US ITER Project

Providing a Facility for Burning Plasma Research

Working with the US community to position the US for Burning Plasma Research

Ned Sauthoff
Project Manager, US ITER Project

APS/DPP meeting
Philadelphia, PA
October 31, 2006
Structure of the Talk…

ITER Challenges

US Contributions to ITER & Related Activities

US ITER Project, Budget and Schedule

Risks and their Management

Bottom Lines and Paths Forward
ITER is a unique and complex facility and program

ITER is also a challenging experiment in international collaborative project management
Contributions:
- In-kind hardware
- International Organization support
  - staff and infrastructure
  - cash for assembly/installation/
central procurements

Bottom Lines and Paths Forward
2006 U.S. “in-kind contribution” hardware scopes

- 7 Central Solenoid windings
- 8% of Toroidal Field conductor
- 15% of port-based diagnostics
- 100% Ion Cyclotron transmission lines
- 100% Electron Cyclotron transmission lines
- 20% Blanket/Shield
- Roughing pumps, standard components
- 8% of Toroidal Field conductor
- Steady-state power supplies
- 75% Cooling for divertor, vacuum vessel, …
- Pellet injector
- Tokamak exhaust processing system
Major Areas of Cost
Magnets
Six of the seven participant teams will provide TF conductor. The US team will fabricate nearly 8 km of TF conductor, including active, dummy, and test samples for qualification.

The U.S. Team will use CS conductor provided by the Japanese Team.
US contributes about 8% of TF conductor
- 9 “long” double-pancake lengths (about 765 m each) + 1 dummy length
- Nearly 7 km of “active” CICC
- Nearly 38 t of Nb₃Sn wire
Central Solenoid

CS Coil Modules
- 6 modules + 1 spare
- All identical
- In-line conductor butt joints between sections

• CS structure positions the assembly and provides axial pre-compression of modules
• Mounts off the TF cases
Scope – CS External Piping, Extensions & Joints

Less critical because they’re outside the coil, more accessible for repair
Power-handling
In-vessel structures
Scope – Blanket Module

Module Allocation

BM07
BM12
BM13
(PORT LIMITER)
(PORT LIMITER)
Scope – Blanket Module

Blanket Module 07

First Wall Panels (4)

Shield Module
Port Limiter

Plasma Facing Head Orientation

- Port Limiter Head Assy
- BE Tiles
- Cu Heat Sink
- Shield Cooling Lines
- Shield
- FW Cooling Lines
- Vacuum Vessel
Plasma control, heating, current drive
ICH system

The ITER ICH system will deliver 20 MW of power to the plasma for ion heating and for central current drive.

It is:
- One antenna, 8 or 24 current straps
- Eight rf sources, each feeding one set of straps in the antenna
- 40-55 MHz frequency range
- Adjustable phasing between straps for heating or current drive

It can be used for:
- Tritium ion heating during DT ops
- Minority ion heating with initial H/D ops
- Central current drive for AT ops
- Minority ion current drive at sawtooth inversion radius

ITER ion cyclotron system block diagram
**Issue: Matching system depends on antenna, impacts component, quantity details and risk**

*2001 Internal-match baseline design – load-tolerant antenna*

*8 Feed lines of 2.5 MW ea. into VSWR ≤ 2.0.*

Antenna is load-tolerant with internal matching components (sliding stub-tuned triax).

**Risk:** 5MW section connects combiner and splitter. 2.5 MW center conductor cooling required. Antenna performance and reliability is now deemed inadequate

**Internal-match design – load-tolerant antenna**

*12 Feed lines of 1.7 MW ea. into VSWR ≤ 1.6.*

Antenna is load-tolerant with internal matching components. Pre-match keeps VSWR ≤ 1.6.

Hybrid not used since it is incompatible with phasing requirements.

Internal tuning similar to JET-EP and Tore Supra load tolerant antennas.

**Risk:** 12 feed lines increase transmission line & matching cost. Smaller lines still need inner cooling (1.7 MW).
Issue: Matching system depends on antenna, impacts component, quantity details and risk

8 Feed lines of 2.5 MW ea. into VSWR \leq 1.3.
Antenna not load-tolerant, simple design with no moving parts. Pre-match keeps VSWR \leq 1.6. Reflected power (plasma load variations) absorbed in dump resistors, not available for plasma heating. Rearrangement of baseline components with minor changes
Risk: Some loss of power/performance during ELMs. Lowest risk option for transmission line and matching

- External-match design - ELM dump
- RF Source
- RF Source
- Comb./Splitter
- Hybrid
- Matching
- Near sources
- Near antenna
- Antenna

4 Feed lines of 5 MW ea. into VSWR \leq 1.6.
Antenna load tolerant with no moving parts, but requires significant external components near antenna. Pre-match keeps VSWR \leq 1.6. May need additional tuning components near antenna. Tuning architecture to be tested on JET A2 antenna
Risk: Extended length of high power line (5 MW). More matching components required.

