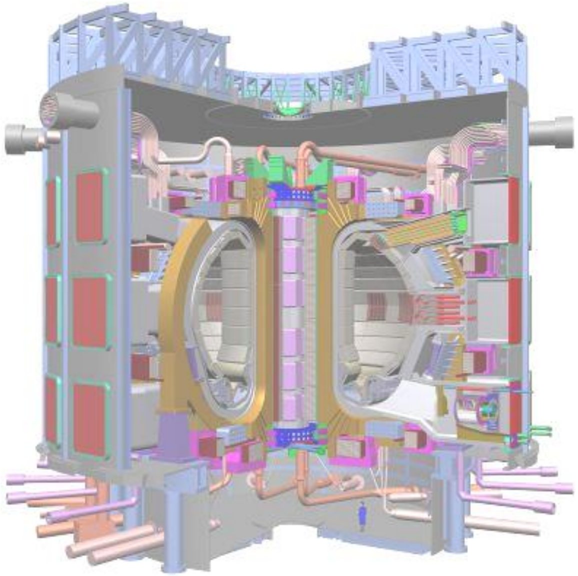
ITER Construction
- Plant System Integration -

Summer Schools

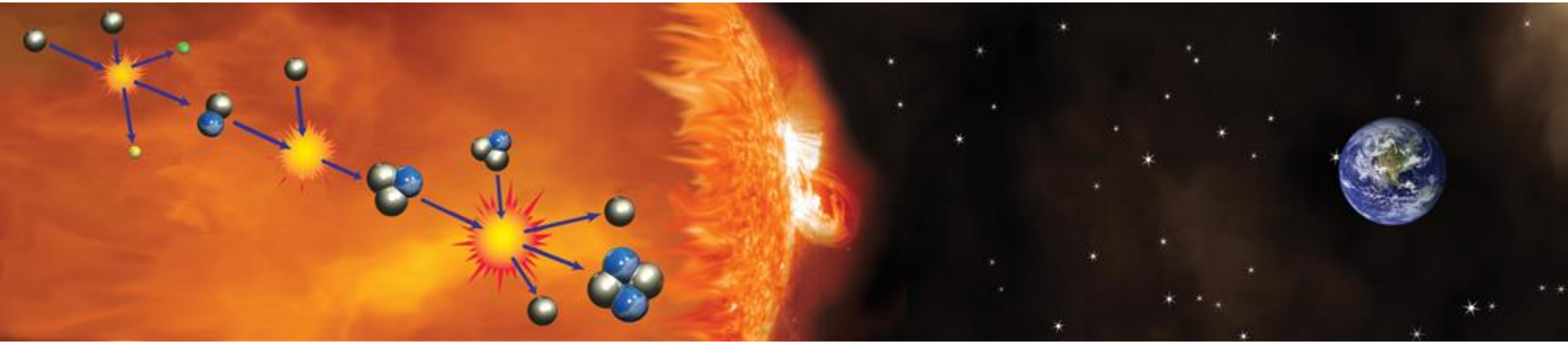
23 July, 2008



Prepared by E. Tada (ITER)

Presented by S. Matsuda (JAEA)

Outline



ITER Construction

- Plant System Integration -

- **International Cooperation**
- **Integral Project Management**
- **System Integration**
- **Site and licensing preparation**
- **Summary**

The Tokamak

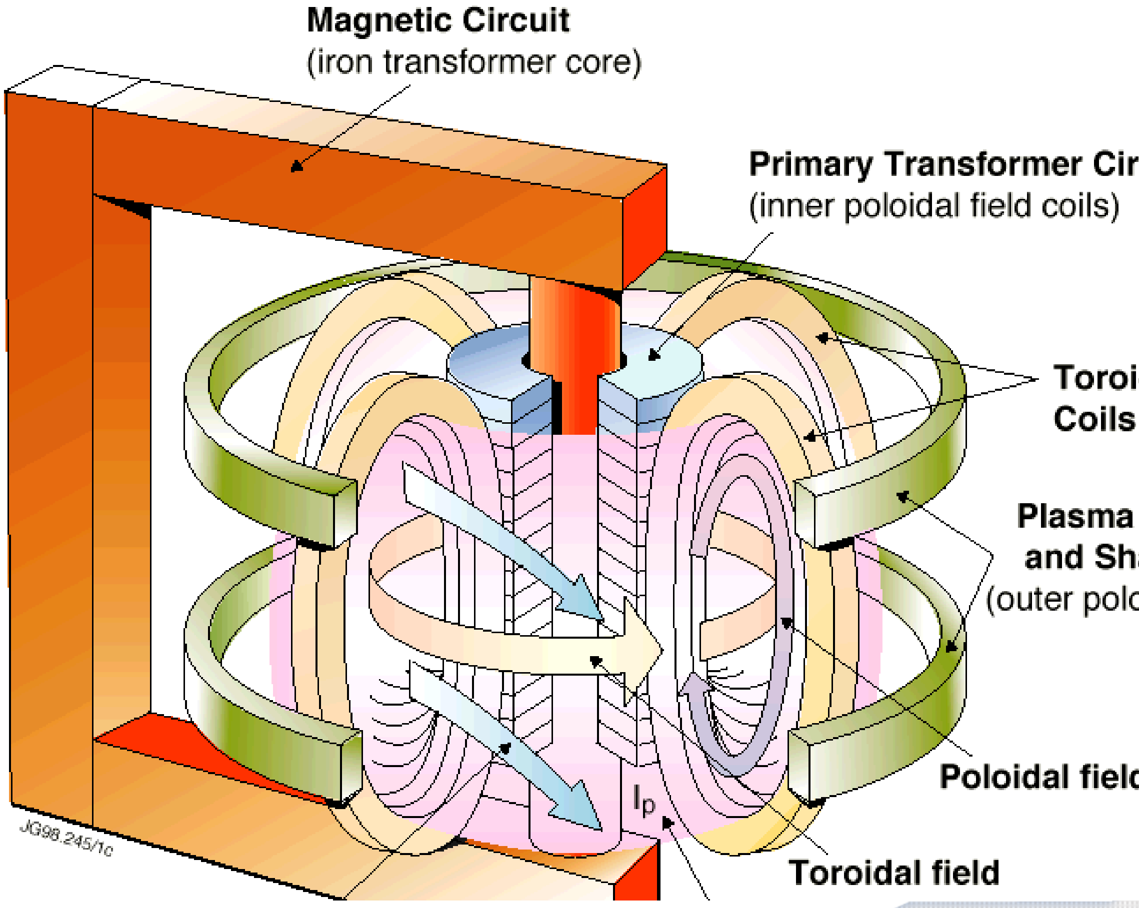
"тороидальная камера в магнитных катушках" (*toroidal'naya kamera v magnitnykh katushkakh*) — toroidal chamber in magnetic coils (Tochamac)).

The major <u>toroidal magnetic confinement</u> configuration

The Tokamak:

- operationally, is essentially an electrical transformer
- toroidal magnetic field is produced by external magnetic field coils
- plasma current produces poloidal magnetic field
- result is a set of nested helical surfaces

  ⇒ plasma confinement

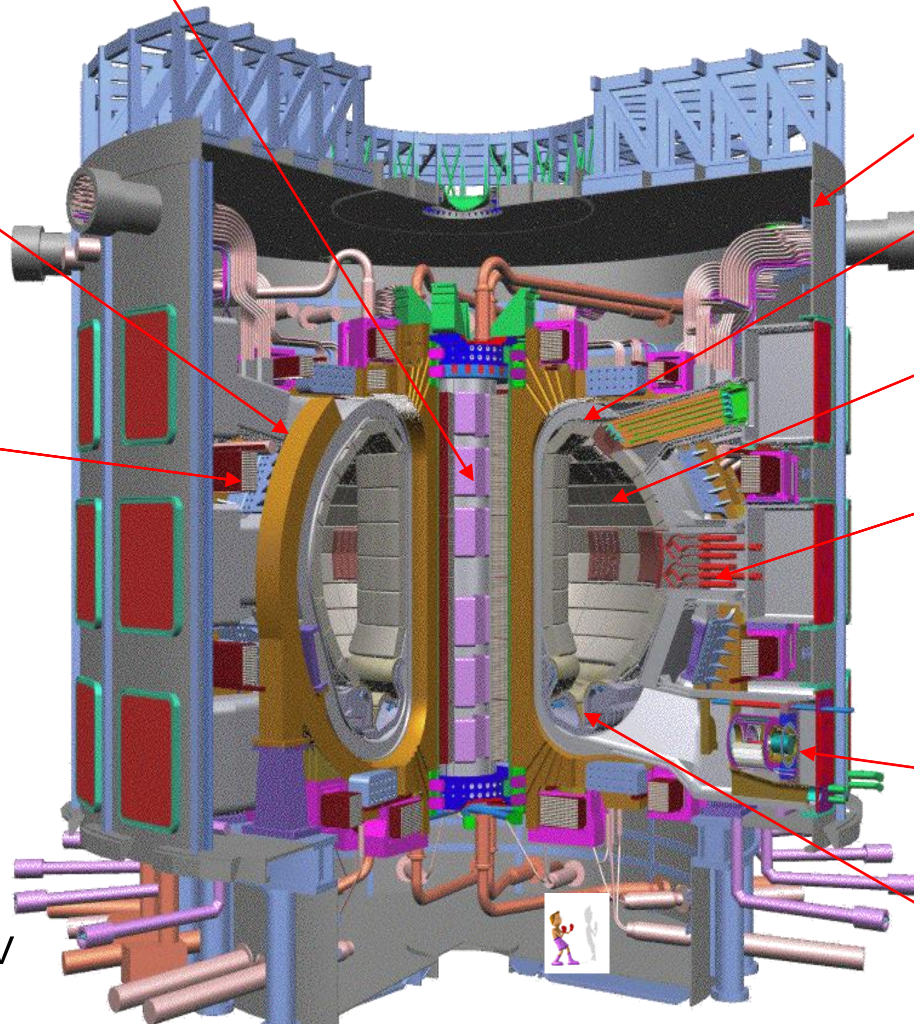


The core of ITER

Central Solenoid
Nb_3Sn, 6 modules

Toroidal Field Coil
Nb_3Sn, 18, wedged

Poloidal Field Coil
Nb-Ti, 6



Cryostat
24 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}

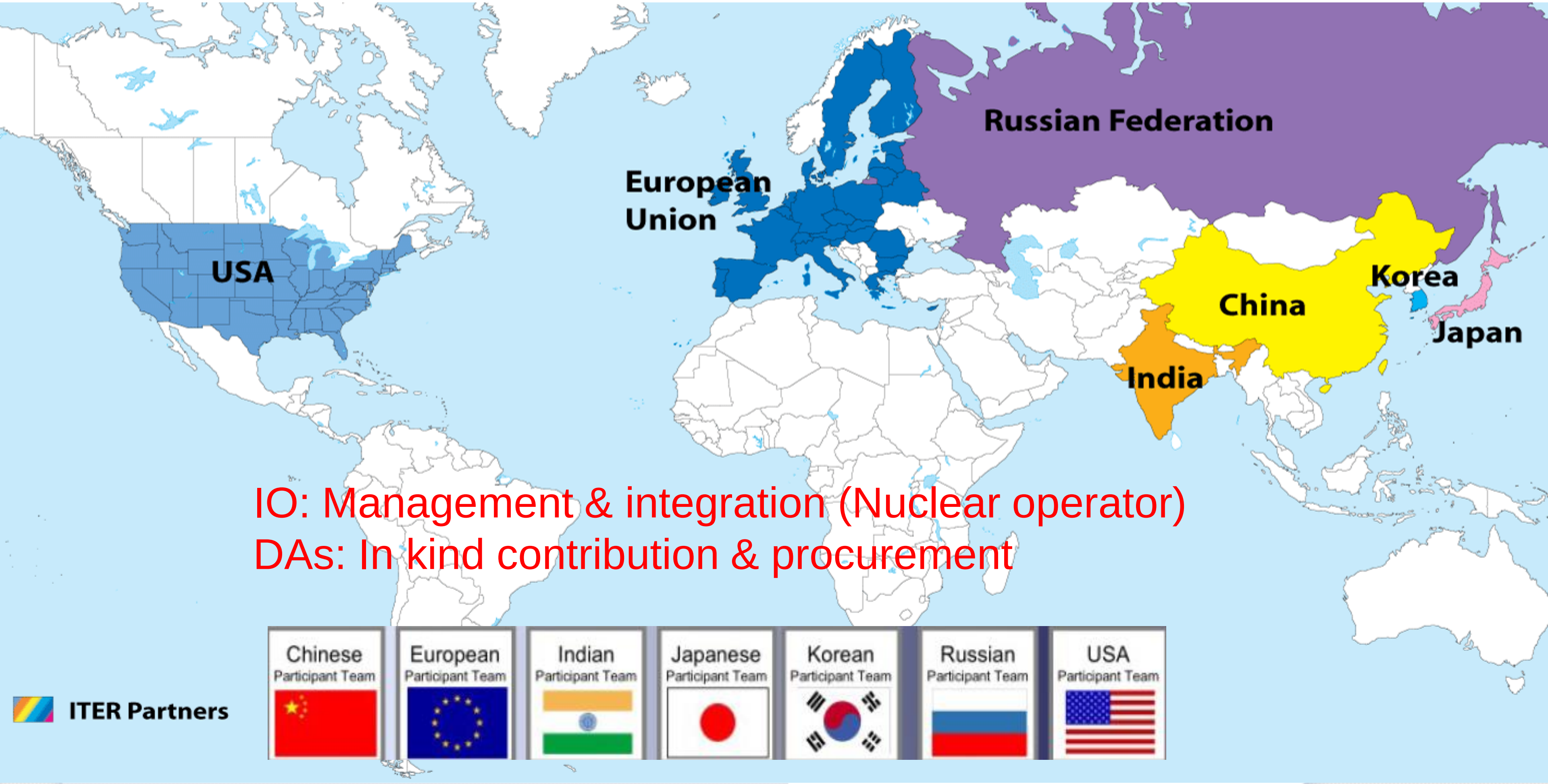
Typical Temperature: 20 keV

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 - International Cooperation

