ITER Construction
- Plant System Integration -

Summer Schools
23 July, 2008

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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 toroidal magnetic confinement 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
\( \text{Nb}_3\text{Sn}, 6 \text{ modules} \)

Toroidal Field Coil
\( \text{Nb}_3\text{Sn}, 18, \text{ wedged} \)

Poloidal Field Coil
\( \text{Nb-Ti}, 6 \)

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: \(10^{20} \text{ m}^{-3}\)
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

[Map showing the ITER Partners]
Construction Sharing

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

ITER Plant System

- Magnet System 26.6 %
- Fuel Cycle 4.1 %
- Cryoplant & Distribution 3.2 %
- Cryostat & Thermal Shield 3.5 %
- Assembly & Remote Handling 6.8 %
- Buildings 13.4 %
- Blanket & Divertor 8.4 %
- Power supplies & Distribution 7.2 %
- Vacuum Vessel 7.9 %
- Heating System 7.7 %
- Diagnostic & CODAC 6.2 %
- Cooling Water System 4.9 %
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).
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 2.8 m
- $B_{\text{max}} = 13$ T
- $0.6$ T/sec

REMOTE MAINTENANCE OF DIVERTOR CASSETTE
- Attachment Tolerance ± 2 mm

DIVERTOR CASSETTE AND PFCs
- $20$ MW/m$^2$

VACUUM VESSEL SECTOR
- Double-Wall, ± 5 mm

REMOTE MAINTENANCE OF BLANKET
- 4 t blanket sector ± 0.25 mm

TOROIDAL FIELD MODEL COIL
- Height 4 m
- Width 3 m
- $B_{\text{max}} = 7.8$ T
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

**Technical scope**
- PS Project Specification
- PR Project Requirements & annexes
- PBS Plant Breakdown Structure
- PD Plant Description
- SF Safety Files
- SRD System Requirement
- S-ICD System Interface Contr. Docs
- Guidelines and handbooks
- DDD System Design Description
- D-ICD PP Interface Contr. Docs
- PTS Procurement Technical Specifications

**Schedule**
- OPS Overall Project Schedule
- IPS Integrated Project Sch.
- IRP ITER Research Plan
- DWS Detailed WBS Schedule

**Cost**
- OPC Overall Project Cost

**Management**
- Project Plan and Resource Estimates
- MQP Project Management & Quality Program
- WBS Work Breakdown Structure
- ESH-P Environment Safety & Health Plan
- Detailed implementation Procedures
- Procurement Arrangements

Management systems/tools
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)
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.

**Execution Components**

<table>
<thead>
<tr>
<th>Project Integration</th>
<th>Magnets</th>
<th>Vessel</th>
<th>Internal Components</th>
<th>Diagnostics &amp; HC</th>
<th>Plant &amp; Fuel Cycle</th>
<th>Electrical Power Supply</th>
<th>CODAC and IT</th>
<th>Civil Construction</th>
</tr>
</thead>
</table>

**Managing Risk**

1. Identify Risks
2. Assess & Measure Risks
3. Determine Handling Strategy
4. Develop Response & Mitigation Plans
5. Monitor, Report & Dispose

**Possible Risk Areas**

- Procurement
- Technology
- Schedule
- Operational
- Hazard

- People
- Process
- Compliance
- Financial
Overall Work Relationship for System Integration

- Dept. for Safety & Security (QA)
- Technical Departments (construction)
- Project Office
- Dept. for Fusion Science & Technology
- Dept. for Admin.
- Finance & resources
- Research plan

DAs

- QA & Conformity
- Technical scope (Performance)
- Coordination of Management & resources
- In-kind Procurement

IO

DAs
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.

<table>
<thead>
<tr>
<th>Conceptual Design</th>
<th>Preliminary Design</th>
<th>Final (detailed) Design</th>
<th>Fabrication, Assembly, Installation, and Test</th>
<th>Operations</th>
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<tbody>
<tr>
<td>System level (PBS Level 1)</td>
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<tr>
<td>Plant Model</td>
<td>Configuration Model</td>
<td>Project Specification (PS)</td>
<td>Project Requirements (PR)</td>
<td>Establish product “as-built” baseline</td>
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<tr>
<td>Develop requirements, define concept</td>
<td>Establish functional baseline</td>
<td>CDR</td>
<td>Develop ISTP</td>
<td>Experimental operations</td>
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<td>Allocate functions</td>
<td>Decomposition and definition</td>
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<td>Perform First Plasma</td>
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<td>Subsystem level (PBS Level 2)</td>
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<td>SRD</td>
<td>Interface Control Documents (ICDs)</td>
<td>Establish allocated or “design-to” baseline</td>
<td>Establish product “build-to” baseline</td>
<td>Perform subsystem testing</td>
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<tr>
<td>Establish allocated or “design-to” baseline</td>
<td>Subsystem design documentation (schematics, PFDs/PRIDs, layout drawings, preliminary CAD models/drawings)</td>
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<td>Install subsystems</td>
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<td>Develop design documentation for procurement and assembly</td>
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<td>Develop installation and test procedures</td>
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<td>Product Specifications</td>
<td>Fabrication and assembly drawings</td>
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<td>Fabricate components</td>
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<td>Develop manufacturing, inspection, and test procedures</td>
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# ITER Construction Life Cycle

## Conceptual Design

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<th>Requirement</th>
<th>Validation</th>
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<td>Built-to-print</td>
<td>Architectural design</td>
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<td>Detail design</td>
<td>Implementation</td>
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<td>Functional spec</td>
<td>Verification</td>
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## Life Cycle Stages

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<th>Stage</th>
<th>Conceptual design</th>
<th>Layout &amp; analysis</th>
<th>Detail design</th>
<th>Technical spec</th>
<th>Manufacture</th>
<th>As built</th>
<th>Acceptance</th>
<th>Installation</th>
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## Interface Management

### System Interface Control among systems

### Procurement Interface Control among DAs

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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.

1\textsuperscript{st} Confinement System
- Vacuum vessel
- VV extensions
- etc

2\textsuperscript{nd} Confinement System
- Port cells
- Vaults
- etc

Dynamic Systems
- Vent & cleanup system
- etc
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

- 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

Site New Entrance

Platform view, 25% completed

Contractor Area (~500 people) and JWS 2
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 Development

Fusion Plasma Research

Structure Development

Component Technology

Test Blanket Module

IFMIF

Heavy Irradiation

System engineering and integration

Fusion Plasma Research

JT-60 Superconducting Coils

JT-60 JET

ITER

ITER&DEMO Physics Support Activities

Tokamak DEMO Reactor
Together with us