Plans for US Contributions to ITER

Ned Sauthoff
U.S. ITER Project Manager

Fusion Power Associates
Oak Ridge, TN
December 4, 2007
U.S. 2006 ITER In-kind Hardware Contributions

- 100% ion cyclotron transmission lines
- 100% electron cyclotron transmission lines
- 15% of port-based diagnostics
- 7 central solenoid windings
- 8% of toroidal field conductor
- 75% cooling for divertor, vacuum vessel, ...
- 20% blanket/shield
- Roughing pumps, standard components
- Steady-state power supplies
- Tokamak exhaust processing system
- Pellet injector
ITER’s Magnet system

- Nb$_3$Sn toroidal field (TF) coils produce confining/stabilizing toroidal field
- NbTi poloidal field (PF) coils position and shape plasma
- Modular Nb$_3$Sn central solenoid (CS) coil induces current in the plasma.
- Magnet system weighs ~ 8,700 t.
Exploring:
- Seam-less tube conduit
- Perforated central cooling tube
Fabrication of TF Conductor

8-stand tube-forming mill with double turks-head for straightening
Central Solenoid Coil

Originally, all JA-supplied Conductor

Exploring US supplying initial CS cable
Plans for US Contributions to ITER

Cooling Water System

US Scope

IN Scope

Water Circulation System (WCS)
Component Cooling Water System (CCWS)
Chilled Water Systems (CHWS)

Water Circulation System (WCS)
Component Cooling Water System (CCWS)
Chilled Water Systems (CHWS)

Safety Related
(a) Vault cooler
(b) Air conditioners for hot-cell, radiacell and tritium buildings
(c) Distribution System
Current design

- Failure of any one of 14 components can shut down plasma operation

System re-design is required to:

- Improve availability, reliability, operational flexibility
- Reduce capital equipment and maintenance costs through standardization
- Improve flexibility of schedule and construction

Revised Design Concepts:

- Replace unique components with standard, off-the-shelf equipment
# US ITER Diagnostics Scope

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper IR/Visible Cameras</td>
<td>monitor for hot spots on outer target surface</td>
</tr>
<tr>
<td>Low Field Side Reflectometry</td>
<td>pedestal and SOL density profiles, fluctuations</td>
</tr>
<tr>
<td>Motional Stark Effect</td>
<td>safety factor q(R)</td>
</tr>
<tr>
<td>Electron Cyclotron Emission</td>
<td>$T_e(R)$, and MHD</td>
</tr>
<tr>
<td>Divertor Interferometer</td>
<td>line density, several chords across divertor throats</td>
</tr>
<tr>
<td>Toroidal Interferometer/Polarimeter</td>
<td>line density along tangential chords at midplane</td>
</tr>
<tr>
<td>Residual Gas Analyzer</td>
<td>gas composition in pumping ducts</td>
</tr>
</tbody>
</table>

## Port Plugs

<table>
<thead>
<tr>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes design, fabrication, assembly and testing. Also includes integration of both US and other party’s instruments in US plugs and support for US instruments in plugs provided by other parties. Also includes integration in interspace and port cell areas.</td>
</tr>
</tbody>
</table>