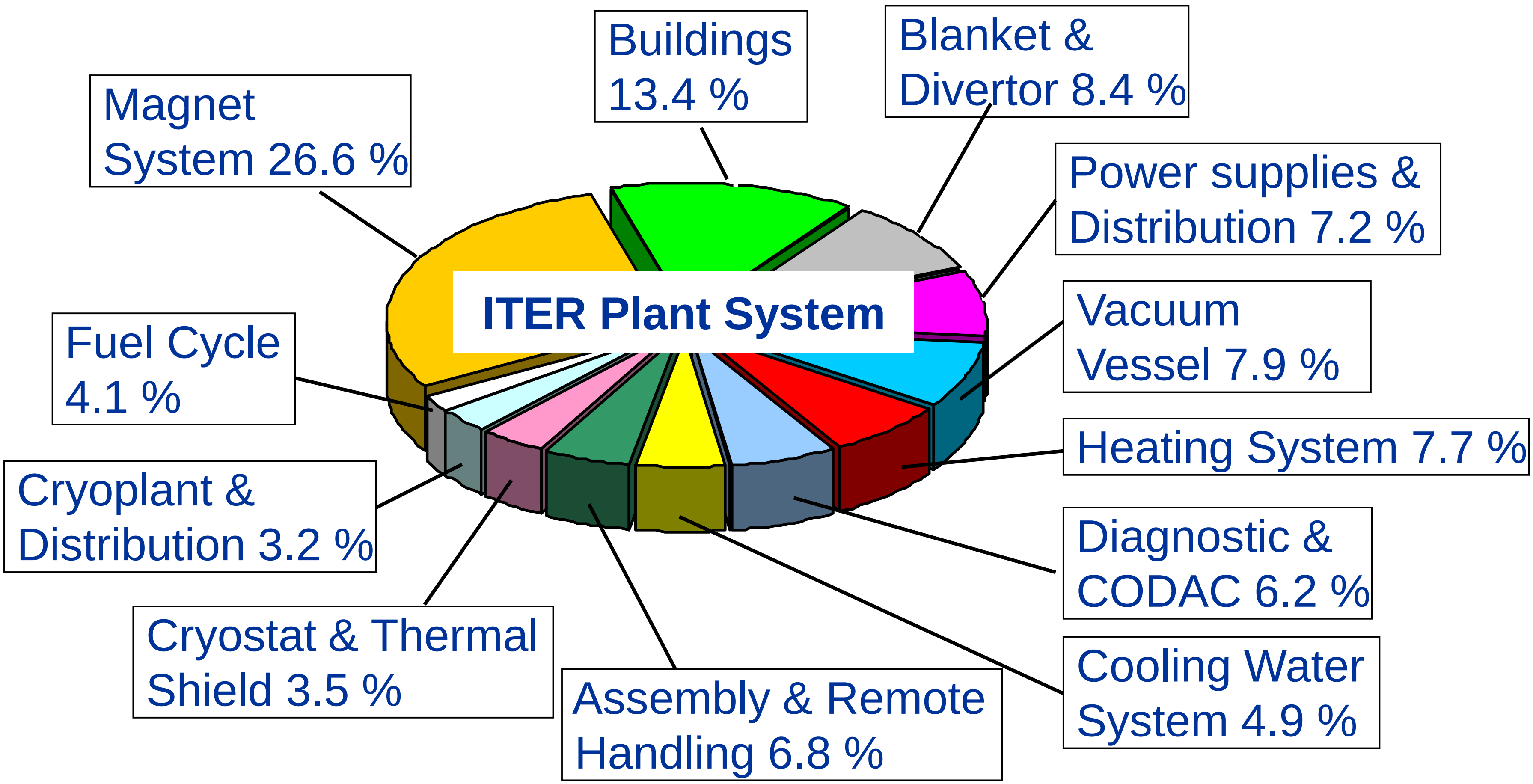
Construction & operation by the ITER Organization (IO) with support of the Domestic Agencies (DAs) of the seven parties



IO: Management & integration (Nuclear operator)
DAs: In kind contribution & procurement

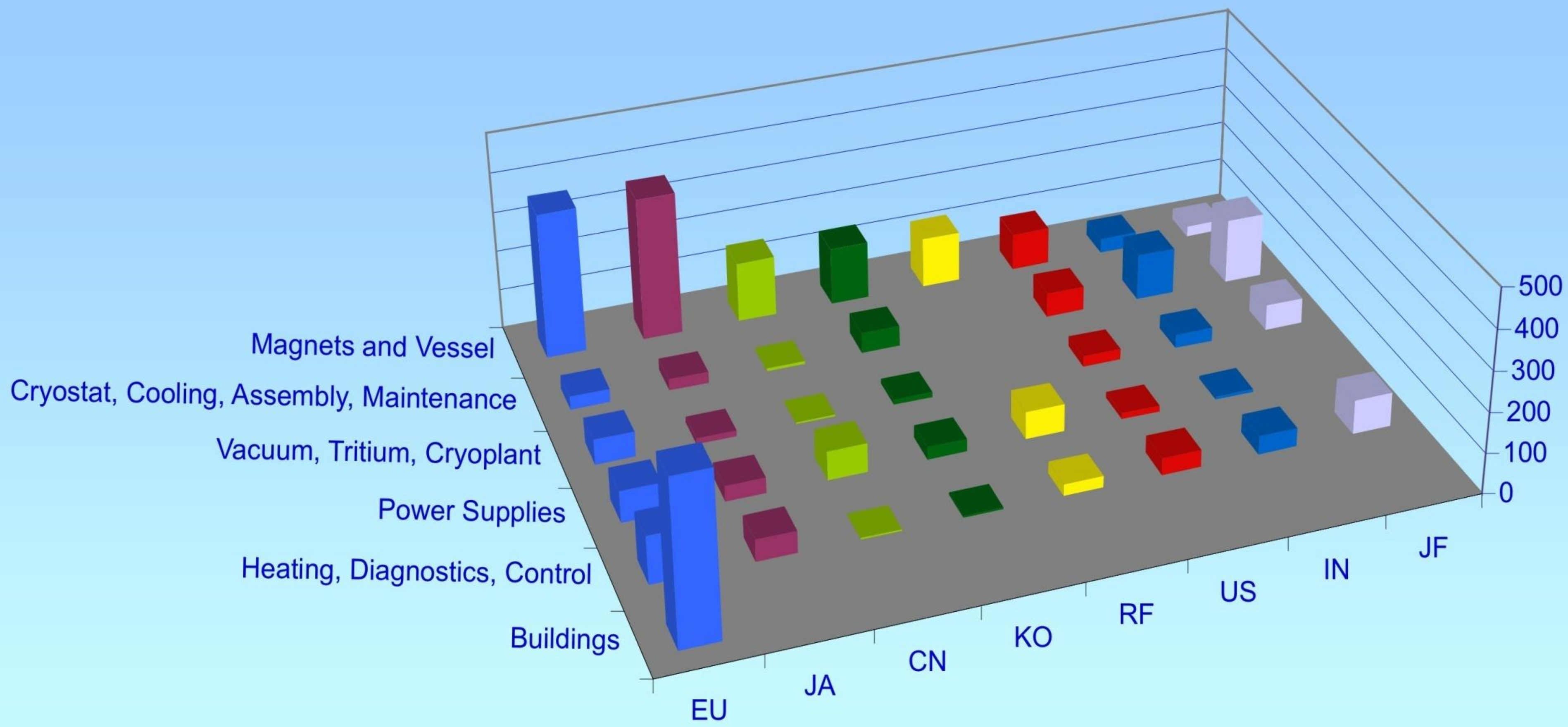
Construction Sharing

Complex plant system with advanced technology
Sharing: EU 5/11, other six parties 1/11 each
90 % in kind procurement



Procurement In Kind

Involvement of the parties in key fusion technology areas
A fair sharing of the cost of the device by ‘value’ and not by currency
Interfaces management and integration by IO



General Roles & Responsibilities for Construction

- ITER IO
  - Planning/Design
  - Integration / QA / Safety / Licensing / Schedule
  - Installation
  - Testing + Commissioning
  - Operation
- Parties – DAs
  - Detailing / Designing
  - Procuring
  - Delivering
  - Support installation
- IO and DAs plus Fusion Community work together on exploitation of ITER. ITER IO coordinates and participates in the program (e.g. Test Blanket Module program for power generation).

ITER Organization

ITER Council

Management Advisory Committee

Science and Technology Advisory Committee

Financial Audit Board

Kaname Ikeda
Director-General
Senior Advisor
(P. Amenc-Antoni)

Norbert Holtkamp
Principal DDG
Two Senior Advisors

- Office of the Director-General (H. Matsumoto)
- ITER Council Secretary (S. Ishizaka)
- Legal Office (P. Tuinder)
- Communication (N. Calder)
- Office of Audit Service

Dept. for Safety & Security

DDG Carlos Alejaldre

- Safety Control
- Quality Assurance

DDG Wang Shaoqi
Senior Advisor

Dept. for Administration
- Finance & Budget
- Procurement & Contract
- Human Resources

DDG Valery Chuyanov
ADDG (D. Campbell)

Dept. for Fusion Science and Technology
- Science
- Technology

Project Office (E. Tada)
- Design Integration & Configuration Control
- Project Management
- Technical Co-ordination
- System Analysis
- Environment, Safety & Health

Domestic Agencies
- China
- EU
- India
- Japan
- Korea
- Russia
- USA

Civil Construction and Site Support Office
(J. Sovka)
- Building System
- Site Layout
- Nuclear Buildings
- Steel Frame Buildings

DDG Dhiraj Bora

Dept. for CODAC & IT, Heating & CD, Diagnostics
- CODAC and IT
- Heating and Current Drive
- Diagnostics

DDG Yong-Hwan Kim

Dept. for Central Engineering & Plant Support
- Plant Engineering
- Fuel Cycle Engineering
- Electrical Engineering
- Design Office

DDG Gary Johnson

Dept. for Tokamak
- Magnet
- Vessel
- Internal Components
- Assembly & Maintenance

Field Teams
- Field Team Leader
- Staff (QA, C&S, Audits, etc.)
- Technical Support

Revised on 15 May 2008

Domestic Agencies

- **China**: ITER China Office is acting as DA which will be formally established soon.
- **EU**: F4E (Fusion for Energy) was established as DA in Barcelona.
- **India**: Indian ITER Office to be established with the Institute for Plasma Research to function as DA.
- **Japan**: JAEA (Japan Atomic Energy Agency) was appointed as its DA.
- **Korea**: ITER Korea was established within the NFRI (National Fusion Research Institute).
- **Russia**: A special department was established within the Kurchatov Institute to function as its DA.
- **US**: ITER Project Office was established in the ORNL.

Integral Project Management
- Baseline: scope, schedule, cost & management -

- **Technical scope**

  Reference Design elaborated through R&D in the design phase and up-to-date design review with the DAs and fusion community
- **Schedule**

  First plasma in middle of 2018 as a reference, consistent with the procurement schedules in the DAs
- **Cost**

  Bottom-up estimate to achieve scope and schedule
- **Management**

  Management systems/tools for project execution to achieve the technical scope within schedule and cost.

