2020
- D-T Operation 2027
- Level 0 Reference Schedule within Baseline Boundaries



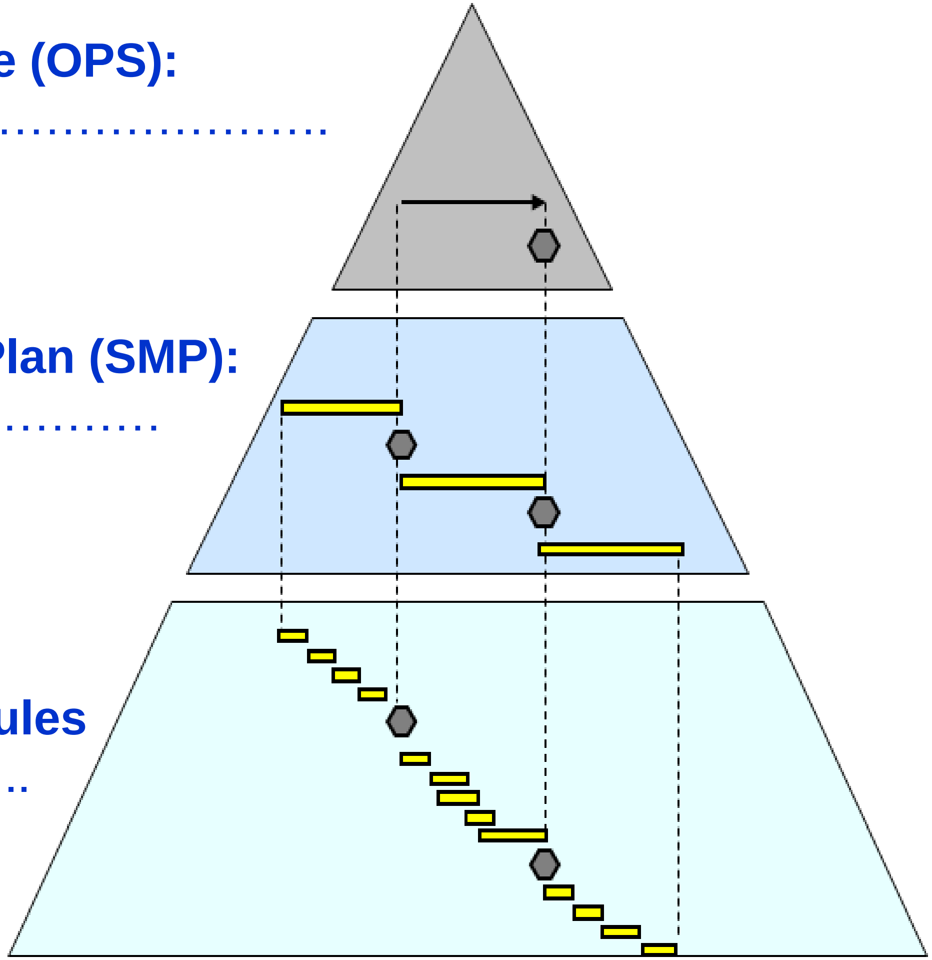
Achievement of Schedule Structure and Management

