# Challenges in Design Integration  ITER

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ITER Organization

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

# The sources of the ITER Integration difficulties - in brief

- ## The technical complexity of ITER

  a prototype - > many steps from the previously designed tokamaks

  Large use of new technologies (performances uncertainties to be dealt)

  It is a nuclear machine

  The design is highly integrated (but what does this mean?)

- ## Organizational constraints

  Decentralized Design activities

  Different contractual or collaboration agreements,

  Different languages, design practices and tools

- ## Schedule constraints

  The construction is in progress but many of the ITER systems are still in the design stage =>Different levels of design maturity makes difficult to manage interfaces

# Integrated design – what does it mean?

Large project are managed by subdividing the overall scope in many lower elements » Work Breakdown Structure, WBS

Each WBS describes **activity** (or **Work package**) defines what shall be done, by whom, and by when.

The resulting activities are then scheduled to be performed either

- **in parallel** (little mutual impacts)
- **sequentially** (result of activity **A** needed for the start of activity **B**)

A third case exists: **interdependent activities** or **tasks**

results of activity A is needed for the start of activity B, but the completion of activity A requires input from activity B

# Example of tasks organized in a Design Structure Matrix

Spaghetti type graph:

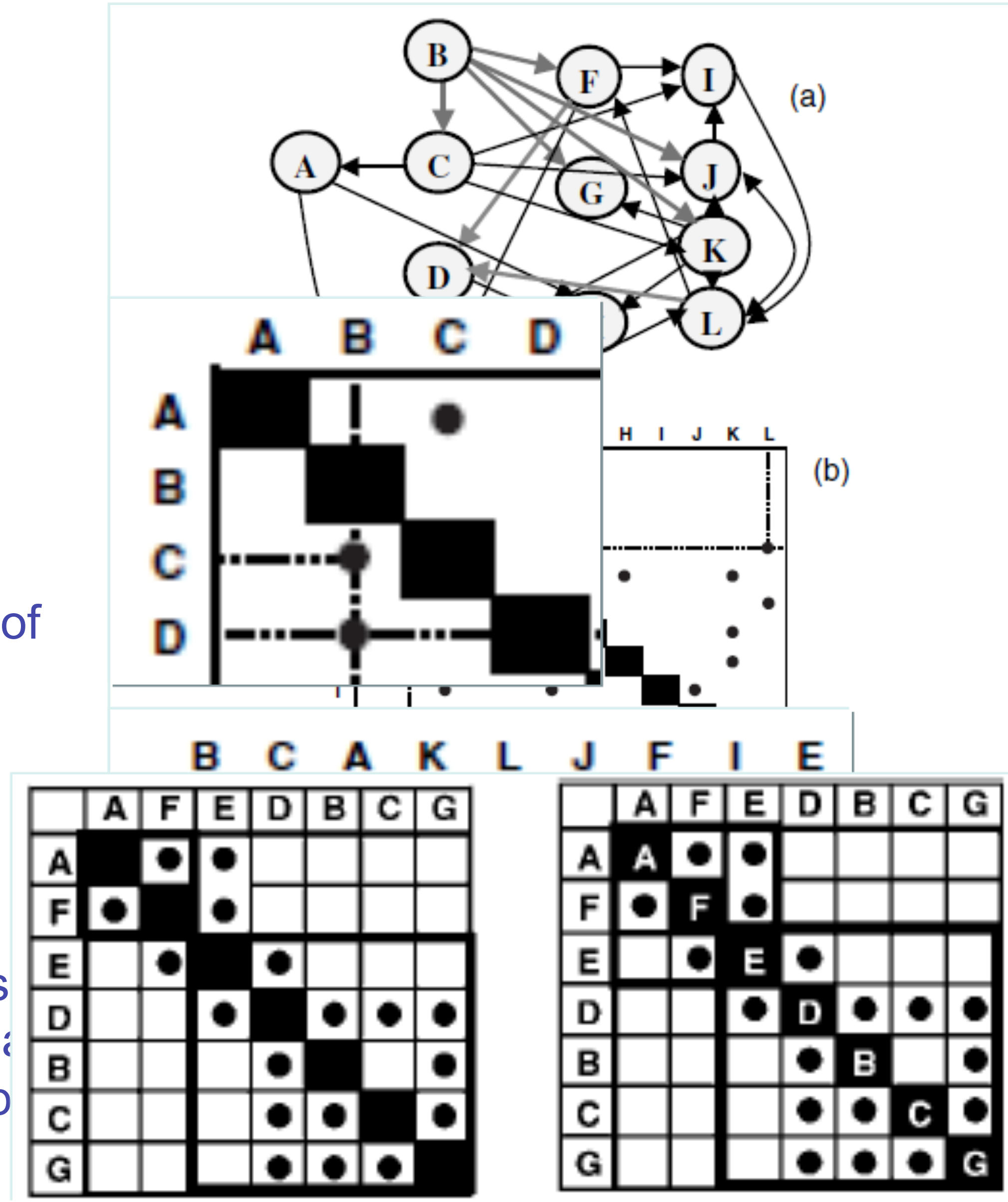
tasks and their relationships are identified

Base DSM:

tasks are organized in rows and columns and their interactions is represented as dots at the crossing of rows and line

Partitioned DSM :

the number of feedback actions is minimized and interdependent tasks are grouped in cluster of systems tha may be independent or loosely coup