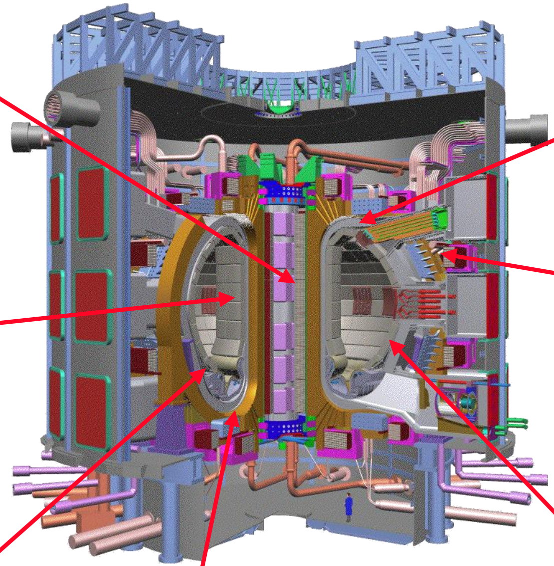
Key Technology Development in the Design Phase

CENTRAL SOLENOID MODEL COIL

Radius 3.5 m
Height 2.8m
B_{max}=13 T
0.6 T/sec

TOROIDAL FIELD MODEL COIL

Height 4 m
Width 3 m
B_{max}=7.8 T



BLANKET MODULE

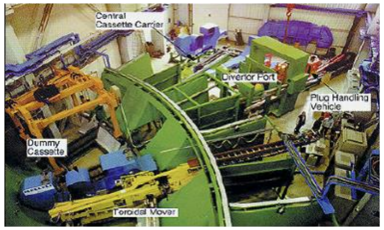
HIP Joining Tech

VACUUM VESSEL SECTOR

Double-Wall, ± 5 mm

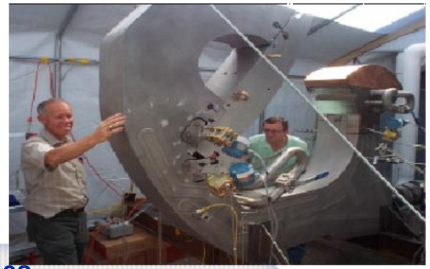
REMOTE MAINTENANCE OF DIVERTOR CASSETTE

Attachment Tolerance ± 2 mm



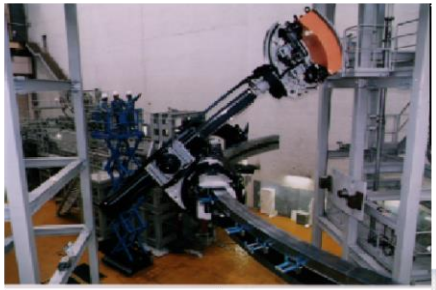
DIVERTOR CASSETTE AND PFCs

20 MW/m^2

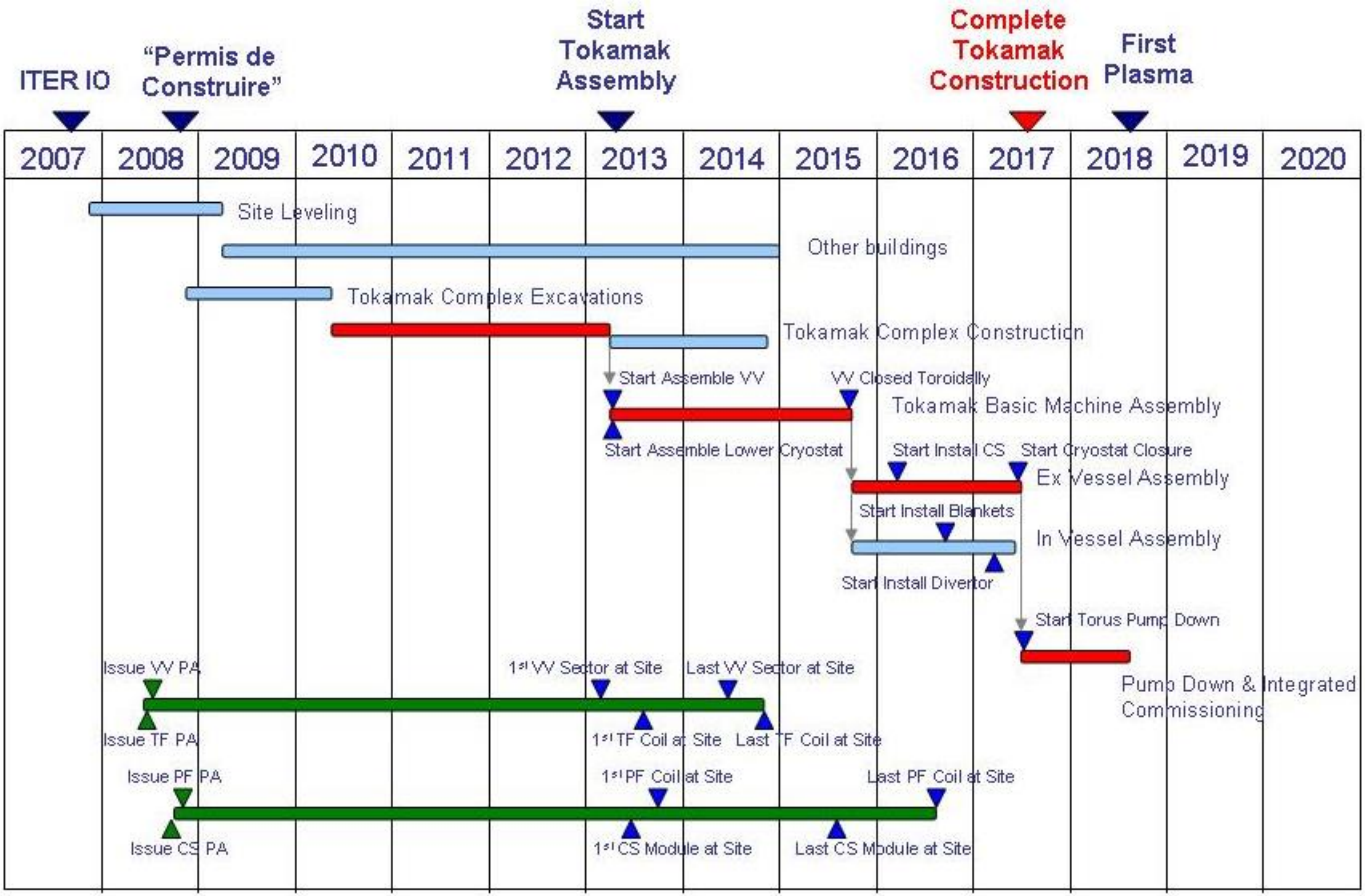


REMOTE MAINTENANCE OF BLANKET

4 t blanket sector ±0.25 mm

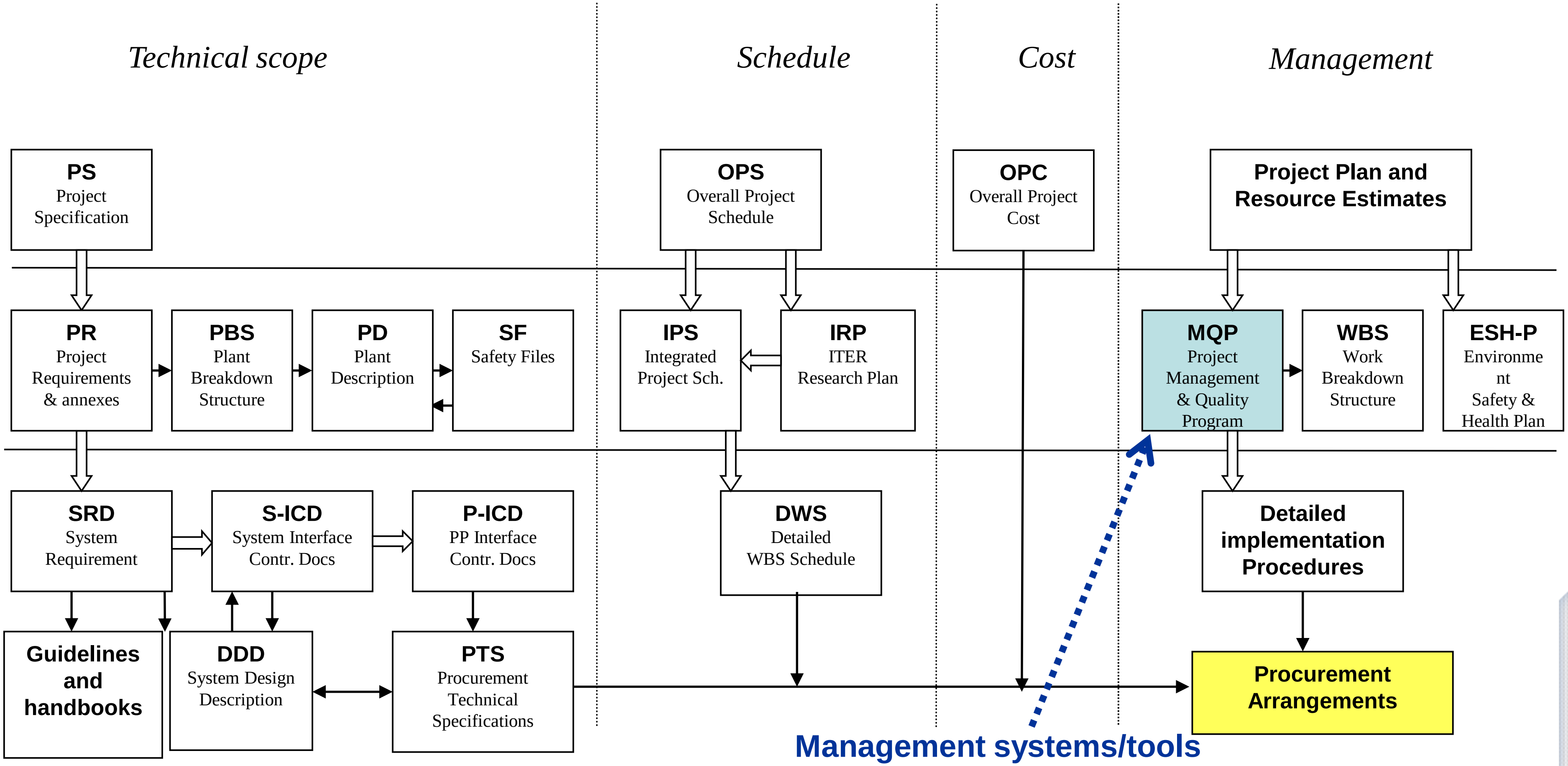


Reference Project Schedule



Baseline Document Structure

- **Categorized to define scope, schedule, cost and management plan**
- **Layered for the approval authority, corresponding to the organization structure: Council, Management (DG/PDDG) and Departments (DDGs)**
- **Integrated into Procurement Arrangement for construction**



Integral Management

Project Plan and Resource Estimate (Council level doc.)

- Overall project schedule & construction schedule
- Management systems for the project execution
- Work plan and resources for construction

MQP (Management level doc.)

- Cost & Schedule Management (Earned Value Management)
- Configuration Management – change control
- Procurement management – in-kind procurement by DAs
- Risk Management – avoidance, reduction and mitigation
- Quality Assurance – graded approach based on importance

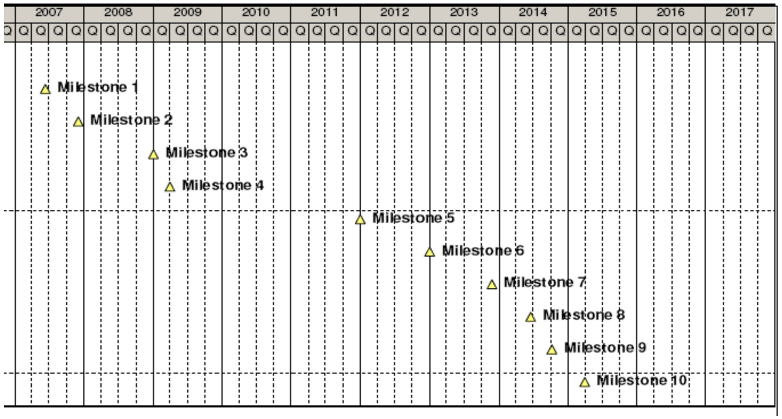
Detailed Procedures & PA (Department level doc.)