- External-match design – load-tolerant
- RF Source
- RF Source
- Combiner
- Near sources
- Near antenna
- Antenna
ECH&CD Transmission Lines

- (24) 1 MW, 170 GHz Gyrotrons (EU, JA, RF)
- (24) DC Power Supplies (EU, IN)
- (3) 1 MW, 120 GHz Gyrotrons (IN)

24 Transmission Lines (US)

Equatorial Launcher (JA)
(3 or 4) Upper Launchers (EU)
Diagnostic instrumentation
Instrumentation is key to science on ITER
A Significant (16%) Diagnostic Role in ITER Supports a Strong Research Presence

- **Seven Diagnostic Systems**
  - Motional Stark effect polarimeter
  - 6 visible/IR cameras in upper ports
  - Low-field-side reflectometer
  - Electron cyclotron emission
  - Tangential interferometer/polarimeter
  - Divertor interferometer
  - Residual gas analyzer

- **Five Diagnostic Port Plug Structures**
  - 2 upper plugs
  - 2 equatorial plugs
  - 1 lower plug structure
Instrumentation Example Reflectometer

- Designed to measure density profiles with high time resolution and density fluctuations.

- Instrumentation packages consist of
  - Front-end components embedded in port plug
    - mirrors, waveguides/horns, shutters, calibration sources
  - Ex-cryostat components some of which are far removed
    - fiber optics, transmission lines, sources, detectors
Scope - US Port Plugs

Upper Plugs (U5, U17)
(4.5m long, ~25T in-vessel)

Equatorial Plugs (E3, E9)
(2.2m high, ~50T in-vessel)

Plugs provide
- Vacuum seal, radiation shielding
- Cooling water and support for blanket shield modules
- Support and access for diagnostics

Divertor Side Panels and Back Boxes (L8)
• Diagnostics from other parties need to be integrated into plug E3
  ▪ 2 visible/IR camera views (EU)
  ▪ 2 edge CXRS views (RF)
  ▪ 2 Hα arrays (RF)
  ▪ X-ray crystal views (IN?)

• The division of integration design responsibility between the IT and the parties has not been fully negotiated.
Preparations Leading to Major Diagnostic Design Effort for US Diagnostic Systems

- Over the next 6-9 months, USIPO will be assisting the ITER Organization to prepare procurement documents to more clearly define the US diagnostic scope.
  - First award for major design of a US system presently scheduled for early FY08.

- A number of “assessment studies” were recently launched to re-engage US diagnostic experts.
  - Resulting performance assessments and revised cost estimates will help guide procurement arrangements.

- Core engineering team will assist US diagnostic designers to integrate instrument front-ends into the plugs.
Ongoing Studies Assess Reference Designs for US Systems

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<tr>
<th>Diagnostic Package</th>
<th>Task Summary</th>
<th>Institution(s)</th>
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<td>Upper Visible/IR Camera</td>
<td>assess optical design, central tube concept</td>
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<td>LFS Reflectometer</td>
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<td>Neutronics Analysis</td>
<td>benchmark neutronics models for plug integration using ATILLA</td>
<td>UCLA-PPPL</td>
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- **Focus on identification of ‘front-end’ configurations**
- **Upcoming meetings provide opportunity for broader input**
  - USBPO Workshop 6 - 8 February 2007 at General Atomics.
  - ITPA Diagnostics TG Meeting 26 - 30 March 2007 at PPPL.
Fuelling and exhaust processing
ITER Pumping and Fueling Systems
ITER Roughing Pump Sets

- Roughing pump sets - 4 identical pump assemblies
  Piston pumps, Blowers, mounted in glove box assembly with associated valves, instrumentation and controls
ITER Vacuum Standard Components

- Standard components consists of
  - ICRF vacuum system - 64 getter pumps and 32 valves
  - ECH vacuum system - 130 sputter ion pumps, 10 TMPs, 10 dry pumps & 220 valves
  - Guard and service vacuum system - 86 cryo pumps, 2 dry pumps and 1738 valves
Pellet injection the only known method to achieve efficient core $T_2$ fueling
- Pellets ~90% efficient
- gas puffing < 1% efficient
- NBI fueling negligible

Guide tubes bring the pellets through the divertor ports to the inner wall.
Pellet Injector Design

Two concepts are available for ITER pellet acceleration

- ITER baseline design assumes a centrifuge accelerator
  - Low (~10%) recirculating gas from accelerator
  - Existing designs do not meet the needed reliability
  - Significant development needed to meet the ITER reliability requirements

- Gas gun technology may be a better choice
  - High reliability has been demonstrated for slow pellets
  - Propellant gas valve can be optimized for low gas usage
  - A recirculating propellant gas system can be employed to minimize impact on the tritium plant
ITER Gas Gun Pellet Injection System
Conceptual Design