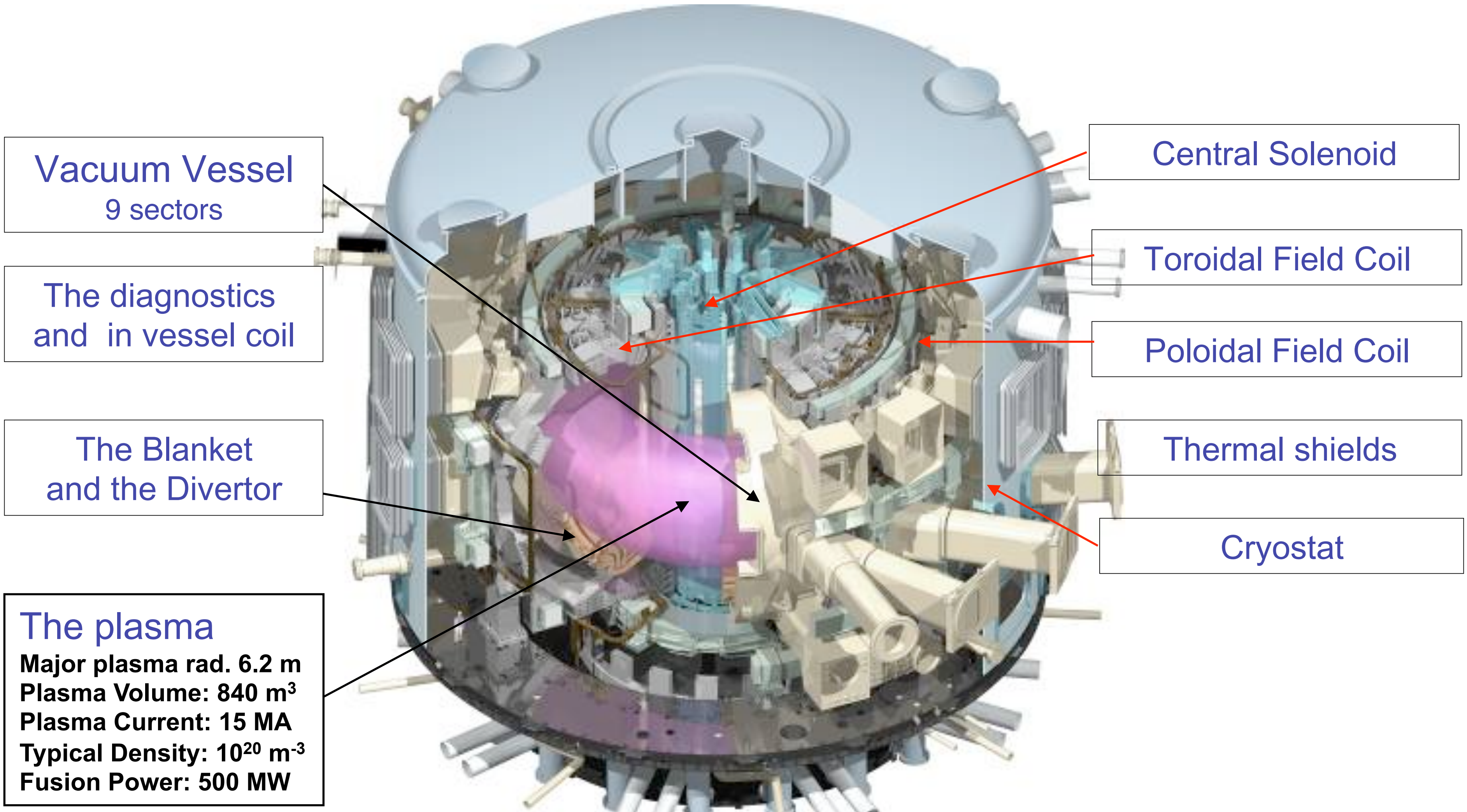



Ref.: **Complex Concurrent Engineering and the Design Structure Matrix Method** Ali Yassine,* and Dan Braha

# The ITER Integration approach

- Simplify the problem by separating the variables (*divide and conquer*)
  - Regroup the ITER systems in clusters ( "integrated systems") comprising many disciplines and subsystems among which strong and bidirectional interfaces exist
- Ensuring efficient concurrent engineering
  - Control the design maturity of the systems and synchronize those with strong interfaces
  - Manage the configuration and make it available timely to all involved staff
  - Create functional groups based on the integrated systems to improve communications and allow early identification of issues
- Formalization of the integration activities: ITER Overall design process
  - Identify performances/requirements that cannot be allocated to a single system
  - Define the scope of work of the integration activity required to achieve them
  - Assign clear responsibilities for these activities
- Ensuring an efficient and controlled system of data exchange

# The Tokamak as an integrated system

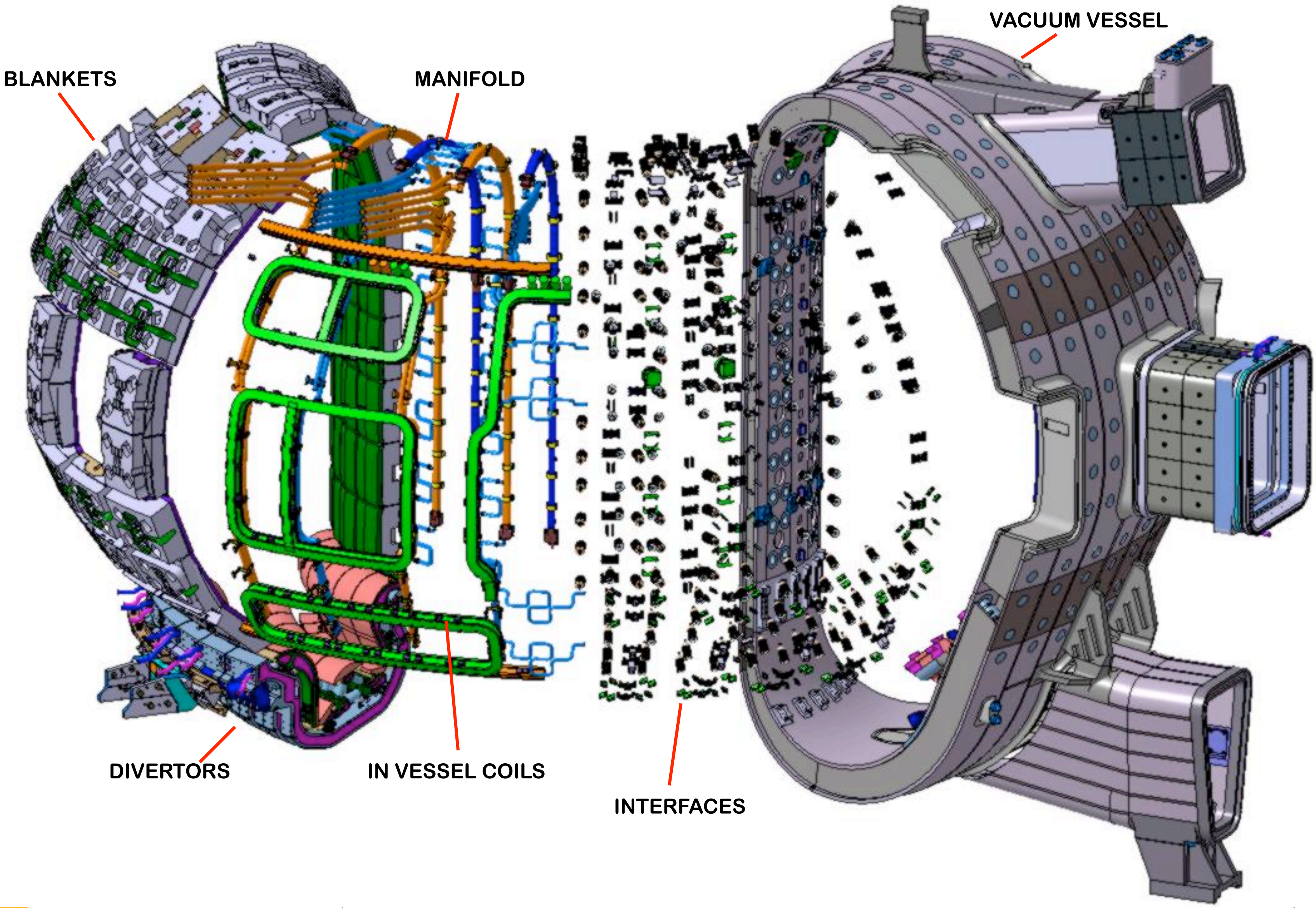



## The plasma

**Major plasma rad. 6.2 m**
**Plasma Volume: 840 $m^3$**
**Plasma Current: 15 MA**
**Typical Density: $10^{20}$ $m^{-3}$**
**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

# A multi-layers structure …



# The integration challenges for the Tokamak 1/2

## Variable levels of design maturity

- Vessel, Divertor, Toroidal Field and Poloidal Field magnets, magnet feeders , Cryostat: Final design review passed
- Thermal shields: Final design review planned later this year
- Blanket, manifolds, in vessel coils and most of the diagnostics systems : just passed the Conceptual Design Stage.

## BUT for prototypical components such as these late adjustments of the design (for the most advanced systems) are still possible because

- Feedback from manufacturing study and integration of RCC-MR welding/ inspection prescription
- Integration of I&C in the design
- Operation and maintenance consideration
- Refinement of installation processes,
- Modification deriving by cost reduction initiatives

# The integration challenges for the Tokamak 1/2

- There are strong interdependence of the systems' structural behavior
- The clearances between the different "layers" have been minimized

