ITER Project Status

Positioning the US for ITER

Ned Sauthoff
U.S. ITER Planning Officer

FESAC
3/30/04
<table>
<thead>
<tr>
<th>Area</th>
<th>US emphasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Structure</td>
<td>effectiveness</td>
</tr>
<tr>
<td>Staffing</td>
<td>accessibility</td>
</tr>
<tr>
<td>Procurement Systems/Methods</td>
<td>in-kind/in-cash; changes</td>
</tr>
<tr>
<td>Procurement Allocations</td>
<td>project success and US interests</td>
</tr>
<tr>
<td>Resource Management Regulations</td>
<td>visibility and changes</td>
</tr>
<tr>
<td>Risk</td>
<td>recognition and management</td>
</tr>
<tr>
<td>Intellectual Property</td>
<td>benefits and protection</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>amount and timing of the funds</td>
</tr>
</tbody>
</table>
ITER value is about 50% in “high-tech systems”
Guidelines for the US in-kind offers

• The total value of the US offers matches the negotiated percentages

• The cost of the the US offer is within the Administration’s dollar-limit
  – in-kind contributions
  – construction management, and
  – US domestic agency, contingencies, reserves, …

• The scope is consistent with US export controls, US Trade Representatives’ guidelines, etc.

• The scope is of interest to the US

• The scope is consistent with US capabilities
Burning Plasma Program Advisory Committee

• Membership
  – Stewart Prager (U. Wis.), chair
  – Mohamed Abdou (UCLA)
  – Réjean Boivin (GA)
  – Harold Forsen
  – Jeffrey Freidberg (MIT)
  – Richard Hawryluk (PPPL)
  – E. Bickford Hooper (LLNL)
  – Stan Milora (ORNL)
  – Gerald Navratil (Columbia)
  – Tony Taylor (GA)
  – George Tynan (UCSD)
  – Michael Ulrickson (Sandia)
  – James Van Dam (UTex)
BPPAC criteria, metrics and priorities for US contributions

1. **US research positioning (High)**
   - Metric: Extent to which activity positions the US for key science/technology roles in ITER

2. **ITER-value per dollar (High)**
   - Metric: ITER value/(US cost of full scope of ITER-specific R&D + design + fab + contingency)

3. **Relative value or strength of US contribution to ITER (High/Medium)**
   - Metric: High relative strength to meet a critical need of the ITER project

4. **Contributions to US fusion research program (Medium)**
   - Metric: Enhancement of US capability for activity both in ITER and outside ITER

5. **Enhancement of fusion-relevant capability of US industry (Medium/Low)**
   - Metric: Extent activity increases industrial capability in fusion areas

6. **Development of US fusion workforce (Low)**
   - Metric: Extent to which activity builds a suitable US fusion science and technology work force.
US cost-estimation for procurement-areas of interest

Magnet Systems
[Minervini/Antaya (MIT)]

Diagnostics
[Young/Johnson (PPPL)]

Ion Cyclotron H&CD
[Swain (ORNL) / Hosea (PPPL)]

Electron Cyclotron H&CD
[Temkin (MIT) / Hosea (PPPL)]

Divertor
[Ulrickson (SNL)]

Tritium
[Willms (LANL)]

Vacuum Pumping and Fueling System
[Gouge (ORNL)]

Cooling water, power supplies
[Hill (LLNL)]

US area experts
(labs and universities)
Tentative US in-kind contributions by Value

Lower-Tech
- Cooling water: 23%
- Power supplies: 5%
- Diagnostics: 7%
- Electron cyclotron system: 12%

High-Tech
- Magnets: 28%
- Blanket: 5%
- Tritium: 4%
- Vacuum-pumping/fueling: 5%
- Ion Cyclotron system: 11%
### Overview of tentative US in-kind contributions

<table>
<thead>
<tr>
<th>System</th>
<th>Description of US portion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnets</td>
<td>4 of 7 Central Solenoid Modules</td>
</tr>
<tr>
<td>Blanket/Shield</td>
<td>Module 18 (baffle)</td>
</tr>
<tr>
<td>Vacuum-pumping/ fueling</td>
<td>Roughing pumps, standard components, pellet injector</td>
</tr>
<tr>
<td>Tritium</td>
<td>Tokamak exhaust processing system</td>
</tr>
<tr>
<td>Cooling water</td>
<td>Cooling for divertor, vacuum vessel, ...</td>
</tr>
<tr>
<td>Power supplies</td>
<td>Steady-state power supplies</td>
</tr>
<tr>
<td>Ion Cyclotron system</td>
<td>44% of antenna + all transmission/RF-sources/power supplies</td>
</tr>
<tr>
<td>Electron cyclotron system</td>
<td>Start-up gyrotrons, all transmission lines and power supplies</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>Diagnostics Working Group recommended</td>
</tr>
</tbody>
</table>
Major Components of ITER

