Progress of the ITER Project

Gary Johnson
Deputy Director General - Tokamak
Cadarache, France, May 31, 2010
Contents

• ITER Project
• Scale of ITER
• Technical Systems & Status
• The Future
ITER Project
ITER - A Unique Scientific, Technological and Industrial Project

**Objective** - Demonstrate the scientific and technological feasibility of fusion energy

**Goal** - produce a significant fusion power amplification (10x the energy input): \textbf{output 500 MW}

**Costs** - \( \sim 5 \text{ B } \text{€} \) for construction (Based on 2001 FDR)

(Note – A new cost baseline is expected to be approved by the IC in June 2010.)

Plus contributions of local area – 467 M €
In-Kind Contributions (Credit Values)

EU – Buildings & Excavation PA’s – 377 kIU A (~580 Million €)
EU – VV & Magnet & Divertor PA’s – 297 kIU A (~460 Million €)
JA – Magnet & Divertor PA’s – 310 kIU A (~466 Million €)

In-Kind Credit - Status
• 44 PA’s signed to date
• 1729 kIU A (~ 2.7 Billion €)
• ~ 60% of total in-kind PA value
ITER Organization Structure

Revised on 20 January 2010

Management Advisory Committee

ITER Council

Science and Technology Advisory Committee

Financial Audit Board

DOMESTIC AGENCIES

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

Office of the Director-General (H. Matsumoto)

ITER Council Secretariat (S. Ishizaka)

Legal Office (P. Tuinder)

Communication (N. Calder)

Office of Audit Service

Office for Central Integration and Engineering (E. Tada)

- IO-DA coordination
- Technical Integration
- Assembly and Operation
- Nuclear Safety and Environment
- CAD & Design Coordination

Civil Construction and Site Support Office (T. Watson)

- Building System
- Site Layout
- Nuclear Buildings
- Steel Frame Buildings

ITER Organization Structure

- DDG Carlos Alejaldre
  - Safety Control
  - Quality Assurance

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

- Norbert Hollkamp
  - Principal DDG
  - Senior Advisor (G. Janeschitz & J. Farineau)

- Project Office (P. Swenson)
  - Project Control
  - In-kind Management
  - Scheduling

- Office of the Director-General (H. Matsumoto)
  - DDG Wang Shaoqi
    - Senior Advisor (F. Digby-Grant)
    - Dept. for Administration
      - Finance & Budget
      - Procurement & Contract
      - Human Resources
      - Logistic

  - DDG Valery Chuyanov
    - ADDG (D. Campbell)
    - Dept. for Fusion Science and Technology
      - Science
      - Technology

  - DDG Gary Johnson
    - Dept. for Tokamak
      - Magnet
      - Vessel
      - Internal Components

  - DDG Yong-Hwan Kim
    - Dept. for Central Engineering & Plant Support
      - Plant Engineering
      - Fuel Cycle Engineering
      - Electrical Engineering

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

  - Office of Central Integration and Engineering (E. Tada)
    - IO-DA coordination
    - Technical Integration
    - Assembly and Operation
    - Nuclear Safety and Environment
    - CAD & Design Coordination

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

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

ITER Organization Structure
Staffing (Feb 2010)

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<th>Country</th>
<th>Professional staff</th>
<th>Support staff</th>
<th>Total</th>
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Professional Staff:
- EU 60%
- CN 5%
- JA 8%
- IN 5%
- KO 7%
- RF 7%
- US 5%
Proposed Baseline Schedule for 2019 First Plasma

ITER Construction

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Finalization of the Project Baseline

- Submitted for the approval of IC-6 in June 2010
- Proposed First Plasma Date – Nov 2019
- Proposed DT operation to begin – 2026
Licensing Process

• Construction Permit was awarded in April 2008;

• On 31 January 2008, the files for “Demande d’Autorisation de Creation”, including the Preliminary Safety Report, were sent to the French Nuclear Authorities;

• In July 2008, the French Authorities asked questions and requested additional documentation from IO;

• The IO will provide the French Nuclear Authorities with the updated information and RPrS documentation by the end of March 2010;

• The ITER CLI (Commission Locale d’information), including international experts, was already established by the end of 2008, and the first meeting of ITER CLI was held on 7 December 2009;

• Public Enquiry is expected in autumn 2010.
• Main platform-leveling work is complete (~40 acres)
• Handover of the ITER site from CEA to the IO is expected in June 2010;
• Tokamak Excavation to start in July 2010
• Construction of the PF Coil Winding Building & ITER Office building to begin in July 2010
ITER Buildings

39 Buildings, 180 hectares
Roads Upgrades Complete

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, & PF1 Coil)
The Scale of ITER
Cryostat Size Comparison

ITER Cryostat
~28 m Tall x 29 m Dia.