  Cost dependency from radial built

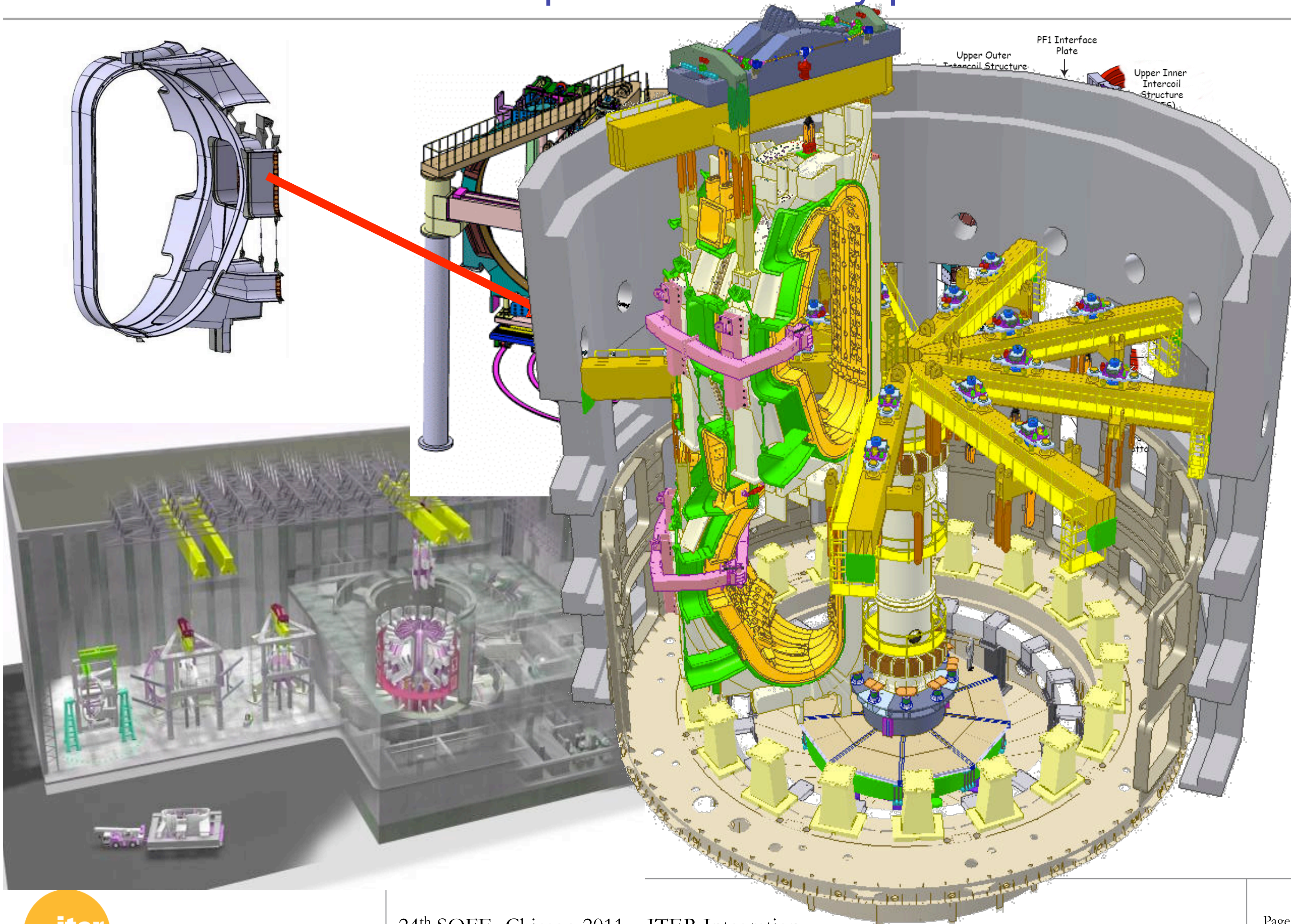
  Magnetic flux losses

  Nuclear shielding requirements
- The requirements on final positioning of plasma facing components depend on tolerances and behaviors of virtually all other main systems
- Complicate assembly process

- All these constraints make very difficult to accommodate changes

- … in addition the procurement scheme introduces other aspects in the technical assessment of the changes.

# ..and a complicate assembly process



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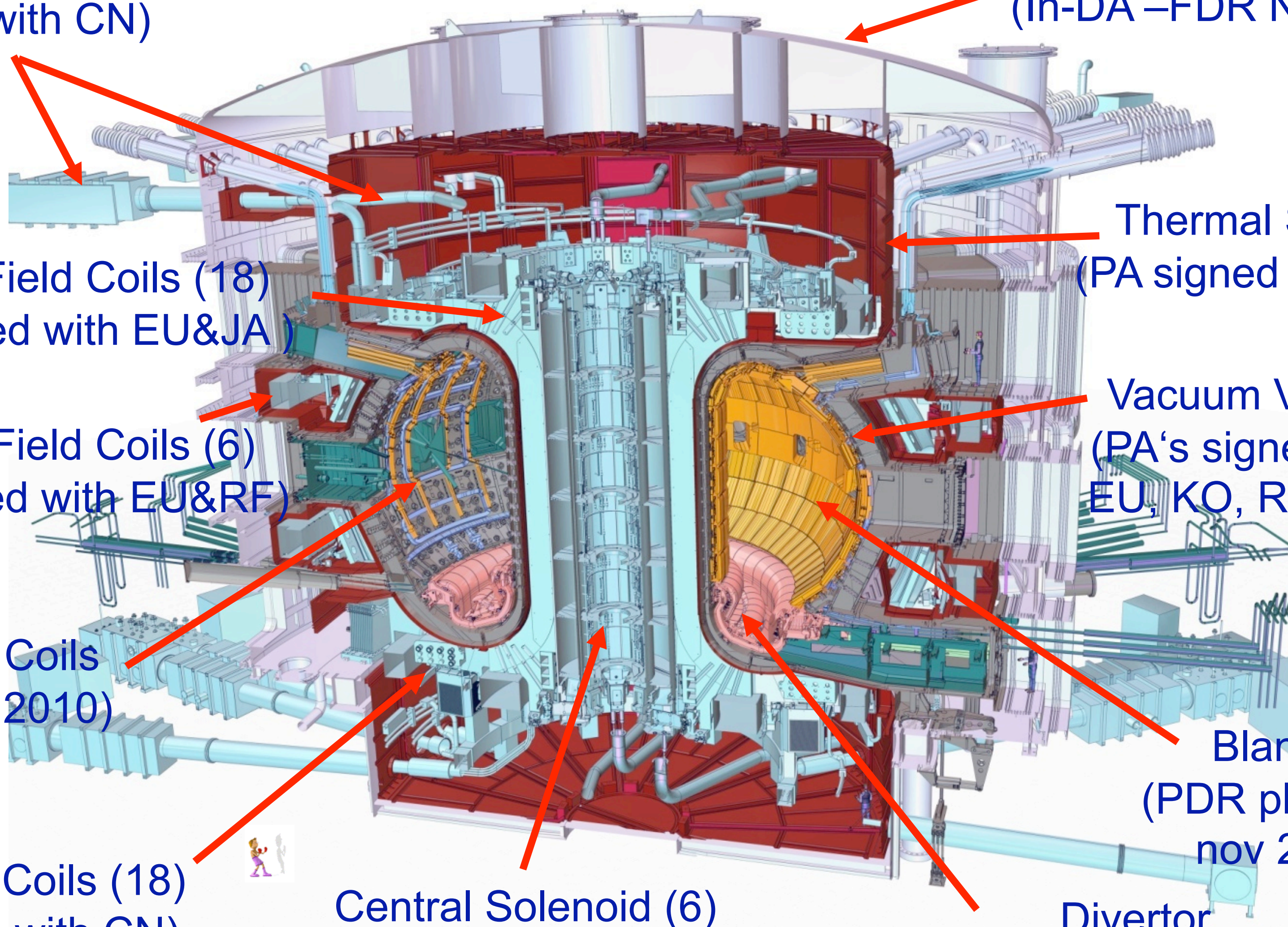
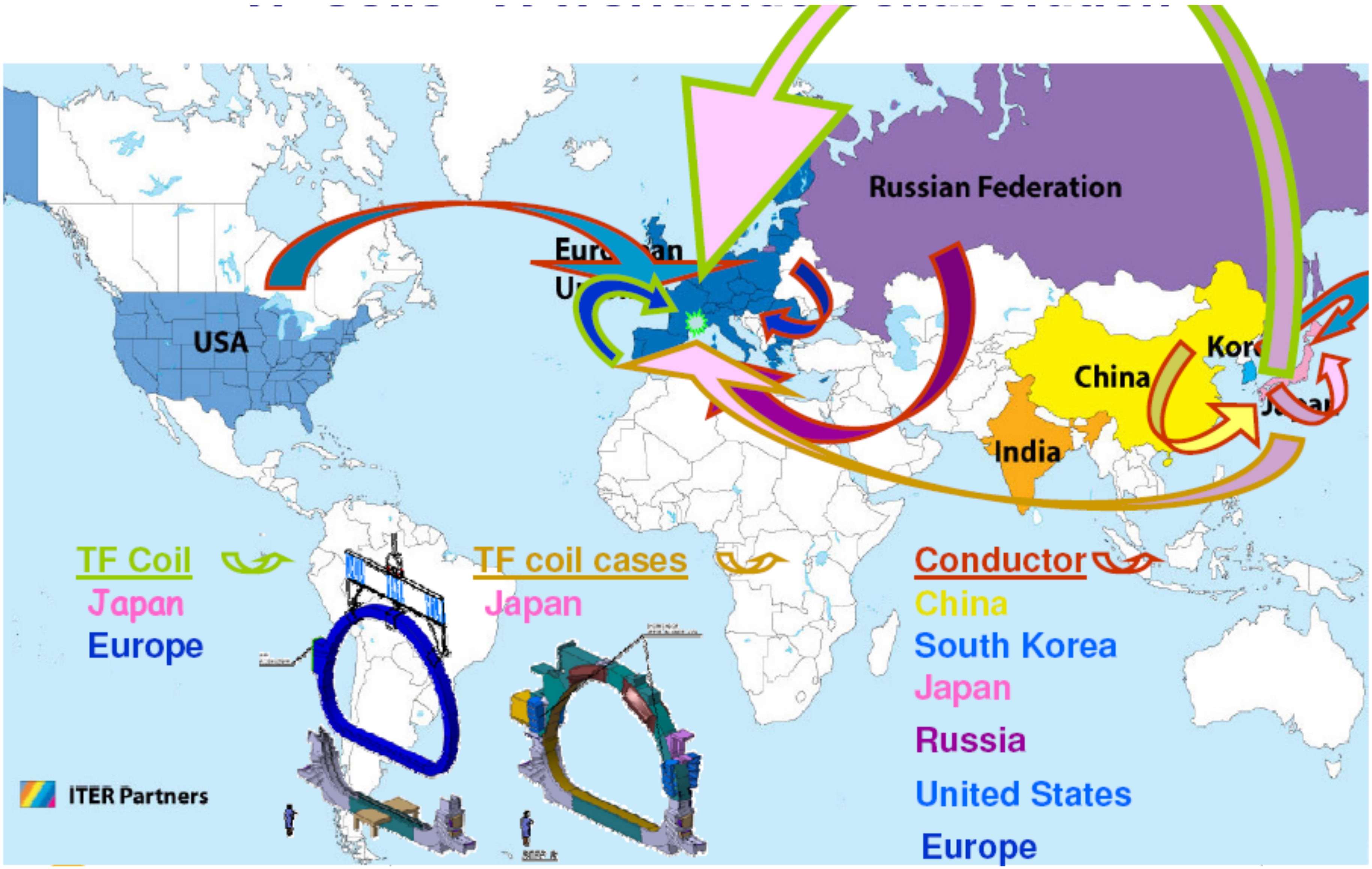
All these constraints make very difficult to accommodate changes