- Toroidal Field Coil
  - Nb$_3$Sn, 18 coils

- Poloidal Field Coil
  - Nb-Ti, 6 coils

- Central Solenoid
  - Nb$_3$Sn, 6 modules

- Blanket Module
  - 421 modules

- Vacuum Vessel
  - 9 sectors

- Port Plug
  - 6 heating
  - 3 test blankets
  - 2 limiters
  - rem. diagnostics

- Cryostat
  - 24 m high x 28 m dia.

- Divertor
  - 54 cassettes
## ITER’s Schedule

<table>
<thead>
<tr>
<th>REGULATORY APPROVAL</th>
<th>Construction Agreement Initialled</th>
<th>ILE Established</th>
<th>CONSTRUCTION LICENSE</th>
<th>Months</th>
<th>0</th>
<th>12</th>
<th>24</th>
<th>36</th>
<th>48</th>
<th>60</th>
<th>72</th>
<th>84</th>
<th>96</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
<td>v</td>
</tr>
</tbody>
</table>

### Construction
- **Excavate**
- HVAC ready
- Purchase Order
- **Tokamak Building**
- **Site Fabrication Building**
- PFC site fabrication bldg.
- Place first TF/VV in pit
- Complete VV torus
- Complete Blanket/Divertor installation
- **TOKAMAK ASSEMBLY**
- Install cryostat bottom lid
- Place lower PFC
- Install CS

### Startup & Commissioning
- **System Startup & Testing**
- **Integrated Commissioning**
- Complete leak & pressure test
- Magnet excitation
- 1st Plasma

### Procurement
- **MAGNETS**
- First purchase order
- TFC fab. start
- CS fab. start
- Last TFC complete
- CS fab. complete
- First VV sector
- Last VV sector
- Last blanket and divertor
- First purchase order
- PFC fab. start
- Last PFC complete
### Magnets: Central Solenoid

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIUA) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 of 7 Central Solenoid Modules</td>
<td>9% of full system; 57% of central solenoid</td>
<td>74.2 [$107M]</td>
</tr>
</tbody>
</table>
Overview of Central Solenoid

- Max. B: 13.0 T (IM)
- Max. I: 45.0 kA (EOB)
- Nb$_3$Sn CICC
- Conduit: JK2LB
- 6 independent modules
- 9 tie-plates (SS316LN)

Each Module is slightly larger than the complete CS Model Coil

Before assembling structure

After installation in Tokamak
Central Solenoid Model Coil
Central Solenoid Conductor
## Changes from the FDR drive need for R&D and design

<table>
<thead>
<tr>
<th>FDR</th>
<th>Present Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Solenoid</td>
<td>Segmented Solenoid</td>
</tr>
<tr>
<td>~12m Tall</td>
<td>6 Modules</td>
</tr>
<tr>
<td>Bucked by TF Coils</td>
<td>Free-Standing Solenoid</td>
</tr>
<tr>
<td>Conductor in Compression</td>
<td>Conductor in Tension</td>
</tr>
<tr>
<td>Layer Winding</td>
<td>Pancake Winding</td>
</tr>
<tr>
<td>4-In-Hand/Series Connected</td>
<td>6 Hexa-Pancakes and 1 Quad-Pancake</td>
</tr>
<tr>
<td>Lap or Butt Joints</td>
<td>Butt Joints</td>
</tr>
<tr>
<td>Incoloy Alloy 908 Jacket</td>
<td>JK2LB Stainless Steel Jacket</td>
</tr>
<tr>
<td>SS was an option</td>
<td>49 mm x 49 mm</td>
</tr>
<tr>
<td>(2 Grades - 45 mm square and 49 mm square)</td>
<td></td>
</tr>
<tr>
<td>Nb$_3$Sn Strand</td>
<td>Nb$_3$Sn Strand</td>
</tr>
<tr>
<td>650 A/mm$^2$ $J_c$</td>
<td>&gt; 700 or 800 A/mm$^2$ $J_c$</td>
</tr>
<tr>
<td>CSC Ratio - 1.5:1</td>
<td>CSC Ratio - 1.0:1</td>
</tr>
<tr>
<td>2 K Temperature Margin</td>
<td>&lt; 1 K Temperature Margin</td>
</tr>
</tbody>
</table>
# Plasma-Facing Components: Baffle