Jefferson Memorial
(Washington DC)
~29 m Tall (floor to top of dome)
ITER Tokamak – Mass Comparison

ITER Machine mass:
~23000 t
28 m Tall x 29 m Dia.

USS Enterprise mass:
~93000 t (fully loaded)
1123 ft (342 m) long
(Commissioned 1961)
Vacuum Vessel - Mass Comparison

VV & In-vessel components mass: ~8000 t
~19.5 m outside diameter x 11.2 m tall

Eiffel Tower mass: ~7300 t
324 m tall
(Completed 1889)
**Mass of (1) TF Coil:**
16 m Tall x 9 m Wide, ~360 t

**Boeing 747-300**
(Maximum Takeoff Weight) ~377 t
ITER Buildings and Facilities

PF Winding Building – ~250 m (820 ft) x 45 m (148 ft)

Tokamak & Assy building – 6 levels @ 166 m x 81 m x 57 m high (~36000 m²)

Tritium building – 7 levels @ 25 m x 80 m (~14000 m²)

Largest throughput in world (~300 kg/yr).

Area - 60 hectares (~150 acres)

Cryoplant – 65 kW at 4.5 K & 1300 kW at 80 K

Second largest in world

Magnet power convertors buildings (~1000 MW output power)

Hot cell – 60 m x 70 m
Technical Systems & Status
ITER Tokamak

- Cryostat (29 m high x 28 m dia.)
- Thermal Shield (4 sub-assemblies)
- Vacuum Vessel (9 sectors)
- Blanket (440 modules)
- Divertor (54 cassettes)

- Central Solenoid (6) (Nb3Sn)
- In-vessel Coils
- Feeders (31) (NbTi)
- Toroidal Field Coils (18) (Nb3Sn)
- Poloidal Field Coils (6) (NbTi)
- Correction Coils (18) (NbTi)
- Feeders (NbTi)
Magnet System

Facts
48 superconducting coils
- ~9800 tons
- ~187 km of conductor
11.8 T (peak TF field)
68 kA (peak current)
Stored energy – 51 GJ
Magnet Energy Comparison

Superconducting Magnet Energy:
~51 GJ

Charles de Gaulle Energy:
~38000 t at ~180 km/hr
or
The energy of ~19000 Audi A5’s each at ~180 km/hr
ITER Magnet Field

Earth's Magnetic Field
~ 0.5 gauss or 0.5x10^{-4} Tesla

ITER Field
~10 Tesla or 200,000 x Higher
Conductor Status

TF - Status
• All six TF conductor PA’s signed
• Contracts placed in JA, CN, KO, RF, US for TF cond. proc.
• Three jacketing lines built (TF, PF,& CS)
• Strand production underway in JA, KO, RF, US, and EU
• Strand production non-conformances issued and resolved in Japan, Korea, Russia, and US (QA documentation issue)
• Cabling underway in Japan, Korea and Russia
• Jacketing underway in Japan

PF - Status
• All three PF conductor PA’s signed (CN, RF, & EU)
• Contracts placed in CN for PF conductor procurement
• Agreement between EU and RF for collaboration on P6-P1 conductor supply to reduce duplication

CS Status
• CS conductor PA signed (JA)
• 316LN (low carbon material as in TF conductor) selected for CS jacket and trial batch fabricated by Cevifal

CC & Feeder Status
• CC & feeder conductor PA signed in May 2010 (CN)
TF Strand Production Status

- JA, KO, RF, EU, US have launched strand industrial production and started data input into ITER Conductor Database.
- As of today, ~80 tons (>15 000 km) of strands have been registered into the Database; this corresponds to the material needed to manufacture ~4 TF coils.
TF Cable Production Status

- JA, KO and RF have produced 760 m Cu dummy cable qualification lengths, and JA and KO have produced first superconducting cable lengths.

Cabling of 760 m Cu Dummy at VNIIKP, RF (Feb. 09)
TF Conductor Production Status

- JA has completed jacketing of 760 m Cu dummy cable and first three superconducting cables (100m and 2 x 420m).
Status

Japan
- Signed a procurement contract for TFC PA's (Toshiba is main contractor; KHI and CNIM are sub's).
- Commissioning of winding machine @ Toshiba in progress
- Welding trials in progress @ KHI for TFCS and TFC Case

Europe
- Signed a procurement contract with CNIM (FR) and SIMIC (IT) for prototype radial plates
- Winding Package (WP) call-for-tender underway
- Contract signed with CSM (Centro Sviluppo Materiali – IT) for the qualification of the TFC Case welds

TF Winding Pack
TF Coils Progress (KHI-JA)

Welding Trials for attachment of Pre-compression Ring Flange to TF Coil Case

TF Coil Case Straight Leg
The biggest Nb3Sn conductor procurement in history!
CS, PF, & CC Status

Central Solenoid
(13.6 m tall x 4.2 m dia ~1000 ton)

PF Coils (6)
(PF3 - 24.8 m dia & ~386 ton)

Correction Coils (9 pairs)

Status
• CS Conductor FDR - Sept 09
• CS Coil CDR - Sept 09
• Design in progress in US

Status
• PF Coil 2,3,4,5,&6 PA signed with EU
• PF Coil 1 drawings being prepared for RF
• PA signing expected in June 2010.