Cask layout from P. Fogarty, ORNL
Tritium Processing System

Note: \( Q = H, D \) or \( T \)
Steps of the Tokamak Exhaust Processing

- Battery of front-end permeators (first process step)
- Cracking or conversion reactions (impurity processing, second process step)
- Counter current isotopic swamping (final clean-up, third process step)
Tritium-breeding: Test Blanket Modules (Outside the ITER Construction Project and US ITER Project)

Dual Coolant Lead- Lithium TBM

Schematic view of solid breeder thermomechanics unit cell test articles housed inside helium-cooled pebble bed box
Cooling Water
Seven sub-systems distributed throughout Tokamak building

Primary Heat Transfer:
- Vault
- Upper Pipe Chase
- Roof
- Lower Pipe Chase

Support Systems:
- Draining and Refilling (WBS1.2.1.6)
- Chemical and Volume Control System (WBS1.2.1.5)
- Drying (WBS1.2.1.7)
Steady-state Electric Power
ITER AC Power Systems: Generic Site

Pulsed Power Electric Network

400kV Host

EU + China

500MW
400MVAR
650MVA Pulsed

~ =

Magnets

~ =

NBI & RF

P,Q Control

Steady State Electric Power Network

230kV Host

EU + US

120MW
50MVAR
130MVA Continuous

~

Class IV: CWS 37MW
Cryo 27MW
Other 50MW

Class III (Safety): 8MW
Structure of the Talk…

ITER Challenges

US Contributions to ITER & Related Activities

US ITER Project Organization

Budget and Schedule

Risks and their Management
Highest Level Management Structure

ITER Organization

Council

- Science and Technology Advisory Committee
- Management Advisory Committee
- Director-General (DG)
- Auditors

Staff (professionals + support staff)

- Central Team
- Field Team (for construction phase)

Supporting Services

Contracts

Support for Project Management, Computer Network, Technical works, etc.

Host country

Domestic Agency

e.g., US ITER Project
The US ITER Project Office (US IPO) is established
The US IPO management team has been fully staffed, with all seven WBS Managers now on board.”
Support of the International Team

- **Cash, as part of “Staff and Infrastructure”**
- **Domestic Staff support of the IT**
  - Design and facilitation of systems with US-scope
  - Project management expert support
- **Candidates to fill “Urgent Positions”**
## IT-selected US Secondee Candidates and Visiting Researchers

<table>
<thead>
<tr>
<th>Area</th>
<th>Individuals</th>
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<tbody>
<tr>
<td>DDG/Tokamak</td>
<td>Gary Johnson (ORNL)</td>
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<td>Buildings</td>
<td>Jerry Sovka (ATI)</td>
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<td>Diagnostics/in-vessel [VR]</td>
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<td>Remy Gallix (General Atomics)</td>
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<td>Paul Holik (ORNL)</td>
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<td>Vacuum Vessel</td>
<td>Chang Jun (PPPL)</td>
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Future IT/IO staff selections

- **Now posted in the US:**
  - Diagnostics Engineer
  - Diagnostic Physicist
  - Superconductor Engineer
  - Coil Designer

- **Expected soon:**
  - ~50 additional positions in physics, technical, administrative, and project management areas
International Design Review

• To enable US domestic project progress, the US seeks a revised baseline for the US scope by Summer 2007

• Schedule for the Design Review
  – Now: Preparation, submission and prioritization of “issues;” development of design approaches/solutions
  – Winter 2006/7: International Team Design Review meeting
  – Winter/Spring 2007: International Team, Working Groups and Participant Teams update the design and schedule
  – Spring/Summer 2007: revised Design Baseline
  – ??? 2007: Council-approved Design Baseline
## US ITER Preliminary Schedule

### Critical Decision Milestones

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US ITER Budget Request ($M), summing to $1.122B
Structure of the Talk…

ITER Challenges

US Contributions to ITER
- Related Activities

US ITER Project,
- Risks and their Management

Major Risks

Risk Mitigation Actions
- IT support/joint work
- participation in the design review
Major Risks and Issues

- Uncertainties about International “need dates” for US components

- Uncertainties about contents and availabilities of Internationally-provided component specifications and requirements
  - Design Baseline
  - Procurement Agreements (technical and management aspects for US procurements)
  - Codes, standards, and Host regulations

- Uncertainties about drivers of US cost linked to other parties
  - Sub-components from other parties
  - Responsibilities for costs related to regulatory requirements imposed by the Host
Summary assessment and path forward

• A strong international ITER Organization is key to ITER success
  – the central ITER team is growing in strength, improving its ability to
    perform necessary system integration and project leadership

• The US Domestic Agency senior management is assembled, is building it team and tools, and is developing its FY2007 Work Plans

• US Near-term Activities focus on:
  – Completing R&D, design, and re-baselining of the US scope
    • Positioning for updated scope, and firmer cost and schedule
      estimates by the end of 2007
    • Supporting the International Team with secondees, on-site experts, and domestic work
  – Enabling the US scientific and technology communities to participate in the upcoming ITER Design Review to make ITER as good a research tool as it can be...