Completion of DWS

Level 0 Overall Project Schedule (OPS):
~ 50 Activities……………..……………………………

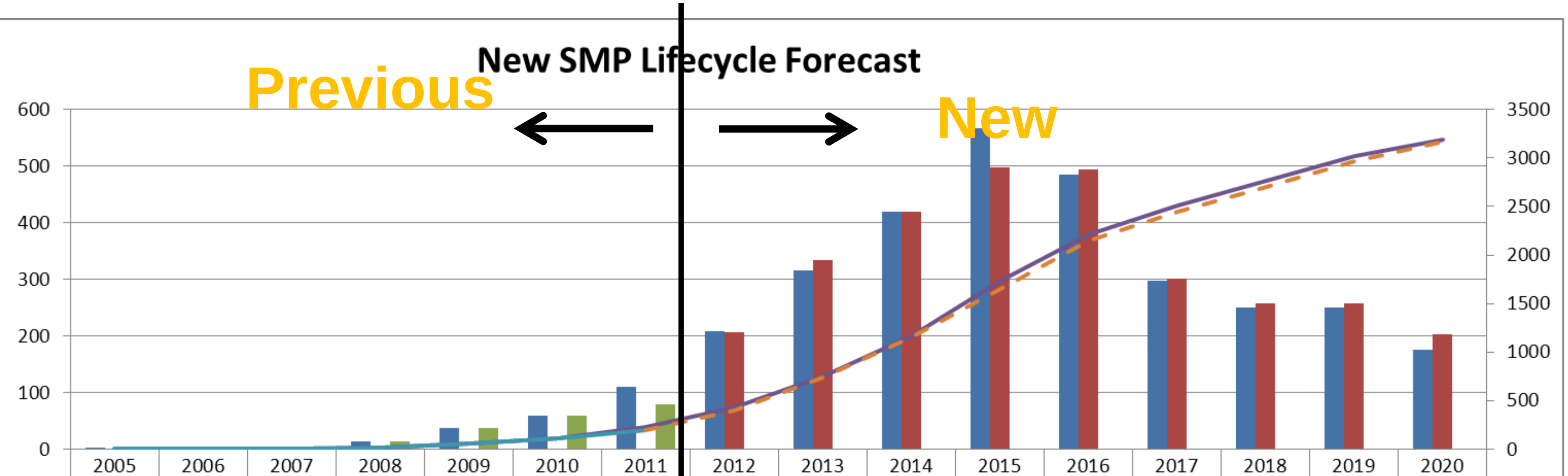
Level 1 Strategic Management Plan (SMP):
~ 3000 Activities ……………………………

Level 2 Detailed Working Schedules (DWS): ~ 150k Activities……………..
(Including IO and DAs)



DWS has been completed on 28th June and reviewed
Milestones are monitored and become controlled.

New SMP Lifecycle Forecast



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Reference	1		2	13	38	60	110	208	315	419	566	484	298	251	251	175
Forecast								207	333	420	497	494	301	258	258	202
Achieved	1		2	13	38	60	79									
Cum Ref	1	1	3	16	54	114	224	432	747	1166	1732	2216	2514	2765	3016	3191
Cum Achieved	1	1	3	16	54	114	193									
Cum Forecast							193	400	733	1153	1650	2144	2445	2703	2961	3163

- Using the new SMP post 2012

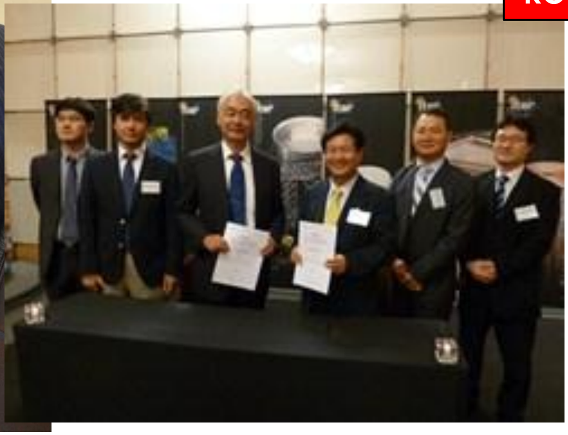
Procurement Arrangements (PA) are important milestones

- **Total number of signed PA is now 80 out of a total of 137**
- **The achieved value to date is 2338.86109 kIUA out of a total In-Kind project value of 2880.52391 kIUA; 81.2 % of value achieved**