- … in addition the procurement scheme introduces other difficulties, both in the completion of the design as in the management of the changes (assessment/approval/disposal).

# Allocation of the procurement



# Distributed procurement



# The Tokamak integration approach

## Establish the reference configuration of the systems

represented and controlled through Configuration Management Models.

## Perform/coordinate cross functional studies to assess collective performances

(nuclear analyses, electromagnetics, maintenance tasks, reliability assessment, etc.)

## Develop strategy for Tolerance management

allows identification of critical tolerance requirements and develop methods to deal with non conformities.

## Control the status of interfaces and the identification and resolution of clashes.

## Execute Systems' Design Reviews at different stages of the design

focusing on compliance with the requirements, completion of the design and (in the last stage) assessment of manufacturing issues

## Execute Design Integration Reviews (DIR)

focusing on interface issues resolution and review of the integration activities (assembly, inspection and maintenance operations, nuclear safety)

## Create Integrated Product team for each major system

to ensure regular communication among IO and DAs and accelerate resolution of common issues and to track the progress in the execution of the work.

*Please attend Jens Reich's presentation on ITER tokamak integration*

# Management of Tolerances

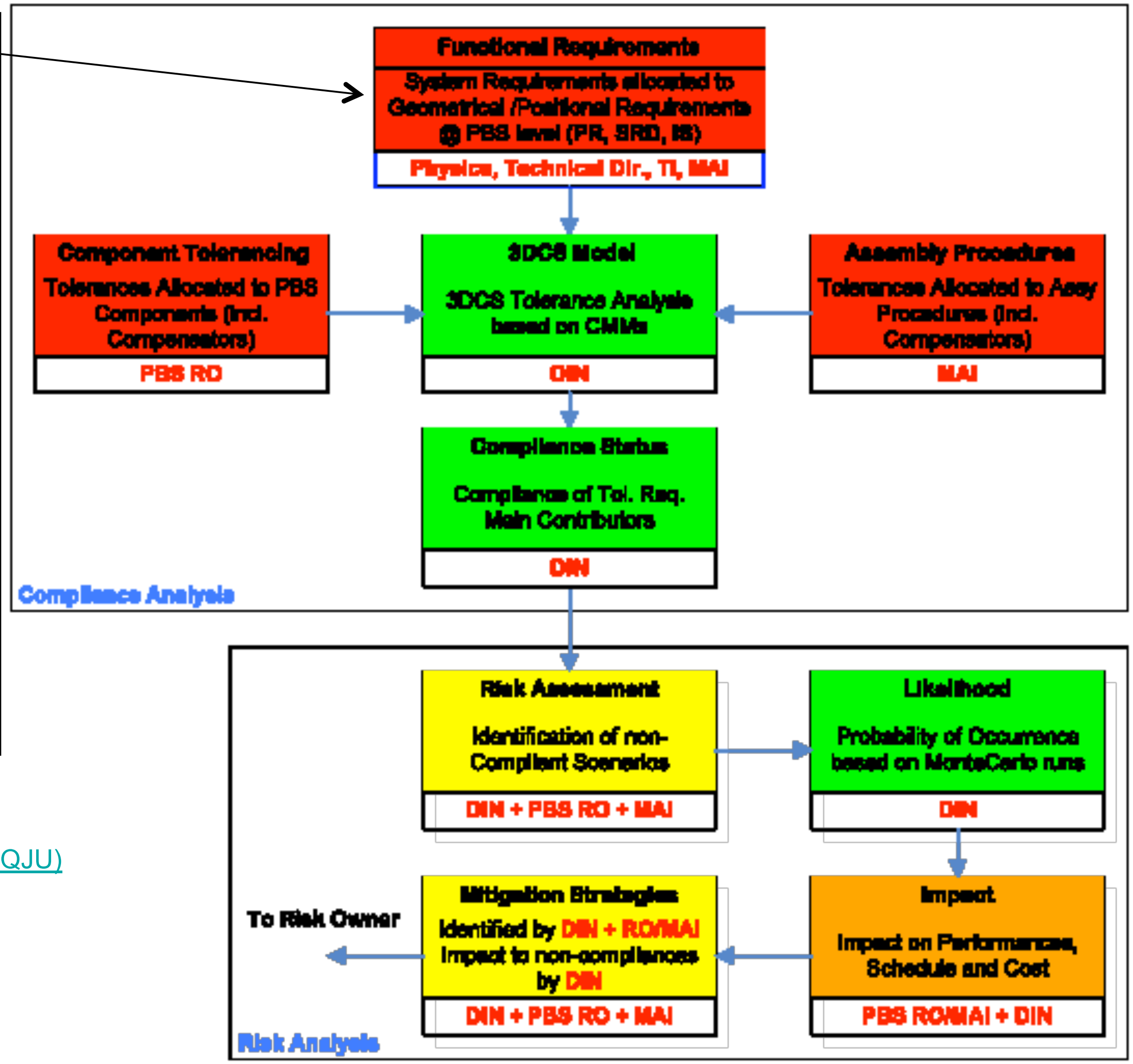
Requirements:

CS, PF and TF coil positions determined by error filed capabilities

ELM and VS coils to be aligned to magnetic field (+/- 20 mm)

PFC First Wall to be aligned with respect to magnetic field (+/- 10 mm) and with max radial step < 5 mm (< 3 mm for divertor targets)

Gap variation in the port plug (+/- 5 mm) (nominal 20)



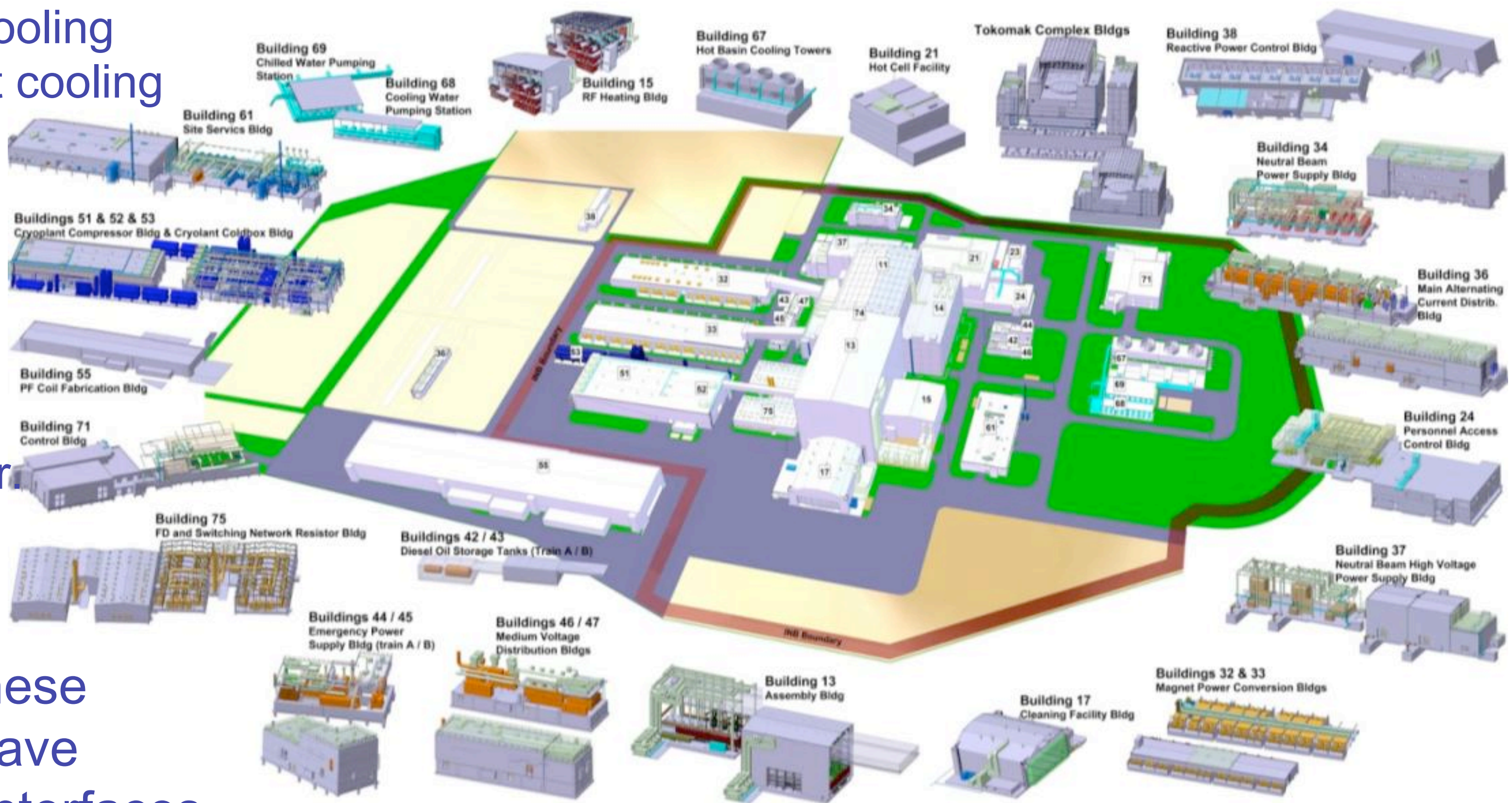

from Tokamak Tolerance Requirements (3LSQJU)

## The integration of plant systems and buildings

39 buildings of equipment

Many different disciplines:

Tokamak cooling
Component cooling
Cryogenics
Vacuum
Gas
HVAC
Tritium
ADS
electric distr




Many of these systems have bi-direct. Interfaces.

The systems layout determines the building configuration and is affected by constraints posed by the building structural and functional reqs.

# The tokamak complex integration challenges

The management of the nuclear building is a special case

•All systems are inside these buildings

•Safety functions limit the possibility of fixing the layout of a system independently from the others

•Many walls with large density of reinforcing re-bars (due to large differential pressure ) => all penetrations and supports must be defined before the construction phase (late adjustment are very expensive)

•Neutron streaming effects through openings must be minimized

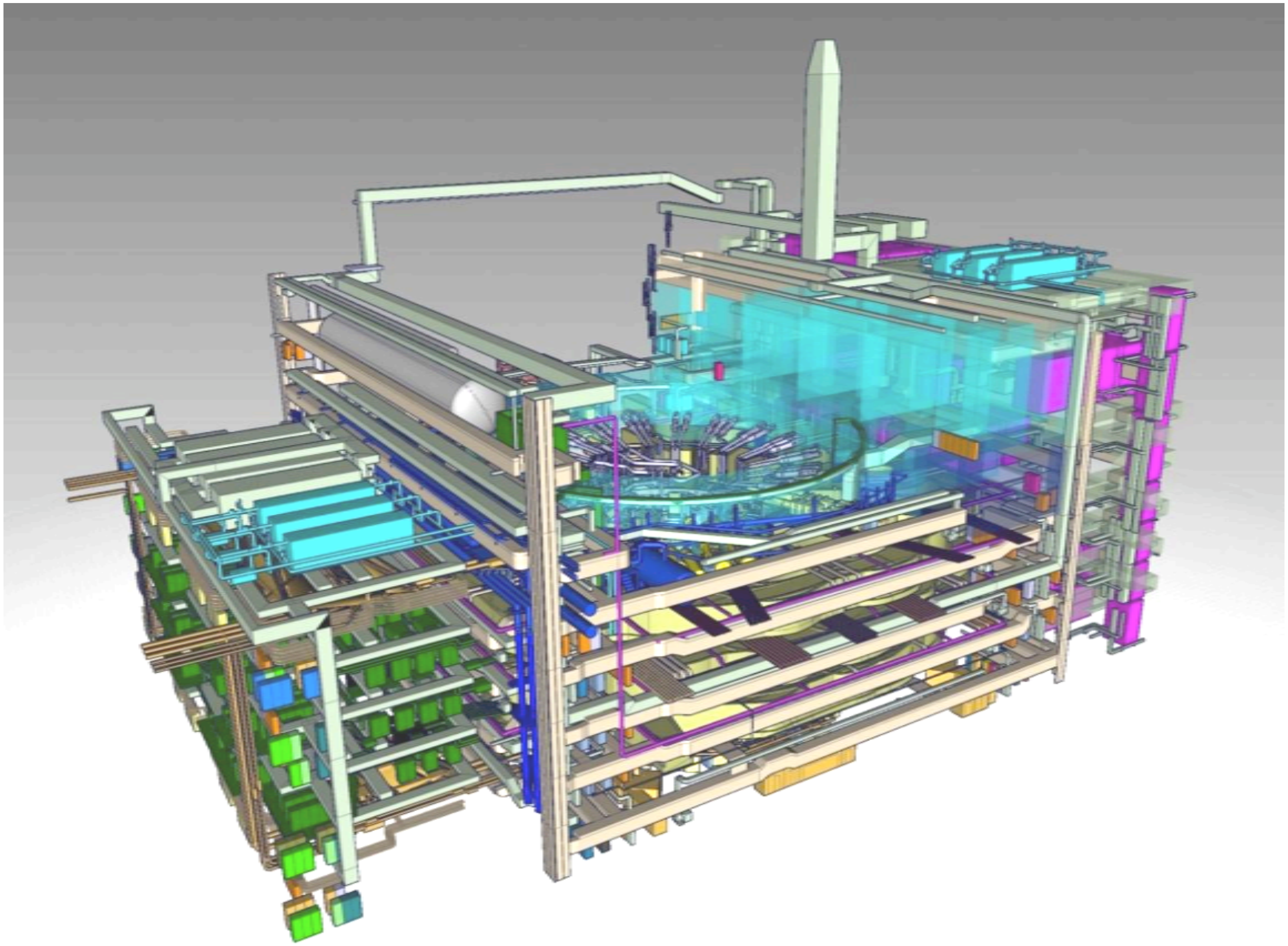
•Unused space to be minimized for cost reason