## Plans for US Contributions to ITER

**December 4-5, 2007**
### Recent Progress and Near-Term Challenges

<table>
<thead>
<tr>
<th>Package</th>
<th>Design/R&amp;D Task Summary</th>
<th>Institution(s)</th>
<th>Phase 1</th>
<th>Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Visible/IR Camera</td>
<td>assess optical design, central tube concept</td>
<td>LLNL</td>
<td>C</td>
<td>C</td>
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<tr>
<td>LFS Reflectometer</td>
<td>determine optimum frequency bands and polarizations</td>
<td>UCLA</td>
<td>C</td>
<td>C</td>
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<td>LFS Reflectometer</td>
<td>optimize front-end configuration, WG tests</td>
<td>ORNL</td>
<td>C</td>
<td>P</td>
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<tr>
<td>MSE</td>
<td>assess usefulness of</td>
<td>B</td>
<td>determination</td>
<td>NOVA</td>
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<tr>
<td>MSE</td>
<td>performance simulation of conventional polarimetry approach</td>
<td>PPPL</td>
<td>C</td>
<td>C</td>
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<tr>
<td>MSE</td>
<td>optimization of optical design</td>
<td>LLNL</td>
<td>C</td>
<td>C</td>
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<tr>
<td>ECE</td>
<td>investigate non-thermal issues, use of oblique view</td>
<td>PPPL</td>
<td>C</td>
<td>C</td>
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<tr>
<td>ECE</td>
<td>review reference design, hot source R&amp;D</td>
<td>U.Texas, U. Md, MIT</td>
<td>C</td>
<td>O</td>
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<tr>
<td>ECE</td>
<td>refine front end design</td>
<td>ORNL</td>
<td>C</td>
<td>P</td>
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<tr>
<td>Divertor Interferometer</td>
<td>develop conceptual design</td>
<td>UCLA/GA</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Divertor Interferometer</td>
<td>refine front-end design</td>
<td>GA/UCLA</td>
<td>C</td>
<td>P</td>
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<tr>
<td>Tang. Interfer./Polarimeter</td>
<td>optimize reference design</td>
<td>GA/UCLA</td>
<td>C</td>
<td>C</td>
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<tr>
<td>Tang. Interfer./Polarimeter</td>
<td>refine front-end design</td>
<td>ORNL</td>
<td>C</td>
<td>P</td>
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<tr>
<td>RGA</td>
<td>develop conceptual design</td>
<td>ORNL</td>
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<td>O</td>
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<tr>
<td>Neutronics Analysis</td>
<td>develop neutronics models for plug integration using ATILLA</td>
<td>UCLA</td>
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<tr>
<td>First Mirror R&amp;D</td>
<td>model erosion/deposition on 1st mirrors</td>
<td>ANL</td>
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<td>O</td>
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<tr>
<td>Shutter R&amp;D</td>
<td>develop candidate shutter concepts</td>
<td>PPPL</td>
<td>C</td>
<td>P</td>
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</table>

- **Progress** in advancing diagnostics designs comes through broad community involvement in short-term performance assessments, cost studies, & R&D tasks.
- **Near-term challenge** is to obtain authorization to proceed to detailed design.
  - Activity presently delayed due to slip in schedule for issuance of diagnostic procurement arrangements by ITER Organization to July, 2009.
  - In many areas, scope definition is also incomplete pending PAs.
Tritium Processing System

Note: Q = H, D or T

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U.S. ITER
Tokamak Exhaust Processing Interfaces

Plots for US Contributions to ITER
December 4-5, 2007

U.S. ITER
Electron Cyclotron Transmission Line and Mode Control

1 or 2 MW transmission lines from the gyrotrons to the launchers
24 lines to the equatorial launcher (EL); 32 lines to the upper launchers (UL)

US ITER ECH Test Facility to develop and qualify T-line components with long pulse gyrotrons (140 GHz and 170 GHz)
Likely upgrades to ECH system impact the Transmission Lines

- Increase sources from 24 to 48 MWs as a substitute for NBI power.
- 2 MWs per line (increased cooling)
- Three possible T-line options

![Graph and Diagrams]

G. Saibene
Tritium ion heating during DT ops.
Minority ion heating with H/D ops.
Central current drive for AT ops.

5 or 2.5 MW transmission lines from the sources to the antenna
4 or 8 lines feed an ELM tolerant tuning/matching (T/M) system
Conjugate T or 3 dB T/M connected to 24 strap antenna array
40-55 MHz High Power, Long Pulse, facility used to develop and qualify components

High power resonant ring and shorted T-line can test components to > 5 MWs for full pulse length
Roughing Pump Set Assembly

Change Over Valve Box Assembly

Roughing Pump System
Leak Detection System

• **Roughing pump sets** - 4 identical pump assemblies
  Piston pumps, Blowers, glove box assemblies with associated valves, instrumentation and controls. Needs to be tritium compatible.

• **Leak Detection System** - Mass spectrometers and RGAs, conventional vacuum hardware, all need to be tritium compatible. Some assemblies in glove boxes.

Mass Spectrometer
LD Type 1
Standard Vacuum 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 Fueling System

- Pellet injection is 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.

- 2 pellet injectors in 2 separate casks
ITER Gas Gun Pellet Injection System R&D and Design underway

Prototype extruder is being tested

Plans for US Contributions to ITER
Control of Type 1 ELMs Is a Pressing Issue for ITER

Reducing the energy loss to <1MJ using ~ 40 Hz pellet pacing has been proposed. Would require at least 2 additional injectors to provide high throughput of pacing pellets.

Loarte et al., Nuclear Fusion, ITER Physics Basis, Chapter 4
Killer pellets have been proposed for Disruption Mitigation

- A “golf ball size” pellet made with D₂ or combination of D₂ and Ne or other impurity is an option to mitigate disruptions.
- A 10 cm³ pellet with 10,000 torr-L is entirely possible.
- A reliable single stage gas gun can accelerate the pellet to 1 km/s speed.
- A “V” groove guide tube to produce quasi-liquid jet looks promising.