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIUA) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 18 (baffle)</td>
<td>10% of full system; 8.6% of full blanket</td>
<td>14.5 [$21M]</td>
</tr>
</tbody>
</table>
ITER FW/Shield Design

- Module 18 of the FW/Shield
  - 36 modules around torus
  - Shield module weight 3.6 Tonnes (316 LNIG steel)
  - PFC area 1.6m²
  - PFC weight 0.8Tonnes (Cu+316)
  - 10% of the first wall area
  - 45 cm thick (PFC +shield)
# Ion Cyclotron System

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIUA) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>44% of antenna + all transmission/RF-sources/power supplies</td>
<td>91% of full system</td>
<td>31.1 [$45M]</td>
</tr>
</tbody>
</table>
Overview of the ITER IC system

• **What it is:**
  - One antenna, eight current straps
  - Eight rf sources, each feeding one strap in the antenna
  - 35-65 MHz
  - 20 MW total power to the plasma
  - Variable phasing between straps

• **What it can be used for:**
  - Tritium ion heating during DT ops.
  - Minority ion heating during initial ops.
  - Current drive near center for AT operation
  - Minority ion current drive at sawtooth inversion radius

ITER ion cyclotron system block diagram
## Electron Cyclotron System

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIUA) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start-up gyrotrons, all transmission lines and power supplies</td>
<td>40% of full system</td>
<td>32.3 [$47M]</td>
</tr>
</tbody>
</table>
Electron Cyclotron System Configuration

(24) 1 MW, 170 GHz Gyrotrons

(24) DC Power Supplies (not shown) (US)

(3) 1 MW, 120 GHz Gyrotrons (US)

Transmission Lines (US)

Equatorial Launcher

(3) Upper Launchers
### Tritium:
TOKAMAK EXHAUST PROCESSING SYSTEM

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIU) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokamak exhaust processing system</td>
<td>14% of full system; 88% of selected subsystems</td>
<td>11.4 [$16M]</td>
</tr>
</tbody>
</table>
Overview of ITER Tritium Plant
## Diagnostics

<table>
<thead>
<tr>
<th>Description of US portion</th>
<th>US fraction of system (by ITER value)</th>
<th>US Value (kIUA) [$M]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allocations being discussed</td>
<td>15% of full system (not including DNB)</td>
<td>20.6 [$30M]</td>
</tr>
</tbody>
</table>
ITER diagnostics landscape

- **Upper Port Plug**
  - 12 used

- **Upper Port 10**
  - X-Ray Survey
  - Imaging VUV Spectroscopy

- **Equatorial Port 11**
  - X-Ray Crystal Spectroscopy, array
  - Divertor VUV Spectroscopy
  - X-Ray Survey
  - Core VUV Monitor
  - Neutral Particle Analyser
  - Reflectometry

- **Equatorial Port 9**
  - MSE
  - Toroidal
  - Interferometer / Polarimeter
  - ECE
  - Wide Angle TV/IR

- **Divertor Port 8**
  - Divertor Reflectometry

- **Divertor Cassettes**
  - 16 used

- **Divertor Ports**
  - 6 used

- **Vessel Wall**
  - 360°
ITER provides Unique Technical Challenges for Diagnostics

- operation in radiation environment, presence of blankets,
- reliability, calibration maintenance,
- control data for machine protection.