Status
• Design complete
• PA signed May 2010 with China
Feeders Status

Status
- TF feeder design complete (9 of 31 feeders)
- Extensive design collaboration with ASIPP-CN
- Feeder Busbars designed
- 10 kA HTS Current Lead prototype in preparation
- Completion of the designs in 2010
- PA signature expected in Dec 2010

TF Coil Feeder
VV Status

Status

• Received preliminary approval of VV design at end of phase 1 (from ANB)
• ELM & VS coil interfaces fully implemented in the VV
• VV sector and port PA’s signed (EU, KO, IN, & RF)
• KO - VV & port contract awarded to Hyundai Heavy Industries
• Final VV models & drawings issued May 31
• Manufacturing schedule is on critical path!!!

Facts

- First safety barrier for ITER
- SS 316 LN-IG
- ~5300 tons (VV, ports, shielding only)
- 19.4 m (63 ft) torus outer diameter
- 11.3 m (37 ft) torus height
Status

• PA signed in May 2010
• Final drawings issued Oct 2010
Cryostat Status

Status

- CDR completed in November 2009
- PDR planned for June 2010 and FDR planned for Sept 2010
- PA signing planned for October 2010
- Interfaces with major Tokamak systems are identified and ICDs are prepared.
- Global Structural, EM, thermal and seismic analysis report is under review.
Baseline Blanket Status

Facts
- 440 blanket modules
- ~4 tons each
- 18 poloidal rows
- 18 or 36 toroidal rows
- ~40 different modules
- Mass: 1530 tons

Status
- CDR held in February, 2010
- Conceptual blanket / FW design for typical modules Nos. 4, 8 and 12 completed
- Design supporting analysis completed for the above modules
- FW shaping in progress
FW Pre-qualification

Objectives

- Demonstrate technical capability prior to start procurement
- Phased approach
  - Mock-up: Demonstration/validation joining of Be/CuCrZr & SS/CuCrZr
  - Semi-prototype: Production/validation of large scale components

Status

- Mock ups provided by US, EU, RF, KO, CN and JP
- Nearing completion of the formal test program - 12,000 normal cycles at 0.875MW/m$^2$ and 1000 MARFE cycles at 1.4MW/m$^2$.
- First wall semi-prototype phase will start with (US, EU, RF and CN) within the next few months.
Divertor Status

Status
• Design complete
• Four of five PA’s Signed
• Licensing classification of Divertor components being resolved (PED/ESPN are out of scope)

Facts
- 54 Divertor assemblies
- 4320 Heat flux elements
Full-scale Divertor Installation into the Vacuum Chamber at DTP2

Objectives:
- Demonstrate the feasibility to install the divertor assembly into the vacuum vessel by means of RH tools

Status
- Installation of the “second” cassette successfully demonstrated at DTP2 in Finland
Divertor Qualification Prototypes

Objectives
- Qualification of critical divertor components

Status
- All the 3 Domestic Agencies have qualified
- Pre-PA Qualification process successfully completed in all the concerned DAs.
Machine Assembly

TF Coil / Sector Assembly
~1400 ton

Status
• Detailed assemble plans developed
• Assembly tool PA signed with Korea
Where do we go from here?
The Roadmap Beyond ITER

Today's expts.

- upgrade, construction
- Operation

ITER

- Des.
- Construction
- Test/Optimise Blanket
- 2nd DT Op. Phase

IFMIF

- Design
- Construction
- Qualify DEMO Materials
- Optimise Materials

DEMO

- Design
- Construction
- Initial Operation
- Reliability demo

Alternative Confinement Schemes

Commercial Power Plants

Concept
- Design
- Construction
Now we are firmly on ITER (the way)...

Tore Supra
25 m³
~ 0 MW<sub>th</sub>

JET
80 m³
~16 MW<sub>th</sub>

ITER
800 m³
~ 500 MW<sub>th</sub>

DEMO
~ 1000 - 3500 m³
~ 2000 - 4000 MW<sub>th</sub>

- Dominant self heating ————>