•The building construction is on a near-critical path (construction to start soon)

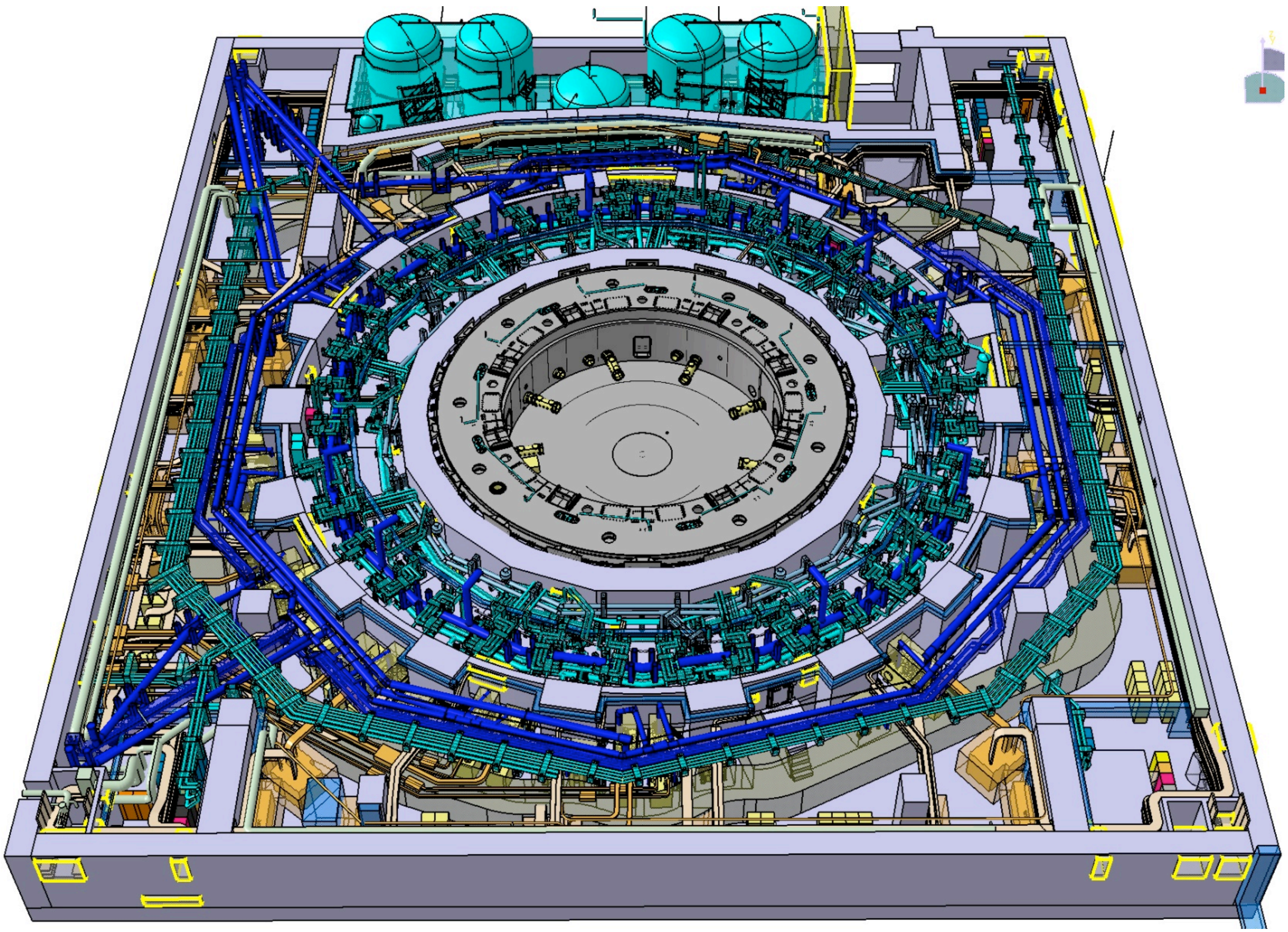
•The buildings in advanced phase of the design, but most of the systems inside at much lower maturity level

•Configuration still rather unstable due to the lack of maturity of some important systems and large number of changes (e.g. for cost reduction)

# Tokamak Complex Plant Systems



# Layout of lowest level of the tokamak building



# The tokamak complex integration challenges

The management of the nuclear building is a special case

- All systems are inside these buildings
- Safety functions limit the possibility of fixing the layout of a system independently from the others
- Many walls with large density of reinforcing re-bars (due to large differential pressure ) => all penetrations and supports must be defined before the construction phase (late adjustment are very expensive)
- Neutron streaming effects and electromagnetic compatibility to be assessed.
- The building construction is on a near-critical path (construction to start soon)
- The buildings are in advanced phase of the design, but most of the systems inside are at much lower maturity level
- Configuration still rather unstable due to the lack of maturity of some important systems and large number of changes (e.g. for cost reduction)

# The integration of plant systems and buildings

To handle the multiple interfaces for each building, in ITER we have appointed Design Integration & Configuration Control Officer for each building. He is responsible for

- The identification of all systems in a building,
- The definition of all specific requirements applicable to the building during the construction and operation phases
- The review of the building System Requirement Document
- The review of the Interface Control Documents among systems in that building
- The allocation of space to all systems through Configuration Management Models CMM
- The assessment of Project Change Requests affecting the configuration of the building
- Organization of Design Integration Reviews

# The tokamak complex integration approach

Building Integration Task Force

established in early 2011 to focus the effort of the systems' responsible officers, building designers and integrators to work together on the resolution of interface issues

•Acceleration of the design activities

Plan of design reviews of the systems having largest interfaces to the buildings to reduce the risk of future changes due to unidentified issues

•Early allocation of penetrations and supporting plates, and these lead the layout of the systems

•Centralized management of common parameters such as

- •heat load in rooms,
- •average weight on the floors,
- •number of power and instrumentation cables in trays and through penetrations
- •total electric power or cooling requirements

•Design Integration reviews performed regularly per building and floors (or rooms when required).