2m high x 1.8m wide x 3.5m long

Weight: 66 tonne
Side and bottom: 130mm thick
Front & port flange: 200mm

Equatorial port-plug concept

Designs by C. Walker (JCT)
Port plugs and interface structures

Port-plug with penetrations for Thomson scattering, interferometry, etc.
IT-Leader-Requested 2003+ Tasks

• **Magnets**
  – Qualification of industrial suppliers of Nb$_3$Sn strands with increased value of $J_c$  
    US/IT-approved/5-month delay
  – Stress Analysis of the Helium Inlet Regions  
    US/IT-approved
  – Conductor Performance and Design Criteria  
    US/IT-approved/4-month delay
  – CS Jacket Weld Defect Assessment  
    US/IT-approved/4-month delay

• **Safety**
  – Support and assistance for the latest fusion versions of computer codes MELCOR and ATHENA  
    US/IT-approved/amendments
  – Safety Design Integration  
    US-disapproved
  – Magnet Safety  
    US/IT-approved

• **Materials**
  – Support of materials activity  
    US-approved/awaiting IT
IT-Leader-Requested 2004 Non-Physics Tasks (2/27/04)

- **Blanket Modules**
  - Qualification of the FW panel fabrication methods and to establish the NDT method for the FW panel.
  - Detailed design of blanket modules and thermal hydraulic analysis of the shield block and the total blanket system.

- **Divertor**
  - Tolerance Study of the Divertor

- **Fuelling**
  - Detail PIS component design

- **Water Cooling System**
  - Industrial design of WCS

- **Vacuum Pumping**
  - ITER VAC Assessment

- **Tritium Plant**
  - Detailed design and integration into overall fuel cycle of tokamak exhaust processing system based on the existing design

- **Safety**
  - Dust Characterization including mobilization and transport
• Diagnostics

  – To contribute to a Port Engineering Task Force (one or two members per PT) to determine the guiding principles for the design and engineering of the diagnostic ports.

  – Support the ITER IT in the writing of procurement specifications for diagnostic port-based procurement packages.
1) NTM control in Inductive and Hybrid Scenario in ITER

2) RWM in Steady State Scenario in ITER

3) VDE, Disruptions and their mitigation in ITER

4) Plasma position and shape control with 3D model of vacuum vessel

5) Error Field Control in ITER

6) ITER Plasma Integrated Model for ITER

7) Development of Steady State Scenarios in ITER

8) Evaluation of Fast Particle Confinement of ITER

9) Assessment of Edge Pedestal and ELMs of ITER
Planned FY04 Part-time Secondees (~3 FTEs)

- The present ITER international team consists of 63 persons: 27 from Europe, 19 from Japan, 13 from Russia, and 4 from China,

- Responding to requests from the ITER International Team Leader, the US is arranging for US persons (visitors/secondees? / all part-time):
  - Magnets [Naka, Japan]
    • Nicolai Martovetsky (LLNL) and Philip Michael (MIT) Approved
  - First Wall/Blanket [Garching, Germany]
    • Dr. Richard Nygren (Sandia) and Mr. Thomas Lutz (Sandia) In Prep
  - Ion Cyclotron [Garching, Germany]
    • David Swain (ORNL) and Richard Goulding (ORNL) Approved
  - Port Plugs/diagnostics [Garching, Germany]
    • Douglas Loesser (PPPL) Approved

- Note: if FDR level were spread over 8 years, then 10% would be 21 senior professionals and 36 junior professionals
ITER Working Groups

• **International Tokamak Physics Activity - topical groups**

• **Magnet Working Groups**
  – TF Coil Windings - Nicolai Martovetsky
  – TF Coil Cases - Peter Titus
  – PF Coils Windings - Timothy Antaya (alternate - Nicolai Martovetsky)
  – Conductors - Timothy Antaya
  – Central Solenoid - Timothy Antaya

• **Test Blanket Working Group**
  – Mohamed Abdou, key member for the US participation
  – Michael Ulrickson
  – Dai-Kai Sze

• **Diagnostics Working Group**
  – David Johnson (PPPL) - member
  – Réjean Boivin (GA) - member
  – Steve Allen (LLNL) - participant

• **Codes and Standards**
  – David Petti (INEEL) - lead
  – Irving Zatz (PPPL)
Bottom Line…. 

• Tentatively allocated in-kind contributions are well matched to US interests, capabilities, and capacities, and to ITER project success.

• Combined ITER-project and VLT-ITER-relevant activities in FY04 and FY05 are covering many of the important tasks necessary for positioning the US to perform its ITER roles:
  – providing the basis for tentative allocations of in-kind contributions.
  – R&D, design, manufacturing studies.
  – qualification of US vendors in key areas, such as superconducting strand production.
  – performance of ITER tasks requested by the leader of the ITER International Team.
  – assignments of US persons to the ITER International Team.

• Partially non-project comment:
  We need to move ahead with the US Burning Plasma Program!