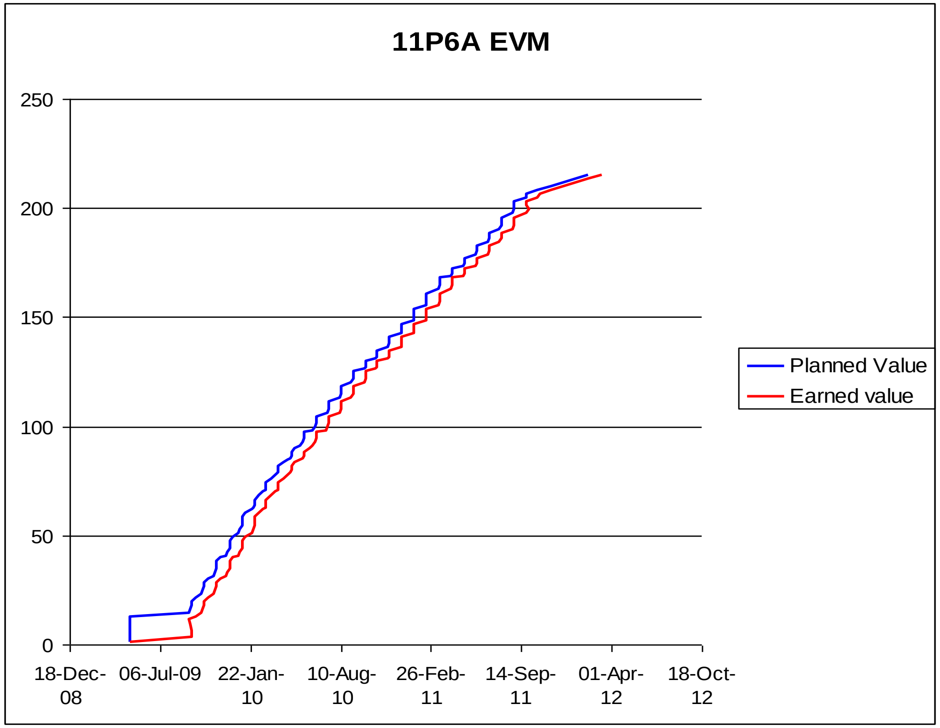
Earned Value Management (EVM)
- Schedule & Cost Control -

Schedule Performance: Earned Value vs. Planned Value
Cost Performance: Earned Value vs. Actual Costs

Schedule performance tracking for in kind procurement:

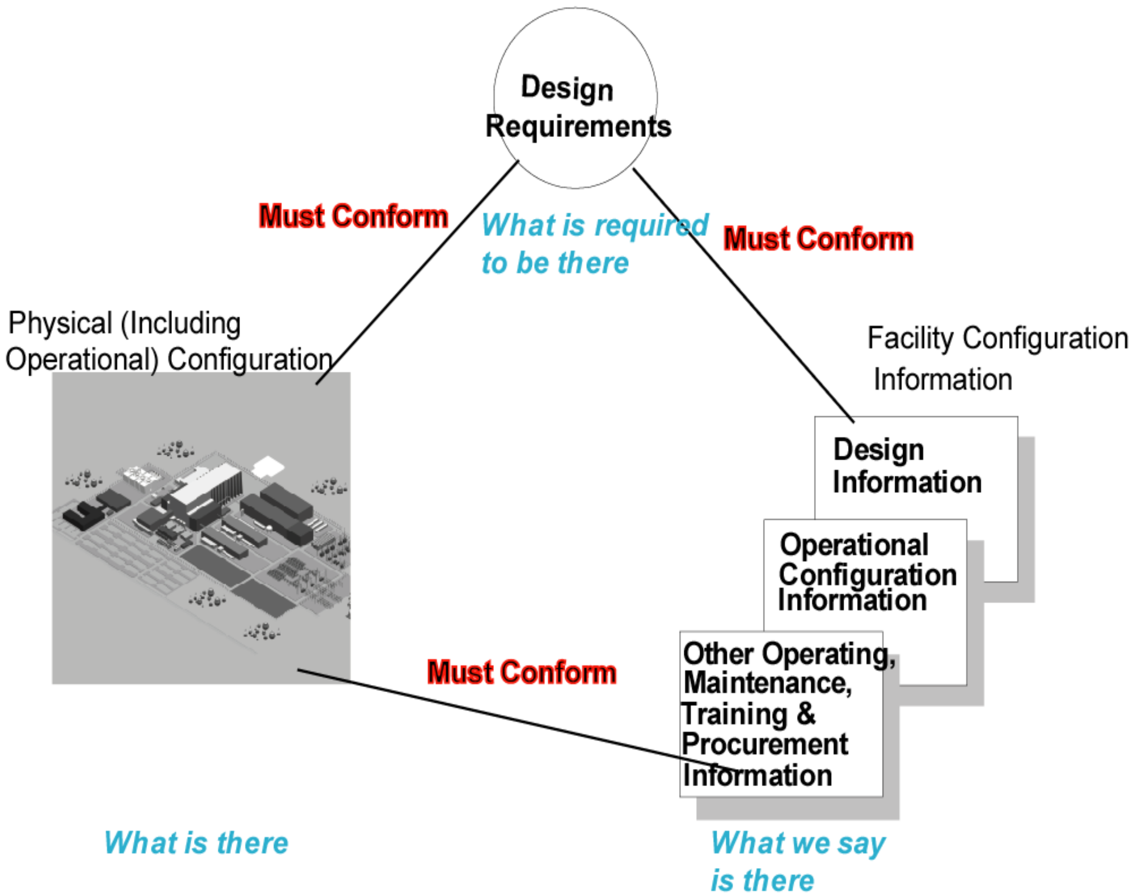
- Milestones defined in PA: measurable/verifiable deliverables
- Credit attributed (IUA) to each milestone
- Milestone achievement: acceptance and then credit allocation





Configuration Management

Configuration Management is the process for establishing and maintaining consistency of a product's performance, functional and physical attributes with its requirements, design and operational information throughout its life.



Main Elements:

- Identification of the configuration baselines
- Management of the Design Requirements
- Management of the Design Changes

Management of Design Requirements

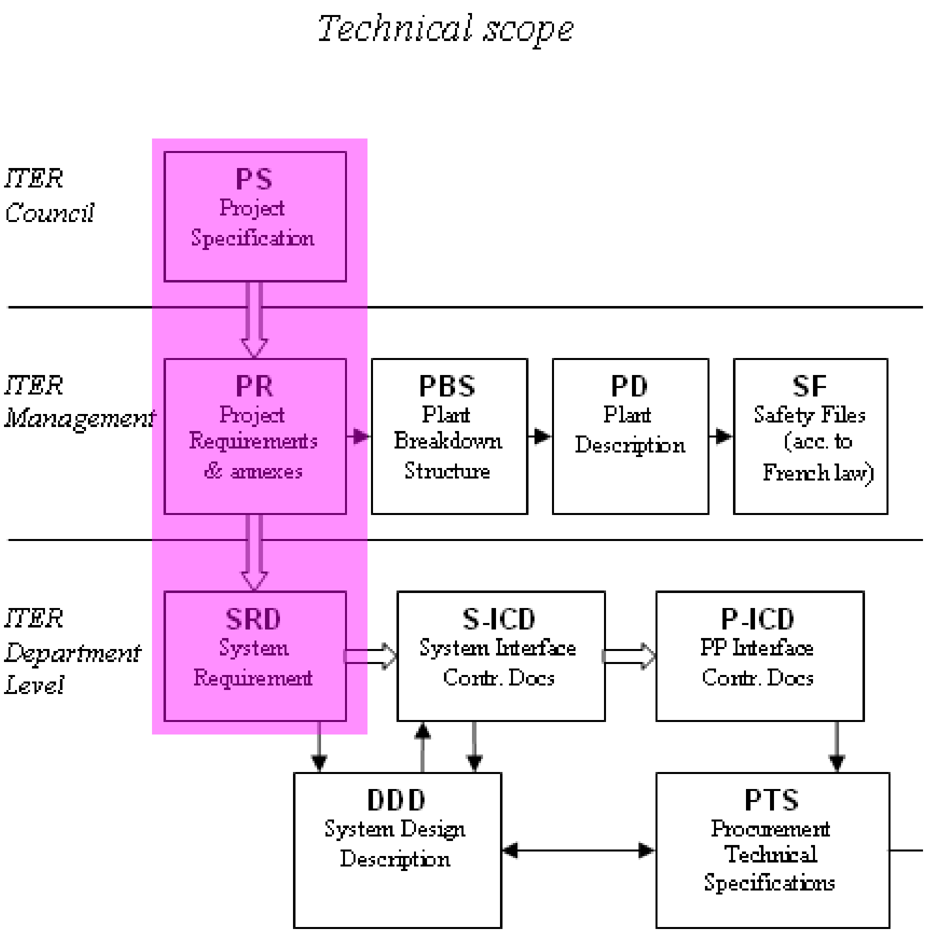
The PS defines the operational features and performance required to fulfil the ITER mission.

⬇

The PR translates the top level mission requirements into engineering terms.

⬇

The SRDs define the requirements for the systems.



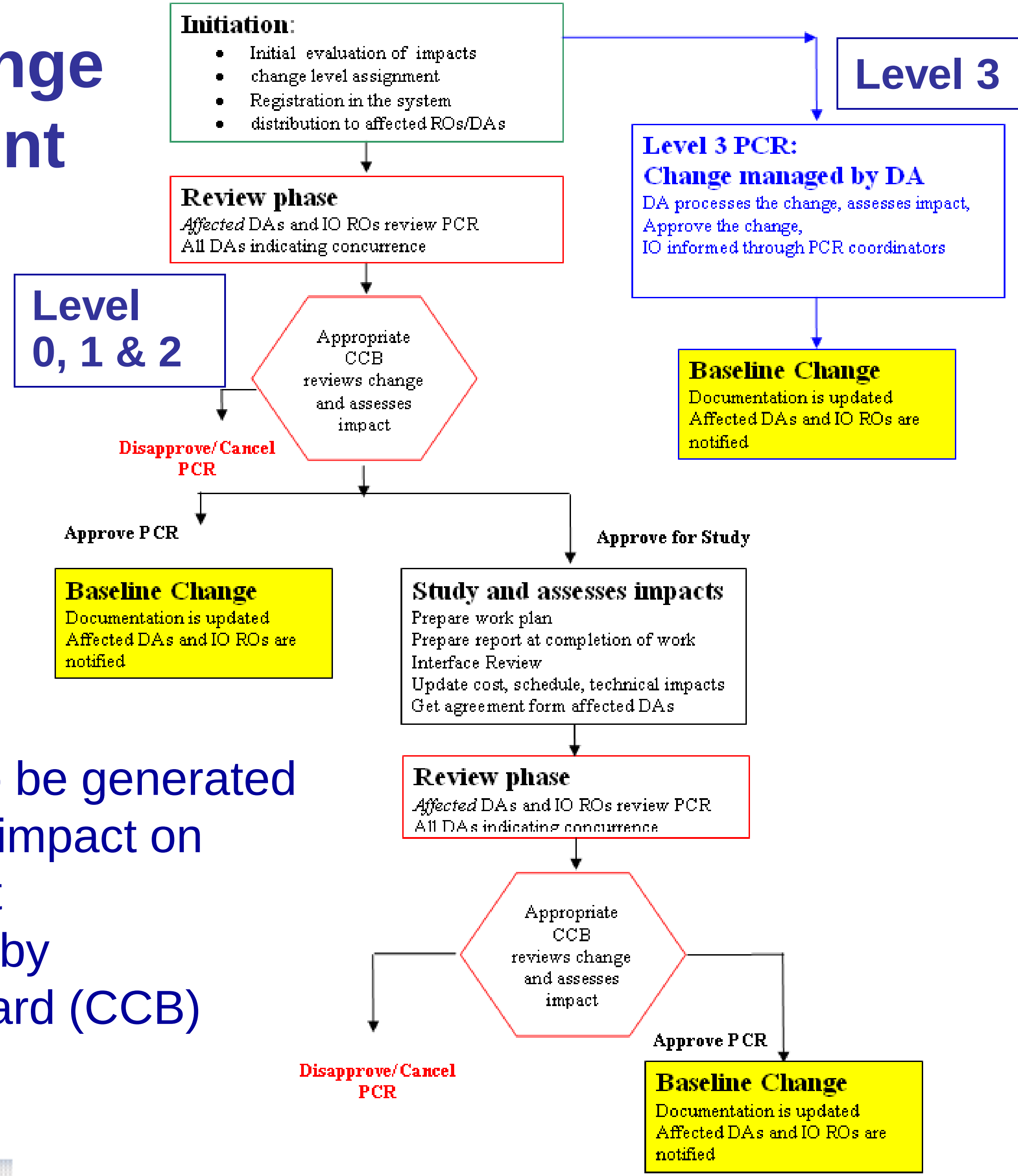
PS : Project Specification
PR : Project Requirement
SRD: System Requirement Document