# The integration of plant systems in the tokamak building

The update and consolidation of the CMM for all systems in the tokamak building is progressing according the schedule by F4 E for the detailed design of the building

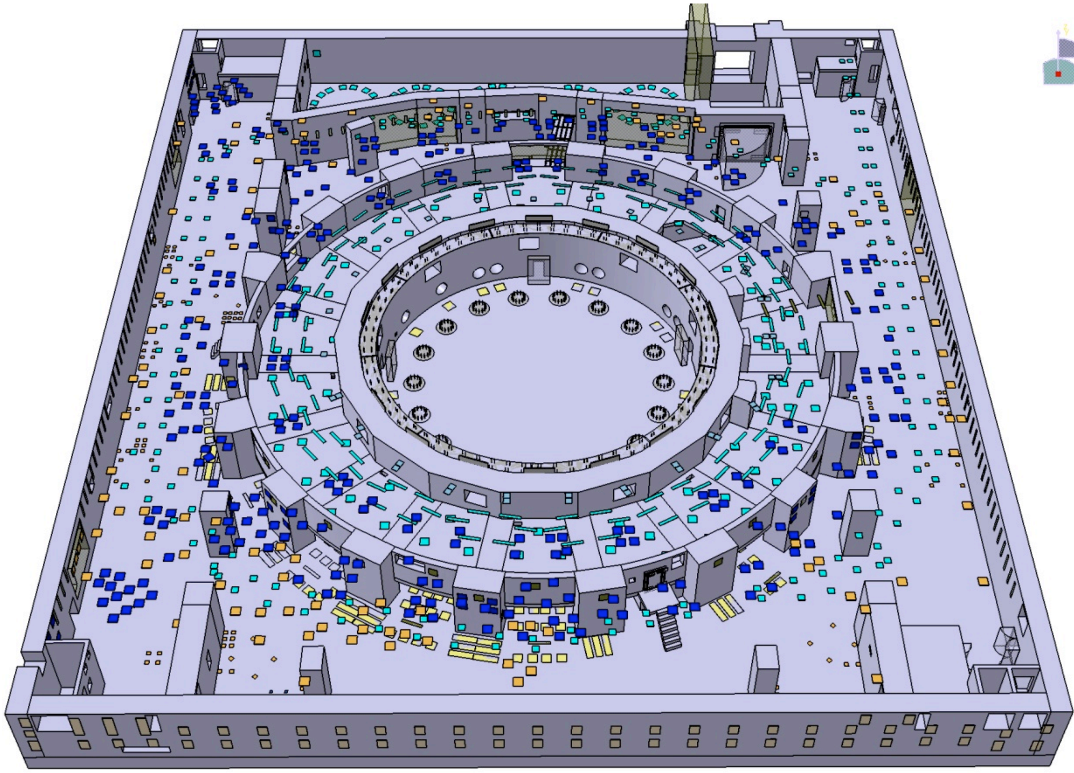
Design Integration Review of level B 2 completed

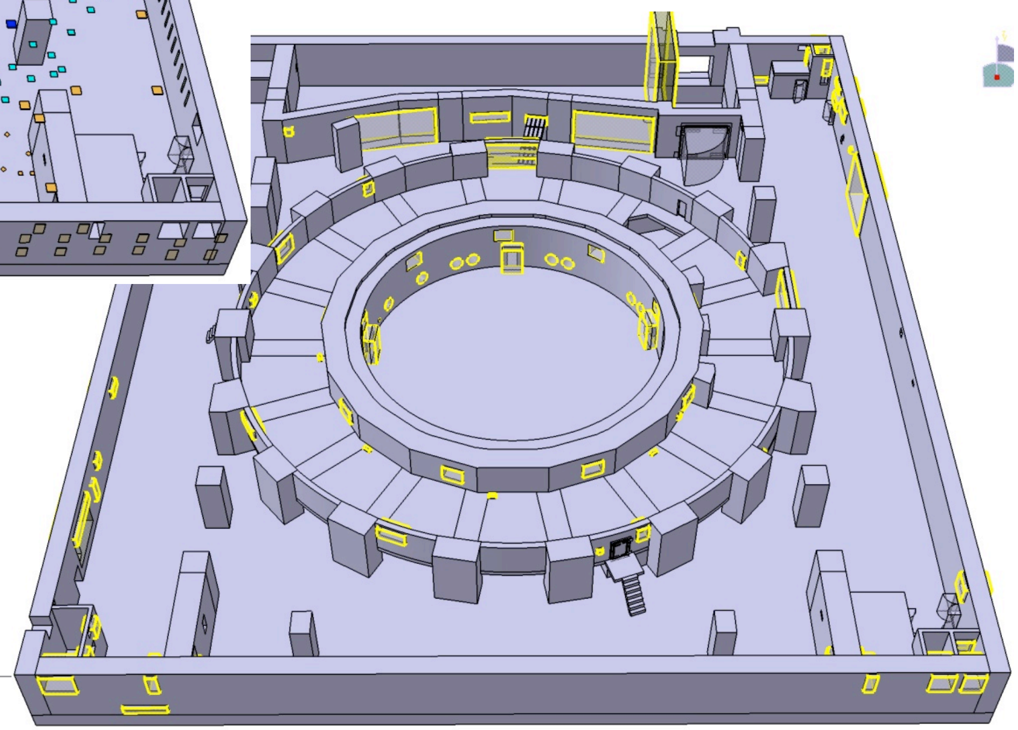
All penetrations and number and types of required embedment plates defined.

Final assessment of final position of embedment plates in Oct 2011.

Design Integration reviews for the other levels planned  during summer (typically every 3 -4 weeks)

# Embedment plates and penetrations

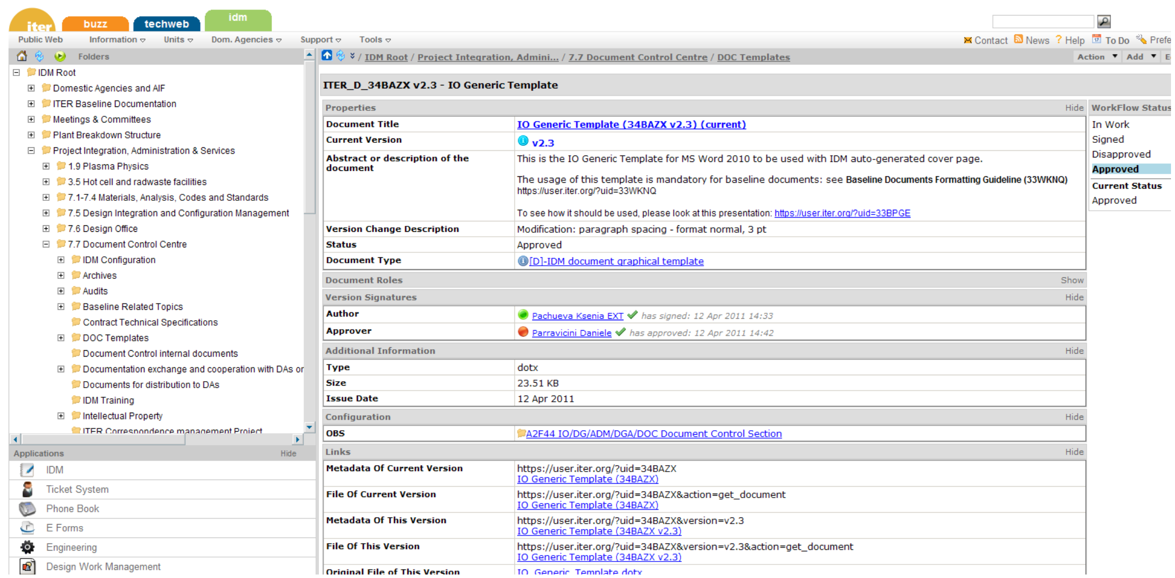




# Data sharing and communication 1/4

ITER has already an efficient system of archiving and controlling documents, IDM (ITER Document Management system)

- Web based application, available anywhere
- Sophisticated access and security management
- Delegation management
- RSS, e-mail and automated reporting notification
- Document workflow scheduling and management
- Automatic PDF rendering with cover page and log sheet generation
- Version control and configuration management
- Parameterization of document classes properties
- 5000+ users



# Data sharing and communication 2/4

However the planning, production and filing of the document and engineering data required a very disciplined approach by the users.