UA

CN

KO

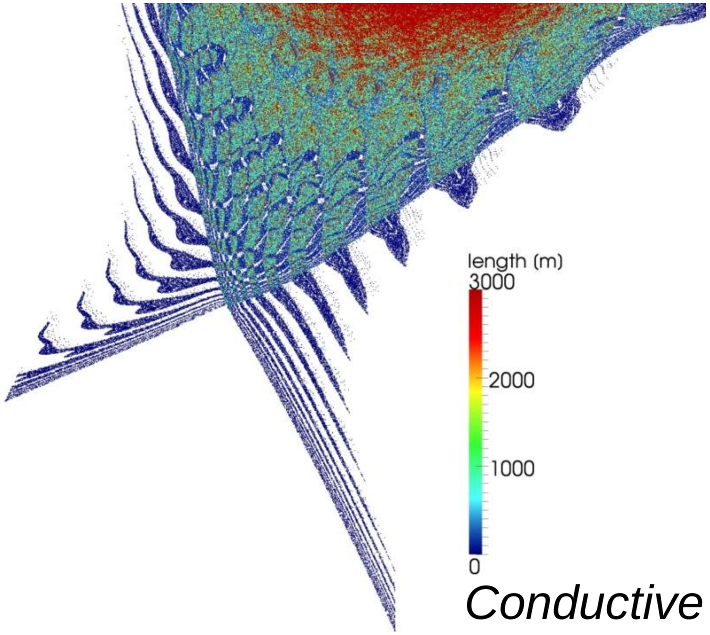


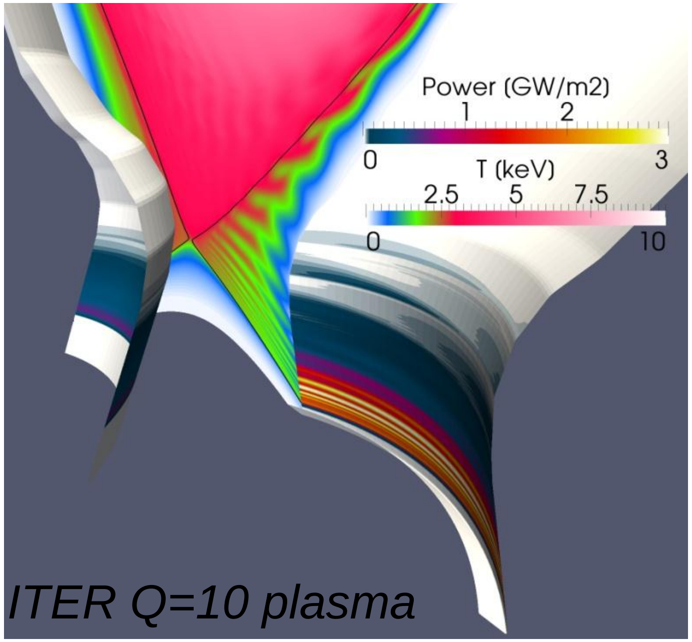
Challenges of Plasma Physics

- Significant progress in modelling of physics processes underlying ELMs and ELM control
- Disruption Mitigation System Conceptual Design
- Full revision of predicted heat loads on PFCs in support of First Wall and Tungsten Divertor design
- Conceptual design of Plasma Control System moving towards completion
- Extensive experimental and modelling R&D continuing in support of development of ITER disruption/ runaway electron mitigation systems

Non-linear Simulation of ELM Energy Deposition

- **ELM simulations in ITER Q=10 plasma scenario (JOREK code)**
- **Conductive ELMs :**
  - large magnetic perturbation leads to ergodic edge with homoclinic tangles
  - parallel conduction on perturbed magnetic field lines
  - broadening of energy deposition scales with magnetic perturbation
- **Convective ELMs:**
  - filament formation, energy density losses in parallel direction
  - broadening energy deposition due to radial distance travelled relative to parallel transport