Design Change Management

Changes categorize and approved depending on the level of impact:

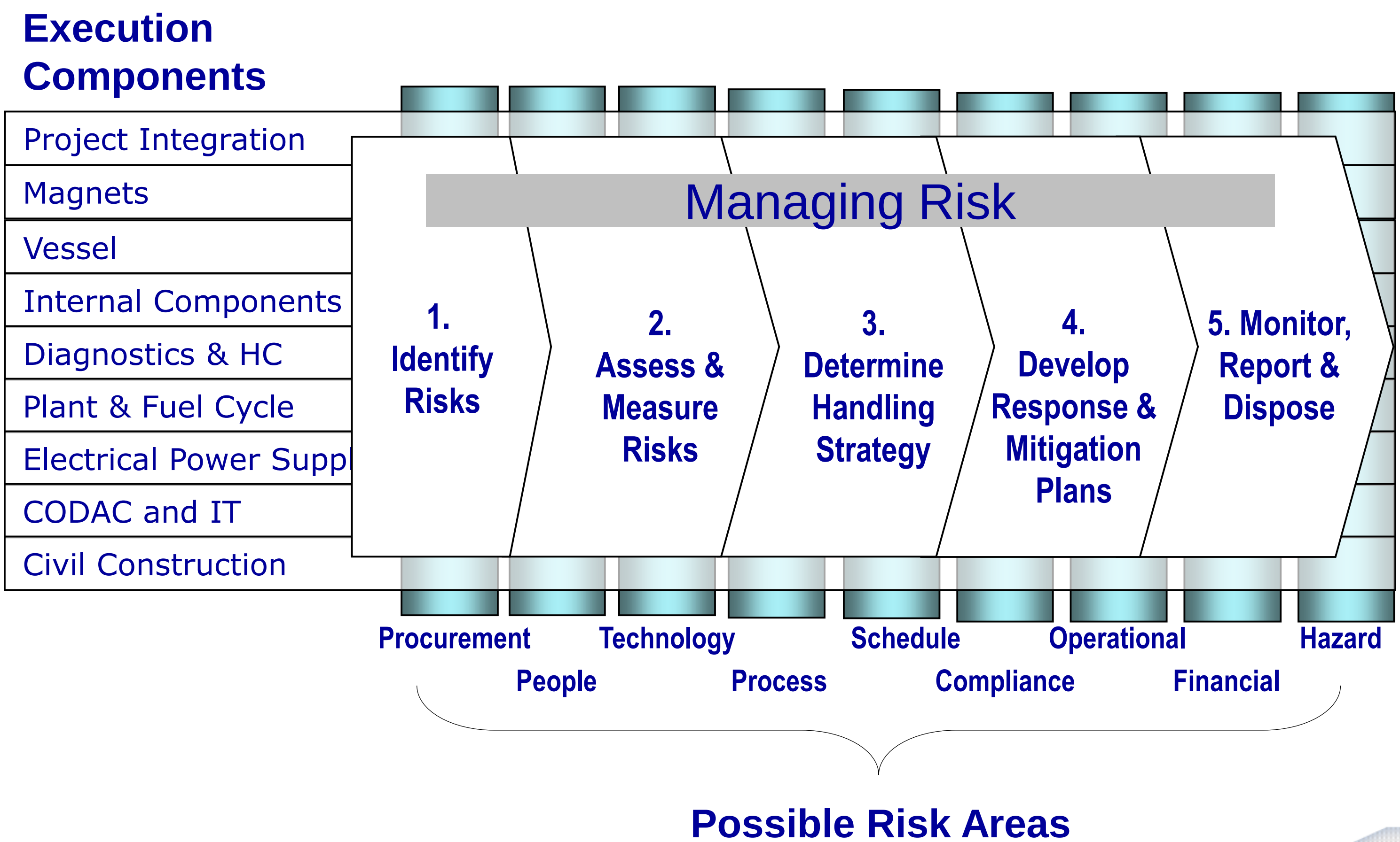
Level 0: ITER Council
Level 1: ITER DG/PDDG
Level 2: ITER DDGs
Level 3: DAs

- Change request (PCR) to be generated and reviewed in terms of impact on scope, schedule and cost
- Changes to be managed by Configuration Control Board (CCB)

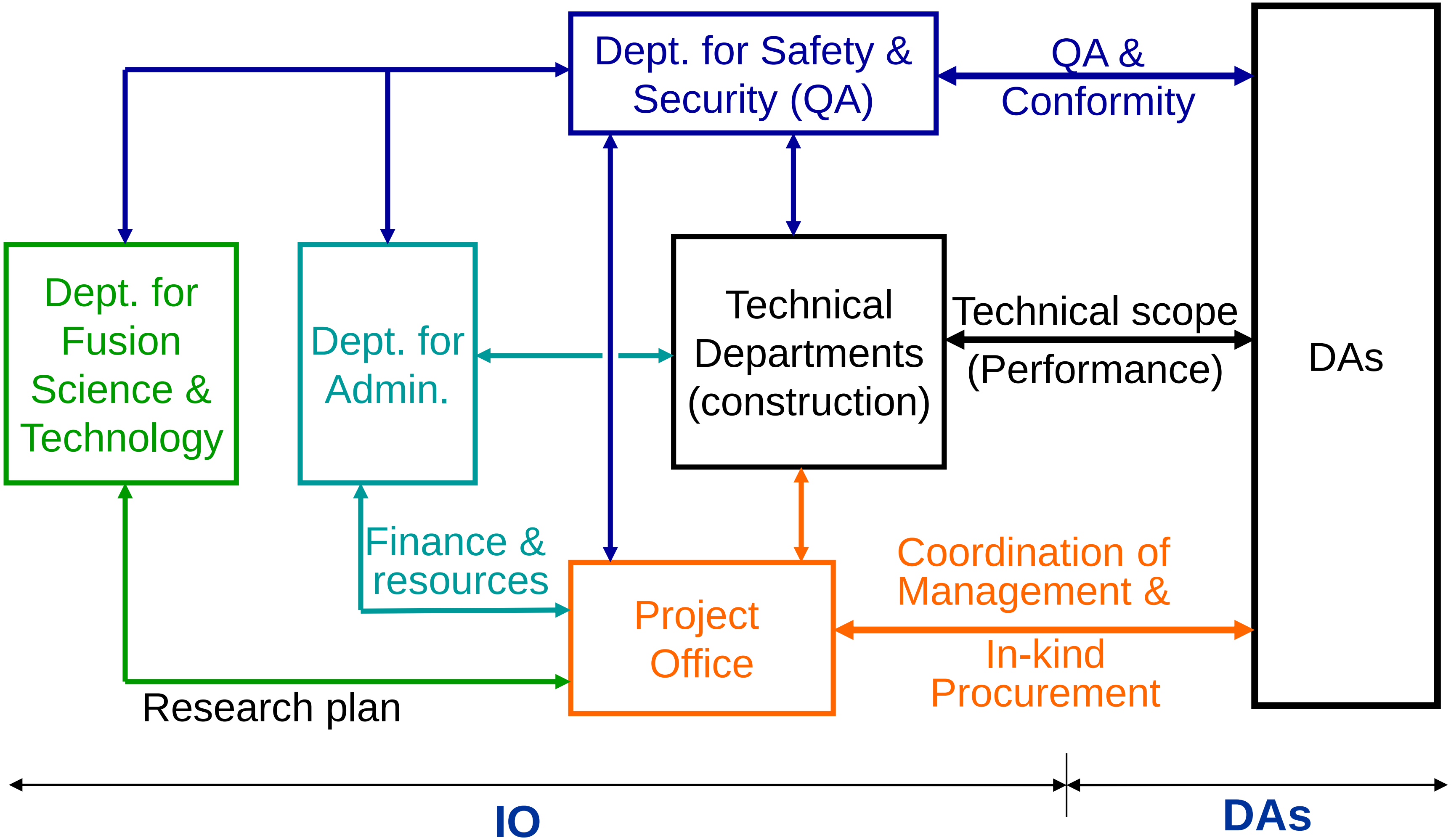


Risk Management

Primary Objective of the ITER Risk Management is to provide a sustainable and consistent process for the management of cost, schedule, technical, and operational uncertainty on the project.

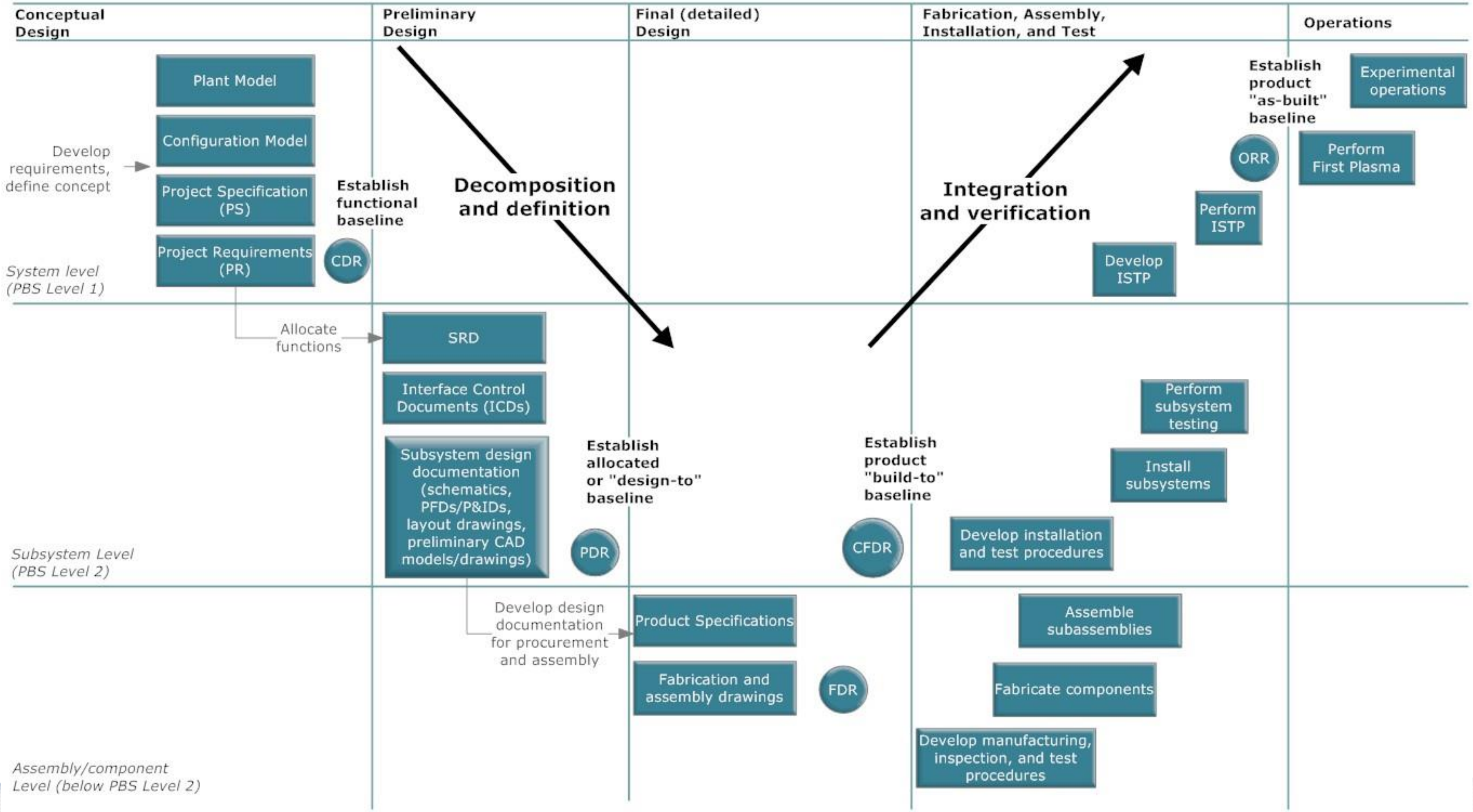


Overall Work Relationship for System Integration

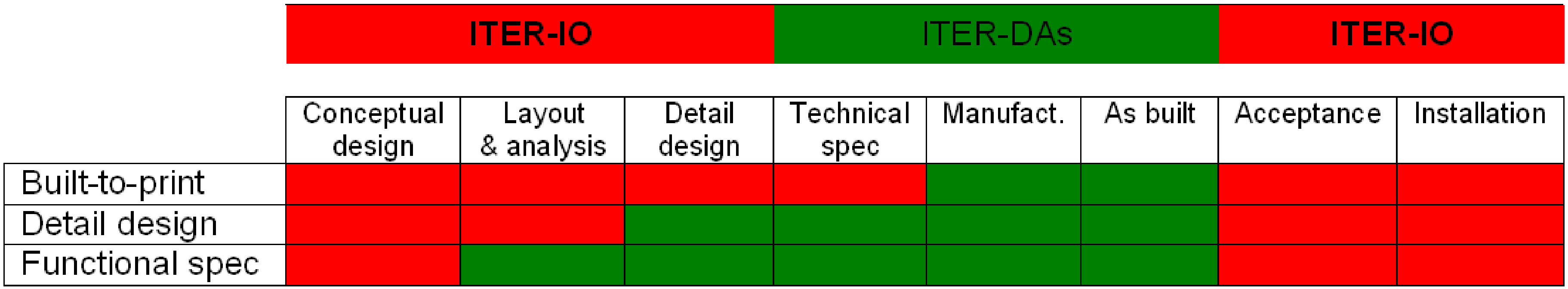


System Engineering Process

ITER System Engineering plan to define engineering processes and clarify roles & responsibilities for integration. It focuses on needs and functionality in the early stage and then integration and verification.