350 m/s  581 m/s  1115 m/s
SSEPN Scope

- 140MVA AC Substation & Power Distribution
- Design, installation, commissioning by EU
- Procurements shared by EU and US

75% by US
~ $20M equipment

25% by EU
Support of the Resolution of Design Issues

- The USIPO provided support for community participation in the “Design Review”
  - The Burning Plasma Organization was a major contributor, particularly in Working Group 1
  - The Virtual Laboratory for Technology contributed in the areas of expertise
  - The USIPO team participated in the US design areas and in general areas

- The remaining issues are being addressed by the ITER Organization, Domestic Agencies, and the fusion communities of the ITER parties
  - International and domestic processes being developed
  - Target resolution by Spring 2008
Design Issues for Resolution

- Vertical Stability
- Shape Control/ Poloidal Field Coils
- Flux swing in Ohmic Operation and CS
- ELM control
- Remote Handling
- Blanket Manifold RH
- First Wall (C/W) strategy
- Capacity for 17MA discharge
- Coil cold tests
- Vacuum Vessel
- Other issues
  - TBM strategy
  - Hot cell Design
  - Buildings/ integrated logistics
  - Heating and current drive strategy related to research plan
The U.S. ITER Project Office (USIPO)

Legend:
LLC  Limited Liability Company
ORO  Oak Ridge Office
PSO  Princeton Site Office
ORNL  Oak Ridge National Laboratory
PPPL  Princeton Plasma Physics Laboratory
SRNL  Savannah River National Laboratory
SROO  Savannah River Operations Office
US ITER In-kind Hardware Contributions

- 100% Ion Cyclotron transmission lines
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- 15% of port-based diagnostics
- 7 Central Solenoid windings
- 8% of Toroidal Field conductor
- 75% Cooling for divertor, vacuum vessel, ...
- 20% Blanket/Shield
- Roughing pumps [swap w/EU?], standard components
- Pellet injector
- Steady-state power supplies
- Tokamak exhaust processing system
Procurement Procedures

- U.S. ITER procurements are governed by Department of Energy Acquisition Regulations (DEAR) as well as the Federal Acquisition Regulations (FAR)
- These DOE regulations are flowed down to the national laboratories through their contracts with DOE
- ITER Agreement terms also flow down through contracts
- Partner labs PPPL and SRNL will manage their own contracts with USIPO oversight
US ITER Procurement Practices

• USIPO and IO jointly perform R&D, design and Procurement Agreements

• USIPO completes enabling work and defines scopes for suppliers

• We expect detailed design, manufacturing design and fabrication to be done mostly by industry

• USIPO will be the contact with the suppliers for US scope

• We have the ability to offer incentives in contracts to motivate schedule performance

• USIPO provides information to the IO on milestones
 Integrated Project Schedule

ITER IO

LICENSE TO CONSTRUCT

TOKAMAK ASSEMBLY STARTS

FIRST PLASMA


ITER IO

license to construct

tokamak assembly starts


Construction License Process

TOKAMAK ASSEMBLY

TOKAMAK BUILDING

OTHER BUILDINGS

Complete blanket/divertor

Complete VV

Install CS

COMMISSIONING

MAGNET

Bid Vendor’s Design

Contract

PFC fabrication start

TFC CS

Last TFC

Last CS

VESSEL

Bid

Contract

First sector

Last sector

First sector

Last sector

Install cryostat

Plans for US Contributions to ITER

U.S. ITER

December 4-5, 2007

Plans for US Contributions to ITER
US ITER Budget Request ($M),
summing to $1.122B

Procurements ~$600M

<table>
<thead>
<tr>
<th>Year</th>
<th>Budget Request</th>
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</table>
To do business with U.S. ITER Project

- Procurement website –
  https://www.usiter.org/pro/

- Register on vendor database:
  - Business opportunities for U.S. ITER
    - ORNL
    - PPPL
    - SRNL
  - Business opportunities with International ITER
Summary

The U.S. Domestic Agency is ready to proceed:

• established and functioning, with a tightly integrated DOE/contractor team

• set up, staffed, and engaged with ITER planning:
  – Technical and Management staff in place
  – Procurement and QA staff in place
  – Plans developed, but dependent on others

• engaging the US fusion community

• actively supporting resolution of key requirements, technical issues, resolution of roles/responsibilities, and receipt of appropriate Procurement Arrangements from the ITER Organization