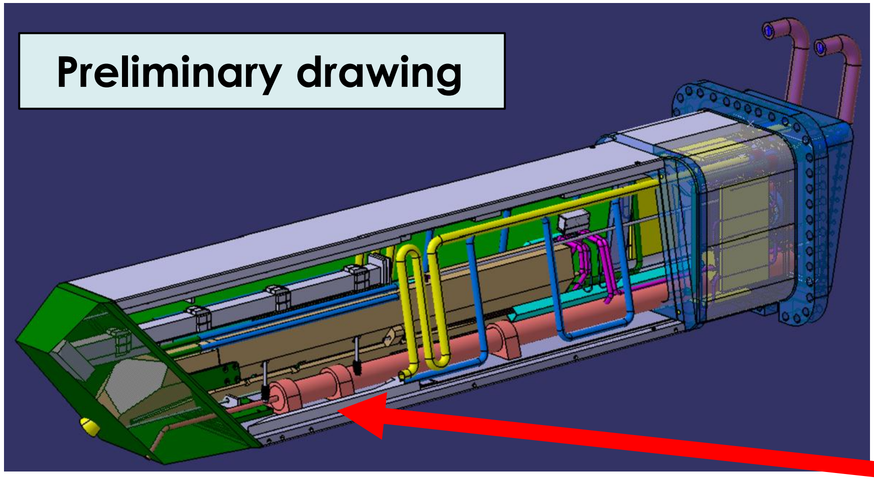
Conductive ELM in ITER Q=10 plasma

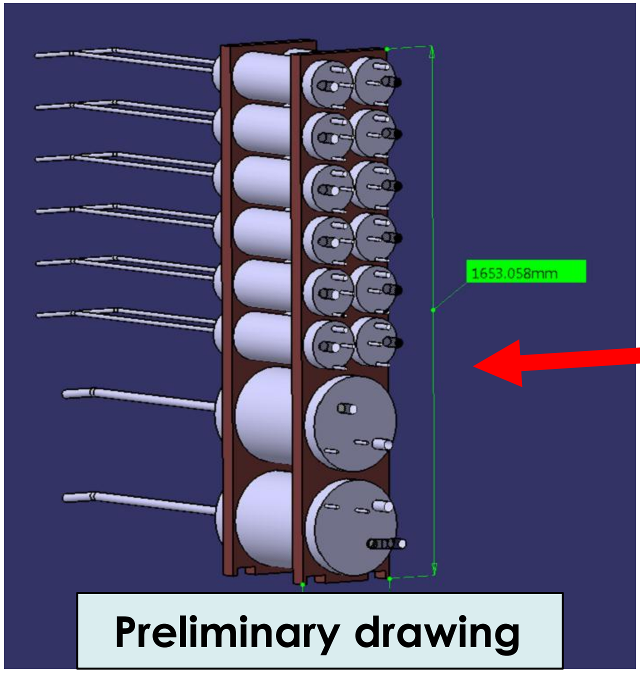
Disruption Mitigation System Conceptual Design

- Disruption Mitigation System is expected to consist of two subsystems:
  - subsystem for mitigation of energy loads on the plasma facing components during Thermal Quenches of plasma disruption (and reduction of electromagnetic forces during Current Quench)
  - subsystem for runaway electron (RE) suppression
- Several candidates are under consideration:
  - Massive Gas Injection with fast valves or cartridges (Ne, Ar, D_2/He)
  - Massive shattered cryogenic pellets (Ne, D_2/Ne)
  - Solid pellets (eg Be) or solid shell pellets (plastic/ Be powder)
- Both subsystems must meet design requirements: operational temperature, radiation conditions, reliability, etc

$\Rightarrow$ Extensive R&D is underway to develop concepts and identify most suitable approach for ITER application

Disruption Mitigation System Conceptual Design



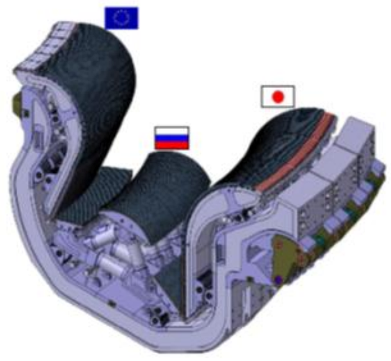


- **Disruption Mitigation System is planned to consist of two subsystems:**
  - 3 Upper Ports primarily for Disruption Mitigation
    - probably a single injection system in each port
  - 1 Equatorial Port for Disruption Mitigation and RE Mitigation
    - multiple injection systems

All-Tungsten Divertor

Status

- The design of an all-tungsten divertor is currently under development at the IO.
- Low fuel retention and low dust inventory
- Significant contribution to schedule saving and cost containment for ITER Project
- Experience gained in operation with W-divertor in non-active phase
- The final design phase is planned to be completed by the end of 2013.



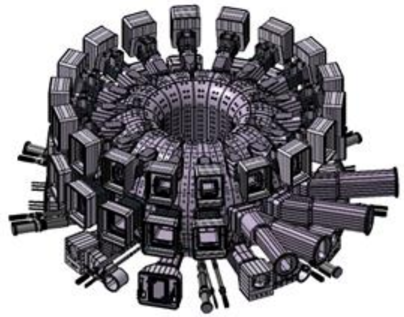
Choice of all-Tungsten Divertor
Low fuel retention and low dust inventory,
Significant contribution to schedule saving and cost containment for ITER Project,
Experience gained in operation with W-divertor in non-active phase

Challenges

- A technology qualification and prototyping programme is being executed in EU, JA, RF responsible for procurement of the W plasma-facing components;
- Target value are 1000 cycles at 10 MW/m^2 (Normal & Steady), 500 cycles at 20 MW/m^2
- Within the Physics R&D Community and ITPA, efforts are underway to provide an assessment of the risks faced by ITER;
- From the physics point of view, the main risk elements are well recognized;
- Work remains to try and quantify them sufficiently well to inform a decision by the IO with regard to a full-W divertor start.