ITER Construction Life Cycle



Requirement definition

Validation

Requirement analysis

Verification

Architectural design

Integration

Implementation

Interface Management

System Interface Control among systems
Procurement Interface Control among DAs

PBS		11	15	16	17	18	22	23	24	26	27	31	32	34	41	43	45	46	51	52	53	54	55	56	61	62	63	64	65
Magnets	11		•	•	•		•	•	•		•	•	•	•	•		•	•					•		•	•			
Vacuum Vessel	15	•		•	•	•	•	•	•	•	•	•	•	•			•		•	•	•	•	•	•	•	•		•	
Blanket systems	16	•	•		•	•	•	•		•		•	•						•	•	•	•	•	•		•		•	
Divertor	17	•	•	•		•	•	•		•		•	•										•			•		•	
Fuelling & wall conditioning	18		•	•	•		•	•	•	•	•	•	•	•		•	•	•			•					•			•
Machine Assembly & tooling & installation	22	•	•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
Remote Handling equipment	23	•	•	•	•	•	•		•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•		•	•
Cryostat	24	•	•			•	•	•		•	•	•	•	•		•	•	•					•			•			
Cooling water system	26		•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•
Thermal shield	27	•	•			•	•	•	•			•		•			•	•					•			•			
Vacuum	31	•	•	•	•	•	•	•	•	•	•		•	•		•	•	•	•	•	•	•	•	•		•			•
Tritium plant	32	•	•	•	•	•	•	•	•	•		•				•	•	•					•			•		•	•
Cryoplant & cryodistribution	34	•	•			•	•		•	•	•	•			•		•	•							•	•	•		
Coil power supplies & distribution	41	•					•			•				•		•	•	•							•	•	•		
Steady state electrical power network	43					•	•	•	•	•		•	•		•		•	•	•	•	•	•	•	•	•	•	•	•	•
CODAC	45	•	•			•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•
Safety & interlock systems	46	•				•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•	•	•	•	•	•	•
Ion cyclotron H&CD system	51		•	•			•	•		•		•				•	•	•							•	•			
Electron cyclotron H&CD system	52		•	•			•	•		•		•				•	•	•							•	•			
Neutral Beam H&CD system	53		•	•		•	•	•		•		•				•	•	•					•		•	•	•		
Lower Hybrid H&CD system*	54		•	•			•	•		•		•				•	•	•							•	•			
Diagnostics	55	•	•	•	•		•	•	•	•	•	•	•			•	•	•			•					•			
Test blankets	56		•	•			•	•		•		•				•	•	•								•			•
Site	61	•	•				•	•		•				•	•	•	•	•	•	•	•	•				•	•		•
Reinforced concrete buildings	62	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•			•	•
Steel frame buildings	63						•			•				•	•	•	•	•			•				•				•
Radiological protections	64		•	•	•			•					•			•	•	•								•			
Liquid and gas distribution	65					•	•	•		•		•	•			•	•	•						•	•	•	•		

RAMI: Reliability, Availability, Maintainability & Inspectability

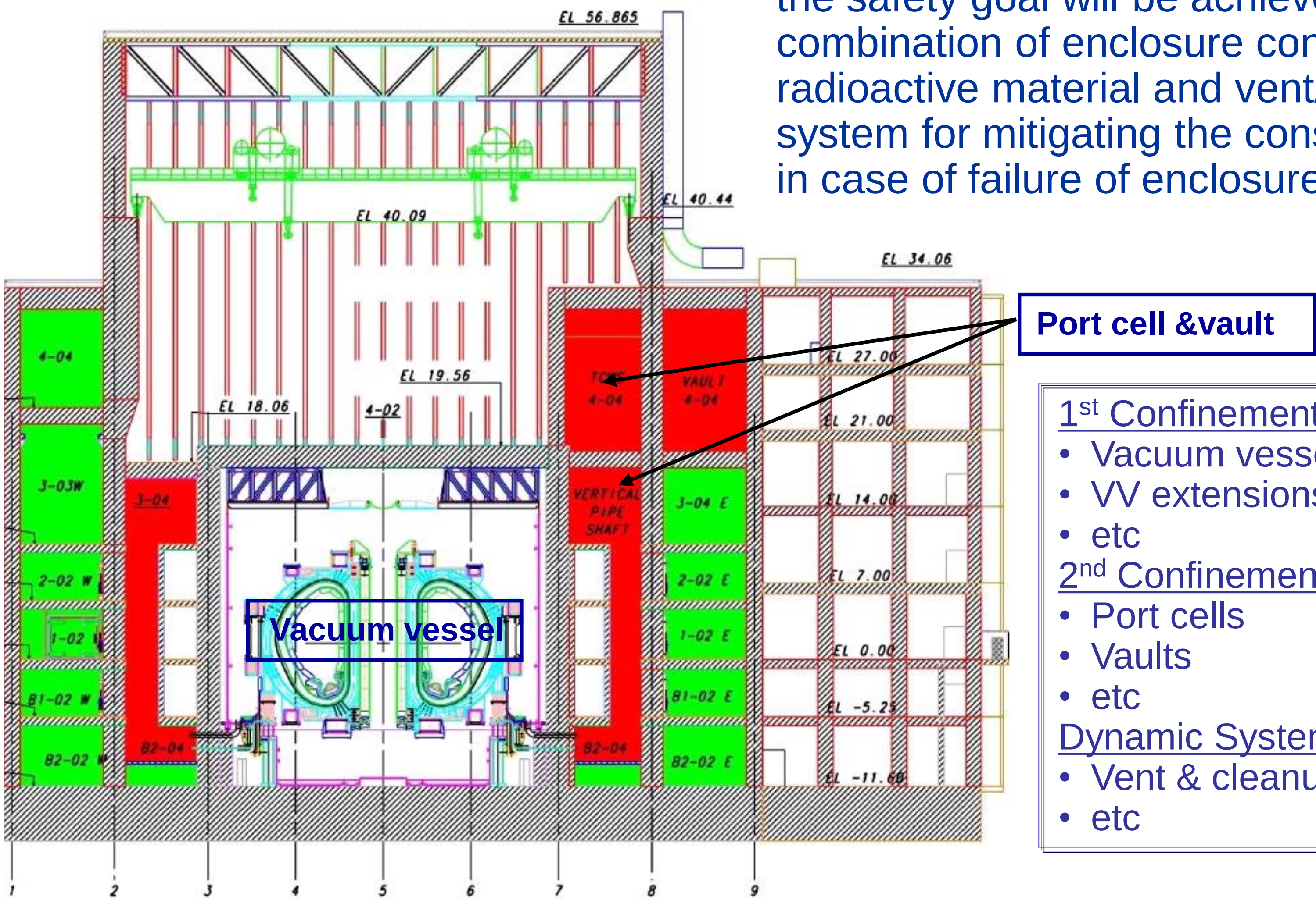
RAMI: Technical Risk Control program for the success and availability of ITER. The ITER RAMI program is declined in 4 stages:

- A classical Functional Analysis to identify the main functions and their possible Failures.
- An analysis of the failure modes, their cause & effects and the establishment of a Critical List according to their importance with respect to the machine operation availability (FMEA).
- Evaluation of Severity, Occurrence and Detectability levels of main failure mode causes: Criticality = S.O.D (FMECA).
- As a function of this criticality level, the risk of a failure can be considered as acceptable or not. When the risk level is too high, measures are to be taken for improvement of Design, Fabrication and Testing to reduce the risk level, and/or for an optimized Preventive Maintenance Plan and an adapted Spare Part Strategy.

Basic Safety Approach

- Confinement of Radioactive Material -

Based on the unique safety features, the safety goal will be achieved by a combination of enclosure containing radioactive material and vent/clean-up system for mitigating the consequence in case of failure of enclosure.



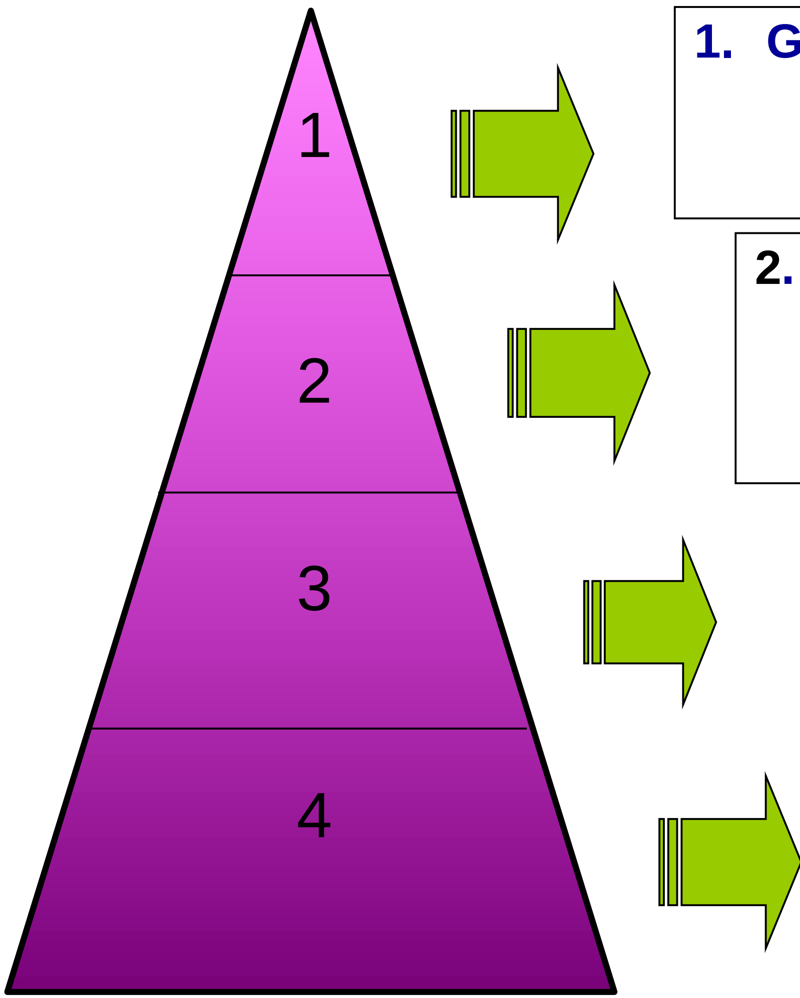
<u>1st Confinement System</u>
- Vacuum vessel
- VV extensions
- etc

<u>2nd Confinement System</u>
- Port cells
- Vaults
- etc

<u>Dynamic Systems</u>
- Vent & cleanup system
- etc

Codes and Standards Application

Internationally recognized codes & standards can be applied for construction but the compliance with nuclear regulation should be justified for the safety important components.