The document structure that is often difficult to navigate.

In 2010 a project has been launched by the Directorate for Central Integration and Engineering in collaboration with the IT section, the Document Control Centre and the other technical directorates

•to reorganize the production and filing of data around the ITER engineering processes and

•to organize the data in order to facilitate the navigation using predefined paths (tree structures).

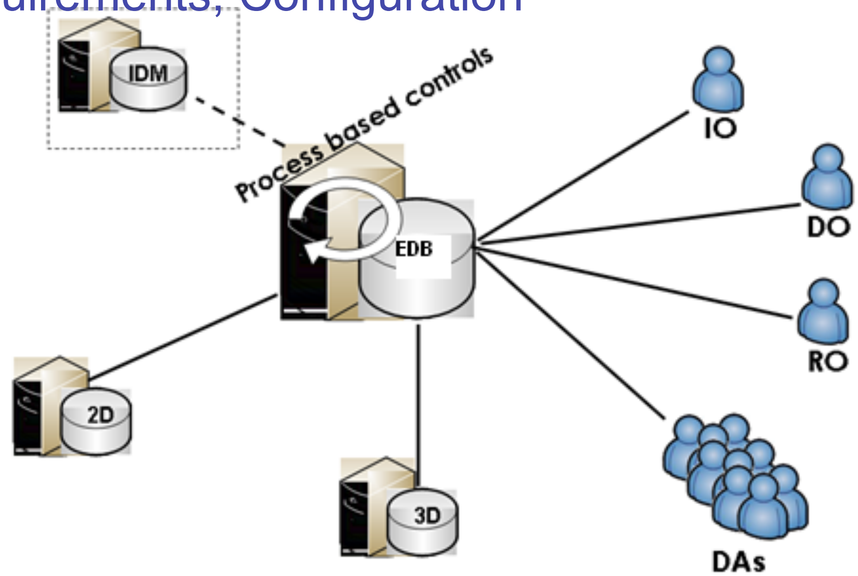
The EDB Project Objectives:

- Provide access to a definitive (and unique) source of engineering information
- Provide data standardization across all of ITER
- Provide workflow to support and expedite design completion

# Data sharing and communication 3/4

Data creation and release driven by:

- Technical/engineering processes (requirements analysis, functional design, layout and integration, detailed design, procurement,..)
- Management processes (Requirements, Configuration Management, etc.)

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Provides methods & Tools for

- Centralization
- Collaboration
- Control of processes

Data independent from authoring tools

- Centralize management of documents, engineering parameters, models drawings
- Facilitate multiCAD approach and multi-disciplines work

Data accessible via web application though all ITER participants

# EDB – Key Goals and status

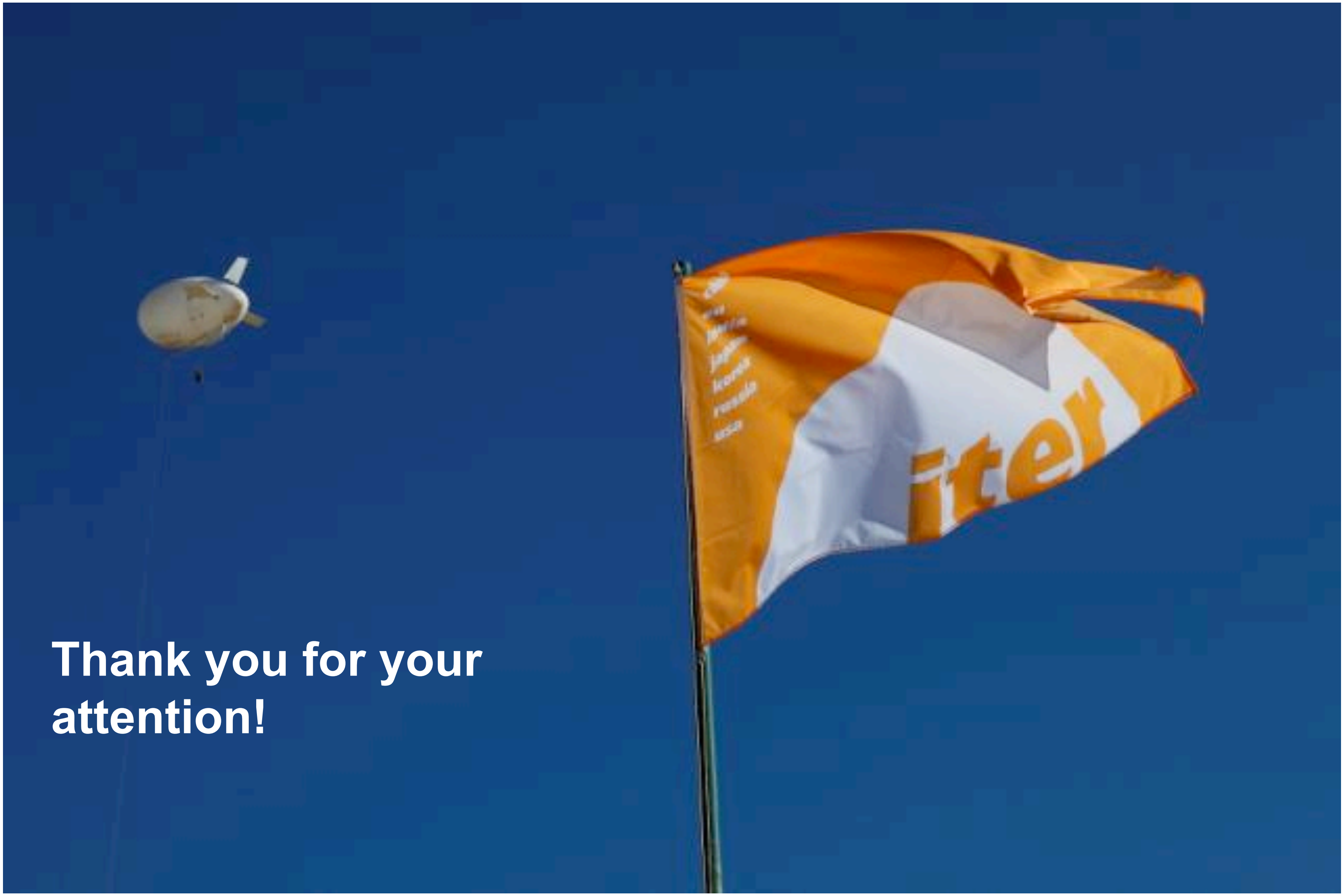
1. Engineering Data Dashboard
   – Easy to navigate portal to explore all engineering data
2. PBS Management
   – Consolidated view and reporting of all technical engineering data
3. Interface Management
   – Out of spreadsheets and into a database
4. 2d-3d navigation
   – Bring together consistently the diagram and the design
5. Engineering workflow
   – Support users in planning, producing, review and approval
6. Configuration management
   – Control changes in a manageable and transparent manner
7. Future functionality
   – Define what is needed in the next step

Beta version is online.

Data migration planned in July

# Summary

- ITER is now in the construction phase: the consolidation of interface data and the completion of the assessment of system and project performance is an absolute must to minimize future changes and cost increase.
- The completion of the detailed drawings of the building determines the pace for the design activities of almost all other systems
- Product centered Integration teams have been formed to address these issues at different levels
  - at system levels to coordinate the activities of different group involved in IO and DAs
  - At integrated systems level to accelerate resolution of interface issues and to manage common performances
- The project has been re-organized to follow these priorities and the responsibilities for the execution of the integration tasks are assigned
- The main tools and processes to execute these work are in place




Thank you for your attention!