Key Technical Challenges of ITER

Vaccum Vessel



- Vacuum Vessel is double-walled stainless steel
  - 19.4m outer diameter, 11.3m height, 5300 tons
  - provides primary tritium confinement barrier

Vacuum Vessel Status

Challenges

- The vacuum vessel is the SIC (Safety Important Component) component
- The first boundary of the nuclear safety;

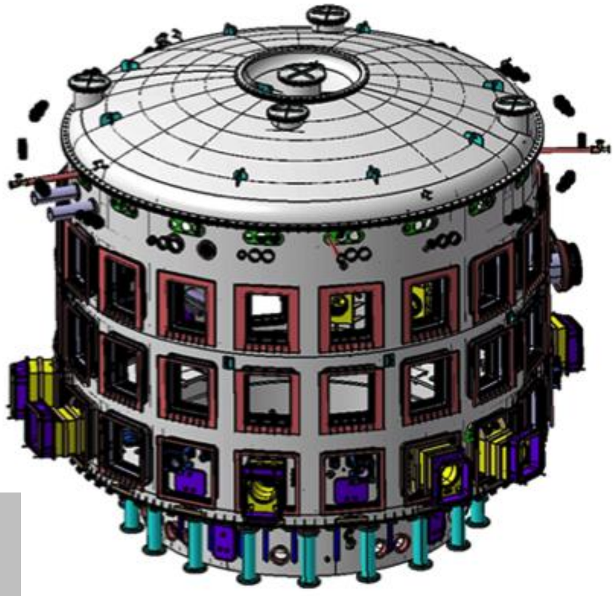
Status

- The design of VV and ports by IO was complete and the manufacturing stage has already started;
- The VV manufacturing design is under preparation by the contracted suppliers of the main vessel, ports and IWS in the EU, Korea and India;
- Mock-up fabrication and testing programs are underway in EU, IN, KO and RF. The material manufacturing already started after the ANB approval;
- All the VV materials, including the main material 316 L(N) IG and bolt materials XM-19 and Inconel 625, were already qualified by the ANB.
- Contract of VV field Joint will be made soon by IO. Evaluation committee made a report;

Cryostat

Status

- One of the most important and critical systems in the ITER project, and has very large number of complex interfaces;
- The cryostat manufacturing contract was signed in August 2012;



3D View of Cryostat
OD: 28.54 m, HT: 29.25 m
Mass: ~3500T

Challenges

- The site workshop will be ready for the cryostat assembly in 2014;
- The first deliveries of components for assembly in the tokamak pit will occur in September 2015;
- Pre-manufacturing activities such as the Manufacturing and Inspection Plan, manufacturing CAD design and drawings and quality plan are being initiated between the ITER organization, INDA and their industrial partners.

Toroidal Field Coils

<u>Status</u>

- The production of the TF coils is split into 3 main production areas: The TF conductors; The TF structures; and the TF windings and coils;
- The TF conductors, which comprise 450t of Nb3Sn, are supplied by Europe, Russia, JA, KO, CN and UA. Over 70% of required 450t of Nb3Sn strand has already been produced;
- It is anticipated that the rest will be completed in two years;
- JADA has signed a series production contracts with Japanese and Korean suppliers to build a first of series for TF winding and for the fabrication of the TF structural section;

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

<u>Challenges</u>

- Both China and Korea have fabricated dummy conductor, which has been supplied to Europe for TF winding trials;
- The TF structures are to be assembled by welding in Japan and Korea.
- The manufacturing feasibility of these large components has already been undertaken by the Japanese Domestic Agency and its industrial partners.

Poloidal Field Coils

- The ITER Poloidal Field (PF) magnet system consists of six PF coils procured by EU (PF2~6) and RF (PF1);
- The two PAs between IO and each domestic agency have been signed;
- Contract with industry by EU will soon made;

PF1 winding equipment in place in the Efremov Institute.

Central Solenoid

- UA is responsible for the supply of the Central Solenoid for which JA supplies the conductors;
- The CS consists of six identical coils and is 13.6m tall, has a diameter of 4.2 m and weighs approximately 1000t;
- The contract for CS module fabrication was placed by the UA in July 2011;
- This was followed by a successful Preliminary Design Review in September 2011. Manufacturing input to structures design is being provided by US industry.;The assembly tooling is on track for Preliminary Design Review in September 2012.
- Conductor test is at its final stage. We will complete several additional tests soon, but we have already one conductor satisfying necessary condition.