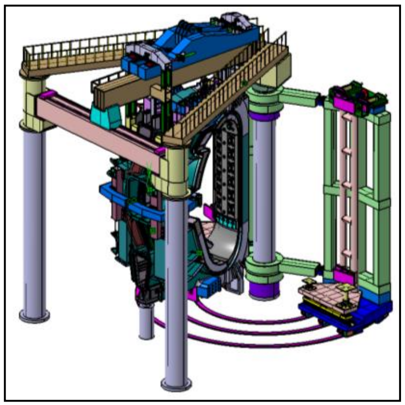
1. Governmental Acts:
- Pressure equipment
- Nuclear pressure equipment
- Nuclear quality

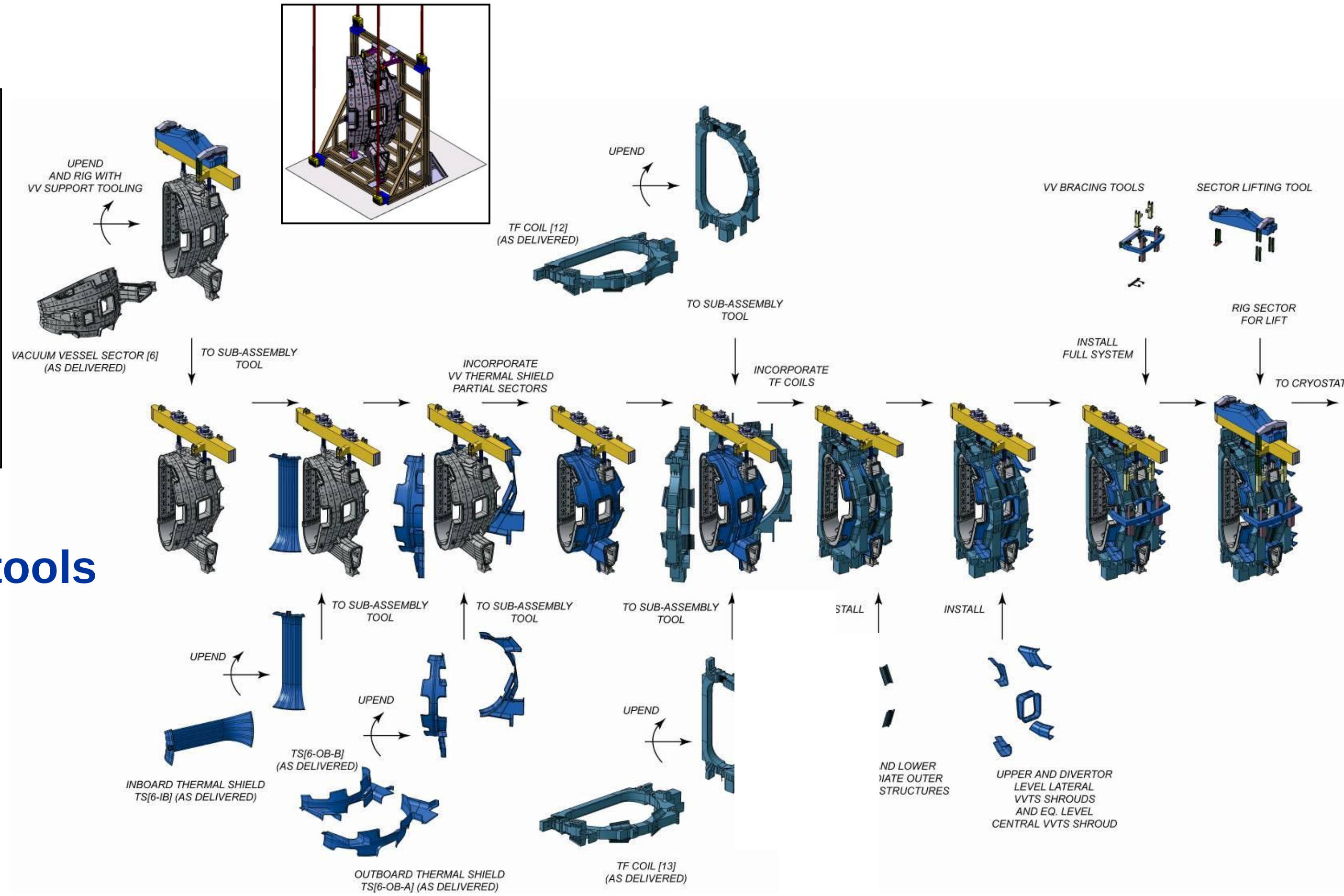
2. Codes:
- RCC-MR (vacuum vessel)
- ASME (Sec VIII, B31.1, etc.)
- EN13445
- EUROCODE (building)

3. Standards:
- ASTM
- EN
- ISO
- ANSI, EJIMA

4. Technical specifications:
defined in Procurement Arrangement

Subassembly of the Integrated Machine Sectors



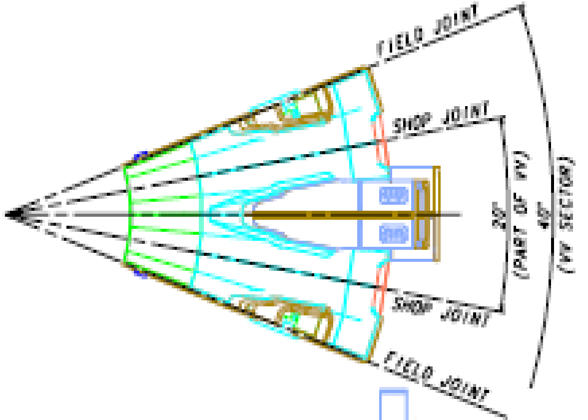


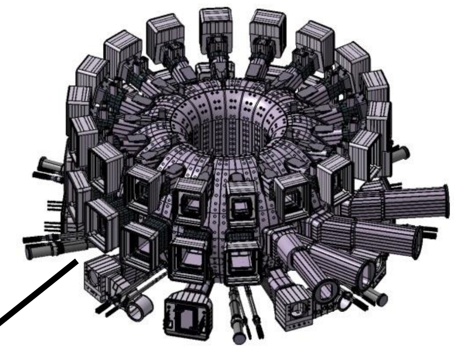
Subassembly

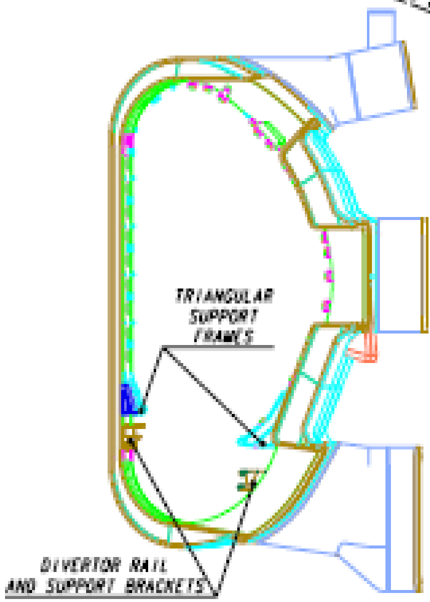
9 sectors with 2 tools

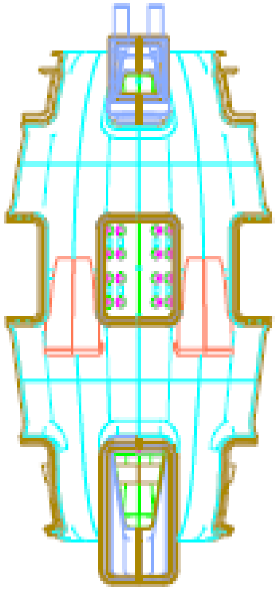
- 2 x TFCs
- VV sector
- VVTS sector
- port shrouds