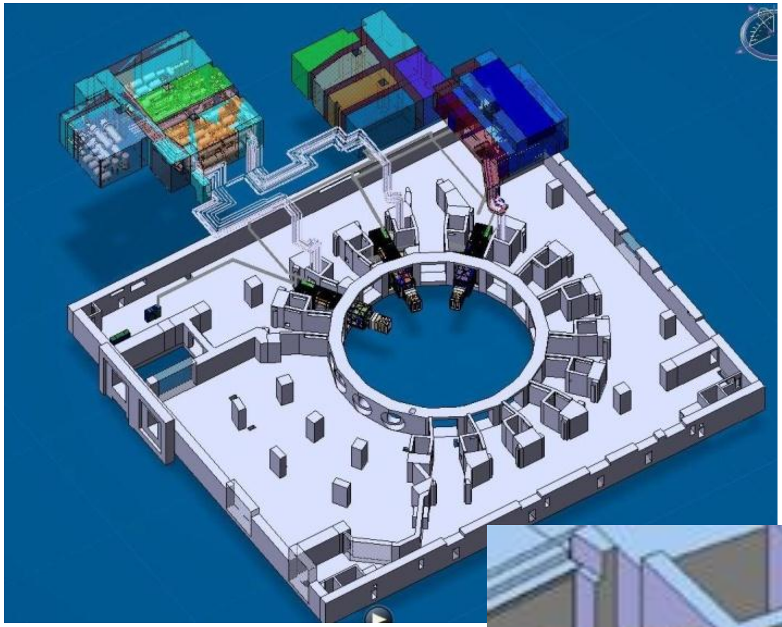
Test Blanket Module (TBM) Program

Status

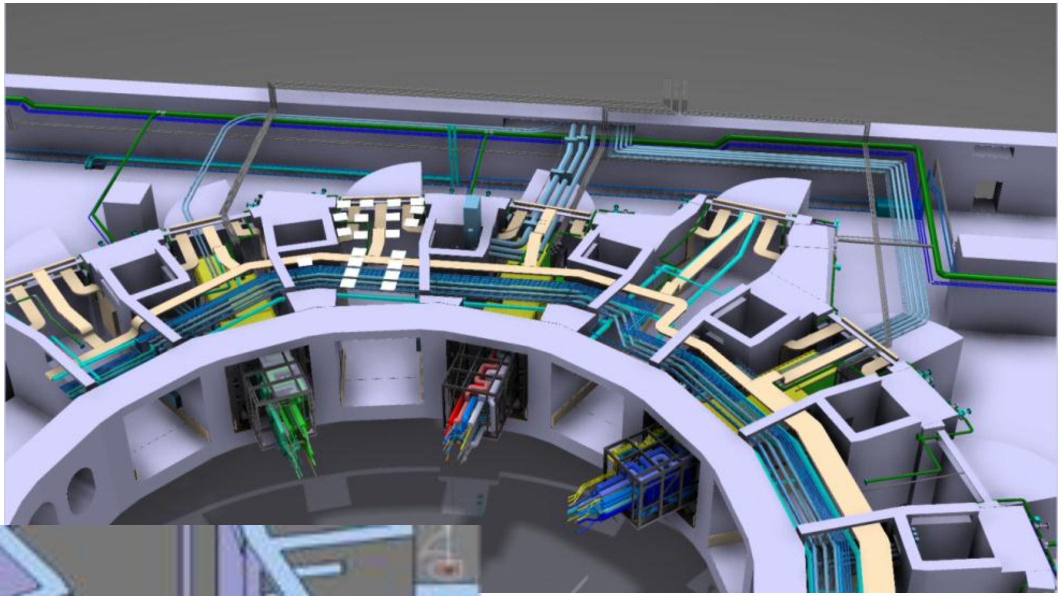
- TBM program provides the first experimental data on the performance of the breeding blankets in the integrated fusion nuclear environment;
- Detailed desing studies of TBM integration into ITER facility and related maintenance strategy performed;
- Agreement on generic TBM Arrangement achieved; right of intellectual properties, nuclear/non-nuclear liability, post irradiation test

- **Challenges**
- The ITER Members are in charge of the design, manufacturing and delivery of the TBSs to the ITER site.
- IO is developing all required interfaces with the other ITER systems and buildings based on input data given by the Members;
- IO is performing all the design work necessary for the TBSs integration into ITER facility;
- The six TBMs are in three dedicated ITER equatorial ports;

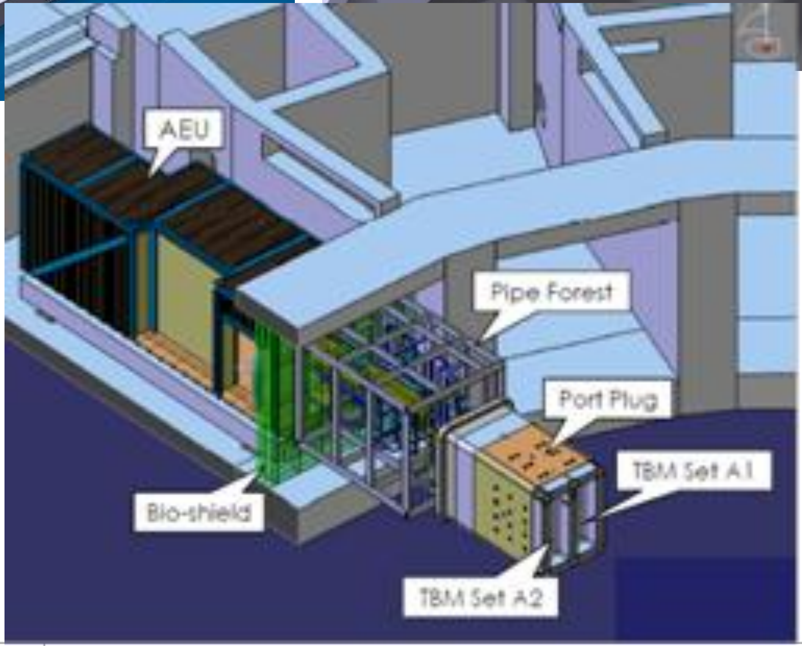
Test Blanket Module Integration



Overall TBM
System Layout



TBM Port Plugs



TBM Port Plug and
Port Cell Layout

Buildings and Site Infrastructure

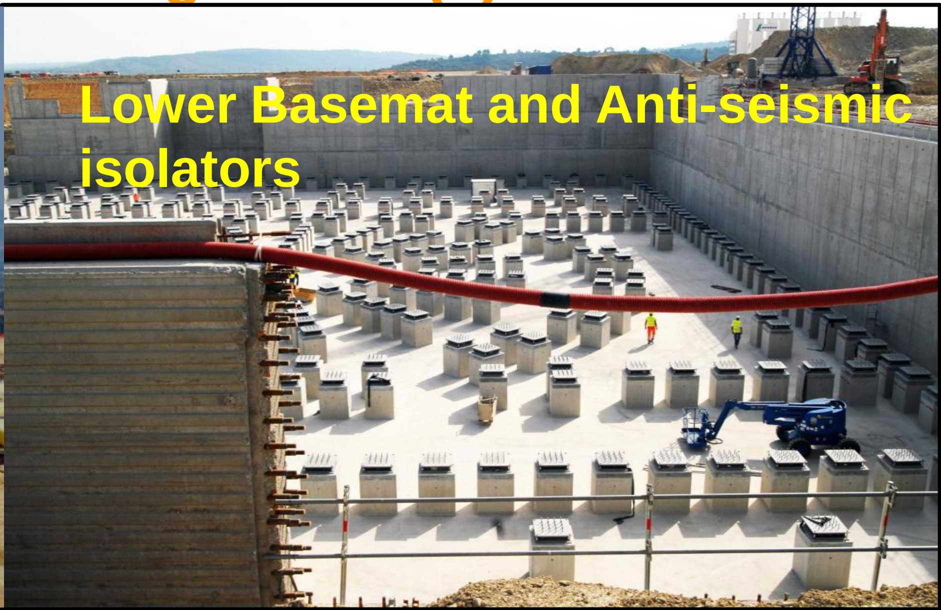
Status

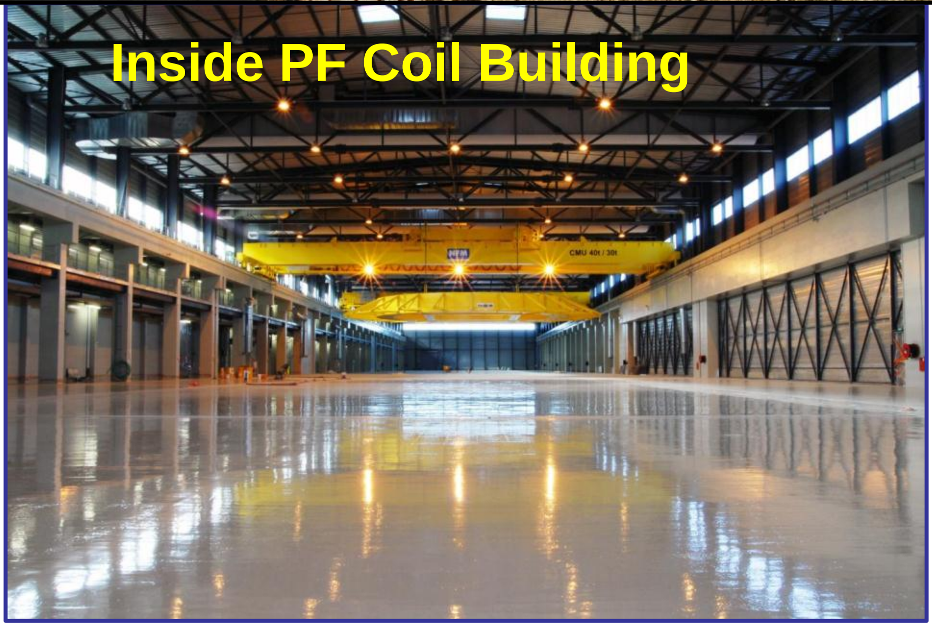
- 50 Hectare level platform finished
- All infrastructure needed to support construction is complete
- 400kV electrical substation constructed
- Poloidal field coils winding building constructed
- Tokamak Excavation, foundation slab and anti-seismic plinths completed
- All 493 anti-seismic bearings fabricated and installed
- New Headquarters building completed and occupied from 8 October 2012
- 100 km "Special Itinerary" to allow the transport of large components from Marseille port to ITER is complete