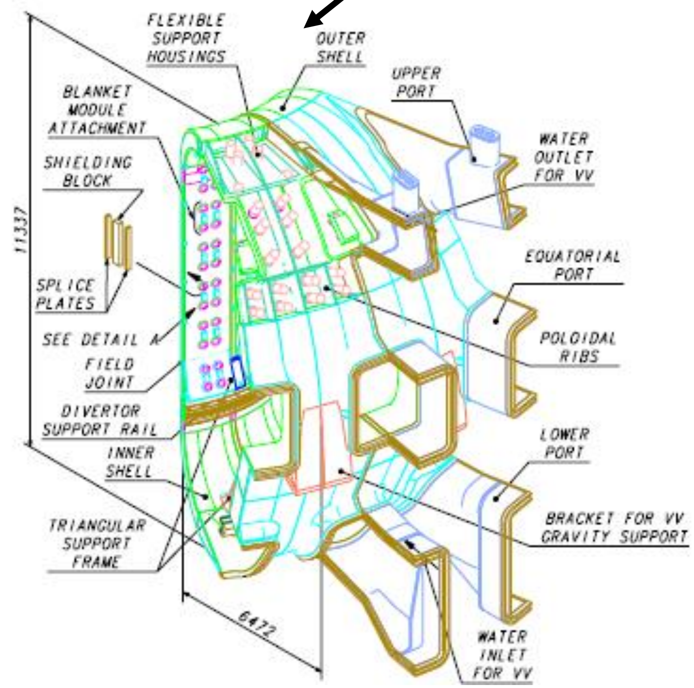
ITER Vacuum Vessel



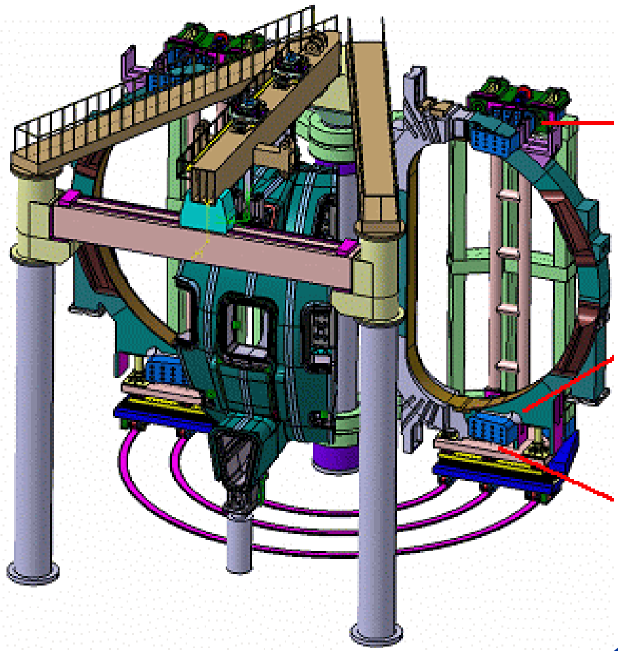


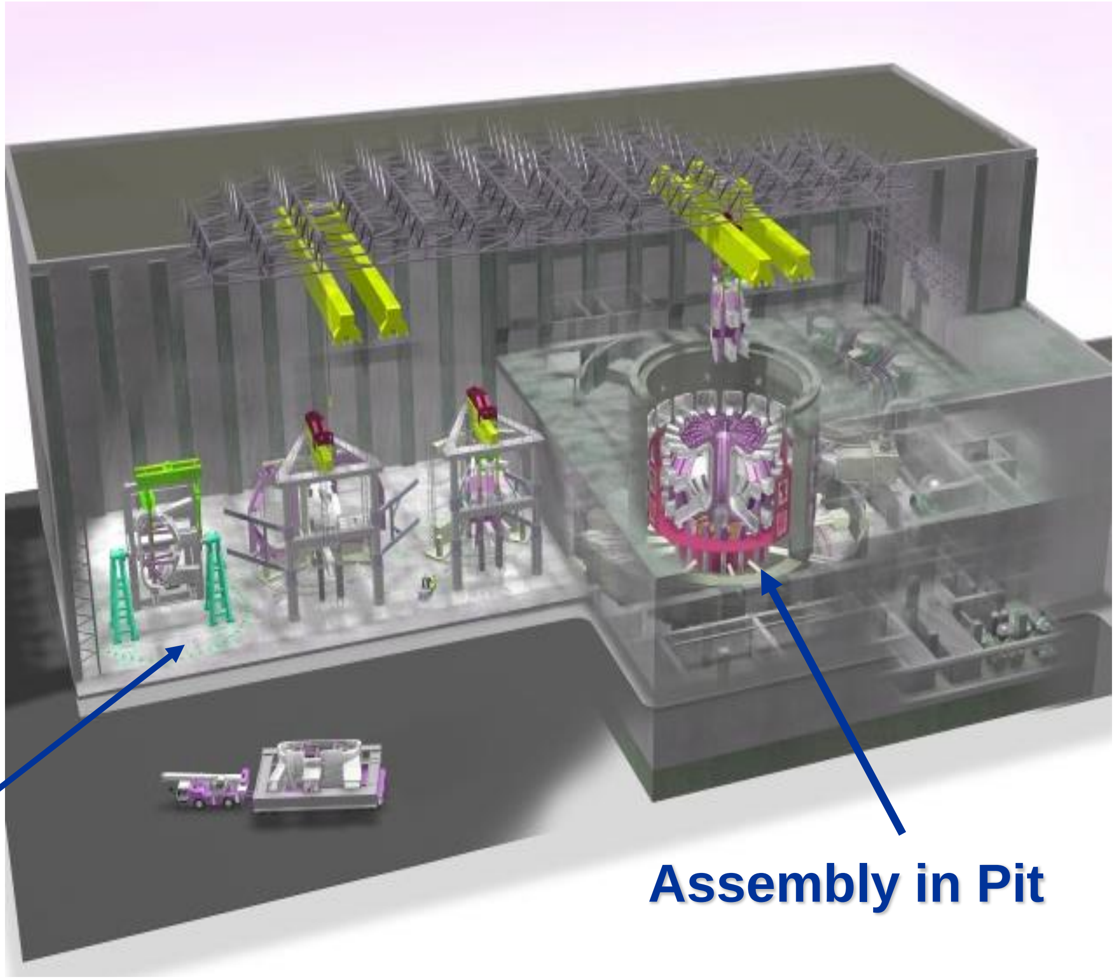






Assembly Operations in Tokamak Complex





Subassembly of
TF Coil/VV Sector
~1400 ton

Assembly in Pit

Site and Licensing Preparation

Plan of ITER Site Layout

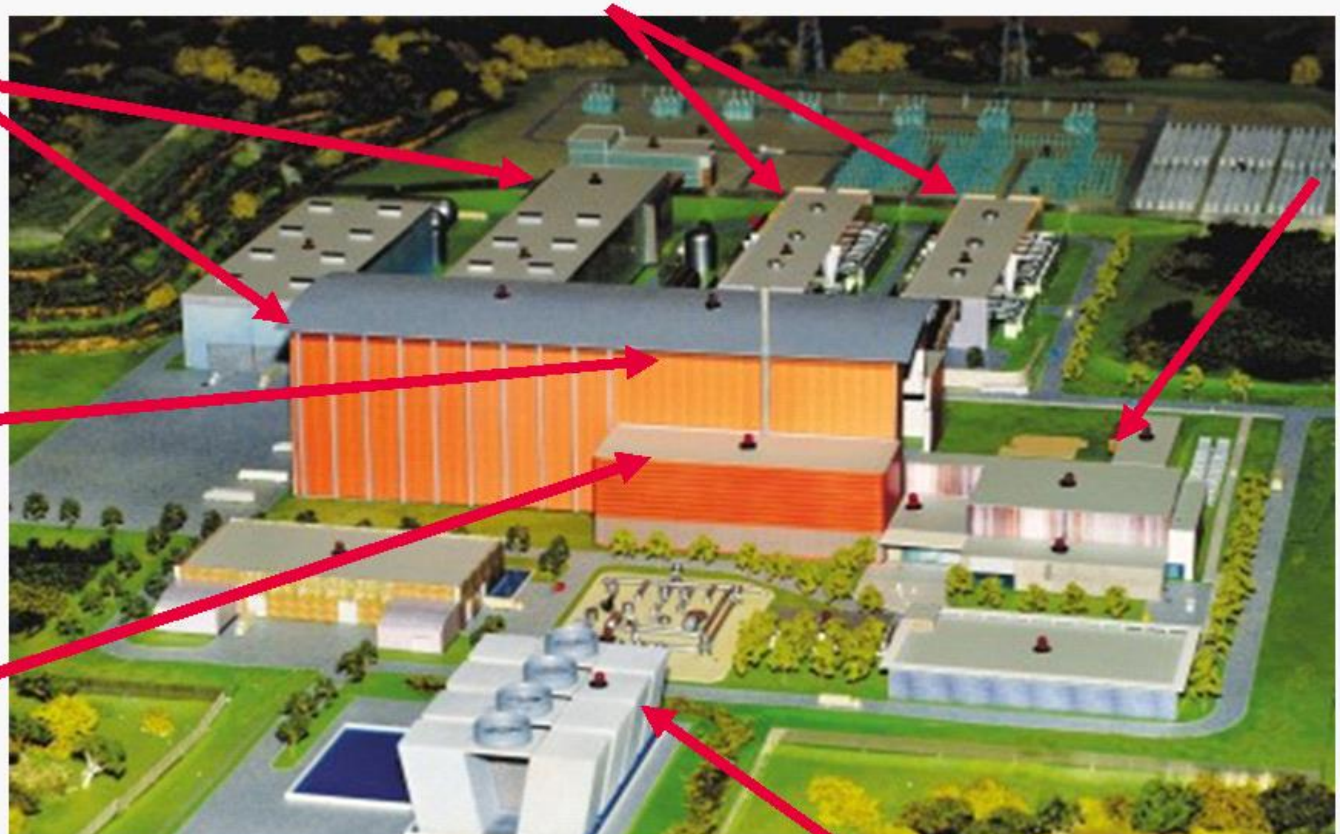
Magnet power convertors buildings

Cryoplant buildings

Hot cell

Tokamak building

Tritium building

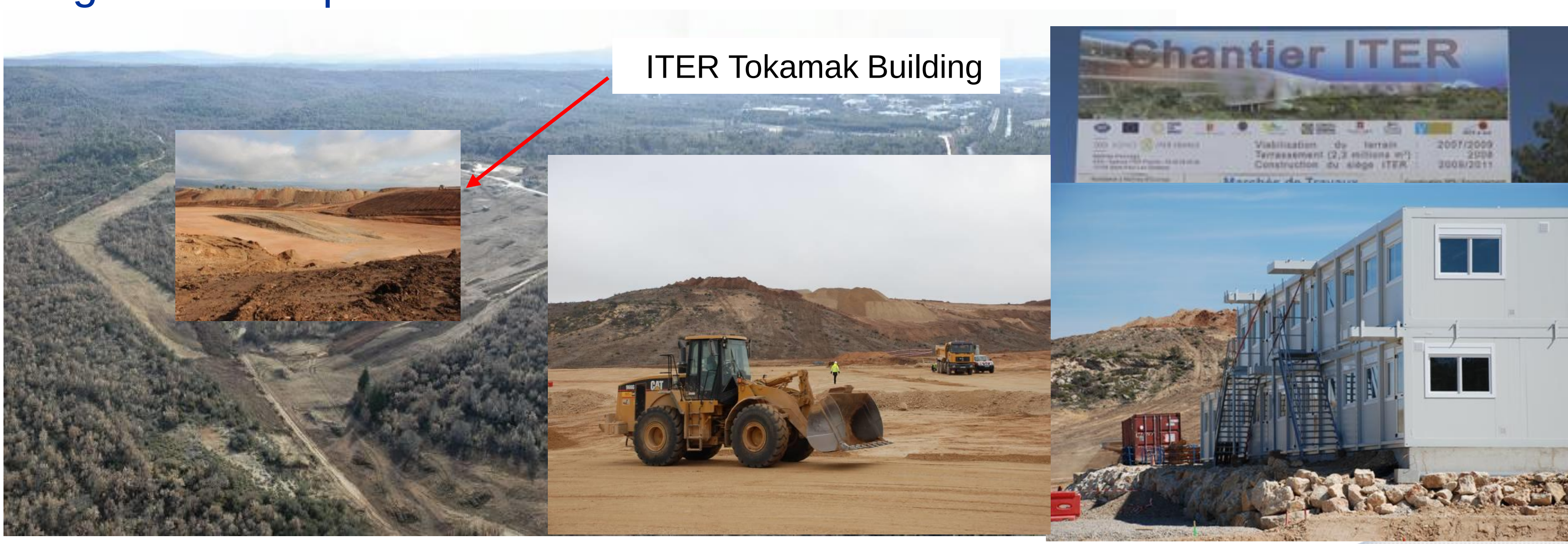


Cooling towers

- Will cover an area of about 60 ha
- Large buildings up to 170 m long
- Large number of systems

Site Preparation & Construction Permit

- The main platform-levelling work commenced on the ITER site.
- Preparations for the construction of the PF coil winding building are under way.
- The 2007 critical path design activities for civil, mechanical and electrical engineering were finished.
- The building construction permit was granted in April.



Site Preparation Status

Licensing Process

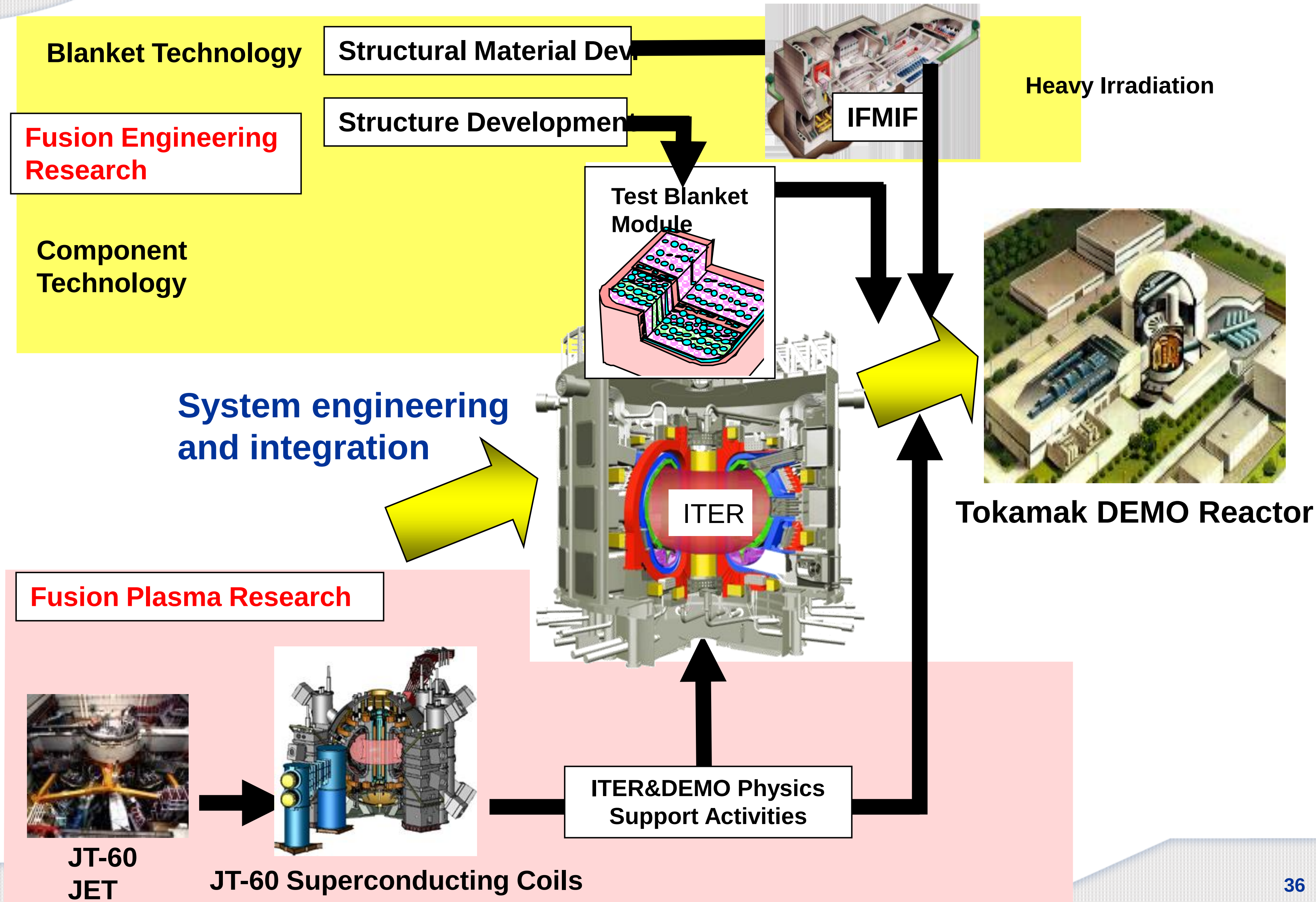
- On 31 January 2008, the safety files (DAC), including the Preliminary Safety Report, in application of the TSN law, were finished and sent to the French Nuclear Authorities.

- Examination of the files are ongoing and the Public Enquiry is foreseen around the end of 2008 or early 2009.

- The issuance of DAC could be expected after the formal examination by the so-called *Groupe Permanent*.

- The following steps in the licensing procedure are related to the authorization for starting to operate with radioactive fuel.

Summary


Blanket Technology
Structural Material Dev
Structure Development
IFMIF
Heavy Irradiation
Fusion Engineering Research
Test Blanket Module
Component Technology
System engineering and integration
ITER
Tokamak DEMO Reactor
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