Challenges

- Building is the biggest critical path of schedule control
- Improvements to "robustness" of some structural elements is being implemented
- Engagement with industry is required to mitigate schedule challenges
- Innovative technical solutions need to be investigated to minimize risks to cost and schedule

Site Construction Progresses (1)





Site Construction Progresses (2)

ITER New HQ Building

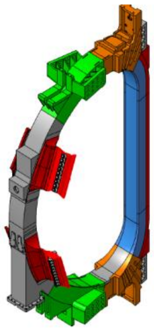
Inside HQ Building

Future ITER Council Room

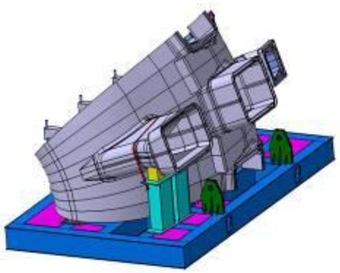
ITER New Amphitheatre

FRANCE

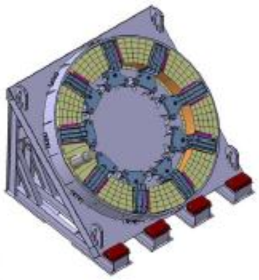
ITER Itinerary
Local Communities Provided Road Upgrades



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

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

Itinerary: March 2013 Test Convey
Beginning of 2014 Real Component will arrive at ITER

Safety and Licensing - Status

- The ITER is a nuclear facility
- The ITER facility is being licensed in France as a Basic Nuclear Installation (INB)
- In March 2010, ITER submitted safety files (including the Preliminary Safety Report, RPrS) to the French Nuclear Safety Authorities (ASN)
- Extensive examination of safety files carried out by ASN and their technical advisors (IRSN)
    - during 2010-2011, over 700 technical questions answered by IO
    - many meetings between IO and IRSN
- In November-December 2011, meetings of the Groupe Permanent, a standing committee of experts convened by ASN
- Independently, assessment carried out by Environmental Authority, which also gave a positive opinion (with recommendations)
- In parallel, in July-August 2011, Public Enquiry held in towns surrounding ITER
    - many questions from public
    - Public Enquiry Commissioners gave favourable advice (with some recommendations)
- In July 2012, ASN announced its decision to grant the decree to authorize the creation of the ITER facility
    - decree now in draft and being discussed - hopeful for signing before end of 2012

Licensing of ITER

ITER files (DAC) submitted in March 2010

- ~ 5000 pages
- > 700 questions asked by regulator
- ~ 10,000 questions during public enquiry
- ~ 180 recommendations and commitments now to be answered in next 2 years

- Representatives of the French nuclear regulator (ASN) make regular inspections of ITER.
- Here they inspect the civil works (April 2012).

In Summary

- This paper has summarized the technical progress that has been made and demonstrates that ITER is well and truly off the starting blocks.
- 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.
- The examples mentioned above in the overview of the status of the ITER project show that ITER is presently well into the construction phase and is facing the problems to be expected in such phases.
- However, ITER has a more complex organization and procurement scheme than other large science projects and so the solution of problems tends to be more complicated and requires more effort.
- The achievements over the last 2 years have shown that an international cooperation such as ITER can work successfully and that it is able to deal with the usual problems which arise in large and technically ambitious construction projects.